CHAPTER 1

INTRODUCTION

"It is a duty, not only to acquire learning by reading, but also, once having acquired it, to make oneself of use to people outside, by what one can say or write."

Ecclesiasticus: Foreword 4 - 6
(132 BC)

CHAPTER 1: INTRODUCTION

1.1 STRUCTURE OF THE DISSERTATION

1.1.1 General

This dissertation is submitted in partial fulfilment of the requirements for the degree of M.Eng (Water resources engineering) at the University of Pretoria. The purpose of the dissertation is fourfold, namely:

1 To give a broad introduction to the general sanitation situation in South Africa and some other developing countries, particularly among the poorer sections of the population, and to explain why conventional sanitation options are not always suitable for solving the serious problems that exist. Chapters 2 and 3 discuss these aspects. It is argued that there is a need for other appropriate technologies to address specific problems.

2. To introduce and describe the development (Chapters 4 to 6) of a new type of interceptor tank for use in settled sewage sanitation systems. This tank is able to desludge itself (i.e. extract the accumulated sludge) automatically without the need of a vacuum tanker or maintenance crew, by means of a siphonic-type outlet mechanism designed and patented by the author on behalf of CSIR Building and Construction Technology (Boutek).

3. To explain the research, development and current status of urine diversion sanitation technology in the world (Chapters 7 and 8). The implementation of South Africa's first project utilising this concept, which was piloted by the author on behalf of Boutek, is also fully described (Chapter 9).

4. To produce preliminary guidelines for the design, construction and operation of the two sanitation technologies mentioned in 2 and 3 above.

As a background to the argument for the introduction of other sanitation technologies, the dissertation commences with a broad discussion on the importance of sanitation in combatting disease and protecting the environment. This discussion includes the influence of different cultures on the choice of sanitation technology, as well as the various types of sanitation systems available and their associated methods of treatment and disposal of excreta. Reasons for successes or failures of various sanitation systems are also discussed. This is followed by an in-depth presentation of the two sanitation technologies mentioned above, as well as preliminary guidelines for their design, construction and operation. Because these two systems are new in the country and are presently being implemented for the first time, it is not possible to provide detailed or final guidelines at this stage. Research is still continuing, not only into the technical aspects such as design, operation and maintenance, but also into social factors like cultural acceptance and behaviour. It is the intention, however, to produce detailed guidelines which will eventually be included in Boutek's publication "Guidelines for human settlement planning and design", commonly known as the "Red Book". The author's employer, Boutek, is the custodian of the Red Book, on behalf of the Department of Housing, and is responsible for the book's continual updating.

1.1.2 Definition of some terms used in this dissertation

For the purpose of this dissertation, the word "sanitation" is taken to mean the safe management of human excreta. It therefore includes the "hardware" (toilets and sewers) and the "software" (regulation, hygiene promotion, etc) needed to reduce disease transmission. It also encompasses the re-use and ultimate disposal of human excreta.

A "wet" sanitation system is a generic term used to define systems which use water to dispose of human excreta, for example waterborne sewerage or septic tanks. A "dry" sanitation system, on the other hand, commonly refers to a toilet in which water is not added for the purpose of disposing or treating of excreta, for example pit toilets and other kinds of composting systems.

1.2 HYDRAULIC DISPOSAL OF INTERCEPTOR TANK SLUDGE IN SETTLED SEWAGE RETICULATION SYSTEMS

Septic tanks are regarded as an "intermediate" sanitation technology. This is so because, in South Africa at least, the lowest level of service recognized by the Government, and for which a subsidy will be granted for its implementation, is a ventilated improved pit (VIP) toilet. At the top end of the scale, the highest level of service is an in-house flushing toilet with a waterborne sewerage system. A septic tank, operating off a flushing toilet, bath, washbasin, kitchen sink, etc, and draining the effluent into a soakpit near the tank, is a commonly used technology fitting in between these two levels of service. This is an example of on-site sanitation, where partial treatment of the waste takes place on the site, i.e. in the septic tank itself, as well as in the soakpit. The settleable solids sink to the bottom of the tank as sludge, while the partially-treated effluent leaves the tank and drains into the ground, where further bacteriological treatment takes place.

Septic tanks together with their drainfields (also called soakpits, soakaways or french drains) represent a fairly high level of sanitation service, in the sense that they allow flushing toilets and sullage disposal. These systems have generally worked satisfactorily and without any problems on farms or plots, where space is plentiful and size of drainfield is not an important issue. There are situations, however, where these systems are inappropriate, for example in areas of relatively impermeable soil, where a drainfield cannot function efficiently. Septic tanks connected to drainfields are also inappropriate in areas with a shallow water table, where aquifer pollution is a very real possibility. Also, regions which are densely populated, with a relatively high concentration of septic tanks, may eventually result in the absorption capacity of the soil being exceeded, with concomitant environmental pollution.

Such limitations in the use of drainfields have led to the development of settled sewage technology. In these systems the effluent from all the septic tanks in an area, instead of soaking into the ground, is collected by a reticulation system of relatively small diameter pipes and led either to a formal treatment plant, or to stabilisation ponds or a wetland system for secondary treatment. Also known as "STED" (septic tank effluent drainage), "solids-free", "small-bore" or "variable-grade" sewer systems, settled sewage technology offers an efficient, healthy and environmentally friendly sanitation system if properly engineered and implemented (Austin 1996).

While settled sewage technology has been used for decades in other countries (e.g. Australia, Zambia and the USA), the installation of these systems in South Africa is still a relatively new experience, with the first projects only being commissioned during 1989 (Austin 1996). It has been found that a settled sewage installation, properly designed and operated, is not only a sound sanitation system but also a technology which, in many cases, can offer easier construction, lower maintenance requirements, cheaper treatment of effluent and generally lower overall cost when compared to a conventional waterborne system. The technology offers a viable alternative in situations where the provision of VIP toilets is problematic due to, for instance, geotechnical conditions. It is also an option where high population densities or poor soil conditions preclude the use of ordinary septic tanks with drainfields, or where the community desires a higher level of service but cannot necessarily afford a conventional waterborne system. This technology should also be considered in cases where the level of water supply is such that a waterborne sanitation system is not an option, for example where the community has access to yard taps only. Even where a full in-house water supply exists, there are many areas in the country, in both low and high income communities, where no conventional waterborne sanitation service is available but where a settled sewage system could offer a level of service higher than a conservancy tank or a septic tank with drainfield. In fact the level of service offered by a settled sewage system is virtually equivalent to that offered by a full waterborne system.

As with any sanitation system, there are certain disadvantages of settled sewage technology which need to be taken into account when considering the various alternatives available. One of the most important factors to be considered is the need for periodic desludging of the interceptor tanks (see chapter 4 for a description of the role of interceptor tanks). This task, illustrated in Figure 1.1, can comprise a large portion of the operation and maintenance costs of the system, as the local authority has to maintain vacuum tankers for this purpose (the number of tankers required will depend on the population served). Alternatively, private contractors may charge the householder between R300 and R500 (1999 rands), depending on the size of the load. In this respect the income level of the community is an important factor, as in all probability this represents an unaffordable amount to a poor family.

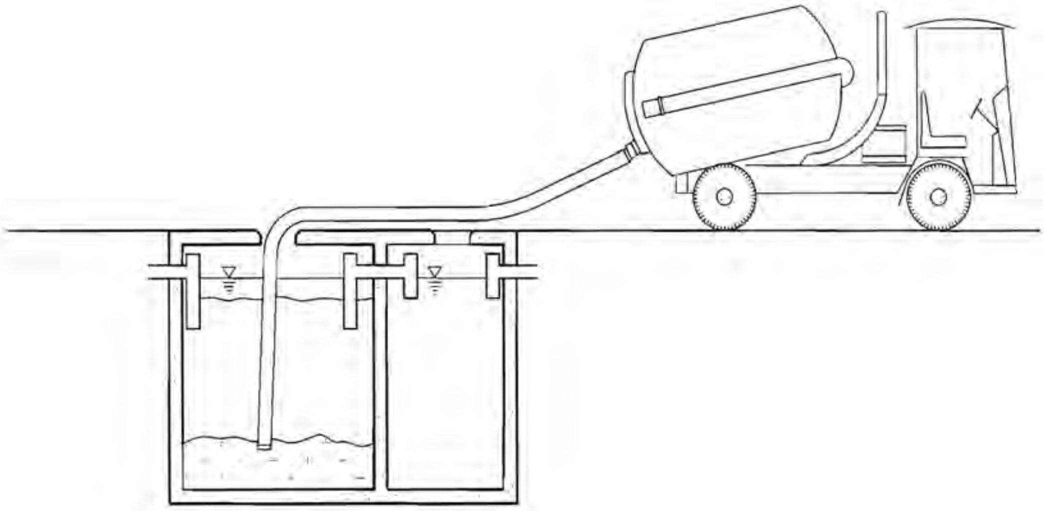


Figure 1.1: Emptying a septic tank by means of a vacuum tanker

Whether or not a settled sewage system operates without any problems, vacuum tankers are still required to desludge the interceptor tanks at certain intervals. In some areas this will be merely a nuisance and possibly a short-lived eyesore for the residents, while in other areas it may be a major undertaking. Where roads are in poor condition it is difficult, and sometimes impossible, for conventional vacuum tankers to reach the affected houses. In other areas, settlement densification often results in additional houses or shacks being constructed in between existing dwellings, thus making it problematic to gain access to the tanks. In some cases the interceptor tanks have to be emptied manually. Apart from the unpleasantness of the task, this may also be dangerous for the people involved, as toxic, anoxic or explosive atmospheres may result from the accumulation of gases produced in the tank (Otis & Mara 1985).

An alternative method of desludging interceptor tanks in a settled sewage system, which would reduce or possibly even eliminate the need for vacuum tankers to gain access to individual tanks, is thus proposed. This dissertation describes the conceptualisation and development of such a system. The accumulated sludge in an interceptor tank is automatically flushed into the reticulation network of the settled sewage system, and a vacuum tanker is not required for this task. The conceptualised process involves a siphon which is automatically activated by an inflow of wastewater into the interceptor tank. Once the sludge enters the outfall pipeline, it is transported hydraulically in the reticulation system, thereby obviating the need for it to be pumped out of the tank by mechanical means. The process of developing this system required an assessment of various hydraulic parameters such as flow volume, pipeline gradient, required pressure head, friction losses, etc.

1.3 URINE DIVERSION TECHNOLOGY AS AN ALTERNATIVE TO VIP TOILETS

The basic level of sanitation service in South Africa has been defined as a "ventilated improved pit (VIP) toilet in a variety of forms, or its equivalent, as long as it meets certain minimum requirements in terms of cost, sturdiness, health benefits and environmental impact" (DWAF 1996). Many community sanitation schemes have been successfully implemented utilising this technology. Unfortunately, others have failed, usually due to poor design and construction practices or to social factors such as lack of community buy-in, or a combination of these. New or unknown technologies are often viewed with suspicion or rejected out of hand. Some cultural beliefs and practices may also make it difficult to introduce alternative technologies into a community. Attempts have been made to find simple, universally applicable solutions to sanitation problems; however, these often fail because the diversity of needs and contexts is ignored. Urban needs usually differ from rural needs, the technological options offered are limited and often inappropriate, and critical social issues such as behaviour are either ignored altogether or badly handled (Simpson-Hébert 1995). Furthermore, the scope of environmental protection becomes so broad that the main purpose of sanitation provision is often lost. Current approaches also tend to stifle innovation.

VIP toilets, correctly engineered and implemented, are an excellent means of providing sanitation in areas where financial factors preclude the provision of a higher level of service. These systems are not without their problems, however. Geotechnical conditions, such as hard or rocky ground for instance, often militate against the choice of this technology. In other cases, non-cohesive soils will require a pit to be fully lined in order to prevent collapse of the structure. Pits should also be avoided in areas with shallow water tables, especially in fracture-flow type of aquifers, where rapid transmission of pollutants is possible.

Full pits are a further problem. In many cases the owners will not be in a financial position to empty them, even if the toilets have been constructed with this in mind. While there may be plenty of available space in rural areas to dig further pits, this will seldom be the case in high-density urban areas. This aspect does not even take the cost of digging a new pit and moving or rebuilding the superstructure into account, so for all practical purposes the initial investment is lost after 10 or 15 years. Some other solution should be sought in these cases. If a dry toilet is designed and constructed in such a way that the faeces receptacle can be quickly, easily and safely emptied, then one of the biggest operation and maintenance problems associated with these toilets will be obviated. If the excreta can also be productively and safely used, for example in agriculture, the technology will become even more attractive. In South Africa, where many rural communities rely on subsistence agriculture, often in poor soils, and with urban agriculture becoming more common in certain communities, this is an important aspect.

