Chapter 2: Literature Review

2.1. Introduction

The primary aim of what is discussed in this thesis is the improvement of the quality of life in low-income communities. However, quality of life is a vague concept and things that may be vitually important for one group of people may have no effect on other groups.

An example of this may be given by comparing the worries related to the health problems of two distinct populations: (1) poor people living in low-income areas of developing countries, and (2) people living in areas where infrastructure services are not a problem (a common situation in developed countries). Whilst the latter group nowadays worries about non-communicable diseases (such as cardiovascular diseases, cancer and stress), which have indeed increased in importance, the former group is still dying from diseases such as diarrhoea and helminthic infections that may be avoided through better environmental conditions and healthier hygiene habits.

Thus, quality of life may be a function of the condition which people are living under as well as of their expectations for improving these conditions. Therefore, this relative concept would be more accurately defined by the communities themselves rather them by any provider of developmental interventions. Nevertheless, infrastructure services resulting in environmental improvements, more specifically (for this study) sanitation services, are believed to be of great impact on the quality of life of low-income communities in developing countries.

Thus, in this chapter, aspects related to the health of the poor are reviewed, focussing on the sustainability of sanitation programmes designed for low-income communities.

2.2. Relation between Sanitation, Public Health and the Environment

2.2.1. The Environment and Diseases

Anthropogenic changes in the environment have influenced the development of a wide range of diseases. As creatures that are constantly interacting with their surrounding area, humans may be the biggest beneficiaries and sufferers from their own imposed environmental modifications.

The effects of the environment on public health may be closely related to the economical status, nature of work, place of living, habits and traditions of people, who usually modify their immediate environment to seek a more comfortable life, although this does not necessarily or always mean a healthier life.

In Murray *et al*. (1993), three large groups of causes-of-death and diseases were defined: communicable, maternal and perinatal (group I); non-communicable (group II) and injuries (group III). In all of these three groups, the causes-of-death and diseases can also be associated with the characteristics of the environment in which people are living. For example, changes in the environment for the provision of proper housing or sanitation facilities may avoid the spread of communicable diseases. On the other hand, environmental pollution due to industries or traffic may contribute to the onset of non-communicable diseases, and also injuries may result from unintentional accidents in the housing, working or leisure environments.

Figure 2.1. shows the fraction of diseases attributed to environment related aspects. Therefore, diseases such as diarrhoea and malaria have 90% of their burden attributed to environmental causes.

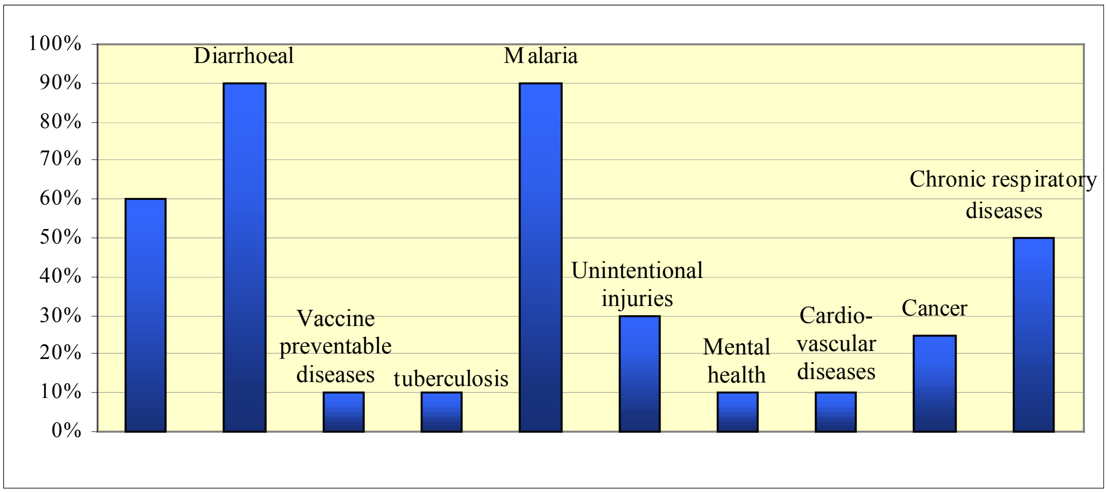


Figure 2.1. – The environment and the burden of diseases *(adapted from DFID, 2000)*

In the specific case of water- and excreta-related diseases, the most accepted classification is related to the environment that promotes the transmission of these diseases (Feachem, 1977; Mara and Feachem, 1999). Moreover, another proposed version of the environmental classification of diseases suggests two transmission routes: the domestic and public domains (Cairncross *et al.*, 1996), dividing the transmission of diseases into the family (private) and the public environments.

Thus, the above examples emphasise the relationship between the environment and diseases. The main importance of this is that once the environment is accepted as a source of diseases, the implementation of disease barriers may be focused on modifications of the environment (preventive) instead of just being concentrated on patients (curative). Cairncross (URL-26, 1999) emphasises, in an example of children treated with drugs against intestinal worms, that treatment is not a sustainable option as the children are quickly reinfected, and the author indicates an environmental intervention (sanitation, in this case) as the sustainable option.

2.2.2. Disease Classification

As suggested previously, diseases may be classified according to the environmental promotion of their transmission rather than by their causative agents or by their effects on patients. Therefore, environmental classifications of diseases are based on the possible transmission routes for the transportation of the causative agents from the environment to people.

Although there are a number of potential routes for the transmission of diseases, the faeco-oral routes are of the highest importance in public health. Figure 2.2 illustrates the four possibilities of faeco-oral infections.

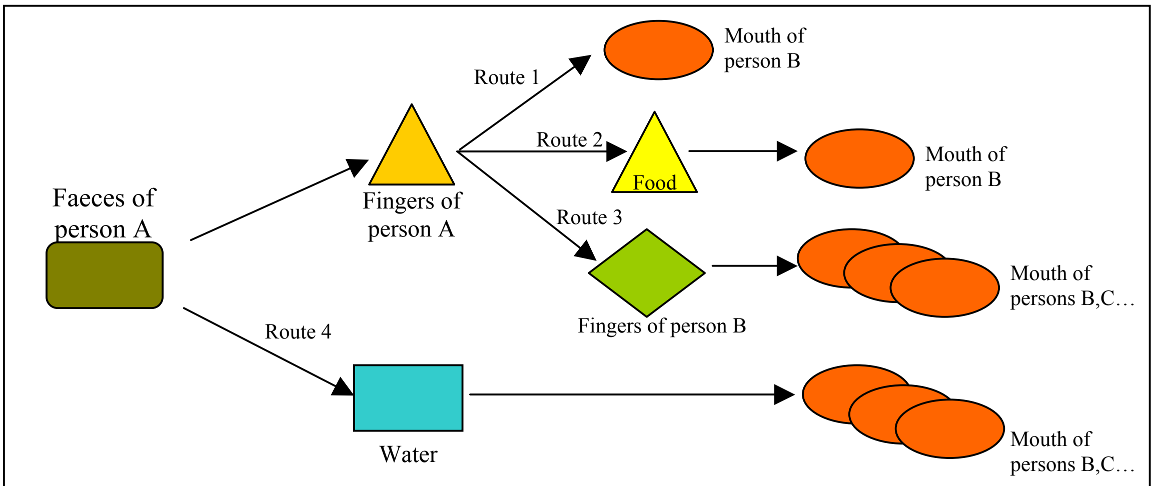


Figure 2.2. - Four possible routes of faeco-oral infections

The routes used by the causative agents of most helminthic infections are also worth noticed. In these routes, faeces are deposited in soil or water and the infective form of the causative agents reaches human hosts by ingestion or skin penetration.

For public health, the *water-*, *excreta-* and *housing-related diseases* have major importance. The ***water-related diseases*** were environmentally classified by Bradley

(White *et al.*, 1972) into four categories. Category I is the water-borne diseases, related with the quality of the drinking water; category II is the water-washed diseases that are mainly caused by the unavailability of a sufficient quantity of water; category III is the water-based diseases, caused by pathogens that spend part of their life cycle in one or more intermediate aquatic host (the main example is schistosomiasis); and, category IV is the water-related insect vector diseases that are caused by pathogens transmitted via insect vectors that breed in (or near) water.

The environmental classification of ***excreta-related diseases***, developed by Feachem *et al.* (1983) and as modified by Mara and Alabaster (1995), is divided into seven categories. Categories I and II include diseases associated with the faeco-oral routes of transmission (non-bacterial and bacterial, respectively), while category III diseases are transmitted through contaminated soils that may reach human body via the mouth, but also via skin penetration. Categories IV and V diseases rely on intermediate host(s) to become infective. Finally, categories VI and VII depend on insect and rodent vectors, respectively, to promote their transmission.

Considering both the identification of several new water- and excreta-related pathogens, and, the fact that many water-related diseases are also classified as excreta-related diseases, Mara and Feachem (1999) suggest an unitary environmental classification for water- and excreta-related diseases.

For public health engineering, a unitary classification sounds more comprehensive than the utilisation of two distinctive classifications, especially when considering the close relation between water supply and sanitation projects in public health improvement programmes. Thus, the unitary environmental classification of water- and excreta-related diseases is presented in Table 2.1.

Inadequate housing is also a factor that affects health. ***Housing-related diseases*** are divided into seven environmental categories, which are sub-divided into three classes: (a) communicable diseases, (b) non-communicable diseases and (c) mental illness and psychosocial disorders (Table 2.2), (Mara & Alabaster, 1995).

Table 2.1. - Unitary environmental classification of water and excreta-related diseases

Environmental transmission	Examples	Control
CATEGORY A: Faeco-oral waterborne and water-washed diseases		
▪ Non-latent (except *Ascaris*) ▪ No intermediate host ▪ Infectivity: medium to low (bacteria), high (others) ▪ Persistence: medium to high (bacteria), low to medium (others, except *Ascaris*: very high) ▪ Able (bacteria) and unable (others) to multiply outside host	▪ *Viral*: Hepatitis A, E and F, Poliomyelitis, Rotavirus diarrhoea ▪ *Bacterial:* Campylobacteriosis, Cholera, *Helicobacter pylori* infection, Pathogenic *Escherichia coli* infection, Salmonellosis, Typhoid and paratyphoid, Yersiniosis ▪ *Protozoan*: Amoebiasis Crystosporidiasis, *Cyclospora cayetanensis* diarrhoea, *Enterocytozoon bienusi* diarrhoea, Giardiasis, *Isospora belli* diarrhoea ▪ *Helminthic*: Ascariasis, Enterobiasis, Hymenolepiasis	▪ Improved water quantity, availability and reliability (water-washed disease control). ▪ Improve water quality (waterborne disease control ▪ Hygiene education
CATEGORY B: Non-faeco-oral water-washed diseases		
▪ Non-latent ▪ No intermediate host ▪ High infectivity ▪ Medium high persistenc ▪ Unable to multiply	▪ Skin infections (scabies, leprosy, yaws) ▪ Eye infections (trachoma, conjunctivitis, including that caused by *Encephalitozoon hellen* ▪ Louse-borne fever	
CATEGORY C: Geohelminthiases		
▪ Latent ▪ Very persistent ▪ Unable to multiply ▪ No intermediate host ▪ Very high infectivity	▪ Ascariasis ▪ Trichuriasis ▪ Hookworm infection	▪ Sanitation. Effective treatment of excreta or wastewater prior to reuse. Hygiene education
CATEGORY D: Taeniases		
▪ Latent ▪ Persistent ▪ Able to multiply ▪ Very high infectivity ▪ Cow or pig intermediate host	▪ Beef and pork tapeworm infections	▪ As C above, plus cooking of meat and improved meat inspection

Continue

Environmental transmission	Examples	Control
CATEGORY E: Water-based diseases		
▪ Latent ▪ Persistent ▪ Able to multiply ▪ High infectivity ▪ Intermediate aquatic host (s)	▪ *Bacterial:* Leptospirosis; Tularemia; Legionellosis ▪ *Healminthic*: Schistosomiasis; Clonorchiasis; Fasciolopsiasis; Guinea worm infection ▪ *Fungal*: Pulmonary hemorrhage due to *Stachybotrys altra* infection	▪ Decrease contact with contaminated water. Improve domestic plumbing. Public education. ▪ Decrease contact with contaminated waters. Sanitation. Treatment of excreta or wastewater prior to reuse. Public education. ▪ Drying of flood-damaged homes. Public education.

Examples	Control
CATEGORY F: Insect- vector diseases	
▪ *Water-related:* Malaria, Dengue, Rift Valley fever, Japanese encephalitis, Yellow fever, African sleeping sickness, Onchocerciasis, Bancroftian filariasis ▪ *Excreta-related:* Fly-borne and cockroach-borne excreted infections[a] , Bancroftian filariasis	▪ Decrease passage through breeding sites. Destroy breeding sites. Larvacide application. Biological control. ▪ Use mosquito netting and impregnated bed nets. ▪ Improved stormwater drainage ▪ Public education
CATEGORY G: Faeco-oral waterborne and water-washed diseases	
▪ Rodent-borne excreted infections[a] ▪ Leptospirosis ▪ Tularemia	▪ Rodent control: Hygiene education ▪ Decrease contact with contaminated water: public education

[a] The excreted infections comprise all those diseases in Categories A, C and D and the helminthic diseases in Category E.

Source: Mara & Feachem (1999)

Table 2.2 - Environmental classification of housing-related diseases

(a) Communicable Diseases	(b) Non-communicable Diseases	(c) Mental Illness & psychosocial disorders
CATEGORY I: Diseases related to defects in building and peridomestic environment		
1. Building-related insect-vector diseases 2. Building-related rodent-vector diseases 3. Peridomestic insect-vector diseases 4. Geohelminthiasis 5. Diseases due to animal faeces 6. Diseases due to animal bites 7. Overcrowding-related diseases	1. Dust-, smoke- and damp related diseases 2. Building-related carcinoma 3. Building-related insect vector diseases 4. Accidents 5. Traffic fumes diseases	1. Neuroses 2. Violence 3. Delinquency and vandalism 4. Drug and alcohol abuse
CATEGORY II: Diseases related to defective water supply		
1. Faeco-oral (waterborne and water-washed) diseases 2. Non-faeco-oral water-washed diseases 3. Water-based diseases 4. Water-related insect vector diseases	1. Water-quality related disease 2. Water-related carcinomas	1. Acute psychoses
CATEGORY III: Diseases related to defective sanitation		
1. Non-bacterial faeco-oral diseases 2. Bacterial faeco-oral diseases 3. Geohelminthiasis 4. Taeniasis 5. Water-based helminthiasis 6. Excreta-related insect-vector diseases 7. Excreta-related rodent-vector diseases	None known	1. Acute psychoses
CATEGORY IV: Diseases related to defective refuse storage and collection		
1. Refuse-related insect vector diseases 2. Refuse-related rodent-vector diseases	None known	None known
CATEGORY V: Diseases related to defective food storage and preparation		
1. Food-borne excreta-related diseases 2. Food-borne zoonoses 3. Food-borne microbial toxins diseases	None known	None known
CATEGORY VI: Industry-related diseases		
1. Air-borne excreta-related diseases 2. Air-borne water-based diseases	1. Diseases due to industrial toxicants 2. Accidents	. Psychiatric organic disorders due to industrial toxicants :. Neuroses

Source: Mara & Alabaster (1995)

The main advantage of environmental classifications of diseases may be the possibility of applying adequate engineering interventions in order to break the disease transmission routes. Therefore, the division proposed by Cairncross *et al.* (1996), dividing diseases into public and domestic domains, may be very helpful in the planning of disease control.

