ABSTRACT
Peri-urban areas vary from area to area therefore, planning must be adapted specifically to the local context and should therefore consider the fact that, as population grows and settlements increase in size, they will begin to compete with neighbouring settlements. Simplified sewerage is an important sanitation option in peri-urban areas of developing countries, especially as it is often the only technically feasible solution in these high density areas. This paper attempts to disseminate this technology more widely in the developing world, so that it can be used in peri-urban sanitation programmes and projects to improve the health of poor communities.

1. INTRODUCTION
Peri-urban refers to all those housing areas which are peripheral to or marginalised from the formal urban space, but which are not rural. Large and small urban slums, informal and illegal settlements scattered around the periphery of an urban space, areas of illegal or temporary housing within the city and all low-income housing areas which lack access to basic urban services including water supply and sanitation. Peri-urban areas are often neglected. Rural programmes offer inappropriate services, while urban utilities lack the mandate and skills to serve them.

2. URBAN GROWTH, SUPPLY OF WATER AND PROVISION OF SANITATION
In developing countries, the number of people living in towns and cities is growing rapidly – both as a result of natural urban growth and because of immigration into towns and cities from rural areas. This will add significantly to the number of people living without clean drinking water or adequate sanitation in urban areas. It will also cause more unemployment and poverty, widening the gap between urban rich and urban poor who lack access to a whole range of basic services besides clean water and sanitation, including health care, education, transport, adequate housing, security, information and justice. The rapid urbanisation has in many places resulted in an increase in slums. According to the UN-HABITAT definition a ‘slum’ household is one that lacks one or more of the following including water, sanitation, durable housing, a living area with a maximum of two people per room, and secure tenure. Poverty is one reason that the number of slums are growing.

However, slums are not the only urban areas without adequate access to water and sanitation. It is a fact that in many cities the necessary infrastructure simply cannot be built quickly enough to keep up with growing urban population. Cities and towns account for a large share of the non-renewable resources that are consumed, producing large amounts of waste and serious air and water pollution in the process. This makes good water and wastewater management, as well as provision of adequate sanitation, essential in order to limit pollution and minimise health risks. With a substantial percentage of their residents living in areas without adequate shelter and basic services, many cities in the developing world are also socially unsustainable. Decision makers, therefore, need to view sustainable urbanisation as a crucial issue for the future of humanity. In doing so, they must recognise that the proper handling of water supplies and sanitation are fundamental dimensions of sustainability.

2.1 Need for Sanitation
Low income communities which do not have adequate sanitation facilities are exposed to high risk of infections with excreta related diseases.
There is an acute need for sanitation in poor peri-urban areas. Sanitation is the key infrastructure component which is required to reduce the unacceptably heavy toll of excreta related diseases. Sanitation coverage in urban areas is currently decreasing and urbanization actually peri-urbanization is increasing. In many but obviously not all peri-urban situations the sanitation technology of first choice is simplified sewerage. The two principal reasons for this are that it can be cheaper than on site sanitation systems, and that it is often institutionally easier that is water and sewerage authorities accept it more readily than on site systems simply because it is a sewerage system and therefore, automatically part of their mindset.

2.2 Simplified Sewerage

Simplified sewerage is an off-site sanitation technology that removes all wastewater from the household environment. Conceptually it is the same as conventional sewerage, but with conscious efforts made to eliminate unnecessarily conservative design features and to match design standards to the local situation. Various approaches to reduce cost of sewerage have been developed in different parts of the world, often independently of each other. The Simplified Sewerage Manual draws on the approach developed in the early 1980s by the CAERN, the Water and Sewerage Company of the north eastern Brazilian state of Rio Grande do Norte. The aim of CAERN was to develop a technically feasible and socio-culturally acceptable solution to the previously intractable problem of sanitation provision in high density low income peri urban areas (de Andrade Neto, 1985; Guimarães, 1986; Mara 1996; de Melo, 1994; Sinnatamby, 1983 and 1986; Sinnatamby et al., 1986). The simplified sewerage approach is now widely used through Brazil. Key features of the system are as follows:

**Layout:** In order to reduce costs, CAERN developed simplified sewerage as an in-block system, rather than as with conventional sewerage an in-road system. The key feature of an in-block system is that sewers are routed in private land, through either back or front yards. This in-block or back-yard system of simplified sewerage is often termed condominium sewerage in recognition of the fact that tertiary sewers are located in private or semi-private space within the boundaries of the ‘condominium’.