The technology of ecological sanitation, or "dry box" toilets, has been used successfully for decades in many developing countries, e.g. Vietnam, China, Mexico, El Salvador and other Central and South American states. Even in a highly developed country such as Sweden there is a great deal of interest in the technology (Esrey et al 1998; Hanaeus et al 1997; Höglund et al 1998; Jönsson 1997; Wolgast 1993). The most important difference between this technology and that of composting is the moisture content in the faeces receptacle. The urine is diverted at source by a specially designed pedestal and is not mixed with the faeces. A schematic representation is illustrated in Figure 1.2. A pit is not necessary as the entire structure may be constructed above ground, or may even be inside the dwelling. Ash, dry soil or sawdust is sprinkled over the faeces after each bowel movement. This serves to absorb the moisture and control odours and flies. The generally dry conditions in the faeces receptacle facilitate the desiccation of the contents, which thus become safe for handling within a relatively short time. The desiccated faecal matter makes a good soil conditioner, while the urine, when diluted with water, is an excellent source of fertilizer, being rich in nitrogen, phosphorus and potassium.

The most common sanitation technologies, be they pit toilets or waterborne sewerage, are based on the notion of human excreta as an unpleasant and dangerous waste product requiring disposal. The urine diversion or "dry box" toilet, however, is based on the notion of human excreta as a **resource** (Winblad 1993). Urine is basically water and dissolved micronutrients. Most of the nitrogen (N), phosphorus (P) and potassium (K) in human excreta are to be found in the urine, and the total amount of N+P+K in one person's urine each year is approximately 7 kg. As will be shown in chapter 7, this is enough to produce 230 kg of cereal. While faeces contain much less of these constituents, the important point is that when they are dehydrated they become odourless, while most of the bacteria and viruses are destroyed. A valuable soil conditioner is thus obtained, which ought not to be wasted (Winblad 1996a).

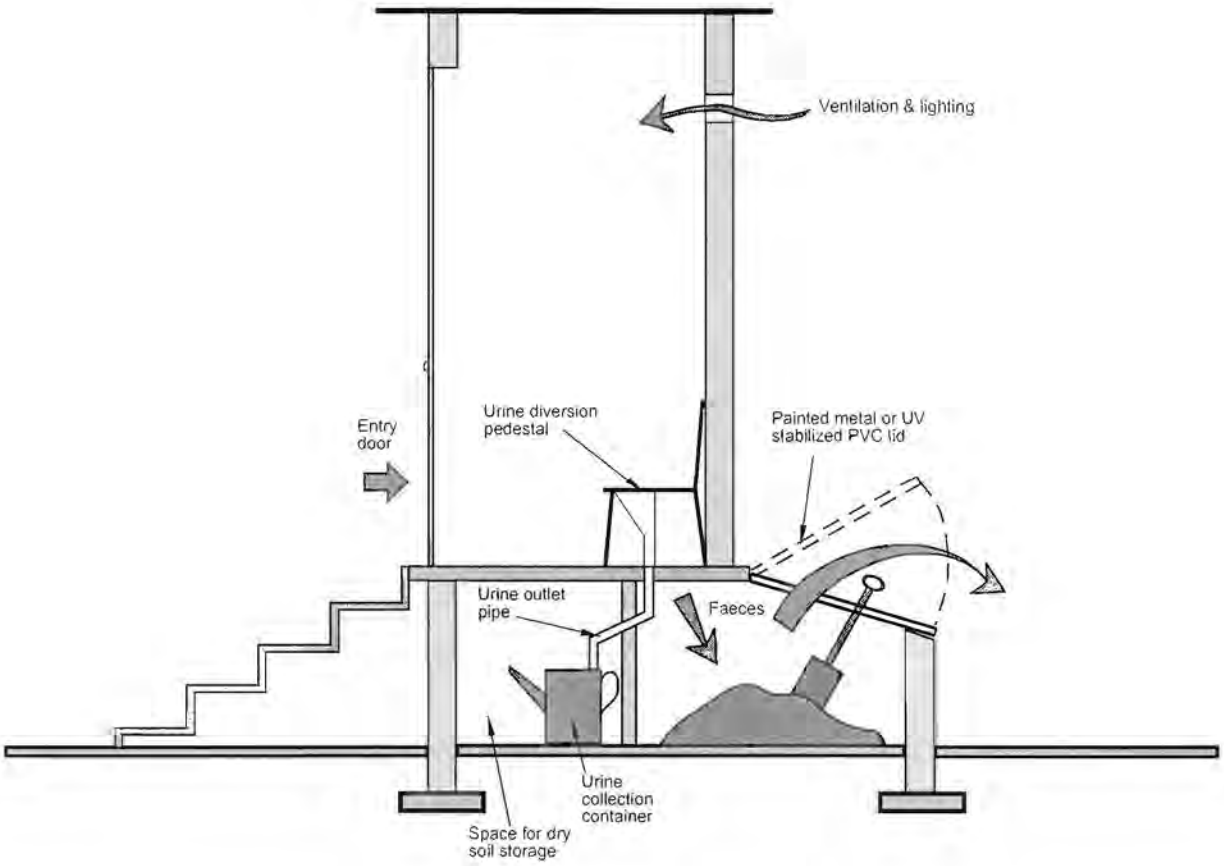


Figure 1.2: Schematic representation of a urine diversion ("dry-box") toilet

CHAPTER 2

THE IMPORTANCE OF SANITATION

"You are to have a place outside the camp where you can go when you need to relieve yourselves. Carry a stick as part of your equipment, so that when you have a bowel movement you can dig a hole and cover it up."

Moses' instructions to the ancient Israelites on keeping the military camp clean. Deuteronomy 23:12.

CHAPTER 2: THE IMPORTANCE OF SANITATION

2.1 SANITATION AND THE ENVIRONMENT

As a result of faulty sanitation systems design, their incomplete implementation, poor operation and improper use, human excreta are spread throughout the environment. Vast amounts of improperly-managed faeces and untreated sewage contaminate the living environment of millions of people, soils and water bodies. Existing systems and available resources are inadequate to deal with the associated social and behavioural factors. This inability of existing sanitation systems to properly manage the increasing volumes of human excreta has contributed much to the worldwide escalation in ecological problems. With the rapid population growth taking place, especially in urban areas, the situation will not improve unless there is a significant change in the manner in which sanitation systems are chosen, designed and implemented (Simpson-Hébert 1997).

Environmental problems in turn undermine the process of development, which is further hampered by rapid population growth. In all developing countries, especially in sub-Saharan Africa, the growth of the population in the urban areas alone is outstripping the capacity of these regions to provide for basic needs such as shelter, water and sanitation. In the city of Dar es Salaam in Tanzania, for example, pit toilets and septic tanks with drainfields serve about 76 % of the population, and this has caused serious faecal pollution of the groundwater, which is generally only 1 m to 3 m below ground level. Faecal coliform levels of up to 3 000/100 mℓ have been recorded (Kaseva 1999). This should be seen against the fact that continuous exposure to drinking water with faecal coliform levels above 10/100 mℓ represents a risk of infectious disease transmission.

Water quality is deteriorating all over the world due to pollution. Some cities in the developing world treat only about 10 % of their sewage (Björklund 1997). Even in South Africa, recent reports have indicated that an alarming proportion of sewage waste in many towns and cities across the country does not reach treatment plants, but flows untreated into the rivers. This is regarded as one of the most pressing water quality problems. In many cases, even when sewage waste reaches the treatment plant, poor operation or malfunctioning systems means that partially treated sewage effluent is discharged to rivers. Litter and other pollutants from poorly serviced areas have also impacted the natural functioning of river ecosystems to such an extent that many rivers near urban areas have lost their ability to assimilate pollutants (DWAF 1999).

One of the constraints to providing efficient sanitation in urban areas is the myth that the only good sanitation system in such places is conventional waterborne sewerage. While this type of sanitation system has been widely successful in controlling the transmission of excreta-related diseases in most cities of industrialised countries, it has also created severe damage to ecosystems and to natural water resources where the wastewater was inadequately treated. Since proper treatment increases the cost and energy requirements of the entire system without being essential to the day-to-day survival of the individual user, this part of the system was often omitted when financial resources were scarce. Consequently, in those cities of developing countries that have a conventional sewer system, only a very small percentage of the wastewater collected is treated at all. In many areas this has resulted in severe ecological damage, with heavy economic consequences (Simpson-Hébert 1997).

Globally, sewage discharges from centralised, waterborne collection systems are a major component of water pollution, contributing to the nutrient overload of water bodies. Although waterborne systems are acceptable to the vast majority of people, they are technologically complex and require institutional capacity and skills that are not always available in Third World cities. Over 90 % of all sewage in developing countries (98 % in Latin America) is discharged completely untreated (Esrey et al 1998).

The success or failure of a sanitation system depends on the interaction of environmental, human and technical factors. The most important environmental aspects are climate, soil and groundwater; these vary from place to place and have a great influence on the choice of the most appropriate sanitation system. The technology selected should therefore be adapted to the local environmental conditions (Winblad and Kilama 1980).

It is better to protect the environment from faecal pollution than to undertake expensive measures to reduce pollution when it has already taken place (Feachem and Cairncross 1978). The approach to the sanitation challenge should be ecologically sustainable, i.e. concerned with the protection of the environment. This means that sanitation systems should neither pollute ecosystems nor deplete scarce resources. It further implies that sanitation systems should not lead to degrading water or land and should, where possible, ameliorate existing problems caused by pollution. Sanitation systems should also be designed to recycle resources such as water and nutrients present in human excreta (Simpson-Hébert 1997).

2.2 SANITATION AND DISEASE

A large number of diseases are spread directly through man's contact with human excrement, indirectly via water, food and soil, or via carriers and vectors like flies, cockroaches and mosquitoes. These dangers of poor sanitation are compounded by increasing population densities. When people move from isolated farms or rural tracts into villages or urban squatter areas, they may be better off in a number of ways, but certainly not with respect to sanitation. Simple disposal methods like defecation in the bush, in fields or in open pits may have few adverse effects for small, scattered populations, but when used in densely built up areas, such practices are positively dangerous (Winblad and Kilama 1980).

Despite all efforts during the International Drinking Water Supply and Sanitation Decade (1981 - 1990), more than 2 500 million people in the developing world still do not have access to hygienic means of personal sanitation. The result has been "a horrifying toll in death and debilitating disease" (IRC 1999). Even at the start of the 21st century, diarrhoeal and other sanitation-related diseases remain highly endemic, despite large-scale attempts over the past few decades to control them. Human excreta is spread throughout the environment as a result of faulty sanitation systems design, their incomplete implementation, poor operation and improper use. Existing systems and available resources do not deal adequately with the associated social and behavioural factors. The inability of existing sanitation systems to manage adequately the increasing volumes of human excreta is the main cause of the high incidence of infectious diseases in most developing countries (Simpson-Hébert 1997).

Health promotion and protection from disease for both the user and the general public are important principles of sanitation provision. This means that sanitation systems must be capable of protecting people from acquiring excreta-related diseases as well as interrupting the cycle of disease transmission. Sanitation technologies should therefore have the demonstrated capacity to prevent the transmission of pathogens (Simpson-Hébert 1997).

Every year millions of people die from diarrhoea that could have been prevented by good sanitation, while millions more suffer nutritional, educational and economic loss through diarrhoeal diseases which proper sanitation could have prevented. Poor sanitation has led to the infection of nearly a billion people, largely children, with a variety of worm infections. Human excreta are also responsible for the transmission of schistosomiasis (bilharzia), cholera, typhoid and many other infectious diseases affecting hundreds of millions of people. While heavy investments have been made in water supply since 1980, the resulting health benefits have been severely limited by the poor progress in sanitation (Simpson-Hébert 1995).

Sanitation, hygiene and safe water can be considered to be the main barriers between the health of people and exposure to disease, with sanitation being the primary factor. Without sanitation the environment is exposed to pathogens. Improved water supply alone is not enough to break the disease cycle. Research on the joint effect of three types of water and sanitation systems (unimproved, intermediate and optimum) on incidents of diarrhoea and the nutritional status of young children, has shown that the highest rates of diarrhoea were found among children without improved sanitation, regardless of the level of water supply in operation (de Jong 1996).

The major communicable diseases whose incidence can be reduced by the introduction of safe excreta disposal are intestinal infections and helminth infestations, including cholera, typhoid and paratyphoid fevers, dysentery, diarrhoea, hookworm, schistosomiasis and filariasis (Franceys, Pickford and Reed, 1992). *Culex* mosquitoes in particular, which are the cause of filariasis and elephantiasis, breed in organically polluted water found in blocked drains, flooded pit toilets and overflowing septic tanks (Kolsky 1997). Table 2.1 lists some of the pathogenic organisms frequently found in faeces, urine and sullage (greywater).

