Rural Water Supply and Sanitation:

A Transfer of Technology

Through the Internet

by

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Declaration

I, Mohammed Cassim Dindar declare that unless otherwise stated, this dissertation is my work and has not been submitted for degree purposes at another University or Institution.

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Abstract

The situation with regard to water supply and sanitation in developing countries is highlighted. Figures on the current level of delivery of services, both worldwide and within South Africa are given. The link between improved water supply and sanitation and the overall development of a country is established. The importance of communication between sector professionals is highlighted as a means of improving the delivery of services within the water supply and sanitation sector.

Issues relating to water supply and sanitation in rural areas are discussed in separate sections with particular reference to the problems experienced in developing countries. In both cases technology appropriate to rural communities within developing countries is presented as part of the solution to the problem of sustainable delivery of services within the water supply and sanitation sector.

The Internet and relating activities are presented as tools that can be used to disseminate sector related information. The design, construction and implementation of an information server based on the Internet is demonstrated as an effective method of disseminating sector related information.

The study concludes by evaluating the effectiveness of the server as a means of overcoming sector related issues. Results show that the information server can be used to solve a number of problems experienced by sector professionals in developing countries.

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ABBREVIATIONS

ARPA	Advanced Research Projects Agency
BOD	Bio-Chemical Oxygen Demand
CCWR	Computing Centre for Water Research
CSIR	Council for Scientific and Industrial Research
DWAF	Department of Water Affairs and Forestry
EHP	Environmental Health Project
FTP	File Transfer Protocol
HTML	Hyper Text Markup Language
HTTP	Hyper Text Transfer Protocol
IDWSSD	International Drinking Water Supply and Sanitation Decade
IAWQ	International Association on Water Quality
IRC	International Reference Centre
NSF	National Science Foundation
SGML	Standardised General Markup Language
UN	United Nations
UNDP	United Nations Development Programme
VIP	Ventilated Improved Pit-Latrine
WENDY	Water and Environmental Sanitation Electronic Network for Developing Country Needs
WHO	World Health Organisation
WRC	Water Research Commission

Chapter One

Introduction

The period from 1981 to 1990 was designated as the International Drinking Water Supply and Sanitation Decade (IDWSSD) by the United Nations Organisation on recommendation of the World Health Organisation (WHO). The aim of the IDWSSD was to promote the well-being of mankind world-wide by bringing about a substantial improvement in the level of services for the poor. However, with each passing year, international aid organisations have realised how enormous the task was of providing a potable water supply for all of mankind. By 1989, four out of ten people world wide still lacked basic services (Department of Water Affairs and Forestry; South Africa, 1994). Today, millions of people throughout the world do not have access to safe drinking water. In South Africa alone more than 12 million people do not have access to an adequate supply of water, (DWAF, 1994). The lack of basic services is more acute in rural areas in South Africa with less than 53 % of the rural population having an adequate potable water supply (Schur, 1994).

With regard to sanitation, nearly 21 million people lack basic sanitation in South Africa, of which an estimated 14.1 million or 85 % live in rural areas (DWAF, 1994). The average child mortality rate for children under the age of 5 years in rural areas is estimated to be 12 %, and 50 % of deaths between the age of one month and one year are faecal related (gastro-enteritis) (DWAF, 1994).

The problems associated with rural water supply and sanitation are many and varied, the most common ones being the spatial distribution of rural settlements, the lack of infrastructure and skills and the difficulty of maintaining remote rural water supply installations.

Traditionally, the emphasis of water supply in South Africa has been on large- scale regional schemes (Schur, 1994). These schemes have high construction and maintenance costs and as a result, have not always been successful. After considerable restructuring of the Department of Water Affairs and Forestry, the emphasis of water supply has shifted from large-scale regional schemes to small-scale schemes with considerable emphasis on community participation.

The causes of poor sanitation in South Africa are closely related to the lack of an adequate water supply. The primary causes of poor sanitation may be summarised as follows:

i. South Africa's race relations policy;

ii. The segmented sanitation authorities;

iii. Poverty and illiteracy;

iv. The lack of a potable water supply;

v. Poor policy guidelines and enthusiasm with regard to sanitation policy;

The importance of a transfer of appropriate technology to overcome the problems of water supply and sanitation in developing countries cannot be over-emphasised. This objective should be complemented by the development of *home grown solutions to home grown problems*. With recent advances in the transfer of textual information via satellite and telephone links, this form of technology transfer has become feasible and viable in the quest for solving developmental problems. The Internet can be used as an effective vehicle in this process. It is with this objective that WENDY (Water Supply and Environmental Sanitation Electronic Network for Developing Country Needs) was initiated. WENDY is a collaborative electronic network of partner institutions in the water and sanitation sector. The objectives of WENDY are to promote and facilitate through the medium of the Internet:

i. the awareness and access to sources of information;

ii. the generation and dissemination of information;

iii. the establishment of effective networking among sector institutions and professionals.

iv. to supplement the needs of developing countries in their goal of providing a suitable water and sanitation infrastructure.

v. to provide a catalogue or signpost to organisations and individuals of data that could be of assistance through all stages of the implementation of water supply and sanitation projects.

vi. to act as a gateway through which people involved in water supply and sanitation can make contact and communicate.

The objectives of the study are:

i. to conduct a literature search on topics relating to rural water supply and sanitation;

ii. to design and create an information server on the Internet to facilitate the transfer of information and communication between professionals involved in rural water supply and sanitation, in order to enhance the delivery and sustainability of services within the sector;

iii. to evaluate the effectiveness of the information server as a tool in solving problems experienced by sector professionals;

This study begins in **Chapter Two** by reviewing the current situation with regard to water supply and sanitation in developing countries. Important data are provided, clearly indicating that the provision of water supply and sanitation in developing countries leaves much to be desired. Guidelines and models to overcome this problem are also reviewed.

This is followed by **Chapter Three** which includes a review of current methods of water supply to rural communities. Various sources of water for rural water supply are identified and the advantages and disadvantages of each source is highlighted. The protection of these sources of water are emphasised in order to make them viable and sustainable in the long term. The pollution of water sources is also mentioned.

Sanitation, which is closely associated with water supply, is reviewed in the second part of **Chapter Three** in similar manner to water supply. The effects of improved health with proper water supply and sanitation is reiterated. Data supporting this view is presented to enhance the validity of the findings.

Chapter Four discuss the transfer of technology or information through the Internet and how this medium can be used as an effective tool in the development of a country's water supply and sanitation sector. The ease of communication and problem solving between water managers in various countries is demonstrated. **Chapter Four** ends with a statement of the project outline.

Chapter Four also includes an outline of the methodology adopted in the study. The means by which information is transferred is outlined. Software used to search the Internet for information relating to water and sanitation is introduced. The creation of an Internet homepage is given in a step-wise fashion.

Chapter Five is a discussion of the findings of the study as well as an assessment of the Internet as a means of communication and problem solving between water managers. These findings are supported by the comments of authorities involved in water and sanitation in South Africa.

The study ends with a discussion of conclusions and recommendations (**Chapter Six**).