In such a classification, domestic domain is understood as the private area of the households including yards and other surrounding areas where the general public have no free access. The common areas such as schools, parks, work places, streets and so forth, are under the public domain classification. Through this division, diseases may be identified as having their main focus of transmission confined among household members and, consequently, requiring "in-house" interventions for their control, or, diseases may have their main focus on public places requiring more extensive interventions involving all community members, or all citizens or maybe whole nations.

However, considering the chaotic situation of urban poor settlements, such as the Brazilian favelas, the division between domestic and public domains may be highly confusing. The high-density occupation of these areas, their precarious condition and the absence of peri-domestic physical limits may compromise health interventions based only on the public or only on the domestic domains.

2.2.3. Diseases and Poverty

In general, diseases that are related to lack of sanitation, inappropriate housing or poor hygiene habits are associated with poverty. These diseases are easily spread in the absence of adequate engineering interventions and under low levels of personal and domestic hygiene, both frequently found in poorer communities.

Accordingly, "extreme poverty" is the world's biggest killer and the greatest cause of ill-health. Extreme poverty is, also, formally recognised as a disease and is classified in the International Classification of Diseases under the code Z59.5 (WHO, 1995, URL-1). UNCHS (URL-2, 2001) estimates that between one-quarter and one-third of all urban households in the world live in absolute poverty.

On a global basis, the "diseases of the poor" are well illustrated by the data presented in the Global Burden of Disease and Injury study (Murray & Lopez, 1996a; 1996b). As shown in Figures 2.3 and 2.4, the communicable group of diseases is responsible for about 50 percent of the total disease burden in developing countries (measured as disability-adjusted years of life (DALYs) lost), while the same group of diseases represents only 9 percent of the DALYs lost in developed countries.

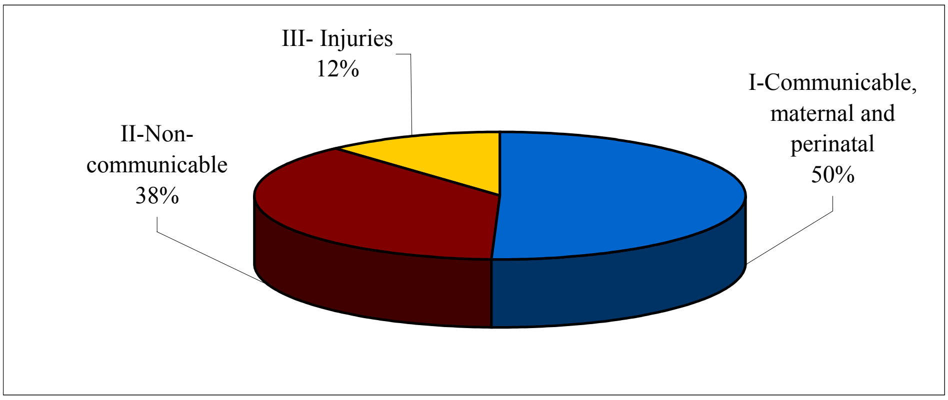


Figure 2.3. - DALY's lost in Developing Countries (1990). *(Source: Murray et al., 1994)*

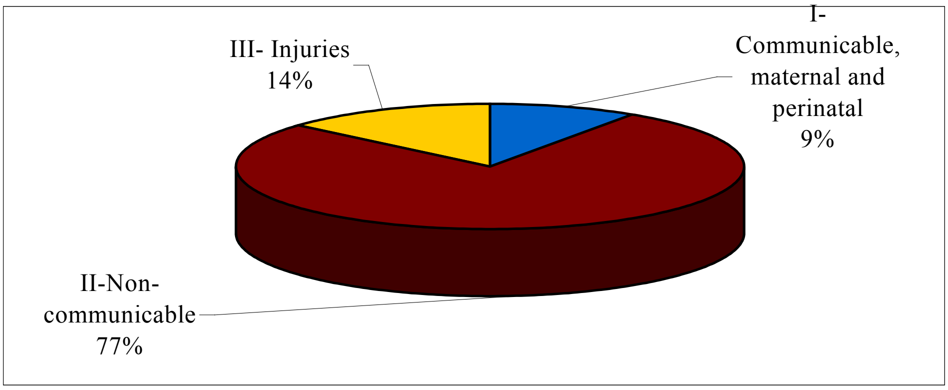


Figure 2.4. - DALY's lost in Developed Countries (1990). *(Source: Murray et. al., 1994)*

Among the communicable, maternal and perinatal group of diseases, those more directly related to the lack of adequate environmental sanitation (infectious and parasitic diseases) are also presented in a higher proportion than the other diseases in the developing countries (Figure 2.5).

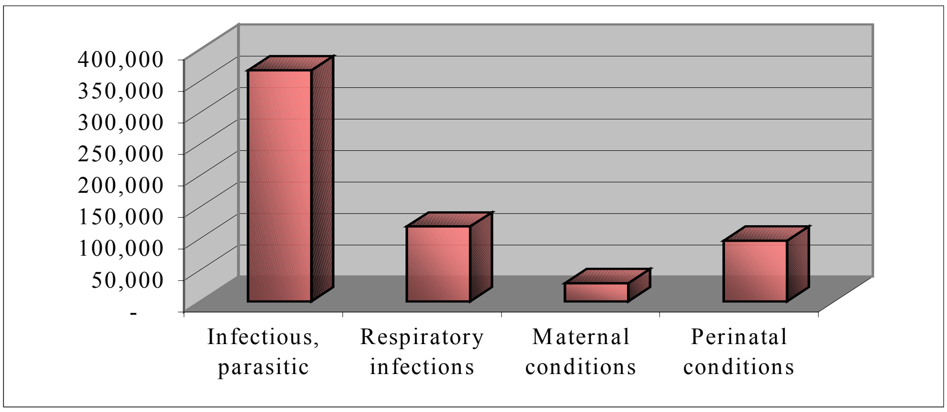


Figure 2.5. - DALYs lost for communicable, maternal and perinatal diseases in Developing Countries (1990) in thousands *(source: Murray et. al., 1994).*

The influence of economic conditions on people's health has driven authors to indicate a better income distribution as the main point to be reach in health improvement programmes (Zaidi, 1988). In order to justify this relation, the "diseases of poverty" were expressed by the following equation (World Bank, 1980):

$$D = f\,(W, S, H, E, N, S_x, H_f)$$

where D = disease of an individual or family; W = water; S = sanitation; H = housing; E = education; N = nutrition; S_x= gender differences; H_f= access to health facilities.

The *water, sanitation* and *housing* factors affecting health have already been discussed. They are formally classified following the concept of environmental classification of diseases and poorer communities are undoubtedly the most affected by these factors. Poor water supply, poor sanitation and poor personal and domestic hygiene are responsible for 7.6 percent of total DALYs lost in 1990 in developing countries (Murray & Lopez, 1997).

The role of *education* in hygiene programmes is essential for improving health. The simple delivery of water and sanitation facilities or adequate housing may have very little or no impact at all if people do not understand and accept the correct utilisation of the new facilities. Quoting Curtis (URL-27, 1999), hygiene education is potentially one of the most effective weapons to reduce the toll of diarrhoeal diseases. Usually, educational programmes focusing on health improvements are targeted at women who, especially in lower-income groups, are primarily responsible for bringing up children, cleansing and food preparation. Better education, however, does not just improve hygiene habits, but also increases the opportunities for better jobs and consequently contributes to higher household incomes.

The *nutrition* factor affecting low-income communities is directly linked to the household purchasing power. This factor is particularly important in cases of undernourished children, for whom diseases such as diarrhoea, measles and whooping cough may be fatal.

Cultural aspects (*gender differences*) may contribute to differences in the raising of male and female children. In societies under food scarcity situations and where girls are still not been seen as capable of generating income, boys usually have their needs given a higher priority. Chen *et. al.* (1981) found that in Bangladesh over 14 percent of female children were classified as severely malnourished compared to only 5 percent of males. Finally, the unavailability of *health facilities* and the unaffordability of medicines are other factors affecting the health of poor householders.

The above factors affecting health, especially the health of poorer households, are interconnected. Once initiated the improvement of one of those factors, householders would be motivated to apply efforts (economical and social) to improve one or more of the other factors. As an example, after the implementation of a condominial sewerage system through the PROSANEAR programme in Brazil, householders started to improve the quality of their houses, and also their social organisation was strengthened, so allowing them to request better health facilities and other needs (Katakura and Bakalian, 1998).

2.3. Public Health Benefits from Engineering Improvements

2.3.1. Sanitation: a Matter of Public Health

Access to water supply and sanitation facilities is frequently indicated as a priority for the control of a wide range of infectious and parasitic diseases. The association between lack of sanitation and diseases transmission is substantial. When the transmission routes of excreta-related disease are understood (see Figure 2.1), people's infection risks can be straightforwardly identified in non-sanitised environments.

In the Global Burden of Diseases and Injury Study, risk factors associated with poor water supply, sanitation, and personal and domestic hygiene were considered the second major contributor for DALYs lost world-wide. Table 2.3 shows the percentage of DALYs for the ten major disease risk factors in 1990 in developing countries (after Murray & Lopez, 1997).

Table 2.3. - Percentage of DALYs attributable to each of ten risk factors in DC's- 1990

Risk Factor	% of Total DALYs
Malnutrition	18.0
Poor water supply, sanitation, and, personal and domestic Hygiene.	7.6
Unsafe sex	3.7
Tobacco	1.4
Alcohol	2.7
Occupation	2.5
Hypertension	0.9
Physical inactivity	0.6
Illicit drugs	0.4
Air pollution	0.4

In Foster (1998), the provision of basic sanitation was indicated by Water for Sanitation and Health (WASH, renamed Environmental Health Project) as the most effective intervention for health improvement.

Also, based on data from WHO, The Economist (1998) published a table showing the reduction of diarrhoea, roundworm, schistosomiasis and guinea worm infection that was attributable to water and sanitation improvements. Among the values given, even the lowest percentage of disease reduction (22 percent for diarrhoeal disease) is an impressive value: it represents 180 million people not affected by the disease (based on 900 million diarrhoea episodes per year). However, the differences among the percentages reported (ranging from 22 to 76 percent) is a reminder that facilities provision is not enough by itself and reinforce the role that hygiene education has to play in the prevention of diseases such as diarrhoea and the geo-helminthiases.

The different impacts in health gained through improvements in programmes focused on the quality of the supplied water, on its availability and on sanitation were assessed by Esrey *et al.* (1985). In this study, the authors concluded that water quality has a smaller impact in health improvements than water availability or sanitation, but well-designed projects combining water supply, sanitation and hygiene education may achieve reductions in diarrhoeal disease morbidity of 35-50 percent.

Moreover, a USAID-supported project found that "*health and nutrition benefits from improved sanitation, especially improved excreta disposal, may be even greater than those associated with better access to safe water alone"* (UNICEF, URL-24, 1998). Accordingly, Annan (URL-25, 2000) states that *"no single measure would do more to reduce disease and save lives in the developing world than bringing safe water and adequate sanitation to all"*.

Another study concluded that of more than 52 million deaths in 1996, over 17 million (i.e. nearly 33 percent) were due to infectious or parasitic diseases (WHO, 1997, URL-3). In Brazil, 21 million people live without access to safe water and 44 million are not served with sewerage networks or septic tanks (Katakura & Bakalian, 1998). The majority of these people survive with hugely inadequate amounts of water, which they usually obtain from "pirate-sellers" or unsafe sources, and they have sewage flowing openly around their houses. This situation may be directly translated into the high infant and under-five mortality and morbidity rates (see Section 1.2.1.) compared with those in developed countries.

2.3.2. Diarrhoeal Diseases

Diarrhoeal diseases are classified by WHO as the second major cause of death in the world (Table 2.4.). They are responsible for 3.1 million deaths per year, which mainly occur in the undeveloped countries. The group of people most affected by diarrhoea are children under-five years of age who carry a disease burden of approx. 86% of the cases in the world and 78 percent in the Latin America and Caribbean region (Murray and Lopez, 1994).

Table 2.4. - The ten biggest killers according to WHO.

Disease	Morbidity (deaths per year)	%
Acute respiratory infections	4,400,000	26.2
Diarrhoeal diseases	3,100,000	18.4
Tuberculosis	3,100,000	18.4
Malaria	2,100,000	12.5
Hepatitis B	1,100,000	6.6
HIV/AIDS	1,000,000	5.9
Measles	1,000,000	5.9
Neonatal tetanus	500,000	3.0
Whooping cough	355,000	2.1
Roundworm and hookworm	165,000	1.0

Source: Mara (1997).

Different definitions of diarrhoea have been applied in different studies. A number of them are based on the frequency of episodes per day, such as "more than two watery or loose motions in 24 hours" (Rahaman *et. al.*, 1979) and "under 1 year of age: 5 or more liquid stools per 24 hours; over 1 year: 3 or more liquid or semi-liquid stools proceeded by 2 weeks of normal stools" (Scrimshaw *et. al.*, 1967). Recent studies however, which have applied a more community-based approach, consider the mother's definition more suitable for the assessment of cases of diarrhoeal diseases (Schorling, 1990; Moraes, 1996).

Examples of diarrhoeal diseases include cholera, typhoid fever, paratyphoid fever, salmonella, rotavirus, campylobacter, shigella, giardiasis, dengue fever, cryptosporidiosis, among others, which are caused by a variety of pathogens such as bacteria, parasites and viruses.

Cholera is an example of a devastating diarrhoeal disease with recurrent pandemics around the world since 1817. The ongoing pandemic, the seventh, started in 1961 in Indonesia, then, spread through Asia, Africa and reached Latin America in 1991 (Tauxe *et al.*, 1995). In Brazil, cases of cholera reached a peak of more than 60,000 confirmed cases and 670 deaths in 1993 (Momem, 1998). It declined to 3,044 officially reported cases in 1997 (Ministério da Saúde, URL-28, 1998). The cases reported in 1997 were concentrated in the Northeast region of the country (98 percent of the cases).