Table 2.1: Occurrence of some pathogens in fresh urine,* faeces and sullage (Franceys, Pickford and Reed 1992)

Pathogen	Common name for infection caused	Present in: Urine	Faeces	Sullage
Bacteria				
Escherichia coli	diarrhoea	•	•	•
Leptospira interrogans	leptospirosis	•		
Salmonella typhi	typhoid	•	•	•
Shigella spp	shigellosis		•	
Vibrio cholerae	cholera		•	
Viruses				
Poliovirus	poliomyelitis		•	•
Rotaviruses	enteritis		•	
Protozoa - amoeba or cysts				
Entamoeba histolytica	amoebiasis		•	•
Giardia intestinalis	giardiasis		•	•
Helminths - parasite eggs				
Ascaris lumbricoides	roundworm		•	•
Fasciola hepatica	liver fluke		•	
Ancylostoma duodenale	hookworm		•	•
Necator americanus	hookworm		•	•
Schistosoma spp	schistosomiasis	•	•	•
Taenia spp	tapeworm		•	•
Trichuris trichiura	whipworm		•	•

* Urine is usually sterile; the presence of pathogens indicates either faecal pollution or host infection, principally with *Salmonella typhi*, *Schistosoma haematobium* or *Leptospirosa*.

Those most at risk of contracting these diseases are children under five years of age, as their immune systems are not fully developed and may be further impaired by malnutrition. The diarrhoeal diseases are by far the major underlying cause of mortality in this age group, accounting for some 4 million deaths each year (Franceys, Pickford and Reed 1992).

Humans themselves are the main reservoir of most diseases that affect them. Transmission of excreta-related diseases from one host to another (or the same host) normally follows one of the routes shown in Figure 2.1. Poor domestic and personal hygiene, indicated by routes involving food and hands, often diminishes or even negates any positive impact of improved excreta disposal on community health. Technology by itself cannot break the cycle of disease transmission and accompanying ill health if hygiene awareness in a community is at a low level.

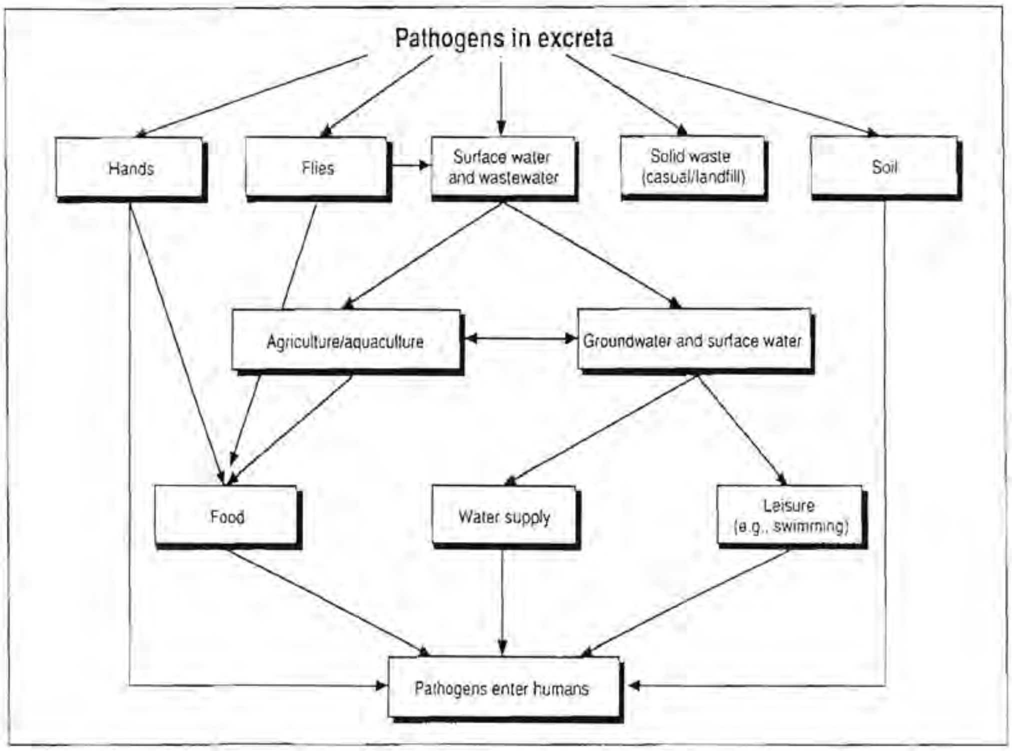


Figure 2.1: Transmission routes for pathogens found in excreta
(Franceys, Pickford and Reed 1992)

2.3 THE CURRENT SITUATION IN DEVELOPING COUNTRIES

2.3.1 General

In many cities, towns and rural areas of the world today, people live and raise their children in highly polluted environments. Urban and peri-urban areas in developing countries are among the worst polluted and disease ridden habitats of the world. Much of this pollution, which leads to high rates of disease, sickness and death, is caused by a lack of toilets and inadequate sanitation services. This lack of sufficient services is a result of many factors, such as inadequate financial resources, insufficient water, lack of space, difficult soil conditions and limited institutional capabilities. As cities expand and populations increase, the situation will grow worse (Esrey et al 1998).

In 1983 the World Health Organisation estimated that in the developing regions of Africa, Asia, Latin America and the Pacific, less than a third of the population had access to adequate sanitation. While urban areas were generally better endowed with some form of sanitation, less than 12 % of the rural people were so served. In most developing regions of the world, rural people traditionally use the field or the bush for defecation. Rural settlements, especially scattered communities, do not have the aesthetic incentive to demand sanitation and rely instead on the natural assimilative capacity of the surrounding countryside to serve their needs (UNCHS 1986).

In many urban centres, poorest groups face the most serious environmental hazards and the least possibility of avoiding them or receiving treatment to limit their health impact (Wall 1997). By early in the 21st century, more than half of the world's population is predicted to be living in urban areas. By the year 2025, this urban population could rise to 60 %, comprising some 5 billion people. The rapid urban population growth is putting severe strains on the water supply and sanitation services in most major conurbations, especially those in developing countries (Mara 1996). In Africa today, over half the population is without access to safe drinking water and two-thirds lack a sanitary means of excreta disposal. It is a situation in which the poor are adversely affected to a disproportionate degree. Lack of access to these most basic of services necessary to sustain life lies at the root of many of Africa's current health, environmental, social, economic and political problems. Hundreds of thousands of African children die annually from water- and sanitation-related diseases. Despite significant improvements during the International Drinking Water Supply and Sanitation Decade, progress has now stagnated. More people are today without adequate services in Africa than in 1990, and at the current rate of progress full coverage will never be achieved (WSSCC 1998a).

The excreta of most urban dwellers in developing countries are disposed of through on-site sanitation systems such as pit toilets and septic tanks. This is in contrast to industrialised countries where excreta are disposed of via flush toilets, city-wide sewerage systems and central wastewater treatment works, all of which constitute standard technologies. However, these are unaffordable to most urban inhabitants of developing countries. A major problem resulting from this is that faecal sludges collected from on-site sanitation installations are commonly disposed of untreated (Strauss and Heinss 1998). The problem is growing, and over the next few decades most Third World urban growth will take place in peri-urban areas without access to basic services (Winblad 1996a).

The task for developing countries is considerably more difficult than for industrialised countries, even though the problems they face, viz. high costs and limited resources, are similar. Water in developing countries is generally much more seriously degraded and is still deteriorating rapidly. At the same time, far fewer financial resources are available for environmental protection, and institutional capacity is weaker (Wall 1997). In the urban areas of El Salvador, for instance, the wastewaters entering the reticulated sewer systems are presently not treated, but are discharged directly into ravines and rivers (Mejia 1997). In Vietnam most of the rivers, canals, lakes and ponds are seriously polluted with human excreta and untreated waste from hospitals, clinics and factories, as well as the uncontrolled use of insecticides in agriculture (Song 1997). In the city of Shanghai, China, about 20 % of the human waste is dumped untreated into rivers (Robson 1991).

Governments tend to base their expenditure on water and sanitation on political and social considerations rather than on purely economic criteria. In many countries this has led to heavy dependence on centralised command and control. The result has in many cases been unreliable projects that produce services but do not meet consumers' needs and for which they are therefore unwilling to pay. The absence of financial discipline, accountability for performance and political interference has furthermore often been the cause of inefficient operations, inadequate maintenance and financial losses (Wall 1997).

The failure of various sanitation technologies to prevent pollution is of particular concern to the Pacific island countries, for example the Cook islands, Micronesia, Kiribati and the Marshall islands. Nearly every Pacific island nation has identified critical environmental and public health problems resulting from the disposal of human excreta. These have included algal blooms and eutrophication in lagoons, dying coral reefs, contaminated drinking water wells and outbreaks of gastro-intestinal diseases and cholera. The causes of this pollution include overflowing latrines, privies, water-seal toilets, septic systems and sewage treatment plants, as well as the complete lack of sanitation facilities in some places (Rapaport 1997).

2.3.2 Why sanitation isn't happening

Despite years of rhetoric, good intentions and hard work, very little progress has been made in improving sanitary conditions for much of the world's population. Without major changes, the number of people without access to sanitary excreta management will not change, remaining above 3 000 million people. Professionals involved in sanitation agree that, with some exceptions, mankind is either losing ground or barely holding the line in its ability to dispose of wastes in a healthy, safe and ecologically sound manner (WSSCC 1998b).

The infrastructure challenges facing developing countries in the water and sanitation sector are formidable. Rapid population growth and urbanisation are stretching the limits of institutional capacities and natural ecosystems. Government budgets cannot accommodate competing demands for investment resources, and many public institutions suffer from weak management. Many initiatives also fall short because they are inflexible and unsustainable for a variety of reasons (Wall 1997).

The Water Supply and Sanitation Collaborative Council Working Group on the Promotion of Sanitation (WSSCC) has found that the barriers to progress are varied and complex, but can generally be grouped into nine linked and overlapping categories (Simpson-Hébert 1995):

1. *Lack of political will*:

There is little political incentive for governments to deal with a difficult subject. Politicians rarely lose their jobs because of poor sanitation, particularly as the people most in need have the least power.

2. *Low prestige and recognition*:

Low-cost sanitation facilities and hygiene promotion campaigns have never been prestigious. Politicians and movie stars do not demonstrate latrines. Among consumers, low-cost sanitation has no prestige in comparison with "conventional" waterborne sanitation as used by the industrialised world and by the economic elite of developing countries.

3. *Poor policy at all levels*:

There is too much attention given to water supply at the expense of sanitation, a focus on hardware rather than on long-term behaviour change, and subsidies that favour other than the poor and indigent.

4. *Poor institutional frameworks*:

Generally speaking, governments in developing countries have failed to promote sanitation, and existing institutional frameworks need to change. The institutional frameworks which are in place in some countries tend to fragment responsibilities between government departments and ignore the powerful role that non-governmental organisations and the private sector can play. Since the writing of the South African government's draft White Paper on national sanitation policy (DWAF 1996), however, the situation in this country is changing radically, albeit slowly.

5. *Inadequate and poorly used resources*:

Sanitation is at least as important for health as water supply and is a far more demanding problem, yet sanitation receives far fewer resources.

6. *Inappropriate approaches*:

Attempts are made to find simple, universal solutions which fail by ignoring the diversity of needs and contexts. Urban needs often differ from rural needs, the technological options offered are limited and inappropriate and critical issues of behaviour are ignored or badly handled. Furthermore, the scope of environmental protection and pollution control becomes so broad that the focus on basic household excreta management is lost.

7. *Consumer perceptions and neglect of their preferences*:

Low-cost technologies are often seen by consumers as low-status technologies, while many "appropriate" technologies are far beyond the economic reach of those most in need. Promoters try to sell sanitation facilities on health benefits, when all people really want is the privacy, comfort and status which good sanitation can offer.

8. *Ineffective promotion and low public awareness*:

People don't want to talk or think about faeces, so selling the idea of sanitation is difficult. Those in charge – the engineers and doctors responsible for selling sanitation – are not trained for the job of promotion.

9. *Women and children last*:

Women are potential agents of change in hygiene education and children are the most vulnerable victims, but men usually make the decisions about whether to tackle the problem, and how.

2.3.3 Responses to change

People resist change for many reasons. There may be resentment towards outside "experts" who know little of local customs and who are perceived to benefit more from the innovation than the local people. Leadership may not be united within a community. For example, those with traditional authority who fear a loss of power and status may oppose innovation supported by political or educated elites. New technologies may be aesthetically unacceptable or conflict with established patterns of personal and social behaviour. Furthermore, households vary widely with respect to the resources of money, labour and time available to them and have their own priorities. For those with limited resources, the costs in the short term of an apparently "low-cost" system may be too great when set against their need for food, shelter and clothing (Franceys, Pickford and Reed 1992).

In many cultures the handling of excreta is considered as taboo, and viewed as a disgusting and dangerous nuisance not to be discussed. No one wants to be associated with excreta; even those who reduce its offensive characteristics for others are stigmatized by association. Problems cannot be solved if people do not want to talk about them and do not want to be associated with their solution. What is needed to turn the sanitation sector around is no less than a revolution in thought and action. It is necessary to define principles, make priorities, create strategies and search for new technological, financial and institutional solutions (WSSCC 1998b).