Chapter Two

The Developing World

Over the past two decades the developing countries of the world have made significant progress in various sectors. Per capita consumption, life expectancy, child mortality and educational standards have all improved markedly. However it is against this background that 18 % of the current world population of an estimated 6 billion, live in what is termed *absolute poverty* (Preston, 1994). According to the World Development Report (1990) more than one billion people in the developing world are living in poverty. In many of these countries poverty occurs mainly in rural areas. The problems of malnutrition, lack of education, low life expectancy, substandard housing and lack of water and sanitation are more sever in rural areas than urban areas (Donaldson, 1989). The current level of service with regard to water supply and santation in developing countries is given in **Appendix 1.**

The level of development in Sub-Saharan Africa is considered to be the lowest in the world. For example, in 1985 life expectancy was 76 years in the developed world but only 50 years in Sub-Saharan Africa; primary education was almost universal in the developed world but was only 56 % in Sub-Saharan Africa; the level of income in these areas is less than $ 370 pa. (World Development Report, 1990). In addition to this the region's population is projected to continue growing at more than 3 % a year for the next decade (World Development Report, 1990). Death, disease, disability and the lack of services such as water and sanitation are a way of life in Sub-Saharan Africa.

The development of a country is widely understood to be a process resulting at least in improved health and longevity, higher productivity and living standards and increased access to essential goods and services (US AID, 1993). The provision of water and sanitation forms an integral part of essential goods and services. Thus, improving the condition of health and sanitation within developing countries is part of the development process of a country. In practice this is often referred to as environmental health engineering, the focus of which is domestic water supply and excreta disposal.

Of the 37 major diseases in developing countries, (see Table 2.1) 21 are water and sanitation related, and water and sanitation are considered primary interventions for ten of these diseases

(US AID, 1993) (See Table 2.2). According to the 1993 World Bank Development Report, in 1990 mortality from the ten diseases was approximately 3 000 000. Improved water supply and sanitation can drastically reduce or even eliminate many diseases and sicknesses which are transmitted by water or excreta. Example, diarrhoea, guinea worm, hookworm, etc., which effects millions of people in developing countries. A WASH report surveying 142 studies on the impact of improved water and sanitation facilities on 6 water-related diseases concluded that broad health impacts can be expected from improvements in water and sanitation: people are less likely to contract the diseases, and when they do, their case is usually less sever (US AID, 1993).

In addition, water supply and sanitation improvements result in a whole range of secondary, nonhealth benefits (Okun, 1987), example, improvements in drinking water quality; improvement of both personal and household cleanliness; increased economic activity of households during the time which was previously spent collecting water as well as the consequent improvement of living standards.

But how does one actually go about solving the problem of water supply and sanitation in developing countries? Cairncross (1993) believes there are two essential requirements, viz., political will of governments and the availability of technology to bring improvements to the poor at a cost which they and their governments can afford. The World Bank according to their 1993 Development Report have suggested the following five policies that are crucial to improving health and sanitation in developing countries:

i. providing solid primary schooling for all children, especially girls;
ii. investing more resources in cost-effective public health activities that can substantially improve the health of the poor;
iii. shifting health spending for clinical services from tertiary care facilities to district health infrastructure capable of delivering essential clinical care;
iv. reducing waste and inefficiency in government health programmes;
v. encouraging increased community control and financing of essential health care;

TABLE 2.1: Incidence and Effects of Selected Diseases in Developing Countries(excluding China)

Disease	Incidence	Estimated deaths/year
Diarrhoea	875 million*	4,600,000
Guinea worm	4 million	**
Hookworm	800 million	**

* Estimated cases per year

** Effect is usually debilitation rather than death

Source: Esrey et al

TABLE 2.2: Expected Reduction in Morbidity from Improved Water Supply and Sanitation

Disease	No	Median	Range
Diarrhoea	19	26%	0%-68%
Guinea worm	2	78%	75%-81%

Source: Esrey et al

Black (1990) in a report to UNICEF titled *From Handpumps to Health,* proposes the following five step model for the evolution of rural water supply and sanitation programmes for very large developing countries:

i. the identification of appropriate technology for water and sanitation systems;

ii. the building of capacity (human, logistical, technical and infrastructural), to carry out the programme;

iii. the transfer of technology to local manufacture and supply, to reduce dependence on imported equipment and develop a water and sanitation support industry;

iv. the development of mechanisms for community participation and self-help, involving women in particular as the prime haulers and users of domestic water supplies;

v. the growth of consumer-driven service, in which the majority of water supply repairs, some proportion of water supply installation and almost all sanitation installation, is undertaken independently of the service authorities;

The adoption of the above strategies by governments and non-government organisations in developing countries could help make the objectives of the UN Water Decade a reality in the near future.

Chapter Three

Rural Water Supply and Sanitation

3.1 Rural Water Supply

The supply of water to rural areas may be more important than that of urban areas since approximately 66 % of the world's population live in rural areas. In order to effectively supply water to rural areas, the water engineer must take into account various factors that may not be relevant in urban areas. These factors include the lack of infrastructural facilities, population distribution, needs of the rural communities, and the lack of skills (Dangerfield, 1983). Dangerfield also suggests that the engineer planning rural water supplies should rely upon first principles and on many occasions, outmoded technology. The planner should also seek the help of various professionals including the hydrologist, meteorologist, health workers, demographers and sociologist.

Before implementing the rural water supply scheme, the planner should establish the needs of the community. This objective can be accomplished through active community participation. Buch (1990) believes that community participation is a precondition to sustainable water development. Fair (1990) quotes the following from a World Bank report *wherever communities are involved in the design, construction, installation, and maintenance of water supplies, water projects are more efficient, cost effective and hence sustainable than would be the case with more centralised decision-making*. In a recent report to the Water Research Commission (Chapman, 1991), the author identified three key elements to ensure the cost effectiveness of water supply and sanitation projects:

i. involvement of the community in all aspects of the project;
ii. the use of appropriate technology;
iii. the need for institution building and training activities in conjunction with the project;

3.1.1 Sources of Water

The first priority in a developing country should be a reliable water source located close to the dwelling. This principle has been adopted by the Department of Water Affairs and Forestry (DWAF) in their basic service provision for water supply. The aim of the policy is to ensure that all South Africans can have access to a basic supply of 25 l/d within a distance of 200 m from their dwelling, at a minimum flow rate of 10 l/min (DWAF, 1994).

The source should preferably be one of good quality, and which can be supplied by gravity. Because of the unreliability of a treatment plant under most rural conditions, the best sources of water are those which do not need treatment (Ciarncross, 1993). Alternatively, the source should be of good quality that requires pumping, and lastly, a surface water source that requires both treatment and pumping. Treatment plants are not likely to be maintained properly, and failure of the plant poses a public health risk (Dangerfield, 1983). For this reason raw water treatment should be a last resort in rural areas. Sources of water that can be used for supply purposes in rural areas include:

i. springs;
ii. wells;
iii. surface water;
iv. rainwater;

Springs

Springs develop at the points where underground conduits discharge water at the surface (Bell and Hamill, 1986). They are a common source of good quality water in rural areas since the water is purified by the filtering action of the soil through which it flows. Springs also have a reliable flow and can make ideal sources of water for a community water supply (Cairncross, 1993). In Africa, outside the desert areas, springs are commonly found at the heads of drainage regions, within rolling topography, carved out by rivers of streams (Umgeni Water, 1991). Springs also commonly occur as seepage from marshy areas, sponges or vleis (Chapman, 1991)

Many rural communities have developed close to springs. In such cases all that is normally necessary is to construct a covered tank to impound the water to a depth of 1 m or more, and lead a supply pipe away from it (Dangerfield, 1983). Adequate provision must be made for domestic and wild animals who visit the spring regularly. This can be in the form of a pan situated away from the eye of the spring, to avoid contamination of the water with animal faeces and saliva.