**Fig. 1 Different Types of Sewer Systems**

![Diagram of Different Types of Sewer Systems](image-url)
**Depth and diameter:** Simplified sewers are laid at shallow depths, often with covers of 400 mm or less. The minimum allowable sewer diameter is 100 mm, rather than the 150 mm or more that is normally required for conventional sewerage. The relatively shallow depth allows small access chambers to be used rather than large expensive manholes.

The Fig. 1 illustrates the way in which all these different types of sewer can be used. This is a theoretical example and it will be unusual for all the possible arrangements to be used together in the way shown in the figure. The key question to be answered by the designer and householders in the area to be provided with sewerage is which form (or forms) of condominial sewer will be most suitable for the local situation.

### 3. PLANNING FOR SEWERAGE

The steps that led from the decision to adopt simplified sewerage to the development of a sewer layout can be summarised as follows:

- Collect existing information, focusing particularly on maps and plans of the area to be provided with sewerage and adjacent areas;
- Determine the area to be included in the sewerage plan, based on topography, the location of existing sewers and the limits of existing and future development;
- Develop a draft sewerage plan, showing the routes of the main collector sewers and the approximate areas of the various condominial systems;
- Undertake additional surveys as required to allow sewer routes and the areas of condominial systems to be confirmed, so that detailed design can be carried out; and
- Finalise the overall sewerage plan and plot the sewer routes at an appropriate scale or scales.

#### 3.1 Collection of Information

The first task in the planning process is to collect all available information on the area to be provided with sewerage. In particular, existing topographical maps and any maps showing the routes of existing drains and sewers should be collected, as these are needed to define the area to be provided with sewerage and determine the overall sewer layout. This information may be available on a number of maps and plans; if this is the case, as much information as possible should be transferred to one base plan. Information on existing management arrangements and responsibilities also needs to be collected. This provides a sound basis for developing institutional arrangements to manage the proposed system.

#### 3.2 Area

The next task is to decide the area to be included in the scheme. There are two possible situations. The first is that the design is for an exclusively local system, which can be connected to a local treatment facility or an existing collector sewer. The second is that there is a need to look at the sewerage needs of a wider area, including both local condominial sewers and public collector sewers. The important point is to ensure that the overall situation is taken into account, as defined by natural drainage areas, the location of existing sewers and possible treatment / disposal locations.

The boundaries of natural drainage areas should be fairly obvious in hilly or undulating areas. They may be much less obvious where the topography is flat. Where this is the case, the routes of existing natural watercourses, drains and sewers will give a good idea of existing drainage patterns. By plotting existing drains on a suitable plan (typically at a scale of between 1:2000 and 1:10,000, depending on availability and the area to be provided with sewerage), the approximate boundaries of drainage areas and the main drainage paths should be able to be defined. As this ‘context plan’ is developed, any land that might be available for local treatment should be identified. This allows the relationship between the scheme area and possible treatment / disposal facilities and sites to be explored.
ownership patterns. Where in existing drainage channel is located along a narrow right of way between existing houses, the sewer should preferably be rerouted along adjacent roads where there is better access for maintenance. The first step is to decide the routes of the main public collector sewers and then consider how local condominial systems can be joined to them. In general, public collector sewers should be designed to include flows from all parts of the drainage area that are likely to be se provided with sewerage. The accuracy with which sewer layouts can be plotted at this stage will depend on the accuracy of the available plans and the availability of information on ground levels. Final decisions on the limits of condominial systems may also be influenced by social factors.

3.4 Physical and Social Surveys

If accurate survey information is not available, detailed physical and social surveys are generally required. Each is briefly considered in turn below.

Physical surveys are required in order to determine sewer routes and levels. If existing plans exist, it may be possible to use them, at least for preliminary design. However, checks on their accuracy should always be made, and they must be updated to include any developments that have taken place since they were produced. Where plans are non-existent or insufficiently detailed, additional surveys will be required to provide information on the overall layout of the area. A full triangulated survey will normally be necessary for larger areas, although there may be the possibility of developing a municipal base-map from satellite imagery or aerial photographs. Plane table survey methods are often used to provide surveys at the condominial level, although a tape survey may provide all the information that is necessary for the design of a small, relatively uncomplicated area.