2.4 THE SOUTH AFRICAN EXPERIENCE

"Adequate sanitation" has been defined in a Water Research Commission report as "easy access to a toilet facility close to or in the house/institution, where the toilet has been designed and constructed to prevent contact with faeces either directly or through vectors such as flies, and is regularly used by all members of the household/institution" (WRC 1995). The same report also revealed that approximately 95 % of rural domestic households, 90 % of rural schools and 50 % of rural clinics are without adequate sanitation. Another Water Research Commission report (WRC 1993) disclosed that at least 31 % of people living in the urban areas of the country do not have access to adequate sanitation, but that the actual figure is thought to be much higher.

With respect to sanitation provision in rural areas, there has been an almost complete failure to improve the situation in the abovementioned sectors (houses, schools and clinics). Public intervention has been largely restricted to crisis management where sanitation-related disease outbreaks have occurred or threatened. In the past, no government department assumed responsibility for rural sanitation. However, this responsibility has now been accepted by the Department of Water Affairs and Forestry, while the Department of Health is responsible for the health component of a national rural sanitation programme (WRC 1995).

Inadequately maintained sewer reticulation systems in urban areas have caused adverse environmental impacts, most often as a result of leaking or blocked sewers, but also sometimes as a result of overloaded or inadequately operated or maintained treatment works and failed pumping stations. In poor areas especially, most of the operational difficulties are concentrated at the user end of the systems, due to the fact that personal cleaning materials other than proper toilet tissue paper are used, and also due to a lack of education on the proper use of cistern flush toilets (WRC 1993).

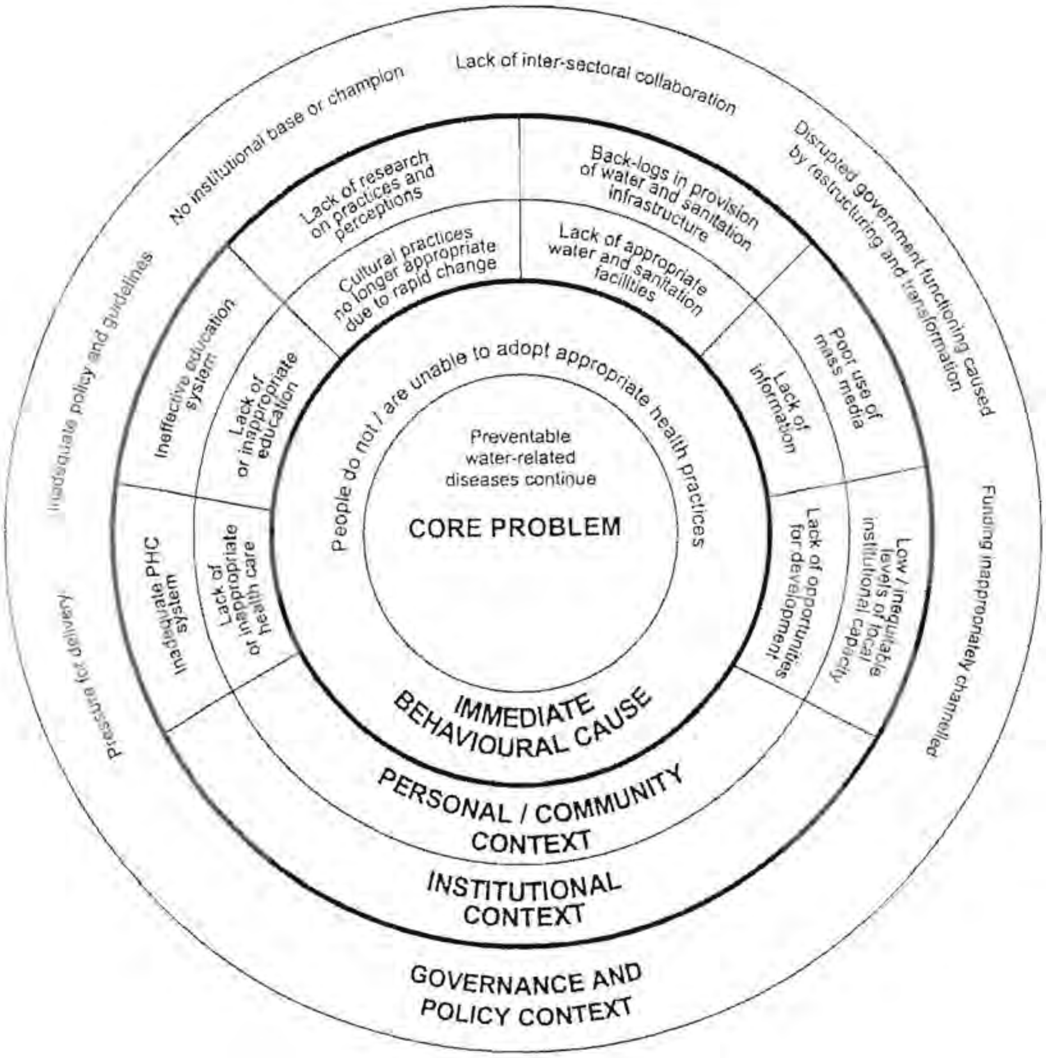
Currently, an estimated 21 million South Africans do not have access to adequate sanitation facilities. The situation is similar to that which exists in many other developing countries, in that it is usually the poorest section of the population that bears the brunt of a non-existent, or at best unsatisfactory, sanitation infrastructure, whether for financial or political reasons. In the past, sanitation provision in South Africa was generally characterised by extreme solutions, with the "privileged" enjoying well-maintained waterborne sewerage systems while the majority had either ordinary pit latrines, buckets or other equally unacceptable systems (Austin 1996).

Even bucket systems require a high level of organisation and funding in order to function properly; however, both were often lacking in many areas. In an attempt to provide a more cost-effective service, efforts were made to introduce other sanitation systems in developing communities, usually without consulting the intended users. The result was all too often a legacy of poorly planned and inadequately maintained systems provided by well-intentioned but shortsighted authorities, who gave very little attention to factors such as environmental impact, social issues, water supply service levels, reliability, upgradability, settlement patterns or institutional needs (Austin 1996). Now, at least, government policy states that the minimum acceptable level of sanitation is a "well constructed VIP toilet".

The link between sanitation and disease was described earlier in this chapter. However, there is still a lack of an integrated strategy for water- and sanitation-related health education and promotion in South Africa and, as a result, the problem merely continues to exist. In-depth research has brought to light a multi-level analysis of the problem, the components of which are illustrated in Figure 2.2 and described briefly below (HEATT 1997):

- The **core problem**, which continues to exist unabated, is that every year there are 1,5 million cases of diarrhoea in children under the age of five, while millions more suffer from diarrhoeal diseases.
- The **immediate behavioural causes** are people's inadequate health and hygiene practices.
- The **personal / community and institutional contexts** refer to the opportunities, resources and constraints that people experience in their lives. These could be economic, socio-cultural, political, or related to gender, class or race, and are also associated with a lack of a comprehensive primary health care (PHC) system.
- The **governance and policy context** relates to the fact that the country has been going through a period of rapid change, with attendant upheaval, complexity and confusion as a result of the major national re-focus of development policies and strategies.

It is seen that, at all levels, the problem is related to socio-cultural, educational and institutional issues, with the lack of appropriate facilities and inadequate guidelines being a contributory factor. New approaches need to be initiated, and technologies that support alternative sanitation efforts should be developed.



Note: PHC = primary health care

Figure 2.2: A multi-level analysis of the sanitation problem in South Africa
(HEATT 1997)

To redress existing inequalities the post-1994 government has developed a national sanitation policy, whereby it is made clear that sanitation is not simply a matter of providing toilets, but rather an integrated approach which encompasses institutional and organisational frameworks as well as financial, technical, environmental, social and educational considerations. It is recognized that the country cannot afford to provide waterborne sanitation for all its citizens, nor, for that matter, should it necessarily aspire to do so. The emphasis has shifted to promoting other "intermediate" technologies instead (Austin 1996). The government also realises that the question of sanitation, perhaps more than most development issues, needs to be seen in the context of an integrated development strategy. Water supply and sanitation are unavoidably linked to the broader development process: sanitation affects, and is affected by, a wide range of issues (DWAF 1996).

2.5 THE WAY FORWARD

It is clear that sanitation is an extremely complex issue. It is an issue which impacts on the daily lives of every human being inhabiting this planet, particularly in the developing countries where the level of service is either poor or nonexistent. There is no single solution that can be applied as a universal panacea, and the situation will continue to worsen unless new approaches are adopted. What then, should be the approaches to addressing the problem, with specific reference to the low-income communities in South Africa?

It is wrong to imagine that simply through construction of toilets, or even the use of toilets, that health conditions will improve. Hygiene is a major issue. Sanitation is not more toilets, but rather the introduction of a new way of life through education, behavioural change and personal hygiene practices. Improved sanitation is also a **process**, not a top-down decree. People must be consulted seriously and involved in sanitation programmes, from planning to implementation and follow-up (de Jong 1996). The technology should also be suitable for local environmental conditions, keeping in mind that urban and rural needs usually differ.

Simpson-Hébert (1996) proposes a number of interrelated guiding principles:

- Incremental change, one step at a time, is more sustainable than the wholesale introduction of new systems.
- Political commitment at all levels is a prerequisite for sanitation promotion. Communities seem more likely to be enthusiastic about a sanitation project they know has strong political support.
- The sanitation sector must continue to innovate low-cost sanitation facilities for people with different needs, from different climates, and with different customs. It is wrong to choose one or two technologies and push them as "the solution". A particular product may be right for a certain section of the market, but not for all consumers and conditions. More research and better designs are still needed.
- There is a need in some societies to recycle human waste as fertiliser, as has been done for centuries in various parts of the world. Human waste can be rendered harmless, and toilet designs that do this in harmony with agricultural and social customs hold promise for the future.

- Toilets are consumer products: their design and promotion should follow good marketing principles, including a range of options with attractive designs based upon consumer preferences, and also be affordable and appropriate to local environmental conditions.

Two major constraints to providing improved sanitation, which need to be addressed, have been identified by Simpson-Hébert (1997), namely, myths and the poor status of the sanitation sector:

Myths:

The first myth is that safe water alone will ensure better health. Since the key to health is pathogen control, it has been proven that for the control of diarrhoeal and other excreta-related diseases, safe excreta management and good hygiene behaviour are at least as important as access to safe water.

The second myth is that large quantities of water are needed for safe excreta management. While it is necessary to have water for personal and domestic hygiene, improving management of human excreta need not wait for improvements in water supply.

The third myth is the assumption that the only good sanitation system for urban areas is conventional waterborne sewerage. This is compounded by the belief that an entire urban area should have the same sanitation system, despite differences in physical and socio-economic conditions which may exist.

Poor status of the sanitation sector:

By associating sanitation with human faeces rather than public health and, more recently, with low-cost services for the poor, the technological approach has contributed to the dismal image of the sanitation profession. The technological approach on its own has ignored the social and behavioural dimensions of improved public health, and therefore lacks a sense of responsibility for the larger issues.

Meagre investment in research and development has contributed to sanitation's poor profile. The sanitation field is also not appropriately represented in academic institutions. Furthermore, the people most in need of improved sanitation services, the poor, have the least voice and limited ability to influence decision-makers to make sanitation a public health priority.

Simpson-Hébert (1997) further emphasises that the approach to the sanitation challenge should be human-centred and ecologically sustainable. It should be concerned with equity, protection of the environment, and the health of both the user and the general public:

> *Equity*, within the sanitation sector, means that all segments of society have access to safe, appropriate sanitation systems adapted to their needs and means. Currently, inequities are found at many levels, between rich and poor, men and women, and rural and urban.
>
> *Protection of the environment*, within the sanitation sector, means that future sanitation systems must neither pollute ecosystems nor deplete scarce resources.
>
> *Health promotion and protection from disease*, within the sanitation sector, means that systems should be capable of protecting people from excreta-related diseases as well as interrupting the cycle of disease transmission.

Sanitation programmes that fulfill all these principles simultaneously should lead to long-term sustainability. Simpson Hébert (1997) makes the following recommendations for implementing sanitation programmes:

- impetus should be provided for research and development for a range of systems applicable to differing cultural and environmental conditions;
- sanitation should be treated as a major field of endeavour in its own right, with sufficient levels of investment to revitalise training programmes and professional standing;
- a demand should be created for systems that move increasingly toward reuse and recycling of human excreta; and
- people for whom the systems are being built should be involved in the design process.

The International Water and Sanitation Centre (IRC 1999) makes it clear that there has been too much focus on providing clean water at the expense of proper sanitation. It is now widely realised that the most effective way of reducing water- and sanitation-related diseases is the safe disposal of excreta. This calls for special approaches to motivate people, that they use toilets, that the toilets are suitable for local conditions, and that people are willing to pay for, construct and manage them.

The Water Supply and Sanitation Collaborative Council Working Group on the Promotion of Sanitation (WSSCC 1998a) maintains that certain constraints to progress in the sanitation sector need to be urgently addressed, for example:

- Institutions responsible for water and sanitation service deliveries in most developing countries operate in an uncoordinated and inefficient way, leading to poor institutional management and low cost recovery;
- networking with key sectors (e.g. health and nutrition, education, environment) has not been given sufficient attention, resulting in a lack of synergy, information sharing and exchange of experiences; and
- the sector has not responded adequately to the problems of urbanisation, resulting in grossly inadequate services to residents of peri-urban areas and informal settlements.