Spring Protection

Spring water can easily be contaminated through contact with human beings, animals and containers etc. Daily washing and bathing and stock watering at the edge of the spring could result in permanent contamination of the spring water. Therefore all springs must be protected. This consists of enclosing the eye of the spring in some form of structure or drainage system (CISR 1988). This is done by covering the eye of the spring with a gravel pack that allows the water to pass through it (figure 3.1). A tank or spring box should then be constructed alongside the gravel pack with an outlet pipe and an overflow pipe, to collect water (Watt, and Wood, 1977). The spring box should be fitted with a removable cover, so that it can be cleaned periodically (Franklin, 1983).

The spring recharge area should also be protected against cultivation and the planting of exotic tree species, particularly Eucalyptus. The recharge or seepage area of a spring can easily be identified by visual inspection of the topography and identification of various plant species associated with saturated ground conditions (CSIR, 1988). This area should be fences off or surrounded with a hedge. The conservation of wetlands is therefore an important part of spring protection and development.

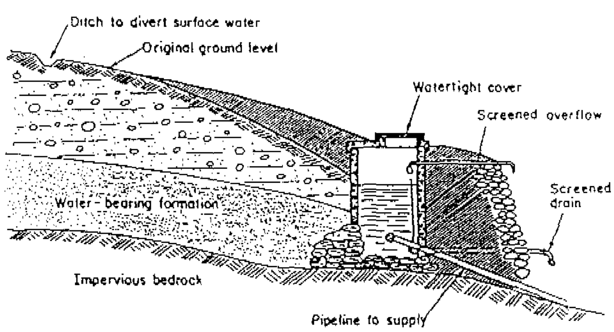


Figure 3.1 Protected Spring (after CSIR 1988)

Thus the objective of spring protection is:

i. to prevent pollution of spring water by humans, animals, insects and surface water run-off (CSIR, 1988);

ii. to enhance the filtration capacity of the spring outlet by removing mud and silt overburden, and by concentrating as much delivery as possible into the outlet pipe (Umgeni Water, 1991);

iii. to make it as convenient and hygienic as possible to fill water containers, without one person's container being able to contaminate the whole water source. (Chapman, 1991);.

Wells and Boreholes

Where groundwater does not emerge in the form of a spring, but is nevertheless within a reasonable depth from the surface, it can be extracted by sinking a well. A well is a shaft which is excavated vertically to a suitable depth below the water table (Cambell, and Lehr, 1971). Since wells are commonly dug by hand, some form of lining is required to prevent the walls from collapsing. Concrete rings are commonly used to support the excavation while still digging the hole. The approach is to lower the first concrete ring in to the excavation and to excavate inside this ring, which will then sink under its own weight (Chapman, 1991). A tube of rings is formed by placing them one on top of another. This tube of rings should extend to between 1 m to 15 m above ground level. Bricks and mortar can also be used to line the well above the water table. The well should be excavated to a minimum depth of 1.5 m below the water table to provide adequate storage, and to accommodate seasonal fluctuations of the water table (Cambell and Lehr, 1971). It is advisable to cover the bottom of the well with a gravel pack to prevent silt from being stirred up as the water percolates upwards into the well, or when water is disturbed by the bucket or pump used for abstraction (Watt, and Wood, 1977). The gap between the well lining and the excavation should be backfilled and compacted thoroughly to prevent subsidence and the infiltration of pollutants. Wells should be protected from pollution by the construction of a well head consisting of a headwall and drainage apron directing access water to a soakaway

(Cairncross, 1993). The sides of the well should be lined with impervious material to a depth of about 3 m to prevent the entry of water flowing near the ground (Pickford, 1983). An impervious apron should also be constructed round the well mouth. The main purpose of the apron is to carry waste water away from the site of the well into a seepage area, which should be slightly downhill from the well, to facilitate drainage (Morgan, 1990). The soakaway could be a hollow in the ground filled with rocks or gravel. The headwall can be fitted with rollers, a pulley or a windlass (figure 3.2 and figure 3.3). Further protection can be provided by covering the well with a concrete slab and fitting a suitable pump (figure 3.4). The concrete slab should be constructed with a raised lip, to stop water draining back into the well. The yield of a well depends on the methods of excavation and water abstraction (Dangerfield, 1983).

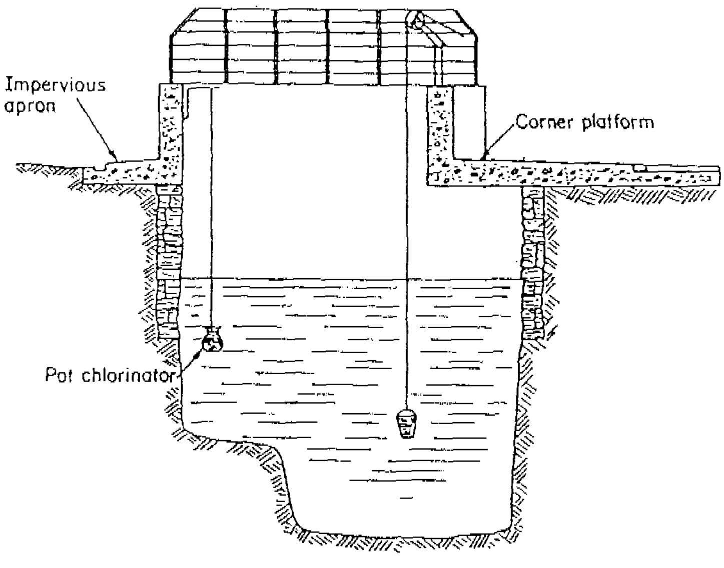


Figure 3.2 Conversion of a large step well into a draw well (after Cairncross, 1993)

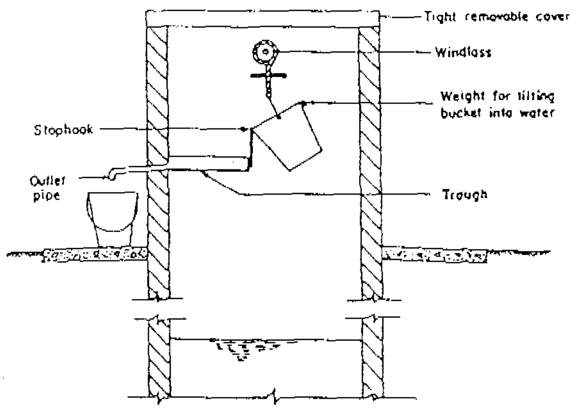


Figure 3.3 Draw well with windlass (after Cairncross, 1993)

The tube well is another method of extracting water that is close to the ground surface. In this method a specially perforated or slotted tube known as a "well-point" or "screen" is hammered into the ground (Cairncross, 1993). Well-points usually have diameters of around 50 mm and can be sunk to depths of up to 15 m (Bell, and Hamill, 1986). Because of their small diameter a pump must be installed to extract water.