Tauxe *et al.* (1995) reported that no effective vaccination is yet available against cholera, but the interruption on the transmission of the causative organism (*Vibrio cholerae*) had successfully prevented and controlled many epidemics. The authors also stress that the provision of safe water and sewage treatment for nearly all people in industrialised nations has made the transmission of cholera extremely unlikely in those countries.

Another highly infectious enteric pathogen is *Cryptosporidium parvum*. This protozoan parasite was for long well known by veterinarians, but was recognised as a human pathogen only in 1976 (Guerrant, 1997). Cryptosporidium is able to infect with as few as 30 oocysts and can cause diarrhoea illnesses lasting longer than 1 to 2 weeks in a previously healthy person and indefinitely in immunocompromised patients. The parasite is transmitted by ingestion of oocysts excreted in faeces of infected humans or animals. The transmission can occur through person-to-person or animal-to-person contact, ingestion of faecally contaminated water or food, or contact with faecally contaminated environmental surfaces (CDC, URL-29, 1995). There is also concern with the waterborne transmission of cryptosporidium. Oocysts were present in 65-97 percent of surface water (i.e. rivers, lakes and streams) in tests throughout the United States (CDC, URL-29, 1995); additionally, this parasite is resistant to chlorine, is small and is difficult to filter, therefore becoming a threat to water supply treatment systems.

A study in an urban slum in NE of Brazil detected cryptosporidium oocysts in human stools in 6.3 percent of samples collected in the dry season and in 14.3 percent of the samples from the rainy season. In animals stools, 10.2 percent of the samples had oocysts, and 22.2 percent of freshwater samples collected from a variety of sources were also positive (this include a sample from the city water company) (Newman *et al.*, 1993).

Dengue fever is a water-related insect-vector disease (Category F of the unitary environmental classification, Table 2.1), which is transmitted by the *Aedes aegypti* mosquito. This mosquito breeds in calm freshwater sites such as household water tanks, vessels and containers accumulating rainwater. Diarrhoea can be one of the symptoms of the disease that may be fatal especially in its stronger version, dengue hemorrhagic fever. Dengue re-emerged in Brazil in the 1970s and large outbreaks followed in the next decades (Momen, 1998). In 1997, a total of 254,987 cases of dengue fever were officially reported in Brazil, with approx. 77 percent of the cases occurring in the Northeast of the country (Ministério da Saúde, URL-28, 1998).

A series of programmes carried out around the world with the objective of reducing diarrhoea mortality has been based on the Oral Rehydration Therapy - ORT, which relies on the administration of an Oral Rehydration Solution - ORS. Among the main advantages of this form of therapy are: the ease with which it can be learned, the rehydration solution can easily be prepared by mothers and that it can usually be afforded by poorer households. Such factors have increased the popularity of ORT and have made it an important lifesaver.

However it must be remembered that ORT is a remedy and does not prevent the occurrence of diarrhoea (Okun, 1988). Therefore, water supply and sanitation improvements, as well as the promotion of hygiene education, are fundamental in reducing the incidence of diarrhoeal diseases (Stanton & Clemens, 1987; Hoque, 2000).

Esrey *et al.* (1985) reviewed 67 studies on the impact of water supply and sanitation on diarrhoea-related issues. The same authors updated this review in 1991 based on an assessment of 17 additional studies (Esrey *et al.*, 1991). Based on these reviews it may be concluded that, although diarrhoeal morbidity and mortality are also strongly related with the level of the mother's literacy, hygiene practices and child nutritional status, water and sanitation play an important role in improving rates of child survival. In the studies considered by the authors as having a more rigorous methodological design, improvements in water supply and sanitation were considered to be responsible for 65 percent reduction in diarrhoea-related diseases and over 55 percent in child mortality.

Moreover, VanDerslice & Briscoe (1995), reported that providing private excreta disposal would be expected to reduce diarrhoea by 42 percent and that eliminating excreta around the house would lead to a 30 percent reduction in diarrhoea. Accordingly, Mertens *et al.* (1992) in a study of excreta disposal in relation to childhood diarrhoea in Sri Lanka, also reported that children from households where excreta were disposed of in a latrine were less likely to have diarrhoea than children whose families disposed of excreta improperly.

2.3.3. Helminthic Infections

Diseases caused by intestinal helminths are also associated with poor hygiene and inadequate sanitation. They are classified in Categories C (geohelminthiases), D (taeniasis) and E (schistosomiasis) of the unitary environmental classification of water- and excreta-related diseases (Table 2.1). The close relation of helminthic infections (especially the geohelminthiases) with a lack of sanitation and poor personal hygiene habits is even more evident in high-density housing areas (such as the urban slums). In these areas the above factors, together with the widespread habit of not wearing shoes and defecating in watercourses, result in a greater susceptibility to infection.

The main geohelminthiases are ascariasis, ancylostomiasis (hookworm infections) and trichuriasis which are caused, respectively, by *Ascaris lumbricoides* (roundworm), *Necator americanus* or *Ancylostoma duodenale* (hookworms) and *Trichuris trichuria* (whipworm). As shown in Figure 2.6, these infections have been reported to occur at higher levels in Latin America and the Caribbean than in sub-Saharan Africa.

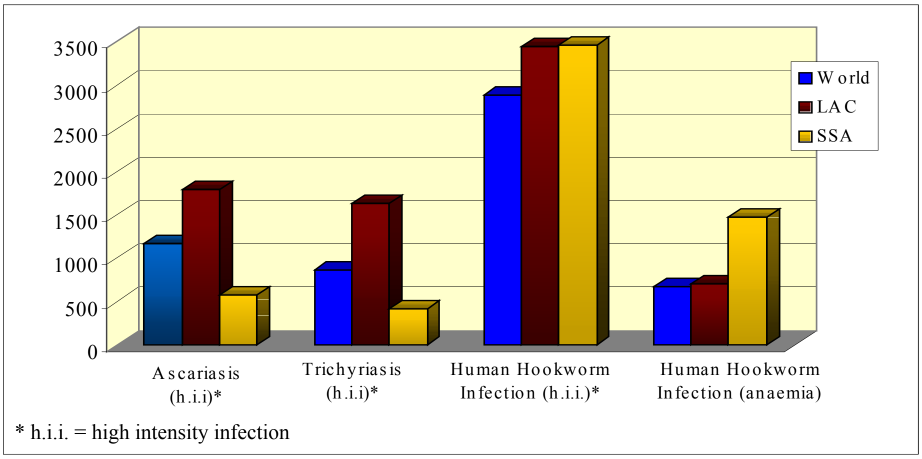


Figure 2.6. - Prevalence rates of geohelminthiases (per 100,000) in 1990. *Source: Murray and Lopez (1996).*

Twenty-five years ago, Wolman (1975) already reported that enteric infections constitute one of the leading causes of diseases and death in central and South America. The author suggested more water supply & sewerage systems, better food preparation and better hygiene comprehension as key points to decrease the burden of these diseases. Additionally, rapid population growth and urbanisation were also indicated as aggravating factors.

Table 2.5 presents the main features of ascariasis, hookworm infections and trichuriasis.

Table 2.5. - Features of geohelminthiases.

Clinical Features	➢ Ascariasis • Transmitted by eggs present in infected excreta disposed in soil, which develop second-stage larvae to become infective. • Human infections occur when infective eggs are ingested (by hands, food, utensils, dust, and so forth) and hatch in the duodenum of infected person. • About 85% of infections are symptomless. • Earliest symptoms are: pneumonitis with cough; dyspnea (shortness of breath); substernal (chest) pain; fever; moderate eosinophilia and blood-stained sputum. • Adult worms in the small intestine may cause: digestive disorders; nausea; abdominal pain; vomiting; restlessness and disturbed sleep. • It has been estimated that a child who has 26 worms may lose 10% of his total daily intake of protein. ➢ Hookworm Infections • Transmitted by eggs present in infected excreta disposed in soil, which in optimum condition hatch developing the subsequent larval stage. • Human infections occur when the third-stage larvae penetrate the skin, usually between toes, on the feet or ankles. • Frequently sympthomless, however acute cases may cause: anaemia with consequently weakness, debility and others; gastrointestinal pain and transient cutaneous and pulmonary symptoms • Grossly anemic individuals may die of high-output heart failure ➢ Trichuriasis • Life cycle, modes of transmission and epidemiologies similar to ascarisis • Symptomless, however may cause slight abdominal pain and diarrhoea. • Heavy infections may cause anaemia, bloody diarrhoea and prolapse of the rectum in malnourished children.
Treatment	➢ Ascariasis and trichuriasis • Chemotherapy ➢ Hookworm Infections • Chemotherapy and Oral iron therapy
Prevention and control	➢ Ascariasis, hookworm infections and trichuriasis • Health education campaigns • Development of basic health services and infrastructure ➢ Hookworm Infections • Use of footwear

(Source: Feachem et al., 1983).

2.4. Physical Sustainability of Sanitation Programmes

2.4.1. Concepts of Sustainability

Sustainable development was defined in 1987 by the World Commission on Environment and Development as: "development that meets the needs of present generations without compromising the ability of future generations to meet their own needs" (WCED, 1987). Sustainability and sustainable development, therefore, became popular since the preparation of the Earth Summit held in Rio de Janeiro in 1992. In that conference, the necessity of nations to sustain their developmental programmes was discussed at a global level. Such discussions gave emphasis to the conservation of resources and ecological systems (the Green Agenda), but also to the need for poverty eradication giving poor people more access to the resources needed for an environmentally healthy life (the Brown Agenda).

Since then, sustainable development has been seen from different angles and a wider range of sectors has adopted it as a target to be achieved. Therefore, specific concepts have been suggested for sustainability and applied in a variety of sectors such as economical, social, cultural, operational, institutional, managerial and so fourth (Pugh, 1996; Hardoy *et al.*, 1992).

Nevertheless, these broader concepts of sustainability have been largely criticised and it is suggested that the term has been inadequately applied (Mitlin & Satterhwaite, 1996; Marcuse, 1998; McGranahan *et al.*, 1996). Generally, the argument is that sustainability is well applied for environmental issues; however, its adaptation to others sectors, such as urban infrastructure and social organisations, is seen as contradictory and inappropriate. Mitlin & Satterthwaite (1996) suggests that human activities and institutions are not appropriately discussed under sustainability, arguing that these sectors are more clearly fulfilled within the *development* component of sustainable development.

Everard (1999), in simple terms, defines sustainability as the capacity for indefinite continuance, whereas sustainable development is the journey that society must necessarily take towards a state of sustainability. This "sustainable journey" is, therefore, what social and infrastructure systems are aiming to establish for the development of sustainable societies. However, a "sustainability deficit", probably resulting from the unsustainable pathways taken by many developed societies, already exists. And, this would be expressed by the exhaustion of natural resources and by social inequalities, which have as a direct consequence the non-accomplishment of basic human needs in the poorer strata of these societies. Therefore, the environment surrounding human settlements in low-income areas of non-developed countries is begging for improvements that are part of programmes being developed under the bandwagon of sustainable development.

Development is, in fact, a dynamic component that in association with sustainability (in terms of urban infrastructure) suggests development based on realistic parameters (technical, financial and social), committed to improvements on human quality of life and without compromising natural resources. This may be understood as just another broad concept, but it allows the implementation of programmes that are more carefully planned, coherent and committed to poverty alleviation. Additionally, according to DFID (1998), sustainable development programmes should also be designed to ensure effectiveness, efficiency and equity.

Consequently, this interpretation of sustainable development and its application for the provision of "human needs" has favoured the development of theories, approaches and action frameworks which support the implementation of infrastructure improvement programmes in low-income areas of developing countries.

2.4.2. Sustainable Sanitation Programmes

In the development of this study, sanitation programmes are considered "the subject" that should be sustained, having as their primary aim to meet users' needs (needs that should be expressed by the users themselves). Therefore, *sustainable sanitation programmes* are expected to be:

- Technically suitable for the characteristics of the area and its users;
- Technically able to function (be operated and be maintained) using viable resources during the totality of its design life, and also being committed to the continuity or upgrading of the system;
- Financially affordable by its users that are "the clients", the primary beneficiaries of the projects and, consequently, the owners of the sanitation system;
- Socioculturally acceptable in order to avoid rejection due to traditions, habits or religious beliefs;
- Health-focused, so as to improve the quality of life and satisfying the user's needs; and

- Environmentally friendly, contributing to the sanitation of the users' immediate environment and not compromising natural resources with effluents or process derived contaminants.

To give a chance for the sanitation programmes to be sustainable, complying with the constraints above, a major factor would be the acceptability and participation of users. The role that communities (users that live in the same area and are involved in the same programme) play in these sorts of programmes has been reported as of fundamental importance for the achievement of the programmes' objectives (Katakura & Bakalian, 1998; Watson, 1995). The significant value of community participation can be identified in the examples of sanitation programmes and approaches discussed next.

2.4.3. Sustainable Approaches

➢ ***Strategic Sanitation Approach (SSA) and Demand-based Approach***

Recognising that urban poverty has no easy solution and that urban institutions and local governments of developing countries still have deficient structures for the management of the water and sanitation sector, the UNPD-World Bank Water and Sanitation Programme suggested the adoption of the strategic sanitation approach -SSA (UNPD-World Bank, URL-4, 1998).

This approach aims to support urban interventions fostering investments, operational efficiencies, and the development of sustainable urban services. For this, four principles were set:

- Interventions in water and sanitation should be based on local, effective demand;
- Water and sanitation should be considered economic, as well as social, goods;
- Interventions in water and sanitation must be based on the needs of the community in general, and of women in particular; and,
- Interventions should be incentive-driven and demand-based.

To achieve the SSA goals and according to the principles above, water and sanitation programmes should be based on (UNPD-World Bank, URL-4, 1998):

- Appropriate choice of technology and service levels;
- The breaking down of the sanitation and water delivery system into separate but technically compatible systems, designing the most efficient solutions at the appropriate levels;

- Economic replicability, aiming at full recovery of investments; and
- Responsive institutional arrangements, allowing the users to play a key role in decision-making and management of services.

With regards to the SSA, Wright (URL-5, 1998) commented that its principles help agencies to build capacity and communities to enhances ability in improving the systems. The author also characterises a demand-based approach by basing improvements on potential users' wants, their financial resources capacity and their potential to manage the installed systems. As suggested by Sara (URL-6, 1998), "*the ideal demand-responsive model is the market model, where there exists some level of demand from householders in a community, and services to meet this demand is paid for and contracted out by community members to providers*".