Many urban areas in developing countries are served by on-site excreta disposal facilities, such as septic tanks for example, yet much of the faecal sludge produced, collected and disposed of within these areas remains unaccounted for. Haulage of relatively small volumes of sludge by motorised vacuum tankers over long distances through urban agglomerations is neither an economically nor ecologically sustainable solution. New excreta collection, transport and treatment concepts will therefore have to be developed in conjunction with sanitation systems selected or adapted to suit the varying socio-economic conditions of urban populations. It is of key importance to minimise the haulage of sludge, while at the same time guaranteeing safe sludge treatment and disposal. Furthermore, accessibility of septic tanks for emptying vehicles could be improved by locating them at easily accessible sites (Strauss, Heinss and Montangero 1999).

It is also of the utmost importance for development agencies to collaborate closely with communities, not only at the inception, but throughout all stages of a development project. This participation by the community should be coupled with capacity building through training. People should remain central to the process, and development should not be focused on the economic dimension alone. Due to the demand for delivery during the last decade, as well as a lack of skills within the communities, community participation was neglected in most projects. Community participation in new projects should be coupled with capacity building through training. Capacity building within the communities, as well as in the local authorities and institutions, is of major importance in the transfer of any technology and is the crux of sustainability of projects or services (Duncker 1999b).

With the continuous growth of urban populations and the high incidence of low-income people living in slums and peri-urban squatter areas, there is no possibility of providing conventional waterborne sewerage to all the urban inhabitants who are currently without adequate sanitation. Other systems have to be employed. Ideally, they should provide the same health benefits as waterborne sewerage but remain affordable to poor people. They should operate well without piped water and provide as great a convenience for users as possible. They should also be simple and reliable to operate and maintain (Cotton et al 1995).

Sanitation approaches based on flush toilets, sewers and central treatment plants cannot solve the sanitation problem. Nor can the problem, in high-density urban areas, be solved by systems based on various kinds of pit toilets. There exists an erroneous assumption that the basic problem is one of "sewage disposal", while in actual fact the problem is the disposal of human faeces and urine, not sewage. This is because the human body does not produce "sewage". Sewage is the product of a particular technology. To handle faeces and urine separately is not a great problem, as each human produces only about 500 litres of urine and 50 litres of faeces per year. The problem only arises when these two substances are mixed together and flushed into a pipe with water to form sewage (Winblad 1996a & 1996b).

While "conventional" sanitation options may be suited to certain situations, in other circumstances where both water and space are scarce there is a clear need for permanent, emptiable toilets which do not require water. Such circumstances are becoming increasingly common. When limits are placed on other variables, such as money and the depth of the water table, the circumstances where options such as sewers and pit toilets are viable become fewer, while the need for permanent, emptiable, waterless toilets grows (Dudley 1996).

Methods of providing good sanitation without the concomitant use of large volumes of water should be sought. Based on recent trends in water use and population growth, availability and utilisation of water have been projected to the year 2030. The results show that South Africa will reach the limits of its economically usable, land-based fresh water resources during the first half of the twenty-first century. A greater emphasis should therefore be placed on water conservation coupled to the most beneficial use of this scarce resource. This should be combined with a comprehensive programme to instill in the public an appreciation of the true value of water and the importance of a changed approach to water utilisation countrywide (DWAF 1997a). Alternative sanitation technologies which support this approach are an important component of the overall strategy.

CHAPTER 3

THE NEED FOR ALTERNATIVE SANITATION TECHNOLOGIES IN SOUTH AFRICA

"Science and technology are neither hostile nor friendly towards human development. They provide tools, and it is the way in which these tools are used by decision-makers, politicians and others that determine whether they are destructive or constructive. The mistake made by scientists, technologists and engineers is that they have not educated people on how to use the tools they have created and the implications of the various uses."

UNCHS, Habitat II: City Summit, Istanbul, June 1996

CHAPTER 3: THE NEED FOR ALTERNATIVE SANITATION TECHNOLOGIES IN SOUTH AFRICA

3.1 BACKGROUND

The importance of a sanitation system being appropriate for a particular project has been incontrovertibly established. What makes a system appropriate depends on a number of factors, with the actual technology itself being, in most cases, less important than the socio-cultural factors involved. Given South Africa's limited financial resources, as well as the urgent need to conserve water and protect the environment, it is essential to look beyond the current restrictions for innovative ways and means of bringing adequate sanitation to the millions of people currently without access to proper facilities. Chapter 2 sketched a broad picture of the existing situation in South Africa and various other developing countries, and provided some pointers for future action, for example:

- research and development for a range of different cultural and environmental conditions is required;
- a demand for systems which reuse or recycle human excreta should be created;
- there should be broad consultation with the people for whom the systems are being built;
- it is necessary to reduce the dependence on sanitation systems which use large amounts of (potable) water;
- capacity should be built within institutions and communities to facilitate the transfer of technology;
- systems should be promoted which are simple, reliable and easily maintained; and
- there is a need to move away from the current fixation with providing either full waterborne sanitation or VIP toilets.

It is necessary to examine some of these factors in more detail in order to develop an understanding of the type of thinking required to develop suitable alternatives to the status quo. Some important principles emerge from the discussion below.

3.2 CULTURE AND SANITATION

3.2.1 Social development perspectives

The days of solving water supply and sanitation problems with concrete and pipes alone are over. Integrated approaches to water supply and sanitation now have people at the centre. A social development perspective, which supports this approach, means understanding and involving users and responding flexibly towards their concerns. Social development objectives in water supply and sanitation should therefore ensure that dialogue and interventions are responsive to demand, reach poor or disadvantaged populations, promote empowerment and ownership, and recognise the different needs of men and women (DFID 1998).

The priorities of donors and governments do not always coincide with those of primary stakeholders – men and women in rural and urban communities, particularly the poor. In the past, the practice of water supply and sanitation provision hardly ever involved consumers in decision-making and management. Recipients of water supply and sanitation projects were referred to as *beneficiaries*, and assessment of needs was not made on the basis of wide consultation and participatory methods. As a result, the services provided often did not reflect user preferences, were not maintained, and were used inappropriately (or not at all), thus reducing potential benefits. It is now accepted that, for reasons both of equity and efficiency, programmes and projects need to be responsive to people's felt needs and based on genuine demand. Assessing these factors before project preparation and design helps achieve interventions that are socially acceptable (DFID 1998).

3.2.2 Cultural beliefs and practices

Excreta disposal, especially in rural areas, is far more complex socially than it is technically, and it is not appropriate to assign total responsibility for sanitation programmes to engineers (Feachem and Cairncross 1978). The introduction of on-site sanitation systems, for instance, is much more than the application of simple engineering techniques. It is an intervention that entails considerable social change. If sanitation improvements (in both rural and urban areas) are to be widely accepted, the relevant social and cultural factors have to be taken into consideration during planning and implementation. It is therefore necessary to understand how a society functions, including the communities and households within it, and what factors promote change (Franceys, Pickford and Reed 1992).

Culture shapes human behaviour in many different ways, including what is deemed to be acceptable personal and social behaviour. As regards sanitation behaviour, defecation is usually a private matter which people are unwilling to discuss openly. Contact with faecal matter is unacceptable to certain individuals in societies where it is the responsibility of low-income or low-caste groups, while taboos may dictate that separate facilities should be provided for particular social groups (Franceys, Pickford and Reed 1992; WRC 1995). The latter issue was clearly illustrated during the planning of the urine diversion sanitation project in Eastern Cape, discussed later in this dissertation. It became evident during the community workshopping process that, in those particular communities at least, use of the same toilet by a man and his daughter-in-law was considered to be socially unacceptable.

Social issues include, among other things, the attitude to defecation, and even the physical location of a toilet is important. Furthermore, issues such as preferences for sitting or squatting may also influence the technology choice. As social practices and preferences are likely to vary considerably from area to area, universal approaches to issues such as technical choice are likely to be inappropriate (WRC 1995).

One cultural practice which has direct technical consequences for consideration by the engineer, however, is the method of personal cleansing employed by the toilet users. Whether water, stones, mealie cobs or thick pieces of paper are used will affect the design of the sanitation system (Franceys, Pickford and Reed 1992). Measures to mitigate the effects of practices other than the use of soft tissue paper therefore need to be considered and taken into account in the technical approach to the provision of sanitation in a community. The approach is likely to differ between wet and dry sanitation technologies.

3.3 COMMUNITY EMPOWERMENT AND INSTITUTIONAL CAPACITY

For many years sanitation projects focused on purely numerical targets, such as the number of facilities installed. More recently, attention has turned towards the need to ensure that sanitation efforts are **sustainable** – not only in terms of maintaining the installed facilities, but also ensuring that the people are empowered with the necessary information and sense of ownership to **effectively use and manage those facilities**. This new emphasis has meant that sanitation efforts have changed to incorporate more participatory methods, with local communities playing a larger role in the design and management of sanitation projects (WSSCC 1998b).

The sustainability of a sanitation project can be heavily influenced by the development of a hygiene education strategy that focuses on personalised education for all family members through home visits, participation of organised women in the implementation of the whole education process, and educational materials as well as monitoring and evaluation instruments which are easy to use. The problems experienced with certain sanitation technologies, for instance some types of dry sanitation, are not the technology itself, but rather the interaction between the technology and the user. The need to achieve behavioural changes, as well as proper use and maintenance, is of vital importance (Gough 1997).

In South Africa it is essential to understand the attitudes and behaviours of developing communities towards water supply and sanitation. Most developing communities rely on the government to make sure that their projects are sustainable, but it is also necessary for the community to contribute towards the sustainability of their projects. This requires effective complementary inputs such as community participation, community capacity building and community training (Duncker 1999a). Any sanitation improvement programme should include resources to develop the necessary institutional capacity to manage the ongoing programme and future operational needs (DWAF 1996).

The type of institutional setup for delivery, as well as for operation and maintenance, has a major influence on the choice of sanitation technology. The simpler the system technically, the easier it is to operate and maintain, and the lower the institutional support requirements. However, even "simple" systems such as VIP toilets need a certain amount of institutional support, for example, the setting up of production centres for basic components such as slabs and pedestals, training of builders and monitoring of construction (WRC 1995). Desludging of full pits generally also requires some form of institutional assistance.

More complex systems may require substantial institutional support, which may not be available in rural areas. This is especially true where people with technical skills are required for operating and maintaining the system. Therefore, if the users will be without much institutional support, then the technology chosen should be as robust and durable as possible. In each situation, an analysis of the institutional requirements and the extent they will be available in an area will have to be made before a technology is chosen (WRC 1995).

Given the different stages of development of local government in South Africa, it is clear that institutional arrangements will vary in several ways. Approaches in developing areas will be different from those in established areas, and rural areas will generally have different requirements from urban areas (DWAF 1996).

3.4 TREATMENT AND DISPOSAL: CATEGORIES OF SANITATION TECHNOLOGY

Research by the World Bank has shown that the possession, proper use and maintenance of a sanitation facility is more important, in terms of improving health, than the actual sanitation technology employed, provided of course that it is affordable and socio-culturally acceptable (Mara 1996). The technical objective of sanitary excreta disposal is to isolate faeces so that the infectious agents in them cannot reach a new host. The method chosen for any particular area will depend on many factors, including the local geology and hydrogeology, the culture and preference of the communities, the locally available raw materials and the cost (Franceys Pickford and Reed 1992).

Basically, there are two ways to handle human waste. It can either be treated on site before disposal, or removed from the site and treated elsewhere. In either case, the waste may be mixed with water or it may not. On this basis the following four groups may be distinguished (CSIR 2000):

Group 1: No water added - requiring conveyance
Group 2: No water added - no conveyance
Group 3: Water added - requiring conveyance
Group 4: Water added - no conveyance.

Table 3.1 illustrates the sanitation systems associated with each of the above groups. It should be noted that some of the systems fall somewhere between the four categories as, for example, where solids are retained on site (primary treatment) while the liquids are conveyed elsewhere for secondary treatment (e.g. a settled sewage system), or where water may be added but only in small quantities. Since increasing the number of categories would complicate the table unnecessarily, these systems have been included in the categories which best describe the treatment of waste (CSIR 2000).

Table 3.1: Categories of sanitation systems (based on CSIR 2000)

	Off-site treatment: requiring conveyance (treatment at central works)	**On-site treatment: no conveyance (treatment, or partial treatment, on site)**
No water added	**Group 1** Chemical toilet	**Group 2** Ventilated improved pit toilet Ventilated improved double-pit toilet
Water added	Full waterborne sanitation Flushing toilet with conservancy tank Settled sewage system	Flushing toilet with septic tank and drainfield Aqua- privy toilet Pour-flush toilet

The operating costs of systems in which waste is conveyed and treated elsewhere can be so high that these systems may in the long term be the most expensive of all. The capital and installation costs of any conveyance network which uses large quantities of potable water to convey small quantities of waste are very high, and a possibly inappropriately high level of training and expertise (for the particular case under consideration) may also be required to construct and maintain such systems. A system that may be appropriate in one community may be a total failure in another because of cost, customs and religious beliefs, or other factors. Furthermore, merely because a particular technology has been traditionally implemented by developers or authorities, does not mean that it should be seen as the correct solution (CSIR 2000).