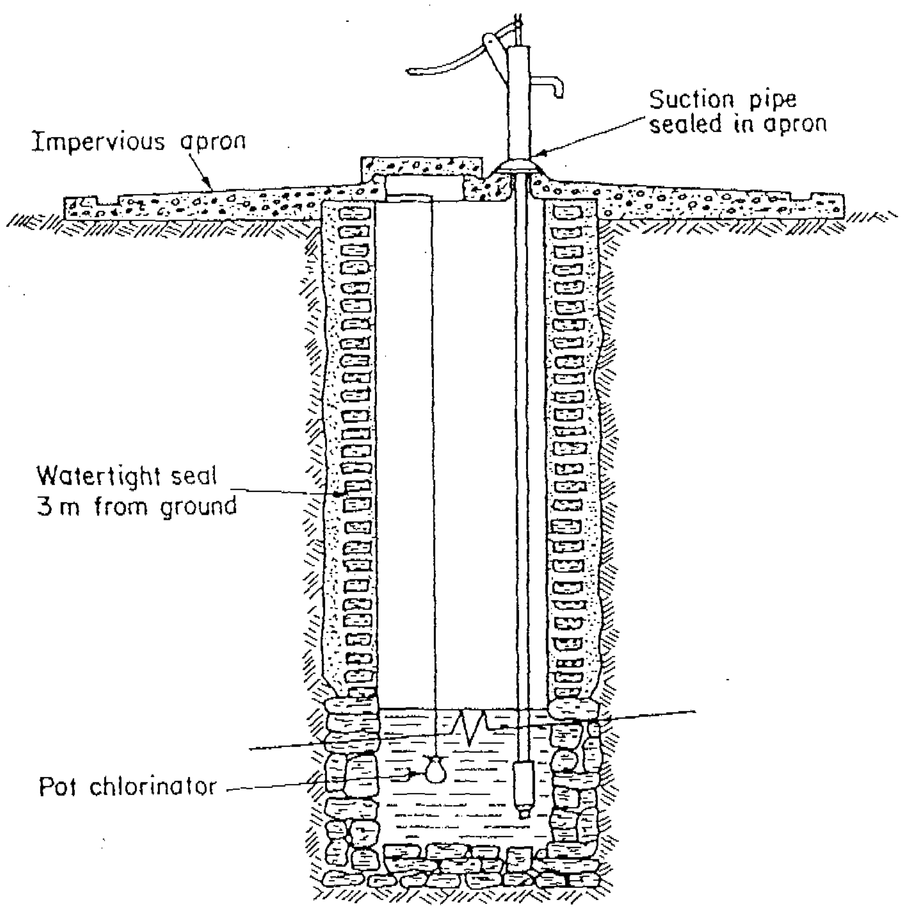


Figure 3.4 Dug well with hand-pump (after Cairncross, 1993)

The bored tube well can be sunk by hand to extract water to depths of up to 40 m (Cambell, and Lehr, 1973). The manually operated *Vonder Rig* developed by the Blair Research Laboratory in Zimbabwe has been widely used in Southern Africa to drill tube wells. Drilling or boring is achieved by excavating soil from the bottom of the hole by rotation of a cylindrical tool known as an auger (Morgan, 1990).

Percussion driving is a method of sinking a tube well by dropping specially designed tools from a height of about 0,5 m onto the bottom of the hole to penetrate of break the soil or rock (Chapman, 1991). A rig similar to the *Vonder Rig* can be used for this purpose.

The jetted tube well is a method of water extraction in which a pipe is sunk into soft ground, while the soil is loosened and removed by water pumped down or up the pipe, while the surrounding hole is kept full of water (Cairncross, 1993).

Boreholes are deep (greater than 15 m), small diameter (100 to 500 mm), holes drilled into an aquifer. A drilling rig is commonly used to drill boreholes. This process requires specialised equipment and a skilled crew, which is a costly process and thus requires thorough planning, to avoid costly mistakes. The typical steps involved in the development of a borehole water supply scheme would be:

i. to establish requirements in terms of the quantity and purpose for which the water is required;
ii. to carry out a desk study of the groundwater resources in the area;
iii. to assess the potential of the various aquifers identified in the area;
iv. to carry out a geophysical survey;
v. to drill a pilot hole to verify details of the desk study;
vi. to drill a production borehole along with observation holes;
vii. to carry out pump tests;
viii. to analyse pumping tests and development a management strategy;

A detailed account of borehole water development is given in Hamill and Bell, 1986.

Surface Water Resources

This refers to runoff from rainfall which collects in streams, rivers and lakes. This source should be used as a last choice because treatment of raw water is necessary (Dangerfield, 1983). This is evidenced by a study conducted by Faechem (1980) who reports that the counts of *E coli* per

100 ml in streams in Lesotho was 5 000, whereas those of protected springs was 9.

According to Stephenson and Petersen (1991), a dam, a pumping station, a pipeline and purification works are all normally associated with surface water resource development, and the cost per capita and per cubic meter is highly dependent on the scale of the project. Thus the capital costs involved in such schemes may be excessive to be applied to small-scale rural settlements. However a gravity fed and operated slow sand filtration treatment system, from a surface water source, could be used to supply rural settlements (Chapman, 1991).

The reliability of surface water resources cannot be guaranteed, especially with regard to non-perennial streams and rivers. The common solution to this is to build a dam to ensure a year round supply of water. In the case of rural water supply schemes, dams are usually small (less than 3 m water height), and are built from material and labour that is locally available.

Studies will have to be undertaken to assess the flow rate of the river or stream and to determine the kind of intake structures that will have to be installed. A weir may need to be constructed and if there is considerable variation in the water level, a floating intake may be necessary. The inlet should be well away from the bank of the river to avoid sediment being collected (Dangerfield, 1983).

Dams and Lakes

Reservoirs created by building small dams may be a feasible option if a suitable catchment is available (Dangerfield, 1983). Studies will have to be conducted to assess the hydrological aspects of the dam. When selecting a site for the construction of a small dam, attention should be paid to the following four basic requirements (Chapman, 1991):

i. the site selected should be the most economical;

ii. the storage should have low seepage losses, stable sides, and will not silt up;

iii. the foundations must be watertight and capable of supporting the dam;

iv. there must be sufficient material for building the dam;

Rainwater

In places where there is sufficient rainfall, rainwater can play an important role in the supply of water for domestic purposes. Rainwater can be collected from roof tops or ground catchments. Even a small roof area can collect a substantial quantity of water. The quantity of water that can be collected from a roof top is the total amount of rain falling on the roof, less losses due to infiltration, evaporation, splashing and overflowing of gutters. A roof area of 1 m^2 will yield 0.8 l of rainwater for each mm of rainfall (Chapman, 1991). The major problem with this apparently low-cost approach is the storage necessary to span periods of droughts (Dangerfield, 1983). There is a wide variety of storage containers that can be used. These include underground tanks, cisterns and wells, surface tanks of reinforced concrete, ferro-cement and corrugated iron tanks.