As stressed by Parry-Jones (URL-30, 1999), demand for improved water and sanitation services is a complex concept. Its characteristics are those presented in Table 2.6.

Table 2.6. – Characteristics of "demand" for water and sanitation

"Demand" may be:	"Demand" is always:	"Demand" is NOT always:
▪ expressed ▪ effective ▪ latent ▪ uninformed ▪ unrealistic ▪ biased ▪ created	▪ unique to each project location ▪ dependent on the alternative existing options ▪ dynamic (i.e. will change with time) ▪ different to water and sanitation ▪ dependent on people's willingness to pay for specific options	▪ equivalent to choice ▪ satisfied by the "best" solutions proposed by professional ▪ the same as what people say they "want" ▪ taken into account!

Source: Parry-Jones (URL-19, 1999)

The three main tools for assessing demand are the Household (HH) or Revealed Preference Survey (RPS), the Participatory Rapid Appraisal (PRA) and Contingent Valuation Methodology (CVM). These techniques are described in DFID (1998) and discussed at length in Parry-Jones (URL-30, 1999). Each of these techniques seems to be preferred by one or other of the groups of professionals involved with sustainable sanitation programmes (engineers, social scientists and economists). However, the appropriateness and effectiveness of these techniques are still controversial and not fully understood.

The main gain in the introduction of a demand-based approach is, probably, the change in thinking of how sanitation and water programmes should be driven. It promotes the transition from supply-driven programmes (characterised by "top-down" decisions that, at least in developing countries, have been shown to be unsustainable and distant from the reality of the poorest communities) to programmes based on meeting users-expressed needs. Garn (URL-7, 1998) suggests that for this transition be successful, it is required that stakeholders:

- Develop rules that give users the incentive to reveal their demand and give supply agencies the incentive to act on that information;
- Develop implementation procedures that encourage adherence to the rules and transparency in their application;
- Actively monitor performance and test hypotheses; and
- Give regular feedback on performance results to users and supply agencies so they can modify the rules and implementation procedures accordingly.

From what has been said, three main actors may be identified in the process of improving sanitation (and water) in developing countries through a demand-based approach. They are the communities, the government and the providers of services (which may be the private sector, NGOs, government agencies, research institutions and others). For the definition of the roles that should be played by each actors, Sara (URL-6, 1998) suggests the participation model detailed in Table 2.7.

Table 2.7. - Participation of actors in demand-based programmes

Community	Government	Providers
▪ Express demand ▪ Finance (part of) the services ▪ Manages project implementation ▪ Owns, operates and manages water and sanitation services	▪ Facilitator ▪ Sets polices and strategies ▪ Legal framework for access for services ▪ Asset ownership ▪ Registration of entities ▪ Financial policies ▪ Attainment of funds ▪ Sets conditions for efficiency and cost-effectiveness	▪ Dissemination of information ▪ Social intermediation ▪ Training of communities ▪ Consulting services ▪ Supervision of construction ▪ Delivery of all goods, civil works and spare parts

Communities owning, implementing and maintaining infrastructure projects represents a change in the position of stakeholders compared to the traditional participation ladder. Therefore, this change requires adaptations, especially in the way in which the actors are now supposed to interact with each other. Some points have already been presented as to how stakeholders should act in this new perspective; however, the importance of the new position of communities in a demand-based approach is still to be emphasised. Thus, Sara (URL-6, 1998) points out that communities should manage implementation because:

- Incentives are put in the right place (the client is the community and not the government or any other agency);
- Costs are reduced;
- There is a rapid increase in the demand for services;
- There is a greater possibility for co-financing from private sector;
- There is greater opportunity for community capacity-building; and
- Communities "want" to be involved.

A study reported by Katz (URL-8, 1998) on the impact of demand responsiveness (demand-based approach) on the sustainability of rural water systems, provided conclusions that may be also applied to sanitation programmes. Field-based teams in Benin, Bolivia, Honduras, Indonesia, Pakistan and Uganda developed the study over a one-year period and found that the demand-responsive approach at the community level significantly increases the likelihood of water system's sustainability. Another finding was that the existence of a formal organisation to manage the water system, and the training of household members in operation and maintenance are also significant factors. The study suggests that, to be effective, the demand-based approach should include procedures for an adequate flow of information and provisions for capacity building at all levels. Also, the approach should permit the re-orientation of supply agencies, allowing consumer demand to guide the investment programmes.

- ***The CINARA Approach***

CINARA is a research and development institute of the Universidad del Valle in Cali, Columbia that has developed a model for planning water supply and sanitation investments at the local level. The model was developed to answer problems faced by local governments that lack knowledge about the magnitude and characteristics of the sanitation and water sector at the municipal level, as well as about the possible solutions that may be applied to solve these problems (Restrepo *et al.*, 1998).

The bases of the model are human development theory, systems theory and sustainability of water supply and sanitation projects. The human development theory states that *human development should be centred on people, taking into account basic* *human needs (subsistence, participation, affection, creativity, understanding, identity, protection, leisure and freedom)* (Restrepo *et al.*, 1998).

For the systems theory, the model is systematised putting institutions and settlements at the same level, finding out and expressing needs, setting policies, resources, plans and programmes, resulting in services and goods. This systems approach is illustrated in Figure 2.7.

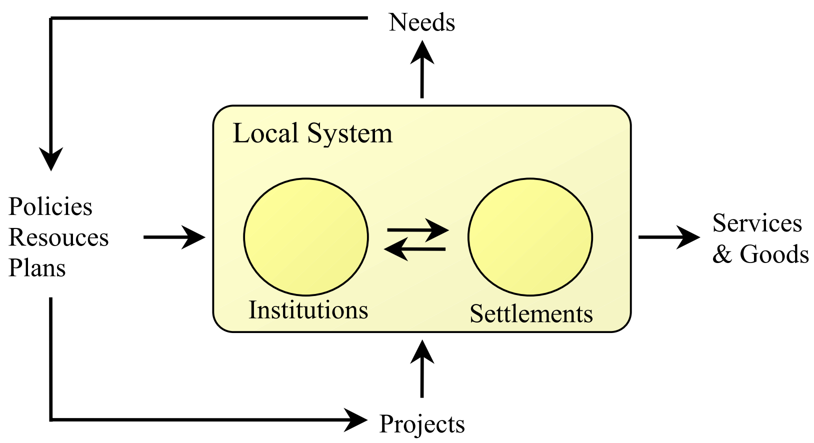


Figure 2.7. - A systems approach: the local level. *(After Restrepo et al., 1998)*

The third basis of the model is the sustainability of water and sanitation projects. In CINARA's perspective, these projects are sustainable when they "provide, over a significant period of time, an efficient and reliable service with a limited but feasible support, using the minimum of resources, including environmental resources" (Duque *et al.*, 1996).

CINARA also suggests that sustainability, in the water and sanitation sector, has three dimensions: community & local institutions, environment, and science & technology (Figure 2.8). The interaction between community & local institutions (first dimension) and the environment in which the community lives (second dimension) results in real or potential risks that may be eliminated or minimised by the efficacy of the third dimension: science & technology. The utilisation of science and technology involves knowledge, skills learning and actions, which would lead to community ownership of the programme and, hence, would consolidate system sustainability.

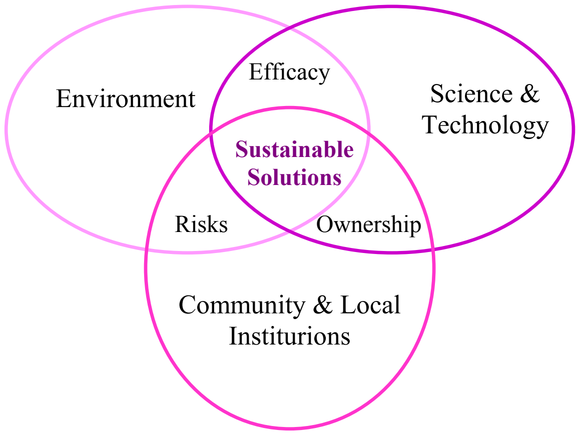


Figure 2.8 - The local level from the point of view of sustainability. *(After Restrepo et al., 1998)*

According to the three dimensions presented above that comprise the basis of the model, CINARA has, therefore, suggested a structured implementation model for water supply and sanitation programmes at the local level (Figure 2.9).

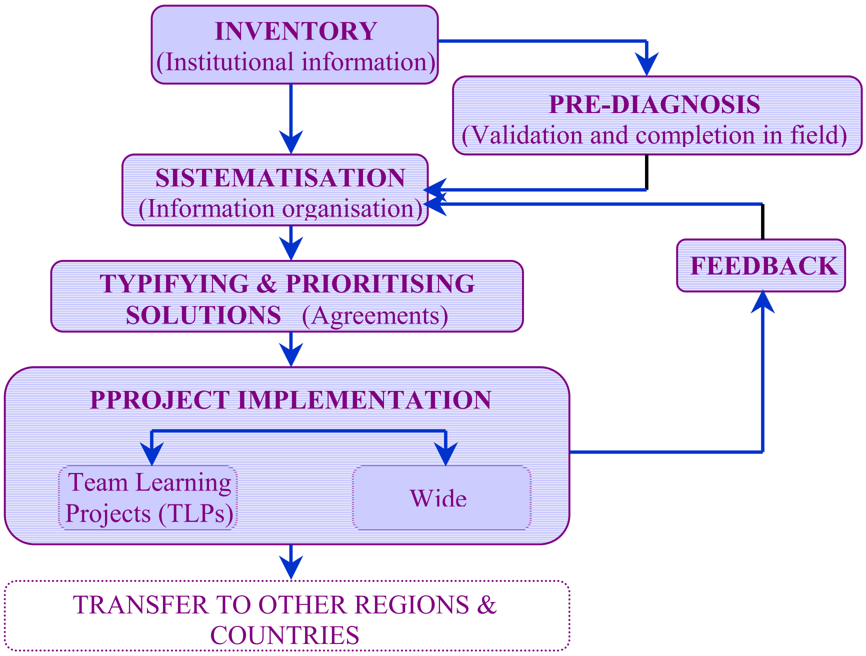


Figure 2.9. - A model for planning water and sanitation investments at the local level. *(After Restrepo et al., 1998)*

The CINARA model was first applied in 112 rural and peri-urban areas of Cali and later in some other areas of Colombia. The programmes are still running, and the results have already shown that, through the model, institutions are recognising the problems identified by the communities. Consequently, institutions are also prioritising and investing in projects that are desired by future users. The projects are planned together, resulting in a better utilisation of resources from the beginning and in the strength of communities as organisations (Restrepo *et al., 1998)*.

➢ *The PROSANEAR Approach*

PROSANEAR is a Brazilian World Bank-funded pilot programme for the implementation of water supply and sanitation projects in low-income urban neighbourhoods. The programme was first launched in 1982 and due to financial and technical difficulties was nearly abolished. However, in 1988, a second version, PROSANEAR I, was established with the objective of finding out what worked in the previous programme, as well as to test new ways to bring water supply and sanitation services into the urban slums. The programme was concluded in 1997, with impressive achievements: one million poor people connected to sewerage systems and 900,000 people to in-house level of water supply in 60 low-income settlements of 17 cities throughout the country (Katakura & Bakalian, 1998).

The PROSANEAR programmes had as their overall goal the delivery of affordable sustainable water and sanitation services to the urban poor, and for that, they were based on the combination of two main approaches: simple low-cost technologies and community participation. PROSANEAR I was designed to also have an "adaptable approach", encouraging learning and innovation at every level and having a site-specific design for each project (Katakura & Bakalian, 1998).

In order to guide project planners, PROSANEAR I did not develop mandatory "guidelines" to be followed; instead, five basic principles were set (Table 2.8.).

Table 2.8. - Principles of the PROSANEAR I programme

▪ Community Participation	Every project must be tailored to the specific needs of each individual community and be designed with the active community participation.
▪ Low-cost Appropriate Technology	Simple solutions may be the best solutions, especially if high-tech systems are too complicated and too costly for poor neighbourhoods
▪ Environmental Protection	Providing water without a way of disposing of it safely can make environmental problems worse. All projects that provided water had to provide sewage collection and disposal as well.
▪ Cost Recovery	Customers will take care of systems they have to pay for. Users were charged for hookups, water used and sewage collected.
▪ House Connection	Household connections are more convenient and equitable than public stand posts in an urban setting.

Based on: Katakura & Bakalian, 1998

The project planners used three main criteria for the selection of the communities:

- Priority was given to urban slums in cities of more than 50,000 people;

- All participating families earned less than three minimum salaries a month, of which at least 40 percent earned less than one minimum salary/month (US$100); and
- Beneficiary families agreed to pay for water and sewerage in accordance with tariff schedules maintained by the water utilities.

For the approval of individual projects, the following criteria were applied:

- Projects must conform with the most appropriate technical and environmental standards for the neighbourhood and represent the cheapest alternative;
- Water project construction costs should be less than US$ 98 per capita and sewerage projects less than US$ 140 per capita; and
- Total investments for bathrooms, drainage and solid waste disposal should not exceed 10 percent of the total cost of the project.

For the management perspective, projects were implemented by *executing agencies* assisted by both *regional* and *national coordinating units*. Thus, the executing agencies were responsible for identifying and assessing candidate communities, establishing a multi-disciplinary project team, building support for the project by community mobilisation, and overseeing the development of technical options, construction, operation & maintenance, training, monitoring and follow-up. The main functions of the regional offices were to facilitate, supervise and monitor local projects, and ensure that the various local projects were moving along in a timely manner. The national office was in charge of planning, monitoring and supervision of all programme advancements. It also was responsible for training and technical assistance to the implementation teams and for providing basic implementation guidelines, model terms of reference and model procurement documents.

Based on the principles, criteria and the organisational model described above, PROSANEAR I was established following the structure presented in Figure 2.10.