The disposal of human waste, whether on-site or off-site, needs to take into consideration the effect on the environment as well as the effect on people. It is not only the pathogen content of excreta that is of importance – the chemical composition of wastewater also requires assessment. Nitrate content, in particular, is important because of the possible effects of its accumulation in both surface and groundwater, on human health (methaemoglobinaemia in bottle-fed infants), and on the ecological balance in waters receiving runoff or effluent with a high concentration of nitrates. Although the major human activity resulting in the increase of nitrate levels is the use of chemical fertilisers, poor sanitation can contribute to this, particularly in groundwater (Franceys, Pickford and Reed 1992).

3.5 OPERATION AND MAINTENANCE ASPECTS

All sanitation technologies have certain negative aspects. These vary according to the specific conditions, both social and environmental, under which each type of sanitation system operates. In chapter 2, a broad background of the current sanitation problem was sketched, and it was made clear that, while improving the situation is not merely a matter of building more toilets, there is a definite need for new approaches and methods.

Proper operation and maintenance is an integral part of an efficient sanitation system. This applies to all systems, but becomes increasingly important as one moves up the sanitation hierarchy. At the top end, with full waterborne sanitation for instance, insufficient attention to operation and maintenance can have serious health and environmental consequences (WRC 1995).

The most common cause of breakdown in toilets is the false, but all too general, impression that once installed they may be left to take care of themselves. Even the best excreta disposal facilities, whether they serve large communities or single families, require some supervision and maintenance. Poorly-maintained toilets may be worse than none at all, especially if they lead people to associate toilets with filth (Feachem and Cairncross 1978).

This dissertation describes, in the following chapters, two new approaches to sanitation provision in which the operation and maintenance aspects are greatly simplified. The first represents an improvement on an ordinary settled sewage scheme, which is a wet system, and the second an alternative to a VIP toilet, which is a dry system. Chapter 1 outlined the basic disadvantages of each of these technologies, which can be summarised as follows:

Basic disadvantage of settled sewage systems:
The main problem with settled sewage systems is that the interceptor tanks have to be desludged periodically. This may be an extremely difficult task in some situations, and is also relatively expensive.

Basic disadvantage of VIP toilets:
There are two equally important negative aspects here. The first is the fact that geotechnical conditions may make it prohibitively expensive or environmentally inadvisable to dig pits. The second is that, when a pit becomes full it must either be desludged, or a new pit must be dug and a new superstructure erected; both these actions have a direct cost implication.

Desludging is therefore seen to be a common problem with both these technologies, as indeed it is with all on-site systems. Any new on-site technology which can facilitate this task, or eliminate the need for it altogether, will thus be a welcome addition to the range of options currently available. It will also raise the general status of on-site systems, which are often regarded as inferior options because of this aspect. Indeed, many communities perceive anything less than a full waterborne system to be an inferior option.

However, inadequate water supplies alone will preclude the possibility of reliable, conventional waterborne sewerage systems for many cities and communities. Sewers can rapidly block if water is shut off for periods. Communities with waterborne sewerage normally require more than 75 litres per capita per day (lcd), compared with less than 20 lcd used in many informal settlements. Alternative sanitation technologies will increasingly be needed on grounds of water unavailability, lack of construction skills, cost as well as sustainability (Mara 1996). Full waterborne sanitation systems should, furthermore, only be installed where residents are able to afford the full operation and maintenance costs of the system. If this policy is not adopted, the operation and maintenance of these systems will continue to drain fiscal resources, leading to lack of funding allocation and a concomitant rapid decline in the value of the assets (WRC 1993). Local authorities thus risk incurring economic disadvantages where low-income households cannot afford the running costs of an expensive system and extensive subsidies are required. Furthermore, where operational costs are not met for lack of consumer payments or ongoing subsidies, environmental problems and clean-up costs may follow (DWAF 1996).

It is not only local authorities who incur economic disadvantages when high-technology sanitation systems are provided to poor communities. Paying for the water required to operate the systems, as well as for the running of the treatment plants (even if these costs are subsidised) is only part of the equation. The proper operation of waterborne sewerage systems demands that only soft tissue paper be used for personal cleansing, and other materials commonly used by poor people (rags, newspaper, plastic bags, mealie cobs, stones, etc) must be strictly excluded from the systems. This is a rigid requirement which cannot be relaxed, and for millions of poor people it may be impossible to adhere to it. Simply stated, if a person's financial situation is such that he or she has to choose between buying a loaf of bread or a roll of toilet paper, then a waterborne sanitation system is simply not a feasible option, despite that person's aspirations.

While the capital cost of sanitation infrastructure is obviously an important consideration, it is the operation and maintenance costs which have the most influence on the sustainability of a project. Particularly in poor communities, therefore, it is essential to install robust, low maintenance systems, where the total life-cycle costs are minimised without the environment being compromised in any way.

CHAPTER 4

BACKGROUND TO THE "SLUDGE SIPHON" CONCEPT

"There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success than to take the lead in the introduction of a new order of things"

Niccolo Machiavelli

CHAPTER 4: BACKGROUND TO THE "SLUDGE SIPHON" CONCEPT

4.1 BASIC PRINCIPLES OF SETTLED SEWAGE SANITATION TECHNOLOGY

A schematic representation of a settled sewage sanitation system is illustrated in Figure 4.1. The operation of this type of system is based on the use of conventional septic tanks (also called interceptor tanks or digesters). However, instead of the effluent from the individual tanks passing into separate or communal soakaways (drainfields) and percolating into the ground, it is collected via a reticulation system of relatively small diameter pipes and conveyed for further treatment either to a system of stabilisation ponds, a constructed wetland or even a remote treatment plant.

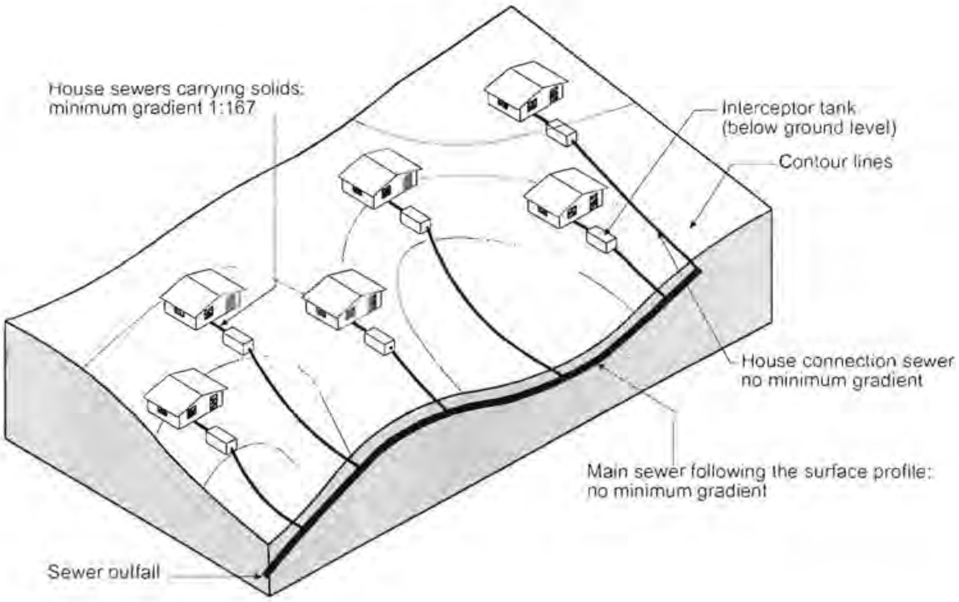


Figure 4.1: Schematic representation of a settled sewage system layout (Reed 1995)

Because the effluent pipes transport mostly liquid, and not the type of solids usually found in waterborne sewerage systems, they may be of a much smaller diameter (often as small as 40 mm). The interceptor tank also attenuates the wastewater flow by providing some surge storage, thereby reducing the peak-to-average flow ratio by more than 60% (USEPA 1991). Larger diameter pipes are only used when hydraulic considerations dictate this.

Furthermore, there may be a certain relaxation of construction standards – pipes may be laid at much flatter gradients and some irregularities in alignment can be tolerated. In Zambia, certain effluent pipes were laid at gradients as little as 1:1 000 and have operated satisfactorily for many years (Austin 1995). Problems eventually occurred in the latter case only because of a lack of regular desludging of the tanks, or because pipelines transporting conventional waterborne sewerage were connected to the settled sewage pipes.

Collector pipes may even be laid at inverse gradients and thus flow under pressure. Unlike conventional gravity sewers which are usually designed for open channel flow conditions, pipelines in a settled sewage system may be installed with sections depressed below the hydraulic grade line (Otis & Mara 1985). Thus, flow may alternate between open channel and pressure flow. Maintenance of strict sewer gradients to ensure the self-cleansing velocities required by conventional waterborne sewerage systems is not necessary. However, the design must be such that an overall fall exists across the system and that the hydraulic grade line does not rise above the outlet invert of any interceptor tank.

Treatment of the effluent from a septic tank is considerably facilitated, as primary treatment has already taken place in the tank (the sewage has been "settled" in the tank and the effluent contains less solids as well as reduced values of COD and other parameters). Table 4.1 gives a comparison between raw wastewater and settled sewage effluent for typical South African municipal conditions.

Table 4.1: Approximate average municipal wastewater characteristics for raw and settled wastewaters found in typical South African wastewater treatment facilities (WRC 1984)

Wastewater characteristic	Raw	Settled
Influent COD (mg COD/ℓ)	500 - 800	300 - 600
Total suspended solids (mg/ℓ)	270 - 450	150 - 300
Settleable solids (mg/ℓ)	150 - 350	0 - 50
Non-settleable solids (mg/ℓ)	100 - 300	100 - 300
Unbiodegradable particulate COD fraction	0,07 - 0,20	0,00 - 0,10

Sections 4.2 and 4.3 which follow hereunder discuss various aspects of the effluent drainage pipes and interceptor tanks in a settled sewage system.

4.2 EFFLUENT DRAINAGE PIPES

4.2.1 Hydraulic design considerations

There are two hydraulic parameters which have to be considered in settled sewage schemes, namely pipe diameters and pipe gradients.

Pipe diameters:

In contrast to conventional sewers, which transport relatively large objects, systems designed to receive wastes from interceptor tanks with a minimum of four to six hours' retention time need not be designed to transport such solids. A minimum pipe size of 75 mm is recommended but smaller pipes may be used provided they can carry the peak flow. However, systems with interceptor tanks designed for 24 hours' retention time may be designed to carry average-day flow rates. A minimum pipe size of 40 mm is usually recommended in these cases, but may be even less. Otis and Mara (1985) assert that the selection of minimum pipe sizes should be based primarily on maintenance conditions and costs, with a minimum of 100 mm being recommended for particular developing countries where specialised equipment for cleaning smaller pipes may not be generally available.

In South African settled sewage systems, the smallest pipe diameters have generally varied between 63 and 80 mm (CSIR 1996).

Pipe gradients:

Pipes exiting from small interceptor tanks can be laid at a minimum slope of 1:220 (Reed 1995). This assumes that the quality of materials and workmanship is good and that the interceptor tanks are regularly desludged. Pipe systems served by large interceptor tanks do not need a minimum gradient: provided there is an overall positive gradient on the system and all interceptor tanks are above the water level in the sewer, the pipe can follow the local topography (Figure 4.1). Short lengths of sewer with negative gradients are acceptable provided they are ventilated (i.e. air valves at high points) and provision is made for emptying. Such systems are completely dependent on regular desludging of the interceptor tanks for their reliability. According to Otis and Mara (1985), high points and points at the end of long flat sections are critical locations where the maximum elevation must be established above which the pipe may not rise. Between these critical points the sewer may be constructed with any profile as long as the hydraulic gradient remains below all interceptor tank outlet inverts.

Conventional sewer design is based on achieving "self-cleansing" velocities during normal daily peak flow periods, in order to re-suspend solids that have settled out in the sewer during low flow periods. However, for pipelines transporting settled sewage, the United States Environmental Protection Agency (USEPA) recommends a minimum flow velocity of 0,15 m/s rather than a minimum pipe gradient (USEPA 1991). The primary treatment provided in the interceptor tanks upstream of each house connection removes grit as well as grease and most settleable solids. Studies have shown that the remaining solids and slime growth which enter the collector pipe system are easily carried out when flow velocities of this magnitude are achieved. It is therefore not necessary to design for self-cleansing velocities as in conventional waterborne sewerage systems.