Runoff at the beginning of rainfall can be contaminated with dust and debris. This runoff can be diverted by installing simple first flush mechanisms that separate the initial runoff from any subsequent runoff. Dust and debris can also be removed by installing prefiltration devices at the inlet of the storage tanks. To prevent the water in the storage container from being contaminated, it is essential that the storage container be covered. Open storage tanks in a hot climate will develop algae within a few days of filling, will become a breeding ground for mosquitoes and other insects and will loose water through evaporation (Chapman, 1991).

The advantage of using rainwater is that the quality of rainwater is generally better than water from other sources. For example, a comparison of water quality from different sources in the Vulindlela district outside Pietermaritzburg by Alcock (1985) revealed that the samples from rainwater tanks and experimental rainwater harvesters consistently showed the best quality of all sources as measured by *E. coli* coliform and total viable organism counts.

Water Quality

Absolutely pure water is never found in nature (Dangerfield, 1983). All water including rainwater has some degree of impurities, which are commonly in the form of suspended solids, colloids and dissolved solids or gases (Smethurst, 1988). In addition to this, the appearance of the water in terms of its taste and colour are frequently associated with water quality.

The sources of water identified for supply purposes all differ in terms of their quality. If any of these sources are considered as a supply option, the quality of that source must be thoroughly investigated since many diseases are transmitted by water.

Springs and wells which usually have a good quality water are easily contaminated by surface water run-off or through the use of contaminated containers (Chapman, 1991). Springs and wells can be contaminated by pit latrines built close to the point of abstraction, and faecal contamination of animal wastes. Figure 3.5 gives an illustration of the most common impurities that occur in water.

In most cases groundwater is of better bacteriological and suspended solids quality than surface water sources (Alcock and Vester, 1987). Boreholes are usually the safest sources of water for domestic supplies, providing a reliable yield even in times of drought with no additional treatment required (Bell and Hamill, 1986). Groundwater, because of its passage through the earth and rocks, as a rule contains higher concentrations of dissolved solids or salts, than does surface water (Umgeni Water 1991). Some boreholes, especially those close to the coastline in arid regions may be brackish and hence unpalatable.

Surface water sources are virtually always contaminated and hence requires treatment for the removal of biological organisms and suspended solids. The level of dissolved solids in surface water is usually always acceptable for drinking water (Chapman, 1991). The degree of contamination by micro-organisms and suspended solids generally increases from the source of the river to the mouth (Chapman, 1991).

Generally rainwater and snow are the purest sources of water naturally available. However this source can be contaminated if appropriate measures are not taken during collection and storage.

Suspended Solids

Suspended solids in water are usually in the form of silt and clay particles, floating plant matter or organic matter. Suspended solids in the form of silt is a common feature in rivers of arid countries. Soil erosion contributes a large amount of the suspended load in the rivers of these countries. Floating matter in the form of weeds is common in tropical countries (Dangerfield, 1983).

The turbidity of water is affected by the concentration of suspended solids. Groundwaters are normally clear because the turbidity has been filtered out by slow movement through the soil, whereas streams in dry weather are clearer than streams in flood because the velocity is lower and dry-weather flow is mainly by groundwater seepage (Steel and McGhee, 1979). A low concentration of suspended solids may result in a relatively high organic turbidity since sunlight is permitted to penetrate freely into the water which stimulates the growth of algae. Turbidity also affects the aesthetic quality of water (Kemster and Smith, 1985). Turbidity may be removed by filtration, or a combination of coagulation, sedimentation and filtration.

Colloids

Colloids are fine particles between 1 to 10 μm and are thus not visible to the naked eye. However a high concentration of colloids imparts colour to the water and they remain in suspension even when the water is virtually at rest (Smethurst, 1988). Colloidal matter can be removed from the water by a process of flocculation (Dangerfield, 1983).

Dissolved Solids and Gases

As water passes through the hydrological cycle it picks up soluble substances such as calcium, magnesium, sodium, potassium, iron and manganese. Gases such as carbon dioxide, oxygen, nitrogen and ammonia may also be absorbed by water. These dissolved substances give the water its taste and other properties like hardness. Water hardness is caused mainly by the bicarbonates, sulphates and chlorides of calcium and magnesium and is normally expressed as milligrams per litre (mg/l) of calcium carbonate ($CaCO_3$) (DWAF, 1993). However hardness in water in not a problem as far as health is concerned (Chapman, 1991). The increase in the amount of soap required to produce a lather and the scale formed on heat exchange surfaces such as cooking utensils and hot water pipes are the two main problems caused by water hardness for domestic purposes.

Few dissolved solids are particularly objectionable in low concentrations (Smethurst, 1988)

- Suspended Impurities
  - Bacteria - some cause diseases
  - Algae - odour, colour, turbidity
  - Protozoans - some cause diseases
  - Viruses - some cause diseases
  - Silt - murkiness and turbidity
  - Clay - murkiness and turbidity
  - Colloids - colour, murkiness and turbidity
- Dissolved Solids
  - Salts
    - Cations
      - Calcium - hardness
      - Magnesium - hardness
      - Iron - hardness and colour
      - Manganese-hardness and colour
      - Others - dissolved solids
    - Anions
      - Bicarbonate - alkalinity
      - Carbonate - alkalinity
      - Sulphate - laxative
      - Chloride - taste
      - Fluoride - teeth mottling
  - Organics - colour, taste, odour and toxicity
  - Gases
    - Oxygen -corrosive, oxidising agent
    - Carbon Dioxide - acid
    - Hydrogen Sulphide - acid, reducing agent
    - Ammonia - caustic

Figure 3.5 Common impurities in water

Source: Steel and McGhee (1979)

Iron and Manganese

Iron in high concentrations (> 1 mg/l) is potentially toxic. However the problems caused by iron is usually at low concentrations. Above 0.3 mg/l iron causes staining of clothes and plumbing fixtures (Steel and McGhee, 1979). The taste threshold for ferrous iron (Fe^{2+}) is approximately 1.0 mg/l (DWAF 1993).

Where manganese exceeds 0.15 mg/l, it imparts an unpleasant taste to the water and stains laundry and plumbing fixtures (DWAF 1993). Manganese is also oxidised into a sediment which clogs pipes, discolours fabrics and stimulates organic growths (Steel and McGhee, 1979).

Fluorides

A small amount of fluoride is required in water for the development and protection of teeth. Under South African conditions the maximum admissible concentration for fluoride is 0.75 mg/l (Kempster and Smith, 1985). An excess of fluoride especially during the formative years of a child results in the mottling and discoloration of teeth. Excess fluoride can also cause bone fluorises.

Nitrates

The process of nitrification contributes significantly to the concentration of nitrates in natural waters. Municipal and industrial discharges, decomposition of sewage wastes, lechate from waste disposal dumps and sanitary landfills and soil leeching in areas where inorganic nitrate fertilisers are used contribute nitrates to rivers and lakes (DWAF 1993).

While being relatively non-toxic to adults, nitrate is potentially lethal to infants causing methaemoglobinaemia at concentrations in excess of 10 mg/l (Chapman, 1991).