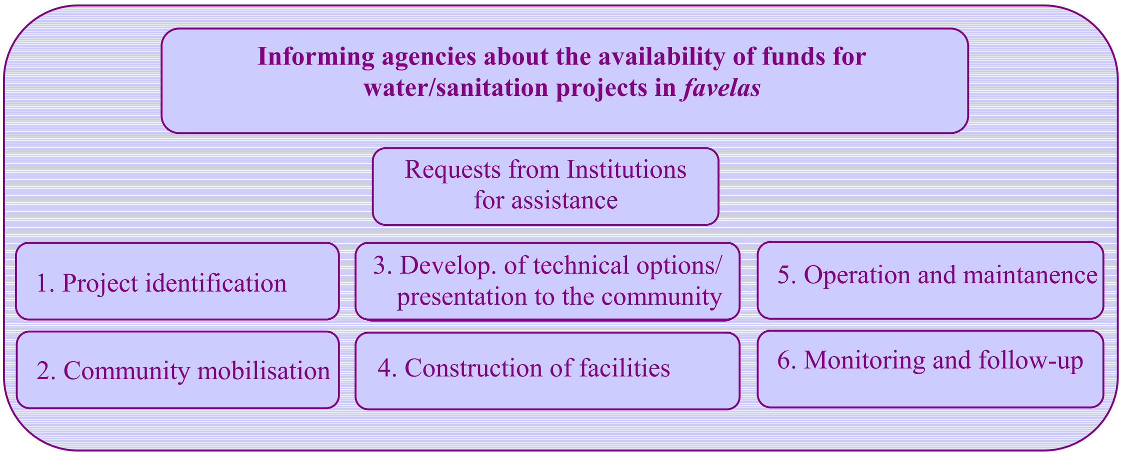


Figure 2.10 - Model for the implementation of PROSANEAR I projects. *Based on Katakura &Bakalian, 1998.*

PROSANEAR I believed that the stronger the community participation and organisation, the greater the chances for the project to succeed. In order to guarantee effective community participation, a framework was developed based on the following four main elements (Katakura & Bakalian, 1998):

▪ *Information Dissemination:*	A continuous feedback in which the community learn about potential activities in the area and the project team about community dynamics.
▪ *On-going Discussions:*	Project teams and communities engaged in regular discussions of community conditions and dynamics.
▪ *Proposal and Decisions:*	Project team and communities moving from discussions to decisions regarding the technical option that suited the particular community.
▪ *Responsibility:*	Project team committed to provide water and sanitation systems that suited the community, guaranteeing the operation of the system and charging fair rates. Users committed to pay for the service, using the system properly and maintaining the equipment.

PROSANEAR I achieved more than its initial objectives: the number of people connected to water systems was fourfold higher than the original target and people served by sanitation systems was 43 percent more than the estimated number. The main lessons learned by the programme are listed below (Katakura & Bakalian, 1998):

- Community participation must start at the very beginning of project preparation;
- Cost recovery and subsidy rules must be set in a clear and transparent manner;
- Formal, long-term arrangements for operating and maintaining the systems must be an integral part of the design; and
- All feasible technical options and their costs must be discussed with the communities.

Table 2.9 presents some features regarding the implementation of sewerage systems in the PROSANEAR I programme.

Table 2.9. - Features of sewerage systems implemented under PROSANEAR I.

State	City	Pop. (000)	ewerag benef. ›opulat.	Main geograph. situations/ Pop. density	Sewer. Collect. option	Sewage treatment	Const. costs per capita (US$)
Amazonas	Manaus	1,011	3,523	Flat; Low density	Absorpt. pits		21
ará	Belém	954	126,411	Flat, subject to floods; High density	Cond.	UASB	232
Ceará	Fortaleza Crato Quixadá Juazeiro do N.	3,049 173	186,452	Flat, river nearby prone to floods; High density Flat, dry; Medium density	Cond.	Stabilization ponds and communal septic tanks	78
ernambuco	Recife	1,298	8,590	Close to river prone to flood; High density	Cond.	UASB	209
Minas Gerais	Juíz de Fora	386	12,122	Hilly; Low-medium density	Cond.	Communal septic tanks	51
1ato Grosso o Sul	Campo Grande Dourados	526	17,146	Low density	Absorpt pits Cond.		51
Rio de Janeiro	Rio de Janeiro Angra dos Reis	5,587 149	445,285* 69,744	Hilly; High density Mostly hilly; Low density	Cond. Cond./ Abs. pits	Existing treatm. Plant UASB	87 61
anta 'atarina	lorianópoli: Chapecó Joinvile Lages	234 118 388 151	25,896	Medium density Hilly, Low dens. Flat; Low-Med. density Low-density	Conven Conven Conven	 Sep. tank + filter Sep. tanks + filters	59
TOTAL			895,169				

* Estimated / cond.= condominial sewerage *Based on: Katakura & Bakalian, 1998*

2.4.4. Sustainable Steps

The involvement of communities in the improvement of their own needs is presented as a key point for the sustainability of low-income sanitation programmes (i.e. the programmes discussed in the previous section). Therefore, this results in additional steps to the traditional framework applied for the delivery of sanitation projects.

Project ***Identification*** between providers and users has been recognised as one of the first steps, if not the very first, for programmes following a demand-based approach. During this step, communities should express their needs, discuss their problems and set their priorities. The process suggested by this step may face different degrees of difficulty according to the level of organisation existing in the community;

therefore, a multi-disciplinary team, including social scientists, has been reported as being the most appropriate (Watson, 1995).

Project ***Planning*** is the next step, which should already have all the actors involved and supporting the programme (community, executing agencies, financing agencies and others). The presence of multi-disciplinary teams is again emphasised in this step. It is here that communities take their decisions, and for this, the various options should be raised and properly explained to the future users. Next, responsibilities must be allocated to all involved actors with the maximum possible transparency during the decision-making process, especially for issues regarding money (financing and cost recovery) as well as "after-implementation" responsibilities (operation and maintenance of the project).

After decisions have been made and agreements signed, the ***implementation*** step takes place according to defined construction arrangements. This is followed by ***continuity*** actions, mainly characterised by the system's operation and maintenance tasks. The actions suggested by this latter step are of essential importance for programme sustainability. Although it has been advocated that the operation and maintenance tasks (or at least some of them) should be delegated to the communities, the agencies must give them the necessary support. Watson (1995) suggested four key elements to be performed by executing agencies in this post-implementation phase of condominial sewerage projects:

- Staff continuity between the construction and operational phases;
- Specialised condominium maintenance crew;
- Face-to-face contact with residents; and,
- Ongoing network monitoring and repairs, and customer "education".

Taking a vision beyond the implementation of a single sustainable project, the programme continuity step may also include the improvement of other community needs which may be motivated by the programme itself. Nevertheless, these actions should keep the same characteristics: attending to the needs expressed by the community and adopting affordable technological solutions, whilst keeping in mind their requirements for operation and maintenance, as well as for continuity in the educational programme's actions.

2.5. Sustainable Sanitation Technologies

2.5.1. Technology Appropriateness

Sustainable development has increased the concern over the *application, efficiency* and *efficacy* of technologies in urban infrastructure services (particularly, water and sanitation systems). The past records of these services (especially in low-income settlement of developing countries) are full of experiences of failure that have contributed to the well-known health problems as well as to the detriment of the urban environment itself.

Technology ***appropriateness*** is one of the key points to overcome the failure of past programmes. This aggregates technical, socio-cultural and economical parameters, which certainly lead to the selection of alternative low-cost technologies.

Throughout the fieldwork developed for this study, programmes applying different low-cost sanitation technologies were studied. The selected technologies and their main features are, therefore, discussed below.

2.5.2. Simplified (Condominial) Sewerage

Simplified sewerage was first implemented in Brazil based on the review of the design criteria used for conventional sewerage (Bakalian *et al.*, 1994). The innovative part of this system is essentially the adoption of locally based revised standards, instead of the excessive high technical standards that were currently applied. In this sense, a team of engineers from CAERN, the state Water and Sanitation Company of Rio Grande do Norte - Northeast of Brazil, developed the condominial version of the system. Thus, condominial sewerage applies the same design criteria as simplified sewerage; however, it differs in its design layout as well as in the incentive (or requirement) for community interaction with the sanitation programme.

Considering that simplified sewerage was mainly developed in order to reduce the costs due to the conservative design criteria adopted in conventional projects, the concepts presented below compare the parameters of this system with those of conventional systems.

➢ ***Layout***

In conventional design layouts, trunk pipelines should be built in the streets around the house blocks to potentially allow individual connections for all the households.

On the other hand, simplified systems are designed in a way that the wastewater from households in the same block is collected by a shallow and small diameter pipeline and then, delivered to the trunk sewers by a single (or just a few) connection, as illustrated below.

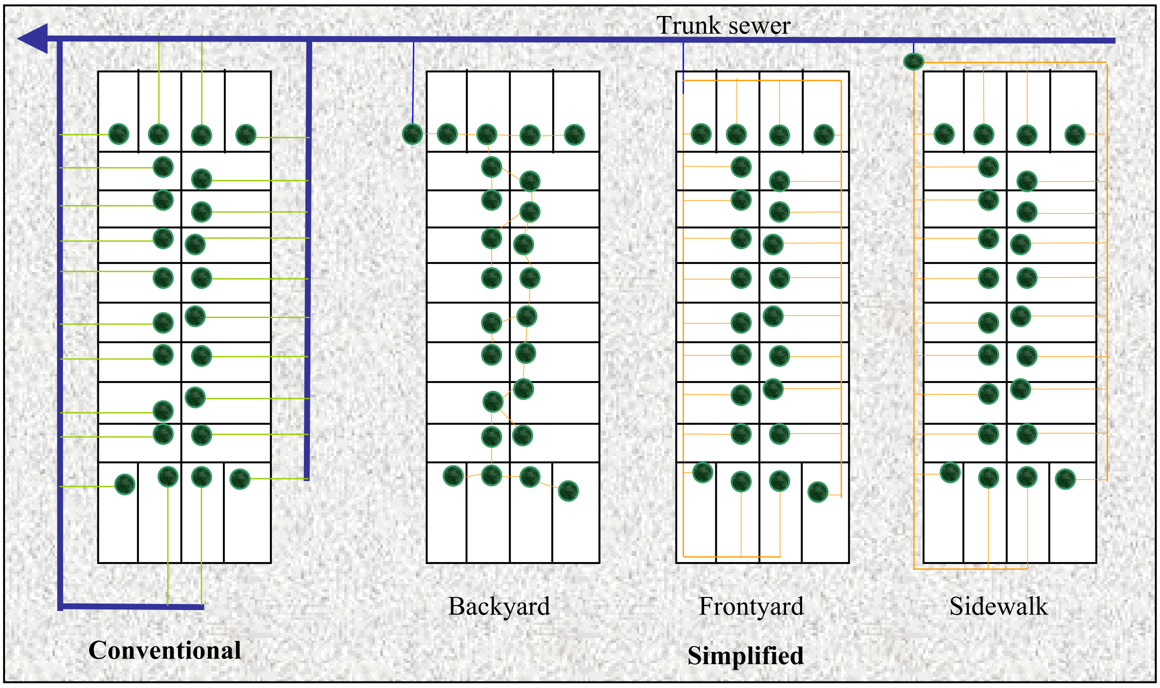


Figure 2.11. - Conventional and simplified sewerage layouts. *Based on Watson,1995.*

➢ ***Component parts***

- ***House connections:*** Simplified sewerage receives all wastewater generated by the households, i.e. both toilet wastewater and sullage. Essentially, any type of waterseal toilet can be used in this system (pedestal seat or squat pan, normal or reduced flush); however, considering that the system does not require a large quantity of water for its functioning, reduced-flush toilets are preferable. Therefore, connections between the households and the in-block sewer may occur through two pipelines: a 75 mm pipeline connecting the toilet wastewater to the inspection chamber, and a 50 mm pipeline connecting the sullage wastewater to the 75 mm pipeline or directly to the inspection chamber. In areas with low water consumption (up to 50 m^3/day), the installation of a grease/grit trap for the sullage is recommended. Moreover, ventilation pipes should be installed in the house connection pipes; these also serve to ventilate the whole system.

- ***Inspection chambers:*** These units are used for: house connections with the in-block sewer, changes in direction, changes in slope and maintenance of the sewers. In conventional sewerage, manholes are commonly used, especially for pipeline maintenance; however, in simplified systems their usage is reduced by the installation of inspection chambers. This substitution is possible mainly due to the shallower characteristics of the system; therefore, the manholes are only used where the sewers are laid at greater depth, thus reducing the quantity of manholes required and consequently decreasing the overall costs of the system. The shape of inspection chambers can be square or circular and their dimensions usually vary between 40 and 80 cm (in length or diameter), depending on the depth of the sewer. They can also have different internal designs for their different purposes (i.e. house connections, cleanout and changes in direction).

- ***Sewers****:* Two pipelines are used in simplified systems: *in-block sewers* (condominial sewers) and *trunk lines* (or main sewers). The former receives the household wastewater through the house connections and, as shown in the layout (Figure 2.11), can be located in the back or front yards (condominial version) or beneath the sidewalks. The trunk lines are laid in the streets and receive the sewage delivered by the in-block sewers. The hydraulic basis for sewer design is discussed later.

- ***Pumping stations:*** These usually comprise one of the most expensive units in sewerage systems and hence, whenever possible, are not included in the design. Their requirement in projects is very topography-dependent; however, the gradient of the sewers, as well as the boundaries of the area adopted by the systems, also influences the number of stations required.

- ***Sewage treatment plant:*** Simplified sewers have no hydraulic restrictions for their connection with any conventional treatments plants, which may be the option in areas where there is an existing conventional treatment unit. However, low-cost solutions for wastewater treatment (such as waste stabilisation ponds) are more desirable.

- ***Design area***

The simplified sewerage project area usually recommended is, where possible, limited by drainage basins. In fact, this approach may allow the systems to be more easily managed and can also reduce the number of pumping stations required.

- ***Depth of sewers***

A number of authors have designated simplified sewerage as "shallow sewerage"; this nomenclature however was changed to avoid confusion with other systems. Nevertheless, the shallow depth at which the sewers are laid in simplified designs is one of its most important characteristics, having direct effects on both capital and O&M costs. Two parameters are mainly responsible for the shallow depth of the sewers: *layout* and *gradient*.

In comparison with conventional systems, simplified sewerage layouts allow a reduction in the overall length of the sewer lines, which is especially true in backyard condominium layouts. The sewer gradient may be directly related to the flow velocity or to the shear stress (as discussed next). The flow velocity is also the parameter adopted in conventional designs; however, simplified sewerage applies this parameter in a less conservative way resulting in a design with a lower gradient.

With the association of these reductions in sewer extension and gradient, the pipelines can be kept shallower, and hence decrease the cost of excavation as well as the number of pumping stations required. Moreover, the in-block sewers are laid in areas without heavy traffic and, consequently, the cover layer over the crown that is required for protection (cover to soffit) of the sewer can be thinner than in conventional sewerage designs.

- ***Hydraulic concepts***

Two hydraulic design approaches can be used for the design of simplified sewers: minimum self-cleansing velocity and minimum tractive tension.