Simple social surveys should be used to provide information on household sizes and incomes, existing sanitation and water supply facilities, attitudes to sanitation and user preferences. Questionnaire surveys are useful for providing quantitative information. Semi-structured interviews and focused group discussions are more likely to provide information on attitudes and preferences. The options for management can be explored in community meetings. It will be particularly important to explore the degree of cooperation present within the community when in-block sewers are being considered. This is because the sewers pass through private property and it will be necessary to negotiate agreements on access for routine maintenance and dealing with blockages and other problems. Ideally, there should be some form of written agreement between the households concerned regarding access to the sewer. If surveys reveal uncertainty about the degree of cohesion present within the community, it will probably be wiser to route sewers in public rights of way.

3.5 Final Sewer Routes

Once good survey information has been obtained, it can be recorded on suitable plans and detailed design of the system can commence. Minor changes to the routes of collector sewers may be required as a result of improved survey information. More substantive changes may be necessary in condominial systems as a result of the findings of both the physical and social surveys. The preferred options for condominial sewers should be decided in consultation with local people.

4. DESIGN INPUT PARAMETERS

- **Average Household Size:** This is multiplied by the number of houses in an area or along a sewer leg to determine the design population in that area or contributing to the sewer leg. Results from the social survey will provide information on the average household size in the area to be provided with sewerage.

- **Average Per Capita Water Consumption:** This is multiplied by the design population for any area or sewer leg to calculate the total amount of water used during a typical day. Information on average per capita water consumption may be available from meter readings.

- **Return Factor:** This defines the percentage of total water consumption that will be discharged to the sewer. It is often assumed to be 80% or 85%, although there are indications that lower return factors may be appropriate in some areas. The wastewater
flow from an area will be equal to the water consumption in the area multiplied by the return factor.

- **Peak Wastewater Flow Factor:** This is required to allow for the fact that the wastewater flow varies through the day, reaching a peak when people get up in the morning and falling to almost nothing during the night. The peak foul flow in any sewer can be taken as the average flow in that sewer multiplied by the peak factor. Peak factors tend to decrease as the population contributing to the flow increases.

- **Groundwater Infiltration:** This needs to be considered where some sewers are laid below the groundwater table. Infiltration is commonly estimated on the basis that it is a set percentage of the average per-capita wastewater flow. A theoretically more accurate approach will be to assume an infiltration rate per unit length of sewer.

- **Allowance for Storm Water:** Sewers can be designed as separate, partially combined or combined. Separate sewers carry only wastewater; partially combined sewers are designed to carry some stormwater in addition to wastewater, while combined sewers are designed to carry the full wastewater and stormwater flows. Normal practice in many industrialised countries is to provide nominally separate wastewater and stormwater systems. The situation in low-income peri urban settlements in developing countries is unlikely to be different. Even if householders are educated about the problems that are likely to be caused if stormwater run-off is introduced into sewers, some will still connect their yard or roof water into the sewer.

- **Minimum Cover:** Cover is required over a sewer for three reasons:
  - To provide protection against imposed loads, particularly vehicle loads;
  - To allow an adequate fall on house connections; and
  - To reduce the possibility of cross-contamination of water mains by making

Simplified sewerage should be designed with the objective of minimising cover by locating sewers away from heavy traffic loads and as close as possible to existing sanitary facilities. The need to prevent cross-contamination of water mains also has to be considered. The cover over water pipes can be reduced by laying them, like sewers, away from heavily trafficked areas whenever possible. Another possibility is to use small diameter polyethylene or PVC pipes (typically with diameters of 50mm or 63 mm rather than 100mm) for tertiary distribution. These can be laid at relatively shallow depths. Wherever possible, water mains and sewers should also be separated horizontally.

### 5. DESIGN: OVER-RIDING PARAMETERS

#### 5.1 Minimum Sewer Diameter

It is necessary to specify a minimum sewer diameter because sewers transport wastewater which contains gross solids. There is no theoretical reason why the minimum sewer diameter should not be 100 mm. Every effort should be made to introduce appropriate standards, but it may be necessary to accept a higher minimum diameter than is absolutely necessary. In such circumstances, it is best to seek what is possible rather than the ideal. For instance, the acceptance of a 150 mm minimum diameter would be a big step forward in Pakistan.

#### 5.2 Minimum Flow

Conventional sewer calculations assume steady-state conditions. In practice, the flow in sewers at the upper end of the system is highly transient. The amount of flow at any time depends on the number of taps running to waste and WCs being flushed. By far the largest flows occur when a WC is flushed. A wave passes down the house connection and into the sewer, becoming attenuated all the time by the effects of friction. Of course, the attenuation will tend to be greater if there is any interruption to its smooth flow for instance, where a house connection enters a connection chamber above the sewer invert so that flows from the connection have to drop into the main sewer.