Microbiological constituents

There are many bacteria found in water of which only a few are pathogenic. The most common sources of pathogenic organisms are from faecal material. Thus drinking water should be free from any form of faecal pollution. Groundwaters, due to the effect of filtration through the soil, are usually free from bacteria. However pollution of springs and wells may introduce bacteria into groundwaters.

Algae is a collective term referring to a wide range of pigmented oxygen-producing photosynthetic organisms, which do not have true roots, stems and leaves, which are present in water (DWAF 1993). Algae thrive in nutrient rich waters exposed to sunlight. Algae causes taste and odour problems and can clog filters in water-works. According to DWAF (1993) the target guideline of algae in water for domestic purposes is between 0 to 5 μg/l.

With regard to **bacteria** the coliform group of organisms, especially *Escherichia coli* are of particular importance. The main source of *Escherichia coli* is from human faeces and to a lesser extent from the faeces of poultry, cats, dog and rodents. They are the most common bacterial indicators of faecal pollution and hence the presence of faecally-assocaited pathogens in water (DWAF, 1993). According to the South African Water Quality Guidelines for Domestic Use (1993), their concentration should be limited to 0 counts/100 ml.

Enteric Viruses are essentially particles of protein and nucleic acid. They are more resistant than bacteria and may persist in the aquatic environment for longer periods. When drinking water is contaminated with enteric viruses, two diseases may occur in epidemic proportions - gastro-enteritis and infectious hepatitis (Chapman, 1991). To prevent the contamination of water from enteric viruses the source of water should be protected from faecal contamination.

Protozoan **parasites** are single-celled animals which produce by binary fission (Steel and McGhee, 1979). Two protozoan parasites, Giadia and Cryptosporidium are infective to man.

They can be introduced into a water source through human or animal faecal pollution. Domestic wastewater and agricultural sources of water pollution are also major contributors of parasites to the aquatic environment (DWAF 1993). According to draft guidelines for drinking water proposed by the Rand Water Board (Rand Water Board 1992), a recommended limit of 0 Giadia cycts/1l and 0 Cryptosporidium oocycts/1l is recommended.

3.1.3 Water Treatment

The extent of water treatment for domestic use in rural areas will be limited by the lack of finances and technical skills to maintain a treatment plant. In some cases it may be viable to exploit an unpolluted source that is situated further away rather than treat a polluted source that is closer to the community. According to Pickford (1983), a distant reliable source involving a long pipeline but needing no treatment may well be cheaper in the long run than a nearby source whose waters require a great deal of treatment to make them suitable. The ideal source would be one that needs no treatment at all. There are many aquifers that are high in water quality and may be pumped from the supply and transmission network directly to any number of end uses, including human consumption (Vesilind, Peirce and Weiner, 1988).
If treated water is to be used by the rural community, it should be free from pathogens and more aesthetically pleasing than the source being used. For example if treated water is free from pathogens but has an unpleasant taste and stains clothing, the polluted source will continue to be used. Thus the community will not benefit from the disease-reduction of the treated water.

Design Considerations

The design considerations of treatment plants in rural areas are significantly different from those in urban areas and similarly for developed and developing countries.

The lack of technical skill in the rural community should be addressed during the design of the facility. Construction and operation costs should be compatible with the resource preferences of the users, and limited or no use should be made of imported materials (Chapman, 1991). Scarce human and financial resources should be utilised most efficiently and the potential benefits should be realised (Feachem, 1983). The use of electrical and mechanical equipment should be kept to a minimum. Where such equipment is absolutely necessary, preference should be given to locally manufactured products. The quality of water should be maintained above guideline limitations. The quality of treated water and the performance of the plant should be monitored at regular intervals. The overall consideration in design should be simplicity, reliability and durability (Dangerfield, 1983).

Treatment Methods

Impurities enter water as it moves throughout the hydrological cycle. Human activities also add impurities to water, example, faecal pollution, industrial discharges, agricultural runoff. Smethurst (1988) suggests the following method of removing impurities from water:

i. floating objects by screening;

ii. algae (if present) by straining;

iii. excessive iron, manganese and hardness in solution by precipitation in basins after the addition of chemicals;

iv. normal suspended solids by settling;

v. the remaining fines and some bacteria by filtration;

vi. excessive bacterial pollution by pre-chlorination;

vii. final bacteria surviving filtration by chlorination;

However it is seldom that all these processes are implemented in rural areas, especially for single households.

An important aspect of water treatment is the protection of the source of water, which will result in an improvement in the quality of the water.

Pre-treatment

Sources of water supply are subject to constant change. Rivers for example exhibit wide fluctuations in flow and turbidity as a result of seasonal changes. Some treatment processes may not be able to accommodate these fluctuations. It may therefore be necessary to pre-treat the raw water before it enters the actual treatment process. Pre-treatment involves processes such as screening, raw water storage, pre-chlorination, aeration, algal control, grit removal and roughing filtration. Appropriate pre-treatment during periods of excess silt loading can reduce the load on subsequent treatment units and thus reduce the cost of purification. Pre-treatment is only justified for treating waters from turbid rivers or streams; lakes, surface reservoirs and other quiescent bodies of water inherently provide natural settling for the suspended material (Schulz and Okun, 1984).

In large scale treatment works coarse **Intake Screens** are provided at river intakes to prevent large floating material from entering the works. In rural areas an elaborate screen across the width of the river may not be feasible. An alternative to this would could be a simple wooden crib (Pickford, 1983).

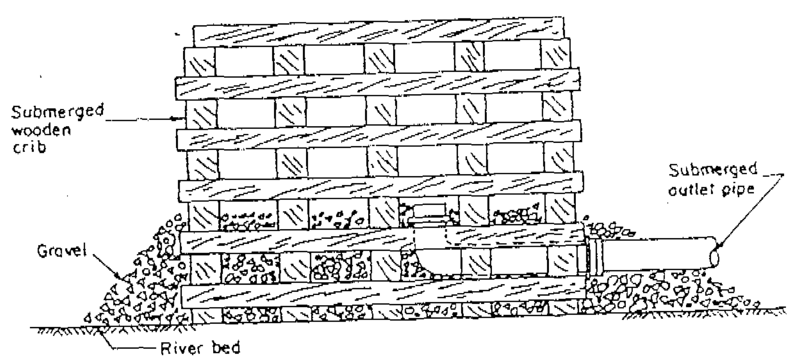


Figure 3.6 Wooden crib at river intake (after Chapman, 1991)

To minimise the abstraction of sediment, the intake should not be close the river bed or the banks of the river. A weir could be constructed to maintain a constant water level at the intake. Where there is considerable variation in water level, a floating intake could be installed. Such a structure could be supported by empty drums to help keep the structure afloat. In arid countries where rivers are laden with silt, filters or strainers fitted to the intake works provide adequate protection.

A wooden crib with strainers is capable of delivering between 12 and 22 m^3 of water per hour, and suspended solid reductions of 98 % and E.coli reduction of 80 to 90 % are claimed (Chapman, 1991).