The first approach is based on the requirement for a minimum flow velocity in order to avoid the deposition of solids into the pipes. This concept considers that the minimum self-cleansing velocity at peak flow calculated for the system will be enough to carry the solids away, even if this is achieved only once a day. This approach is also applied in the design of conventional sewerage; however, it has a more conservative interpretation. While conventional designs consider the minimum self-cleansing velocity of, at least, 0.6 m/s, sometimes even 1 m/s (Mara, 1996), simplified sewers are designed using 0.5 m/s as the standard value for self-cleansing velocity in order to obtain the main design parameters (sewer gradient and diameter). As shown below, the velocity is directly proportional to a power function of the gradient and inversely proportional to a power function of the peak flow, thus, the lower the minimum velocity, the shallower the sewer can be kept. Nevertheless, the value for peak flow, which was taken as 2.2 l/s in the first trials with condominial systems in Natal, is now 1.5 l/s and this is the standard value stated in the Brazilian code (ABNT, 1988). This approach is currently used in condominial designs with successful examples of application especially in the Northeast of Brazil (Mara, 1996; Sinnatamby, 1986).

The second approach, based on minimum tractive tension, also has the objective of ensuring the transportation of solids. However, this approach is based on the tangential force exerted by the flow of sewage per unit of wetted boundary area. Therefore, the design parameters are now obtained by considering that the minimum tangential force (or minimal shear stress) of 1 Pa is satisfactory for simplified sewerage design (Mara, 1996; Bakalian *et al*., 1994).

Comparing both approaches, the adoption of minimum tractive tension appears to provide a more economical design. Although, in the examples studied (Mara, 1996; Bakalian *et al.*, 1994), the comparison between both approaches did not result in significant differences for the pipe diameter, the calculated minimum gradients in the second approach were lower than the one calculated by the minimum self-cleansing velocity approach. Moreover, SANEPAR, the state water company of Paraná in the South of Brazil, has simplified systems designed with a minimum shear stress of 1 Pa which have been operating satisfactorily for over 15 years, thus providing a reliable reference for the application of this methodology, which is also adopted in the Brazilian code (ABNT, 1988).

- ***Design parameters***

Simplified sewers are designed for open channel flow conditions, based on the properties of a circular section and Macedo's modification of Manning's equation (Mara, 1996).

- ***Peak flow:*** The estimation of peak flow is calculated by equation (ii) for all sections of the network pipeline. As demonstrated in equation (i), equation (ii) is based on: the size of the population (initial/final); the percentage of water consumption that returns as sewage (usually considered a loss of 15 percent due to water usage that is not collected by housing connections - i.e. cooking, gardening, cleaning and others), and, the k_1 and k_2 coefficients of maximum daily and hourly flow variation, respectively. Consideration should also be taken for the inclusion of upstream flows discharging into the sewer as well as for the possibility of groundwater infiltration into the pipes. This infiltration may occur due to imperfections in pipe joint sealing and it is typically considered as 0.2-0.3 l/s/km (Sinnatamby, 1986). Therefore,

(i) $Q = [(C \times k_1 \times k_2 \times P \times w) / 86400] + Q_c + Q_i$

Where, Q = peak flow in a sewer section (l/s)
C = sewage return factor (usually adopted 85%)
k_1= coeffic. of max. daily flow variation (=1.2)
k_2= coeffic. of max. hour flow variation (=1.5)
P = contributing population
w = water consumption (l/person x day)
Q_c =flow from upstream flow contributions (l/s)
Q_I =infiltration flow(l/s)

(ii) $\mathbf{Q = [\,1.8 \times 10^{-5} \times P \times w\,] + Q_c + Q_I}$

- ***Proportional depth of flow:*** This parameter is based on the properties of circular sections and expresses the ratio between the depth of flow in the pipe and the pipe diameter. It is used during the design to check if the depth of flow is high enough to ensure the transportation of solids at peak flow and if it is low enough to guarantee sufficient ventilation at the end of the design life. Therefore, the minimum and maximum values for the proportional depth of flow (d/D) are: **$0.2 < d/D < 0.8$**
  - Minimum ➔ 20% of the pipe diameter;
  - Maximum ➔ 80% of the pipe diameter.

1. *Design by self-cleansing velocity:*
   - *Velocity:* This design assumes that a flow velocity of 0.5m/s is enough for the transportation of solids. Therefore, this value is adopted as the self-cleansing velocity applied for gradient and diameter determination.
   - *Minimum gradient:* calculated from the Macedo-Manning equation (iii) (Mara, 1996), from which, the velocity is substituted by the self-cleansing velocity (iv) resulting in an equation for the minimum gradient as a function of the peak flow (v):

(iii) $v = 15.8 \times Q^{1/4} \times i^{3/8}$ Where v = velocity of the flow (m/s)

Q = peak flow (m^3/s)

i = gradient (m/m)

(iv) $I_{min} = (v_{sc}/15.8)^{8/3} \times Q^{-2/3}$

Where I_{min} = minimum gradient (m/m)

v_{sc} = self-cleansing velocity (0.5m/s)

Q = peak flow (m^3/s)

(v) $\mathbf{I_{min} = 0.01 \times Q^{-2/3}}$

Where I_{min} = minimum gradient (m/m)

Q = peak flow (l/s)

2. *Design by minimum tractive tension:*

- *Shear stress:* This approach, which is based on the shear stress expressed by equation (vi), considers that 1 Pa (or 0.1 kg/m^3) is enough to guarantee the transportation of solid particles in simplified sewers at peak flows.

(vi) $\tau = W \times r \times i$ Where τ = shear stress (kg/m^3)

W = specific weight of sewage (N)

r = hydraulic radius (m)

i = gradient (m/m)

- *Minimum gradient:* To calculate the minimum gradient through this approach, the above equation (vi) is incorporated into Manning's equation (vii) and finally, it provides equation (viii) used to calculate the minimum gradient.

(vii) $Q = 7.687 \times 10^{-8} \times (1/n) \times (\tau^{8/3}) \times I_{min}^{13/6}$

Where, Q = peak flow (m^3/s)

n = Manning's Roughness Coeffic. (= 0.013)

τ = shear stress (= 1Pa)

I_{min} = minimum gradient (m/m)

(viii) $\mathbf{I_{min} = 0.0054 \times Q^{-6/13}}$

Where, I_{min} = minimum gradient (m/m)

Q = peak flow (l/s)

Therefore, considering a minimum peak flow of 1.5 l/s (a toilet flush flow), the minimum gradient value can be calculated for both approaches presented:

Approach	Minimum gradient
Self-cleansing Velocity	0.006 (1 in 167)
Tractive Tension	0.004 (1 in 225)

- ***Pipe diameter:*** Regardless of the approach used for the design of sewers, 100 mm is usually recommended as the minimum diameter for pipes applied in simplified sewerage designs (Sinnatamby, 1986). The diameter of sewers can be calculated by the equation below:

$$\mathbf{D} = n^{3/8} \times k_a^{-3/8} \times k_r^{-1/4} \times (Q / I_{min}^{1/2})^{3/8}$$

Where D = pipe diameter

n = Manning's Roughness Coefficient

k_a = coefficient of proportional area ($a=k_aD^2$)

k_r = coefficient of proportional hydraulic radius ($r=k_rD$)

Q = peak flow (l/s)

I_{min}= minimum gradient (m/m)

Sewers in simplified systems essentially require the same operation and maintenance tasks applied in other systems. As suggested by the WPCF (1985), a minimum maintenance programme should include tasks such as cleaning, flushing, repairs and supervision of connections/disconnections. However, it is expected that the shallower characteristic of the sewers allows the implementation of a simpler and cheaper operation and maintenance programme, which may be achieved by the utilisation of less sophisticated equipment that, consequently, requires less skilled labour.

2.5.3. VIP Latrine

The ventilated improved pit (VIP) latrine is an on-site sanitation system. It was developed to avoid the two major disadvantages of traditional (unventilated) pit-latrines, which are foul odours and the attraction of flies, making the system more socially and healthwise acceptable.

VIP latrines are designed to receive just excreta (faeces and urine) without any requirement for water. Thus, the utilisation of water should be totally avoided in personal cleansing activities (Mattos, 1997) and be very limited when cleaning the latrine. This low requirement for water makes the system very suitable for users that do not have an in-house level of water supply; however, this would also constitute one disadvantage because the system requires a separate solution for sullage disposal.

The advantages of this system are its easy construction, its adaptability to diverse types of material, and its usually simple maintenance. As disadvantages, there are possibilities of groundwater contamination and the reduced appropriateness of the system for high density neighbourhoods.

VIP latrines are designed to receive and deposit excreta in the latrine pit where the excreta are digested by the natural biological action of anaerobic bacteria. In two years time the pathogens in the excreta are inactivated and the material accumulated inside the pit can be safely handled.

As said previously, VIP latrines are designed to be odourless and fly-free. The control of *odour* occurs due to the air circulation through the latrine pit and vent pipe. The air is allowed to enter the latrine by the superstructure, then, it goes into the pit through the squat-hole or toilet bowl (which should not be covered) and comes out through the vent pit, guaranteeing air movement and avoiding the risks of odour (see Figure 2.12).

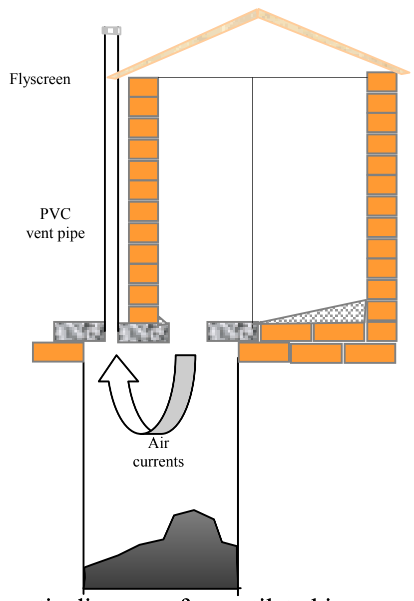


Figure 2.12. - Schematic diagram of a ventilated improved pit latrine. *Source: Mara (1996).*

The *fly control* mechanism is based on two events. Firstly, the flies use the excreta to lay their eggs, being attracted to it by the faecal odours, however, the screen on the top of the vent pipe (where the faecal odour are strongest) does not allow the flies to get inside of the pit for breeding. Secondly, some flies may reach the excreta through the superstructure lying their eggs in the pit, however newly emerging adult flies are attracted by the brightest light to leave the pit. Considering that the latrines are designed not to allow the entrance of light through the superstructure, the brightest light will come from the vent pipe which is covered by the fly screen which therefore keeps the flies inside the pit where they eventually die.

Variations of the basic VIP latrine design alternatives can be adopted to comply with requirements imposed by soil condition (lined/unlined pits), ground water table level (raised/not raised latrines), users' preferences (outside/in-house latrines), economical suitability and institutional support (spiral/rectangular shaped, single/twin pit and emptiable/non-emptiable latrines (Mara, 1985a)).

VIP latrines include the following components (after Mara, 1984):

- ***Latrine pit:*** VIP-latrines may be designed with single or twin pits. Both types are based on: the size of the household, the design life and the solids accumulation rate. Single pit latrines should be designed to have at least 10 years of design life if it is a non-emptiable latrine, whereas an emptiable single pit latrine may have a design life of 2 years and the emptying process must be carried out mechanically. The twin-pit latrine should have at least 2 years of design life. After the first pit is full the second one is used and two years later, when the second pit is also full, the first one will be pathogenically safe and can be manually emptied. It is essential to instruct the users about the proper functioning of the latrine to avoid the utilisation of both pits at the same time. Depending on the stability of the soil, the pit should be lined with concrete blocks, bricks, bamboo or any other suitable material locally available. Free-spaces should also be left in the lining to allow the infiltration of the liquid fraction of excreta (i.e. urine) in the soil.

- ***Cover slab and foundation:*** These parts have two important functions: the isolation of the pit from the atmosphere and the provision of support for the superstructure, the vent pipe and the user. In general, the foundation may be built in a single course of bricks set in cement mortar. The cover slab may be built in a wide range of materials depending on local availability and its capacity of support; however, the most suitable material is reinforced concrete. The shape of the cover slab should follow the same shape of the pit (circular or rectangular) and two holes must be provided: one for the squat-hole or the toilet bowl and the other for the vent-pipe.

- ***Superstructure:*** The superstructure has three different functions: to guarantee the user's privacy, protect the cover slab hole from natural light (which is fundamental for fly control) and channel air through the hole and up the vent pipe. Traditionally, the superstructure entrance is designed with doors; however, it has been reported that doors are frequently left open and consequently do not control flies effectively.

In some African countries, such as Zimbabwe, the use of doors was considered undesirable and a spiral design for the superstructure has become very popular (Morgan & Mara, 1982).

- ***Vent pipe and flyscreen:*** As discussed before, the vent pipe is responsible for both odour and fly control. It may be provided in different materials such as bricks or bamboo, however a 100 mm PVC pipe is generally used. In any case, the top of the vent pipe must be protected with a flyscreen.

The design of a VIP-latrine is based on the volume of the pit necessary for the accumulation of the excreta from users during the design life of the system, or during the emptying interval. Therefore, the volume of each pit is calculated by:

$$\mathbf{V\ (m^3) = r * P * n}$$

Where: r = solids accumulation rate (m^3/person/year);
P = number of users (people);
n = design life or emptying interval (years).

Additionally, some requirements should be followed:

- Cross-sectional area not greater than 2 m^2;
- Distance between the bottom of the pit and the groundwater table level of, at least, 0.5 m;
- A freeboard of 0.3-0.5 m should be added to the calculated depth.
- Solids accumulation rate is usually 0.03-0.06 m^3 per person per year in dry pits and 0.02-0.04 per person per year in wet pits.

2.5.4. Pour-flush Toilets

Pour-flush toilets are also an on-site sanitation system. They consist in the deposition of excreta in a watersealed toilet (bowl or squat pan) that is flushed using a reduced amount of 2-3 litres of water per flush. The flushed wastewater is then discharged into a pit, where the liquid fraction leaches into the soil of unlined pits (or holes left in lined pits) and the solids are retained for consequent bacterial digestion. Problems of odour and fly control are avoided by the waterseal maintained by a trap in the toilet bowl (squat pan).

The pour-flush toilet has the advantage of being a well-tried technology with widespread use in developing countries; it has a low water requirement and is easy to maintain; it is highly social acceptable, has excellent insect and odour control, is easy and safe for use by children, and it may be easily upgraded. On the other hand, pour-flush toilets are not suitable for areas where people use bulky materials for anal cleansing and for soils with low infiltration rates; as in the case of VIP-latrines, pour-flush toilets also have the potential for groundwater contamination and requires a separate solution for sullage disposal.