4.2.2 Pipe materials

Unplasticised polyvinyl chloride (uPVC) pipes similar to those used in potable water supply networks are commonly used. In South Africa, a problem exists because of a lack of pipes and fittings which are specially customised for settled sewage systems. In most cases, therefore, uPVC water pipes and specials have been specified, which are not manufactured to normal sewer configurations, i.e. Y-branches and bends other than 90 degrees (Austin 1996). These generally work without any problems, except that additional access points have to be provided for rodding purposes, and therefore the networks probably cost more than would normally have been the case if these fittings had been available. Cast iron pipes and fittings should not be used due to the septic (and therefore corrosive) conditions which exist in these systems.

4.3 INTERCEPTOR (SEPTIC) TANKS

The following features of interceptor tank design and operation are important:

4.3.1 Operational principles

A typical septic tank is schematically illustrated in Figure 4.2. Generally, the purpose of a septic tank is to receive excreta and other wastes and to treat them in order to provide a satisfactory effluent for disposal into the ground or by other means (Pickford 1980). In a conventional septic tank / soakaway system the aim is to retain as much as possible of the solids in the tank in order to reduce the probability of clogging of the ground around the soakpit. If the effluent is to be transported for further treatment before discharge to surface water or irrigation, the objective is to provide an effluent with the minimum possible proportions of solids, of oxygen-demanding material and of disease-transmitting organisms.

The waste receives primary treatment in the tank itself. Waste material enters the tank, solids separate out to form sludge and scum and a partially-treated effluent is discharged (Pickford 1980). The second stage of treatment is biological breakdown of the effluent which usually takes place as it percolates into the soil from a soakpit. Alternatively the effluent from a large septic tank (such as one serving an institution or a group of houses, for example) may be collected and treated in a trickling filter or other biological treatment process before discharge to a watercourse or irrigation area. In a settled sewage system the effluent often passes to waste stabilisation ponds.

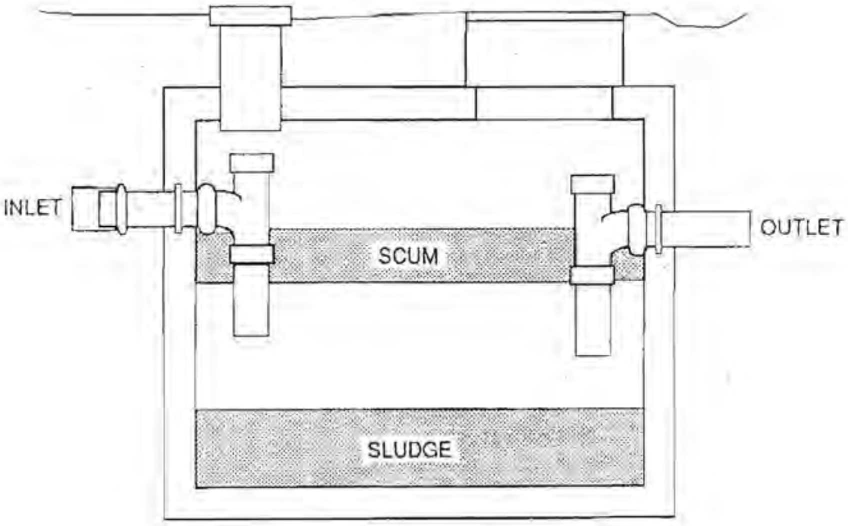


Figure 4.2: Typical interceptor (septic) tank (USEPA 1991)

Composition of sewage:

Most of the sewage entering the tank is water, with each litre of solid matter often accompanied by two or three thousand litres of water (Pickford 1980). The quantity of water used usually depends on the economic level of the household and the availability of water. In developing countries the range may be between 40 and 300 litres per person per day, depending on the level of service of the water supply. Solids entering septic tanks from toilets consist of excreta and personal cleansing material, while bath, laundry and kitchen wastes may also discharge solid material into the tanks. The solids consist of organic and inorganic matter which may be in solution or suspension, and also large numbers of micro-organisms such as bacteria. The organic matter includes carbohydrates and protein in faeces and food scraps, while inorganic matter may include salt and sand.

Solids in sewage:

The quantity of solid excreta (faeces) depends on the person's diet. Pickford (1980) asserts that, for an adult with a diet based on fine white bread, 115 g of faeces are produced per day, while a rice and vegetable diet will produce 410 g. According to Franceys, Pickford and Reed (1992) the amount of faeces and urine excreted daily by individuals depends on water consumption, climate, diet and occupation. Quoted amounts measured in various countries vary between 209 g and 520 g. Jönsson (1997) reports that, in Sweden, faeces represent roughly 10 percent of total daily human excreta (by mass) and amount to between 70 and 140 g; the other 90 percent (approx. 900 to 1 200 g) consists of urine.

4.3.2 Processes within the tank

The processes undergone by sewage in a septic tank are a complex interaction of physical, chemical and biochemical operations. Settlement and digestion take place at the same time.

Settlement of solids:

In still water heavy solids settle to form sludge (Pickford 1980). These may include materials such as sand, stones and ash, commonly used for scouring cooking utensils in lower-income areas. Grease, oils and other light materials rise to the surface to form a floating scum. A layer of liquid, sometimes called the supernatant, is left between the scum and the sludge (Figure 4.2). Very fine particles (colloids) initially stay in suspension, but later coagulate to form larger particles which fall or rise depending on their density. Coagulation is assisted by gases and particles of digested sludge rising through the liquid. Separation is facilitated as temperature rises, but the most important factor is the rate at which the liquid moves through the tank, and this depends on the retention time, as shown in Figure 4.3. It is seen that approximately 65 % of the settlement takes place within about six hours.

The efficiency of solids settlement may be as high as 80% (Franceys, Pickford & Reed 1992). However, much depends on the retention time, the inlet and outlet details and the frequency of desludging. Large surges of flow entering the tank may cause a temporary increase in the concentration of suspended solids owing to disturbance of the solids which have already settled out.

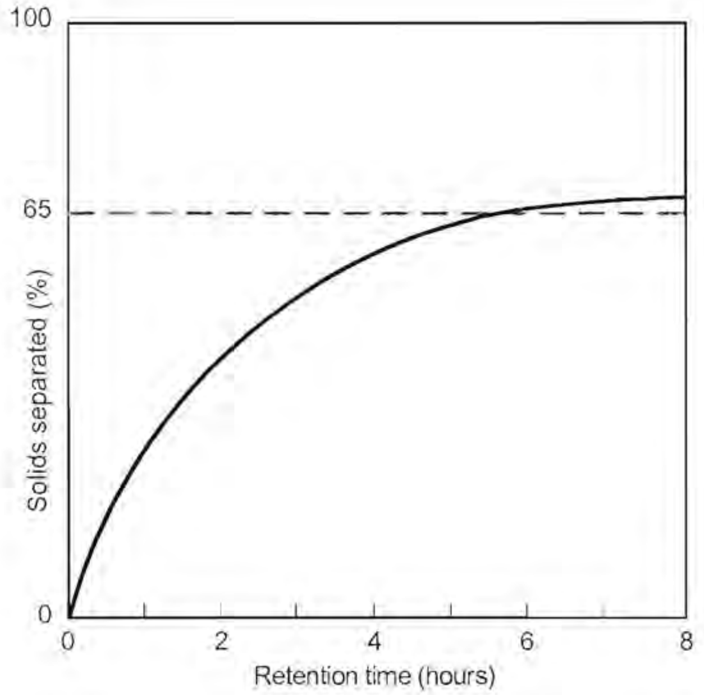


Figure 4.3: Typical relationship between solids separation and time of retention of sewage in a septic tank (Pickford 1980)

Digestion of solids:

Organic matter in the sludge, and to a lesser extent in the scum, is broken down by anaerobic bacteria and mostly converted to water, carbon dioxide and methane (Pickford 1980). The gases rise through the water, taking small particles of partially-digested sludge with them. Digestion is accelerated by an increase in temperature, and so takes place more rapidly (reaching a maximum at 35°C) in the tropics than in temperate climatic zones. During the digestion process the sludge volume is reduced, often by as much as 50 to 80 % (Otis and Mara 1985).

Stabilisation of liquor:

During its retention in the tank, organic material remaining in the liquor is also acted on by anaerobic bacteria, which break down complex substances into simpler ones (Pickford 1980). At first simple hydrocarbons like sugar and starch are reduced to water and carbon dioxide, while ammonia and other compounds containing nitrogen are broken down more slowly.

Mixing:

The flow into a septic tank usually comes in surges, as when a toilet is flushed or a bath or basin is emptied (Pickford 1980). These surges disturb the liquor, especially when the temperature of the incoming sewage is different from the liquor in the tank. According to Pretorius (1997) these disturbances, especially a load of warm water, have a beneficial effect on the rate of digestion.

Growth of micro-organisms:

Many kinds of micro-organisms grow, reproduce and die in the tank. Most are attached to organic matter and so separate out with the solids. Some, accustomed to living in the human intestine, die in the inhospitable environment inside the tank, while some of the heavier ones sink to the sludge layer (Pickford 1980). There is usually a reduction in the total number of micro-organisms present, but generally, viruses, bacteria, protozoa and helminths are present in large numbers in the tank.

4.3.3 Tank geometry and materials

Conventional septic tanks connected to drainfields have commonly been constructed with bricks and mortar, with the inside walls sometimes being plastered and coated with bitumen paint. In the past it was accepted practice to construct tanks with two interconnected chambers, as shown in Figure 4.4. In this case, most of the sludge settles out in the first chamber while the second chamber usually contains liquid only. This prevents drainfields from becoming blocked with sludge, as the outlet pipes are connected to the second chamber. Where settled sewage systems are installed in areas previously served by septic tanks, the practice is usually to modify the outlet fittings, disconnect the pipes leading to the drainfields and connect the tanks to the new reticulation network (Austin 1996).

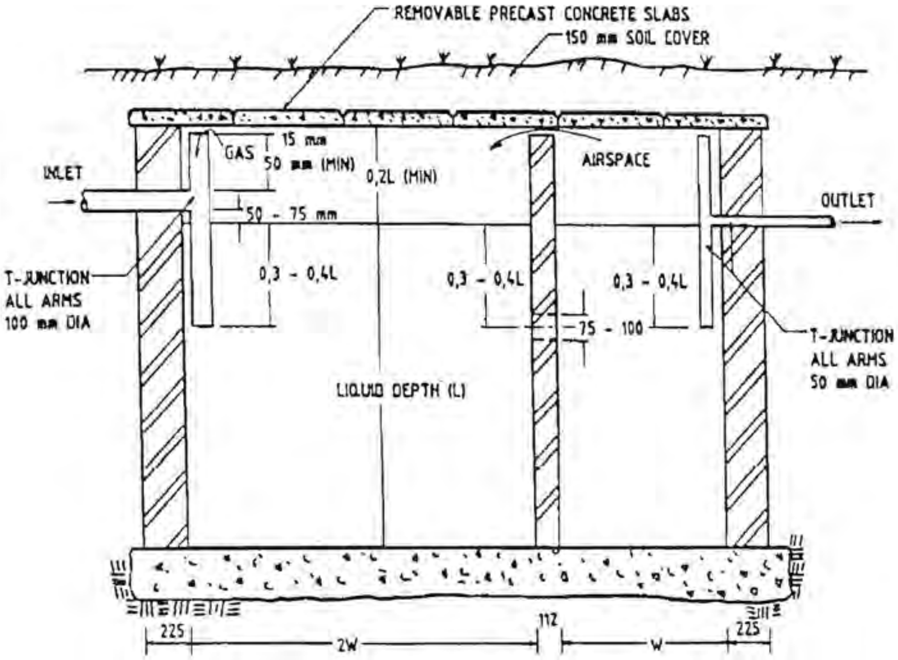


Figure 4.4: Twin-chamber masonry septic tank (De Villiers 1987)

Prefabricated tanks, usually made of moulded polyethylene, are more often used for new settled sewage schemes, due to their ready availability and ease of installation. These commercially available tanks usually consist of a single compartment and are manufactured in various shapes and sizes (round or rectangular), resulting in varying efficiencies which depend on the geometry and hydraulic retention period (Austin 1996). Shallow tanks, or tanks with a greater water surface area for a given volume are preferred designs because of the greater flow attenuation that they provide (USEPA 1991). Shallow tanks also ensure a greater reduction of outflow velocity as well as improved solids retention. However, the liquid depth should not be less than 0,9 m in order to ensure good removal of settleable solids (Otis and Mara 1985).

The preferred shape of an interceptor tank is rectangular with a length to breadth ratio of 2:1, or higher, in order to reduce short-circuiting of the wastewater across the tank, and to improve suspended solids removal (Otis and Mara 1985). The volume should provide sufficient hydraulic detention time for good settling at the estimated daily flow, while reserving a proportion of the total volume for sludge and scum storage. Hydraulic detention times typically vary from 12 to 24 hours. The volume reserved for sludge and scum storage depends on the total quantity of solids which reach the tank daily, the ambient temperature and the frequency of solids removal (i.e. desludging of the tank).

Interceptor tank volume:

Interceptor tanks should be designed to cater for four separate functions (Otis and Mara 1985):

- solids interception;
- digestion of settled solids;
- storage of digested solids; and
- storage of scum.