When abstracting water from ponds or lakes, it may be desired to abstract water from a specific level, example 2m below the surface. This can be achieved by installing multiple level offtakes or a floating offtake. The collector pipe leads to a well built of impervious material or a sand filter and installed with a pump (Pickford, 1983).

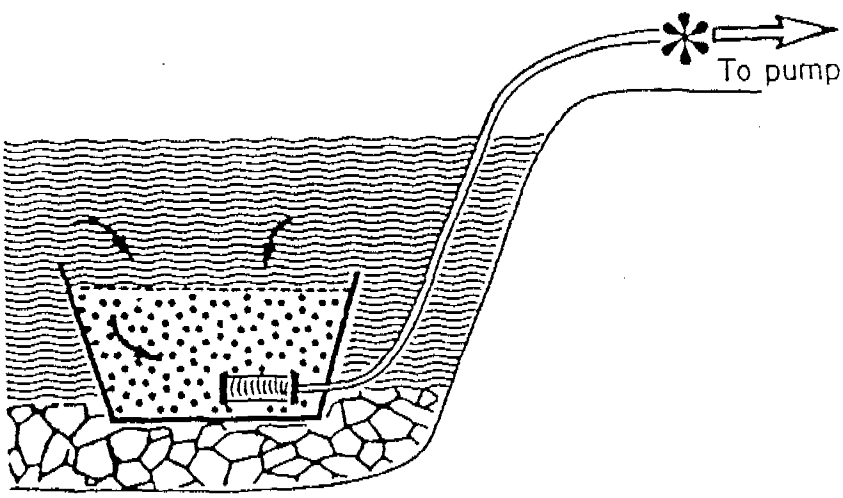


Figure 3.7 Filter in gravel filled container on canal bed (after Schulz and Okun, 1984)

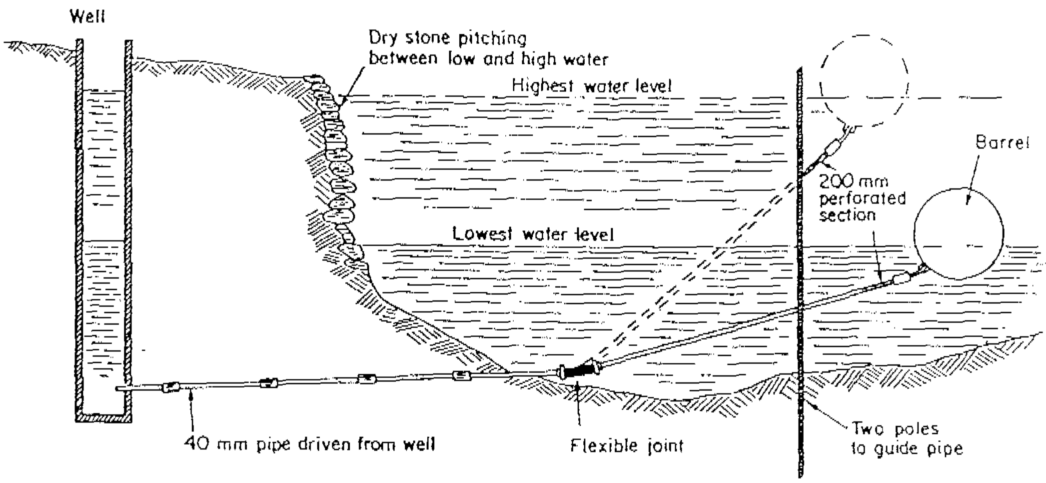


Figure 3.8 Well and floating intake for existing pond (after Smethurst, 1990)

Plain Sedimentation

This allows for the removal of suspended particles in the raw water by gravity and natural aggregation of the particles. No coagulants are used at this stage. According to Smethurst (1990), if the suspended solids concentration habitually exceeds 1 000 mg/l, a plain sedimentation or pre-settlement tank is necessary. The efficiency of plain sedimentation is evidenced by the findings of Kincaid (1953), who found the suspended solid concentration of the Kansas River had a peak of 11 800 mg/l, and for 8 months stayed over 1 000 mg/l. Tests showed that the average suspended solid concentration in the effluent from a 3 h uncoagualted preliminary settling basin was 320 mg/l and never rose above 600 mg/l (Kincaid, 1953). Pre-settlement is quite effective in tropical developing countries for the following reasons (Schulz and Okun, 1984):

i. the turbidity in rivers of these countries can be attributed largely to soil erosion, the silt being settleable;

ii. the higher temperatures in these countries improve the sedimentation process by lowering the viscosity of the water;

iii. The design of pre-settlement basins are similar to that of conventional basins except that the retention time is shorter and the loading capacity is higher.

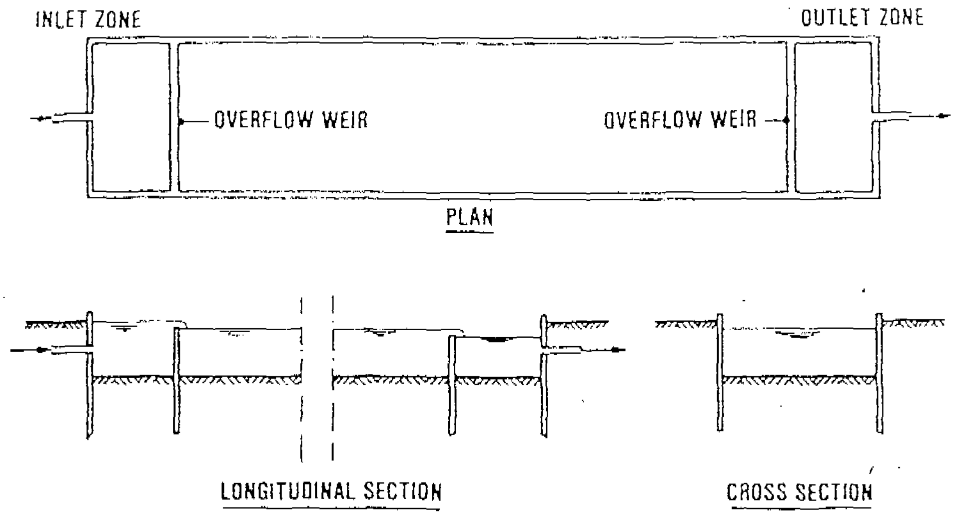


Figure 3.9 Presettling basin constructed with wooden pile sheets

Source: IRC (1981)

Storage

Storage of water is a treatment process itself. The number of faecal coliforms and faecal streptococci will be considerably reduced when raw water is subjected to storage (Chapman, 1991). Some treatment may be obtained by careful design of storage tanks to ensure a slow and even movement of water from the inlet to the outlet, as in a sedimentation tank (Cairncross, 1993). At the same time storage of raw water can act as the first stage of purification. The quality of water being improved by sedimentation of silt and other suspended matter, and by the significant reduction of any pathogenic organisms present. The World Health Organisation list the following beneficial effects of reservoir storage:

i. **Reduction in turbidity.** This depends on the nature of suspended particles and on the settling time. Bacteria and viruses associated with particles will be removed by sedimentation of the particles;

ii. **Reduction in bacteria.** This is especially true for pathogens which do not find the temperature suitable for multiplication. The ultraviolet component of sunlight also helps kill off bacteria;

However storage of nutrient rich water will result in the growth of algae which may become a more serious problem than the one the reservoir was designed to solve. Losses due to evaporation is another drawback of storage. These effects can be minimised if storage tanks are covered which will also prevent dust, insects, air borne pollution and small animals from contaminating the stored water storage (Chapman, 1991).