The toilets in pour-flush systems are usually manually flushed; however, the system can be easily converted to low-volume cistern-flush operation. For that, the two most popular ways are by the Indian squat-pan unit or by the Brazilian pour-flush pedestal seat. In the Indian model, the cistern has a capacity of 15 litres releasing just 1.5 litres per flush. The Brazilian system uses 5 litres of water to flush and the water is deposited in a cistern that is fed by an in-house water supply system (Mara, 1996).

The three main parts that compose a pour-flush toilet system are:

- ***Superstructure:*** An outside structure has the objective of protecting the toilet unit and to provide privacy for its users, however it has no impact on the fly control process as in VIP-latrine systems. It should be built with the floor raised by at least 150 mm in order to avoid the entrance of stormwater and insects (Mara, 1985b). Pour-flush toilets may also be an in-house facility. In both cases, the design should allow easy maintenance and cleanliness.

- ***Latrine unit:*** As discussed earlier, this system requires a waterseal that must have a depth of 20-30 mm in the trap unit. This is to minimise the consumption of flushwater as well as to guarantee the waterseal formation. The wastewater may discharge directly into the leach pit; however, it is more commonly connected to a 75-100 mm pipeline, which is laid shallow at a low gradient, and then discharged into the pit. In cases of twin pit systems, a Y-shaped flow diverter should be included, as shown in Figure 2.13.

- ***Leach pit:*** As with VIP-latrines, the pour-flush systems may be designed with either single or twin pits. In the single pit design, a mechanical emptying process at the end of its design life is required, whereas the twin pit can be safely emptied manually. Leach pits are used for both the storage/digestion of excreted solids and the infiltration of wastewater liquids. For the latter function, the long-term infiltrative capacity of the soil is of essential importance (Mara, 1985b).

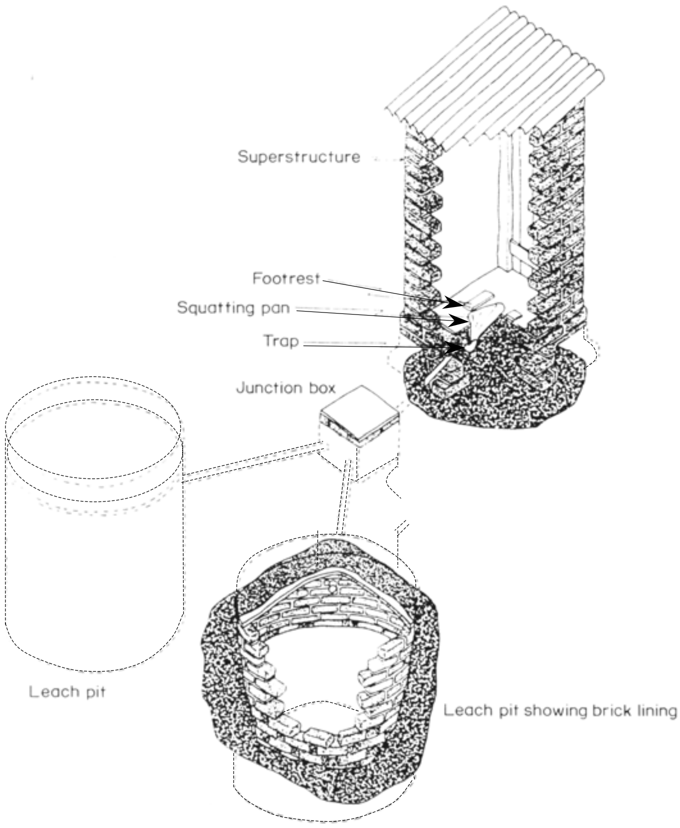


Figure 2.13. - Schematic diagram of a pour-flush toilet. *Source: Mara (1985a).*

The leach pit design for pour-flush toilet systems is based on the volumes required for solids storage and for infiltration. Therefore, the design sequence is presented below (after Mara, 1996):

1. *Solids storage volume*: This volume is calculated in the same way as VIP-latrine pits:

$V_S\ (m^3) = r * P * n$ Where: r = solids accumulation rate (m^3/person/year);
P = number of users (people);
n = design life (years).

2. *Infiltration volume*: This is based on the long-term infiltration rate of the soil, which may be estimated by the *in situ* percolation test or by the long-term infiltration rate of the different types of soil. Therefore, infiltration volume is calculated by the following equation: $V_I = \pi * D^2/4 * h$; $A_I = \pi * D * h$; $A_I = Q/I$

$$\mathbf{V_I\ (m^3) = Q*D/4*I}$$

Where: A_I = sidewall area required for infiltration (m^2);
Q = hydraulic load (litres*capta*day or lcd), discussed below;
D = assumed pit diameter (m);
I = long-term infiltration rate (l/m^2*day);
h = height of the sidewall area (m).

The hydraulic load may be calculated as follows:

$$Q\ (lcd) = N_f*(V_w+V_c) + V_f + (a*N_u*V_u) + V_u$$

Where: N_f = aver. numb. of times that the toilet is used for faeces disposal (person*day);
V_w = volume of flushing water (litres/flush);
V_c = volume of water used for cleansing (litres/cleansing);
V_f = volume of faeces (lcd);
a = constant, if toilet is flushed after urine it is = 1; if not it is = 0;
N_u= aver. numb. of times that the toilet is used for urination (person*day);
V_u = volume of urine (lcd).

- ***Design of single leach pits*:** Although infiltration also occurs through the sidewall area corresponding to solids volume, the effective volume of single pits is determined by the sum of solids storage and infiltrative volumes. This design consideration is especially important to allow a better restoration of the soil infiltrative capacity after emptying. Therefore, the effective volume of single leach pits is calculated by: $\mathbf{V(m^3) = V_S + V_I}$

- ***Design of twin leach pits*:** Considering that the restoration of soil infiltrative capacity occurs during the alternating usage time, the pits are designed using the greater value for volume calculated: solids storage volume or infiltrative volume.

2.6. Assessment of Sustainable Sanitation Programmes

The assessment of a technology-driven system is usually a straightforward exercise. It is comprised of physical components that are designed to produce certain specific outcomes. Thus, the assessment is based on a limited, but well-defined evaluation of the technology's components ("hard" elements) and their expected performance over its design life. On the other hand, social systems are far more subjective. In systems committed to social achievements and interactions among people, their boundary line is not easily determined. Moreover, interaction with human beings is not at all predictable and "the performance" of the system may be subjected to human behaviours and individual aspirations.

The sanitation programmes in a sustainable development context combine both approaches referred to above. Their performance depends on a physically implemented technology, but also on the active participation of users and their interaction with other stakeholders.

2.6.1. Indicators of Sustainability

Indicators may be defined as *bits of information pointing to characteristics of systems or highlighting what is happening* (Hardi *et al.,* URL-10, 1997). They are used as operational elements for the assessment processes facilitating communication and making the quantification of systems possible (Bell & Morse, 1999; Hardi *et al.*, URL-10, 1997; UN, URL-11, 1997). The importance of indicators, as measurement tools of sustainable development, is stressed by their role in decision-making processes, providing information on issues such as the development of trends and pressure points, the impacts or effects of interventions or policies, the feedback of adjustments models (to speed up or slow down the effects of interventions), and on the milestones achieved or the failures that frustrate progress (UN, URL-11, 1997).

Indicators of sustainability can be used as *explanatory tools*, *planning tools* and *performance assessment tools* (Hardi *et al.,* URL-10, 1997). Indicators can also be divided into variables or functions of variables and classified as qualitative variables (e.g. safe-unsafe neighbourhood, participatory-non-participatory decision making); ranking variables (i.e. best or worst training programme, lowest or highest mortality rate) and quantitative variables (i.e. gross domestic product/capita, water consumption in litres/capita day).

Along with other institutions the United Nations is also concentrating efforts on the development and testing of suitable indicators for sustainability (UN, URL-13, 1999). As a result, a working list with 134 indicators was established covering four aspects of sustainable development: social, economic, environmental and institutional (UN, URL-12, 1996,). These indicators are presented in a Driving Force - State - Response framework, where:

▪ Driving Force	(also referred to as control, pressure or process indicator) Indicates human activities, process and patterns that impact on sustainable development. Examples are unemployment rate, population growth rate and GDP per capita.
▪ State:	Describes the state of a variable (such as concentration of a pollutant, human population density and income equality)
▪ Response:	Indicates policy options and other responses to changes in the *state* of sustainable development. Examples are infrastructure expenditure per capita, national councils for sustainable development and the proportion of GDP spent on education.

The strongest criticism against the utilisation of indicators to assess sustainable development is probably their attempt to reduce complex and diverse processes into relatively few simple measures, which also makes sustainable indicators (SI) appear as a reductionist set of tools based on quantification (Bell & Morse, 1999).

Although different sets of variables (quantitative, ranking, qualitative) have been suggested, reductionism may be an intrinsic characteristic for the measurement of systems. The process of breaking down complex systems is commonly applied to make systems manageable and assessable. Thus, the question may be how much reductionism should be allowed in the assessment of systems toward sustainable development. An attempt to answer that may be through the way systems are approached.

SIs may allow the collection of data related to components (reduced parts) of a system; however, none of these parts can be approached in isolation. The interaction among parts of the system and between parts and the environment should be present in every stage of the system analysis (conceptualisation, planning or assessment). Thus, more than with isolated indicators, sustainability indicators must be committed to the systems in a holistic perspective, adopting the process of thinking systematically about problems and making the process interactive, participatory and ongoing.

In Bell & Morse (1999), the sustainability indicators are positioned as represented in Figure 2.14. They collect information from the system, making them capable of interpretation and use. The main questions in this model are still the quantity of indicators that should be applied and which indicators are appropriate. As every potential available indicator may not be applied, an element of simplification would be introduced, and the maximisation of relevant information is also essential.

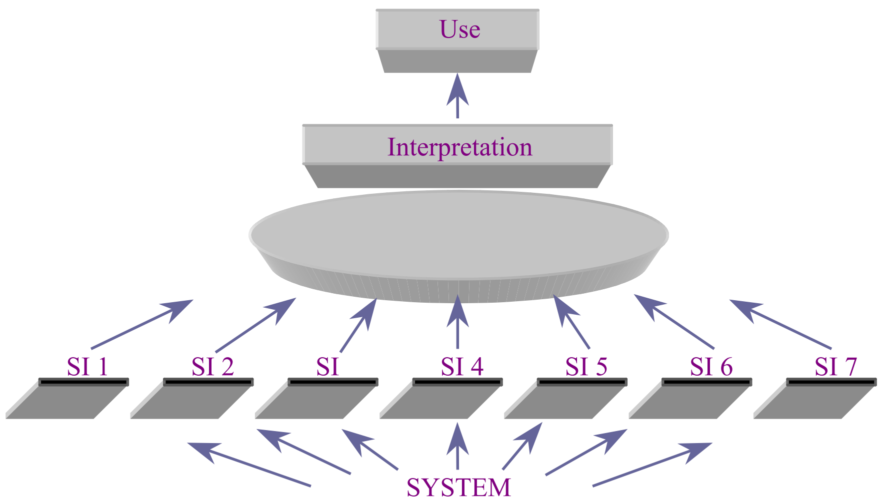
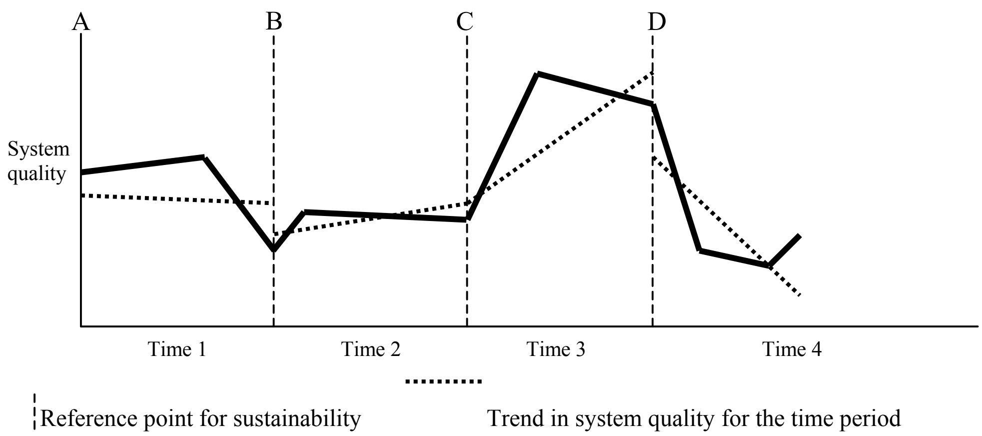


Figure 2.14 - The concept behind sustainability indicators (SIs). *Source: Bell and Morse (1999)*

In the identification of SIs, three elements are present as key issues for the assessment of a system's sustainability. They are space, time and quality (Bell & Morse, 1999). The *spatial scale* defines the boundary of the system. Although it may appear of easy physical determination (a town, a nation, the globe or even a settlement or a community), the elements that should be included inside of the system's limits and the level of "openness" that should be left for interaction (or linkage) of these internal components and outside environment may not be that simple. Also, usually the smaller the spatial scale, the harder it is to draw its limit line.

The *time scale* is a very relative element in sustainability. By definition, it is stated that sustainable development should not "compromise the ability of future generations…", but, as questioned by Bell & Morse (1999), what future generation should be considered (in ten, 100 or 1000 years) ? Figure 2.15. illustrates a variation on the quality of a system used to measure sustainability over time periods. When the reference period for the system assessment is just one of a period of time (1, 2, 3 or 4), different interpretations arise for each period (slightly unsustainable, sustainable, sustainable and unsustainable, respectively). Moreover, if the whole period is taken as reference (period 1-4), the interpretation of the trend will be more or less constant over time. Thus, time (and space, as well) requires a careful selection of reference points to be able to reflect accurately the intended situation.



Time period	Reference point	Likely interpretation
1	A	Unsustainable (slight decline in quality)
2	B	Sustainable (improving quality)
3	C	Sustainable (improving quality)
4	D	Unsustainable (declining quality)
1 to 4	A	Sustainable (overall trend in quality is level)

Figure 2.15. - Importance of the reference point for gauging sustainability. *Source: Bell & Morse (1999)*

The *quality* of the systems (or quality of life, or people's well being) is the third key element suggested. The identification of quality parameters that should be used for the assessment of sustainability make this last element even more controversial than the two previous ones. In fact, if two people assess the same system based on different quality parameters, they may achieve distinct (even contradictory) interpretations.