#### 5.3 Design Output Parameter: Minimum Sewer Gradient

The Design of Simplified Sewerage Systems: The first point is that the minimum permissible sewer gradient should be related to the
construction quality i.e. the better the quality, the flatter the allowable gradient. The second is that flatter slopes will be possible if stormwater, and the silt loading associated with it, can be excluded from sewers or trapped in a gully before entering the sewer. In situations where in practice it is considered that a minimum gradient of 1 in 200 is difficult to achieve, especially in flat areas if pumping is to be avoided, the designer is faced with two options:

- Accept that some siltation will occur and design the sewer on the assumption (which needs, of course, to be translated into a practical O&M requirement) that it will have to be regularly desilted; or

- Provide interceptor tanks on all house connections to remove all but the smallest and lightest solids, i.e. design the system as a settled sewage system (Otis and Mara, 1985; Mara, 1996). This allows much lower gradients to be used, but the system will eventually fail if the interceptor tanks are not desludged at the correct frequency.

5.4 System Sustainability

The long-term sustainability of simplified sewer systems can be ensured by:

- A good partnership between the community served by simplified sewerage and the sewerage authority;
- Good design;
- Good construction;
- Good maintenance; and
- An adequate, but affordable, tariff structure

- Concrete and immediate actions which implement the chosen water and sanitation systems within the peri-urban area in question may be initiated.
- A commitment to explore remaining uncertainties further before proceeding.
- Choices which may be deferred for future reconsideration, possibly including the timing of such future decision making.
- The formulation of contingency plans to deal with future events that may affect the process at hand.
- Simple brick junction chamber for simplified sewerage used in northeast Brazil.
- Junction chamber for simplified sewerage using larger diameter concrete pipes, used in Guatemala.
- Plastic junction chamber for simplified sewerage used in Brazil (manufactured by Tigre S.A.)

A good partnership between the community and sewerage authority is really essential, especially in peri-urban areas (Watson, 1995). Community education is almost always necessary. It is helpful if there is a well organised Residents’ Association.
which can act as the primary point of contact between the sewerage authority and the community.

6. ADAPTIVE PLANNING FOR WATER AND SANITATION IN PERI-URBAN SLUMS

Most planners realise that simply scaling up existing efforts will not substantially expand and improve water and sanitation provision in peri-urban areas, especially not in ways that will benefit low income groups. The key to ensuring that the poor really benefit is to support a diversity of smaller scale local initiatives. Existing large scale systems for water and sanitation are public assets that provide opportunities, but it can be difficult (physically and technically) to adapt them to serve the needs of vulnerable groups. Services at the periphery of these systems can be expanded, however, using complementary, small scale technical systems such as on-site treatment systems. Disposal and treatment of human excreta can, for example, be provided at a decentralised level in a safe and sustainable way without direct access or connection to water, for example, with maintained simple pit compost toilets. To achieve this, however, new or other institutions might be needed to manage and co-ordinate the two different systems.

There is also need to recognise that measures to address scarcity and investments in new infrastructure will not automatically help the poorest and most vulnerable members of society. These groups will only benefit if steps are also taken to safeguard provision in the more deprived areas and to empower disenfranchised groups and include them in the planning process. Urban development needs to balance the needs of marginalised, squatters and peri-urban communities with those of the city. By the same token, city and government decision makers need to set realistic targets, and to develop achievable actions plans. In this way they should be able to allocate sufficient resources (human, financial and time) to bring safe drinking water and basic sanitation in a sustainable way to their population. This should be a priority for all national and local governments.

7. CONCLUSIONS

Peri-urban areas vary from area to area therefore, planning must be adapted specifically in the local context and should consider the fact that, as population grows and settlements increase in size, they will begin to compete with neighbouring settlements. Simplified sewerage is an important sanitation option in peri-urban areas of developing countries, especially as it is often the only technically feasible solution in these high density areas. It is a sanitation technology widely known in Latin America, but it is much less well known in Africa and Asia. It is the purpose of this paper to disseminate this technology more widely in the developing world, so that it can be used in peri-urban sanitation programmes and project to improve the health of poor communities. However, simplified sewerage is not just for peri-urban areas—it can be successfully and appropriately used in middle and upper income areas.

REFERENCES


Hansen, J.M. Peri-urban Water and Sanitation System