The expected sewage flow, as well as the rate of accumulation of sludge and scum, should be ascertained before a septic tank can be designed. For residential developments in low-income areas the wastewater flow is usually directly related to the level of water supply in the area, as shown in Table 4.2.

Table 4.2: Estimated wastewater flow in lower-income areas for various levels of water supply (after de Villiers 1987)

Level of water supply	Wastewater produced (litres/person/day)
Public street standpipes, dry sanitation system	12 to 15
Single on-site standpipe with dry sanitation system	20 to 25
Single on-site standpipe with WC connected to water supply (septic tank system possible)	45 to 55
Single in-house tap with WC connected to water supply (septic tank or full waterborne system possible)	50 to 70

In higher-income areas there is often a relationship between the number of occupants in the house and the number of bedrooms, and it is therefore possible to relate the wastewater flow to the number of bedrooms (Table 4.3).

Table 4.3: Estimated wastewater flow in middle to high income areas (after de Villiers 1987)

Size of house	Wastewater produced (litres/stand/day)
2 bedrooms	700
3 bedrooms	900
4 bedrooms	1100
5 bedrooms	1400
6 bedrooms	1600

The rate of sludge and scum accumulation will depend on various factors such as ambient temperature, living standard, diet, health of residents, their occupations and working conditions, etc. Tables 4.4 and 4.5 (de Villiers 1987) give an indication of the variable accumulation rates that may be expected. Recent research (CSIR 1996) has shown that these figures are somewhat conservative, however, and that an average sludge accumulation rate for design purposes in South Africa may be assumed to be 0,08 litres per person per day (about 29 litres per person per year) with no additional provision required for scum.

Table 4.4: Rate of sludge and scum accumulation for low-income areas (based on de Villiers 1987)

Materials used for personal cleansing	Sludge and scum accumulation (litres/person/year)
Undegradable material:	
Toilet wastes only	55
Additional household sullage	70
Hard paper, leaves and grass:	
Toilet wastes only	40
Additional household sullage	50
Water and soft paper:	
Toilet wastes only	25
Additional household sullage	40

Table 4.5: Rate of sludge and scum accumulation for middle- to high-income areas with multiple sanitary fittings (based on de Villiers 1987)

Desludging period (years)	Sludge and scum accumulation (litres/person)
1	85
2	140
3	185
4	220
5	255
6	290
8	360
10	440

Various methods exist for calculating the size of a septic tank to serve a household (or group of households). A common approach is to assume that the sludge and scum are allowed to occupy two-thirds of the tank capacity before being removed, and that the remaining one-third allows for a minimum liquid retention time of 1 day (Pickford 1980). The required capacity is thus three times the daily sewage flow multiplied by the retention time, as illustrated by the following formula:

$$C = 3Prq$$

where
C = tank capacity, litres;
P = number of people expected to contribute to the tank;
r = minimum retention time for sewage in the tank just before desludging (i.e. when tank is two-thirds full of sludge), days; and
q = sewage flow, litres per person per day

Example: For a 1 000 ℓ tank used by 6 persons with an average sewage flow of 60 litres per person per day, a minimum retention period of 1 day and a sludge accumulation rate of 30 litres per person per year, a desludging period of 4 years is obtained.

A large proportion of the tank volume is therefore taken up by accumulated solids, and the longer the anticipated period between desludgings, the larger the tank has to be to cater for this. Obviously, this is associated with an increase in costs, not only for the tank itself but also for the labour and excavation involved in installing the tank.

4.4 THE "SLUDGE SIPHON" HYPOTHESIS

4.4.1 Background

The problems which are often encountered when interceptor tanks require desludging have been described in chapter 1. Consideration of these problems led to the conceptualisation of the "sludge siphon" as a solution.

When interceptor tanks are desludged, the vacuum tankers are supposed to transport the septage (sludge, scum and supernatant) to the municipal treatment works. Some private contractors may, however, illegally empty their loads into the nearest convenient sewer manhole for further waterborne transportation to the treatment works. Depending on the size of the interceptor tanks, the capacity of the vacuum tankers and the operating conditions, the input of energy for desludging the tanks and transporting the septage by road (even for a relatively short distance) may affect the life cycle cost of installing and operating a settled sewage scheme to such an extent that the technology may not be regarded as a worthwhile investment.

Due to the fact that the sludge eventually ends up in the municipal wastewater system in any case, a method has been proposed whereby it can be automatically flushed out of the interceptor tank and into the settled sewage reticulation system, without intervention by a maintenance crew and without conscious thought by the householder. If the sludge can be automatically removed from the tank and transported along the settled sewage network, even for only a limited distance, then the following savings are realistically achievable:

(a) At the very least, there will be no need for vacuum tankers to gain access to individual interceptor tanks, therefore poor roads or densely built-up areas will not be an issue.

(b) If the sludge can be transported hydraulically for a great enough distance, it can possibly be taken all the way to the final treatment works without having to make use of road tankers at all. This would be the best outcome.

(c) Should it not be possible to transport the sludge hydraulically beyond a certain (as yet to be determined) distance, then this maximum transportable distance can be ascertained. This information can then be used for positioning a settlement tank in an easily accessible position (e.g. within the road reserve) from which it will be a simple task to extract the sludge on a routine basis by means of a vacuum tanker. In this way, then, only one or two large collector tanks per suburb might be required, instead of numerous individual ones situated on private property, and could be easily and cheaply serviced.

(d) If any of the scenarios described above are found to be feasible, it is possible that large fleets of vacuum tankers could be reduced, with local authorities requiring less vehicles than would normally be the case. Large financial savings could thus be realised and the operation and maintenance of settled sewage schemes could become an even more attractive option, with concomitant benefits for society.

It is important that any system purporting to do this should perform its task automatically, without conscious thought or effort by the householder. The system should also preferably operate without any additional plumbing fixtures needing to be fitted into the house and without additional use of water, i.e. beyond that which the householder would use in the normal course of events. The system should therefore be self-contained and self-activated, if possible.

4.4.2 The proposed concept

If the configuration of the outlet pipes can be arranged in such a way that a natural siphon is created, as illustrated in Figure 4.5, then it should be possible to activate such a siphon automatically by simply passing a large enough quantity of wastewater at a sufficiently rapid rate into the tank. The rate of incoming wastewater will initially need to be sufficiently greater than the rate exiting via the outlet pipe in order to allow the water level to rise above the summit of the siphon This siphonic action should then draw the septage from the tank and discharge it into the outlet pipeline. The rate and velocity of flow should be sufficient to keep the sludge in suspension.

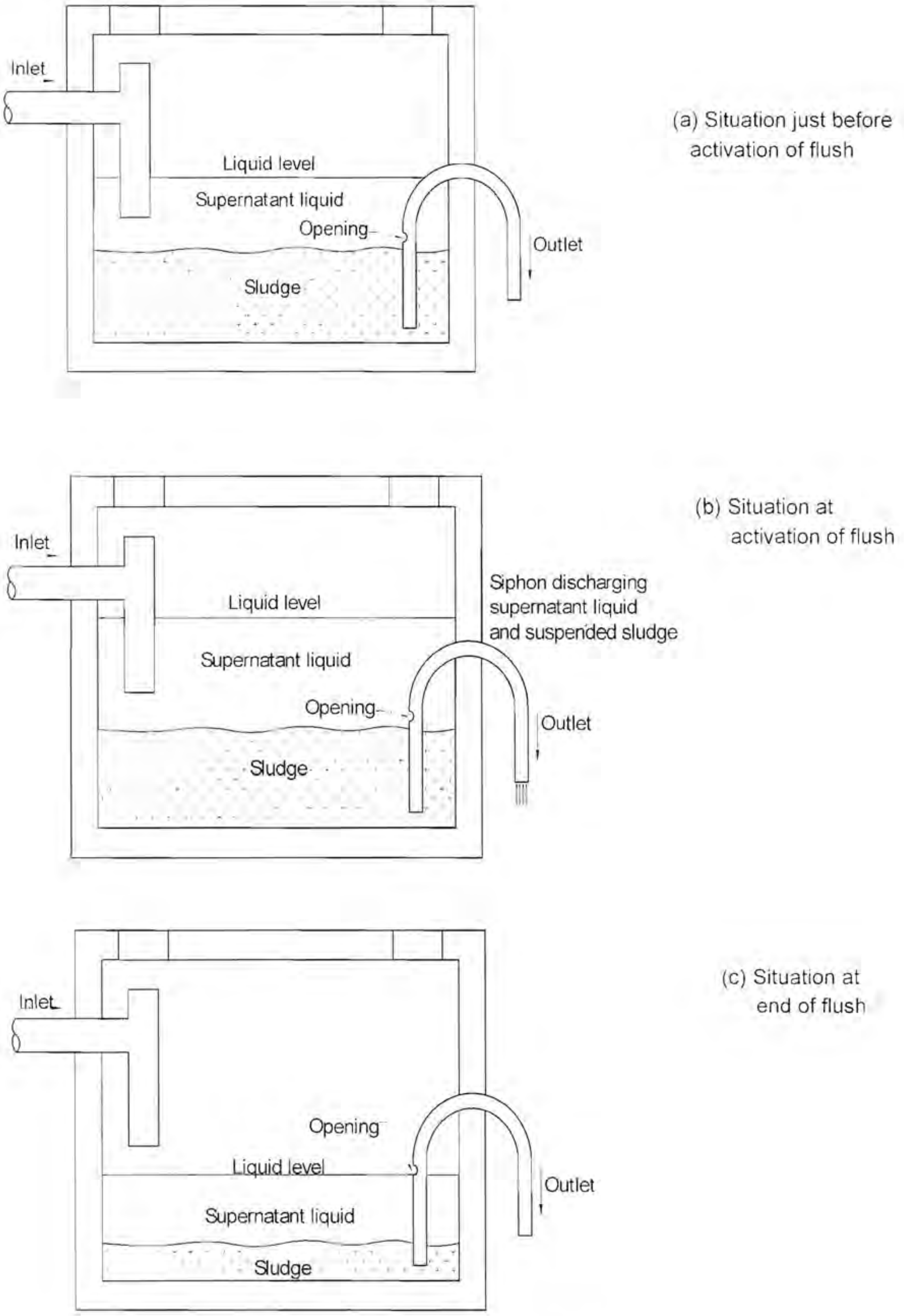


Figure 4.5: Definition sketch for the investigation: Automatic desludging of an interceptor tank by siphonic action

In the situation illustrated by Figure 4.5 (a) the liquid in the interceptor tank is at the normal equilibrium level, i.e. where any further input into the tank will cause effluent to flow via the outlet pipe into the settled sewage reticulation system. Should a relatively large inflow of wastewater enter the tank rapidly enough so that the level of the liquid has an opportunity to rise above the summit of the siphon, then the siphon should theoretically be activated and start emptying the effluent, including sludge, from the tank. This is illustrated in Figure 4.5 (b). Moreover, the siphon should continue discharging until the lower pressure at the summit, which produces the flow, is nullified by the entry of air into the system via the hole in the internal siphon leg (Figure 4.5 (c)). Note that the actual design of the prototype system, described in section 6.7 of this dissertation, prevents the air hole from becoming clogged with scum or other floating matter.

Because domestic septic tanks are usually designed so that up to two-thirds of the volume can be occupied by accumulated solids before they require desludging (see section 4.3 above) they are commonly 1 750 ℓ to 2 000 ℓ in size. It is rare that they are less than 1 000 ℓ. Tanks smaller than this will require desludging too frequently and thus not be an economical proposition. It is therefore also postulated that, should the proposed sludge siphon be found to be a feasible option, then interceptor tanks fitted with this device could be very much smaller, as no space would be required for storage of sludge. The sludge would be withdrawn from the tank before it has an opportunity to accumulate. This would have definite and sizeable cost advantages, not only for the householder but also for the local authority. The householder will only need a tank large enough to provide a hydraulic retention period sufficient to ensure adequate separation of solids in the wastewater, and will thus save on the purchase and installation costs. The local authority will derive the benefit of seldom, if ever, having to send a vacuum tanker and maintenance crew to desludge the community's interceptor tanks – these will only be needed for routine maintenance work or for emergency situations such as blockages or other problems which may occur in the settled sewage system.

It is unlikely that the quantity of influent produced by an ordinary flushing toilet will be sufficient to activate the siphon, as even a 10 ℓ flush entering a 1 000 ℓ septic tank will only raise the liquid level by between 10 and 13 mm, depending on the shape of the tank, while outlet pipes are usually not less than 40 or 50 mm in diameter. Therefore the system design should be such that it can be activated by either a bath or a washtub being emptied into the tank. For a dwelling with in-house plumbing fixtures this should be easily achieved. However, where the level of service is such that there is no in-house plumbing and where the toilet and septic tank are separate from the dwelling, then the minimum requirement will be a washtub attached to the toilet structure, with the outlet drain discharging directly into the septic tank. Systems such as these are fairly common in South Africa, as illustrated in Figure 4.6.

Figure 4.6: Typical washtub attached to exterior toilet with outlet discharging directly into septic tank (aqua privy). Thusang (Northern Province)