The elements considered above are identified on the Bellagio principles for assessment toward sustainable development (IISD, URL-9, 1999 – note that this is not the WSSCC Bellagio principles on environmental sanitation, for that see WSSCC, URL-31, 2000). These principles, established in November 1996, are considered interrelated principles, and they are recommended to be applied as a complete set. They were developed as guidelines for assessment processes and include the choice and design of indicators, their interpretation and communication of results. Four main aspects are covered by the principles as shown in Table 2.10.

In summary, sustainability indicators are not just a question of collecting data from parts of a system. Therefore, the process of selection of a set of indicators must be committed with the system as a whole and follow a systematic framework of analysis. Concerning indicators, Hardi *et al.* (URL-10, 1997) stated that,

"Indicators themselves are also the products of a compromise between scientific accuracy and the needs of decision-making, and urgency of action. This limitation becomes quite clear in the social dimension where many of the variables, such as political stability, cultural aspirations and equity, are hardly quantifiable and cannot even be defined in physical terms".

Table 2.10. – Main characteristics of the Bellagio principles

▪ *Principle 1* :	▪ Guiding Vision and Goal	Deal with the starting point of any assessment - establishing a vision of sustainable development and clear goals that provide a practical definition of that vision in terms that are meaningful for the decision-making unit in question;
▪ *Principles 2-5* :	▪ Holistic perspective ▪ Essential Elements ▪ Adequate Scope ▪ Practical Focus	Deal with the content of any assessment and the need to merge a sense of the overall system with a practical focus on current priority issues;
▪ *Principles 6-8* :	▪ Openness ▪ Effective Communicatio[n] ▪ Broad Participation	Deal with key issues of the process of assessment;
▪ *Principles 9-10*:	▪ Ongoing Assessment ▪ Institutional Capacity	Deal with the necessity for establishing a continuing capacity for assessment.

2.6.2. Physical Evaluation Procedures

During the International Drinking Water Supply and Sanitation Decade (1981-1990), WHO produced a document providing guidelines for a minimum evaluation procedures (MEP) for water supply and sanitation programmes (WHO, 1983).

The document considers three main elements: the *functioning,* the *utilisation* and the *impact* of the facilities. It is also argued that these elements should be evaluated in sequence; there is no point in evaluating impact if the facilities are not appropriately used and, in the same way, there is no meaning in assessing utilisation if the technical system is not working.

The emphasis of the WHO MEP document is on the collection of basic information on the functioning and utilisation of low-cost water supply and sanitation projects. Thus, the document identifies the following steps:

- Decision to evaluate;
- Selection of team leader;
- Establishment of terms of reference (which should define: objectives; project area; design study; methods; organisation and manpower resources; reporting requirements; time schedule, and financial requirements);
- Desk study (project documentation analysis);
- Field visit for planning;
- Decision on focus of the evaluation;
- Collection of data (discussed below);
- Assessment of data;
- Recommendations, report writing and follow-up actions.

The MEP document suggests that there are three main types of data: data on the functioning of the facilities and educating services, data on the utilisation of services and data on the institutional and financial arrangements of the programmes. Table 2.11. summarises the main approaches suggested for obtaining these different types of data.

Table 2.11. – Approaches for data collection in MEP

Type of Data	Approaches	Observations
1. On the functioning of facilities and educational services	▪ Engineering inspection; ▪ Scientific observation; and ▪ Users comments on their perceptions on educational messages and approaches	Opinions and attitude of users should be recorded, but they should be backed up by direct inspection and appropriate laboratory tests.
2. On the utilisation of the services*	▪ Direct observation; ▪ Conversational interview; ▪ Stratified sample; ▪ Information gathering by school children; ▪ Community questionnaire; ▪ Questionnaire survey; and ▪ Workshops.	The selected method (s) for household information (left-side list) should be the least costly approach(es) at reasonably accuracy.
3. On institutional and financial arrangements of the projects.	▪ Desk study (review of documentation); ▪ Interviews	Information may be conflicting depending on their sources. Descentralised sources are likely to be more accurate.

* The document provides further details on the indicated approaches *Based on WHO (1983).*

The items recommended for investigation under the institutional and financial set of data are divided into government and consumer inputs. For the first, the following inputs are used as examples:

- Involvement of consumers in the planning process;
- Promotional and educational programmes;
- Training of project staff (for construction and for O&M);
- Production and delivery of the project components; and
- Construction demonstration and supervision.

For consumer involvement it is suggested that they contribute to:

- The planning process; and
- The construction and O&M in cash or in kind.

Regarding the evaluation of functioning and utilisation of sanitation programmes, the MEP document selected three indicators for functioning (proportion of household that have sanitation facilities, sanitation hygiene and sanitation reliability) and one indicator for utilisation (proportion of people using the facilities). These indicators are detailed next:

1. Indicator of Proportion of Household that Have the Sanitation Facility

The acceptability of the programme is an important factor to improve the sanitation condition of the community as whole, and also for the viability of the programmes. Thus, this indicator consists of a house-to-house survey obtaining the number of households that actually have the facility (i.e. latrine, connection). The indicator can be obtained by the following relation:

$$I\,(\%) = \frac{\text{Number of households having the sanitation facility} \times 100}{\text{Total number of households in the programme area}}$$

It has been suggested that this indicator may be obtained by a house-to-house survey. However, a coverage of hundred percent of the sample in these types of surveys is usually difficult to achieve. Therefore, a minimum percentage sample coverage should be established beforehand (80 percent or above) (WHO, 1983). In addition, the main reasons for why households are not attached to the programme is also expected to be obtained during the collection of data for this indicator.

2. Indicator of Sanitation Hygiene

Facilities that are not kept clean can both discourage people from using them and serve as a focus for the transmission of diseases, whereas the sanitation system has the objective of avoiding them.

This indicator is suggested as best established through physical inspection. However, it is far more subjective than the first indicator and relies on judgements established by the inspector(s). Therefore, a grading system (i.e. good, acceptable, bad and very bad) should be applied for the registration of the data. The aspects to be evaluated will certainly vary according to the type of facility implemented but they should include items such as general cleansing of the toilet area, odour, presence of insects, access to water, presence of lid on the latrine and presence of the water seal, as necessary.

The indicator should be expressed as the proportion of a specific grade for the determined aspect.

3. Indicator of Sanitation Reliability

The requirements of design, construction and O&M services for the applied technology should be properly followed in order to get the best out of the system and stimulate households' participation in the programmes. A house-to-house survey is also applied for this indicator where a "check list" of the technology requirements, containing items such as presence of fly-screen, water seal, system ventilation and emptying interval among others, may be accordingly applied.

4. Indicator of the Proportion of People Using the Facility

Reliable information on the utilisation of sanitation facilities by household members is difficult to obtain. The observation of toilet utilisation is (usually) not physically possible and interviews are not all reliable; people usually state that the facilities are being used even when they are not. Therefore, the MEP document recommends a mixture of interviewing and observation of signals of usage/non-usage in order to draw a more accurate picture of the facility's utilisation.

As in the case of the first indicator (the indicator of acceptability), the reasons for why the facilities are not being used are of great value. Common reasons include inconvenience of the facility's location, unsuitability for younger children, unhygienic conditions and cultural aspects.

Another topic that must be addressed in studies regarding the sustainability of the sanitation programme is the impact of the sanitation system on users' health. A range of factors may influence the state of health in any given community (see section 2.2.3); therefore, the adoption of indicators that will, in fact, measure the health benefits resulted exclusively from sanitation improvements is usually not straightforward. The next section discusses the main implications of the measurement of impact of sanitation programmes on users' health.

2.7. Measurement of Impacts on Public Health of Sanitation Improvements in Low-Income Communities

Assessing the health impacts derived from sanitation (and water supply) programmes presents a series of fundamental problems. These studies have been traditionally based on epidemiological parameters to measure indicators such as incidence rates of diarrhoea/dysentery, prevalence rates of excretion of one or more enteric pathogens, prevalence rates or intensities of intestinal helminthic infections, nutritional status and mortality rates.

Blum & Feachem (1983) analysed the methodology applied in 44 published studies on the impact of water supply and/or excreta disposal on diarrhoea, or on infections related to diarrhoea. They identified at least one methodological problem in each of the 44 studies (which raises serious doubts to the validity of the conclusions presented). The main methodological problems identified were the following:

- Lack of adequate control;
- One to one comparison;
- Confounding variables;
- Health indicator recall;
- Health indicator definition;
- Failure to analyse by age; and
- Failure to record facility usage.

Two cases of *control* problems were found in a number of the studies analysed by Blum and Feachem (1983). These problems were basically the complete absence of an external control sample, and comparability of the control and intervention sample (which was not established prior to the interventions). The *one-to-one comparison* problems were related to studies that select a single control community and compare it to a single intervention community. In these cases, the number of elements in each sample is one; hence, no statistically valid conclusion can be drawn.

Inadequate control of the influence of *confounding variables* was another problem identified. The importance of the control of confounding variables is to avoid those aspects not directly related to the sanitation or water supply projects also influence the health status of the studied population. For example, certain people in the studied community may have easier access to information on health than others (i.e. from TV or radio programmes) and their health conditions may improve due to this sort of information and not necessarily due to the new sanitation facility.

Health indicators that are asked to be *recalled* (such as the number of diarrhoea episodes over a specific period) may present three problems: the variable may not be known by the respondent (the episodes of diarrhoea of all members of the family, for example), unwillingness to divulge the information and a limited ability to remember. A suggestion for the health indicator recall problem is to keep the recall periods as short as possible. Alternatively, the variables could rely on evidence of the infection.

Another methodological problem was related to the *health indicator definition*. The definition of both the disease and the applied indicator should be clear to avoid the impression that measurement of impact is being made on a vaguely defined illness. Environmental impact studies are unevenly distributed among various age groups; therefore the adoption of an *age-specific* approach for the data analysis of the study is necessary. Finally, the last methodological problem discussed for epidemiological evaluation of impact on health from water supply or sanitation improvements is that studies also *fail to record facilitity usage*. Regarding this, it must be remembered that facilities by themselves do not improve the health status of users, which can only be achieved by their proper use. For this, the utilisation of two approaches is recommended: information collected by questionnaire and information collected by observation (Blum & Feachem, 1983).

Cairncross (URL-14, 1999) argues that epidemiological studies depend on the intervention studied and the outcome measured. However, the ideal way suggested to measure the impact of health intervention (double-blind, randomised, controlled trials) is not seen as feasible for sanitation and water supply interventions. Cairncross (URL-14, 1999) states that:

There is no placebo for a pit latrine. Moreover, the unit of intervention usually has to be the community, rather than the household. Besides, it is almost impossible to allocate water supplies and sanitation at random - ethically, politically and practically.

Another factor raised from the discussion of fundamental problems of health impact evaluations is that such evaluations are not an operational tool and the results frequently offer no firm interpretation. Additionally, even if health impacts are satisfactorily detected in an epidemiological study regarding water supply and sanitation projects, no guidance on how the projects may be improved is offered (Cairncross, URL-14, 1999). Therefore, this author suggests that an alternative approach is the evaluation of impact based on patterns of hygiene behaviour, instead of attempting to measure disease rates. The basis for this is that water supply and sanitation projects are usually accompanied by hygiene education programmes that seek to achieve improvements in hygiene practices such as the washing of hands, food and utensils, or the disposal of children's faeces, all of which can be used as parameters for health impact evaluations.

The WHO minimum evaluation procedure (MEP) document (referred to previously) also suggests indicators for hygiene education evaluation (WHO, 1983). As in the case of the evaluation of sanitation projects, hygiene education evaluation is also divided into functioning and usage indicators. The four functioning indicators are related to understanding the language of educational messages, understanding the content of the messages, access to the messages and face-to-face contact with project staff and other educators. In relation to usage, the three indicators suggested are water storage habits, handwashing after defecation and knowledge of oral rehydration. These seven indicators are detailed next (based on WHO, 1983).

➢ ***Indicators of functioning***

1. Indicator for the understanding of the language of the messages

The overwhelming majority of the target audience must have a full understanding of the educational messages (especially among women's groups). The data for this indicator may be collected by surveying the languages in which a representative sample of the target group is fluent and literate. The assessment is thus realised through the proportion of people (or women) able to understand the languages adopted for the transmission of the messages (which may be spoken, written or graphic languages).

2. Indicator for the understanding the content of the messages

The target of this indicator is that the audience should readily understand the content of the educational messages. Data should be collected by asking a representative sample to explain the meaning of some hygiene education messages and the answers may be scored on a three-point scale (good understanding, some understanding and no understanding).

3. Indicator of access to the messages

This indicator is given by the proportion of a representative sample in the target group that have access to the media used for the transmission of the hygiene education messages. Additionally, it is also suggested that information be gathered on the periodicity of which they see or hear the messages.

For the assessment of this indicator, a case-specific criterion should be developed to judge whether the financial investments in the selected media is justified or not, in comparison with the percentage of people that are actually receiving the messages.

4. Indicator of face-face contact with project staff and other educators

It is assumed that staff in face-to-face contact with the target group can:

- reinforce the messages;
- explain and amplify the messages to suit local situations; and
- give encouragement to those who are modifying their hygiene habits.

The data required may be obtained through a survey of a representative sample to determine the proportion of people who have conversed with educators in the past month. Moreover, the quality and the quantity of these interactions among the target group and educators should be assessed asking people to recall their meetings, identifying the educator met and giving the subject of the conversations.

The answers should be recorded and the assessments made by an analysis of the kind of staff that are more effective and what kind of knowledge and activities are being encouraged.

➢ ***Indicators of utilisation: water storage habits; handwashing after defecation and knowledge of oral rehydration***

The assessment of these indicators aims to identify changes in behaviour. The data required for this assessment can be based on observations (whether the water storage recipients have been kept properly protected and hygienically maintained, or, whether there is water and hand washing material easily available near the latrines). For the indicator of the knowledge about oral rehydration, interviews with mothers should be carried out in order to assess their knowledge on how to prepare the oral rehydration solution, when to give it and how much. This information may be graded on a three-point scale:

- Does not know what oral rehydration solution is;
- Proportions of ingredients or application is grossly wrong; or
- Proportions of ingredients or application is approximately correct.

2.8. Conclusions

Sanitation is a basic need for any community, and a need that has been advocated to be met for every person in the world by the end of 2025 (WSSCC, 2000).

Sanitation may be understood in terms of comfort, but it is primarily a question of health. In the first sections of this chapter, data were given on the number of people that are still suffering from diseases that may be avoided if a sanitised environment is available. However, the simple delivery of a sanitation system is not enough to ensure its proper technological functioning or the expected improvements in health.

As noted by Kalbermatten & Middleton (1998), a "strategic planning" system is required that addresses the technical, financial, institutional and social approaches needed for the sustainability of the service.

The next chapter gives the methodology that will be applied in the field study, which is based on the discussions presented throughout this literature review.