Roughing Filtration

The principal processes involved in filtration are sedimentation in the pore spaces, adhesion to the media particles, and in slow sand filters, bio-chemical degradation of the particles that are captured (Schulz and Okun, 1984). In roughing filtration the suspended particles penetrate deep into the filter bed, which has a large storage capacity. The filter media are much larger than that used in either rapid filters or slow sand filters. The material retained by roughing filtration is removed by flushing or manually removing and cleaning the filter media. There are basically two type of roughing filters. The horizontal flow (HF) roughing filter and the vertical flow (VF) roughing filter. Structural constraints limit the depth of the filter bed in VF filters, but higher filtration rates and backwashing is possible, while the HF filter can be constructed to almost any length, but has a lower filtration rate and has to be cleaned manually (Schulz and Okun, 1984). The HF roughing filter consists of a box divided into several sections filled with filter media of sizes graded from coarse to fine (WHO 1989).

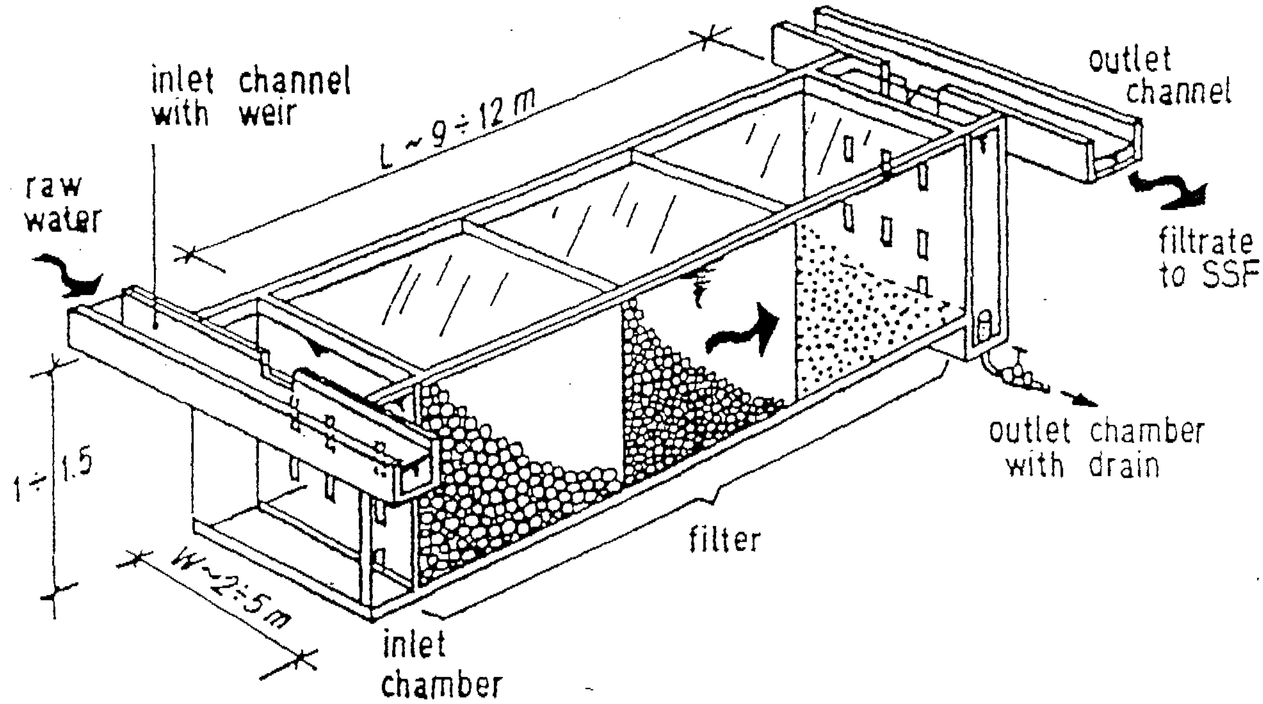


Figure 3.10 Basic feature of a horizontal flow roughing filter

Source: Wegelin, (1982)

TABLE 3.1: Change in water quality due to storage for water supplies in England

Reduction due to storage %

	River Seven	River Derwent
Colour	28	67
Turbidity	70	51
Presumptive coli	95	99
E. coli	94	>99
Colony counts per 1 ml:		
3 days at 20° C	88	-
2 days at 37° C	89	-

Source: Adapted from Smethurst, (1990)

The following design guidelines should be followed when constructing roughing filtration units (Wegelin, 1982):

i. The acceptable range for the filtration rate is 0.5 to 4.0 m/h (face velocity), but an upper limit of 2 m/h should be observed for waters with high suspended solids load and/or colloids;

ii. the filter grains to be used should have two or three zones with sizes ranging from 4 to 40 mm. The sequence of arrangement in the longitudinal direction should be from coarse to fine;

iii. because the first zone of the filter bed stores a higher percentage of suspended solids than the others, the length of the coarse zone provided should be greater than that of the finer zones in order to provide a large silt storage volume. Thus the following range of lengths of individual zones should be provided :

First coarse fraction:	4.5 to 6.0 m
Middle, medium fraction:	3.0 to 4.0 m
last, fine fraction:	1.5 to 2.0 m

As a result the total length of the filter should be 9.0 to 12.0 m;

iv. for a filter with the side walls that above the ground surface, the height should be below 1.0 to 1.5m to allow for easy manual digging out of gravel and refilling it after cleaning;

v. the free water table should be covered by a 100 to 200 mm thick gravel layer in order to prevent plant and algal growth. Hence, the top level of the filter medium should be 300 to 400 mm above the crest level of the outlet weir.

vi. the filter floor should slope in the direction of flow (about 1:100);

vii. the outlet should be provided with a V-notch weir to facilitate discharge measurements;

Oxidation and Aeration

Oxidation is used to remove tastes, odours, colour, to aid in the removal of iron and manganese, and for disinfection. The most frequently used oxidants are chlorine and potassium permanganate. Oxidation should be applied before flocculation, settling and filtration as any oxidised products will then be removed form the water (Chapman, 1991). Oxidation is frequently needed in rural areas to remove iron from borehole water. This is done by aerating the water which converts the water form Fe^{2+} (ferrous iron) to Fe^{3+} (ferric iron) which is insoluble in water and can then be removed by settling and filtration.

Water may be aerated to remove excess gases or to cure an oxygen deficiency (Pickford, 1983). Cox (1964), states that the primary purpose of aeration is to improve the taste by removing hydrogen sulphide (H_2S) and the volatile taste-and-colour-producing wastes of algae or decomposition of organic matter. Aeration is also often used to remove iron and manganese from water supplies. Pickford (1983), identifies four methods of aerating water that are suitable for rural areas:

i. spray nozzles;

ii. cascades;(see figure 3.11)

iii. inclined aprons;

iv. tray aerators;

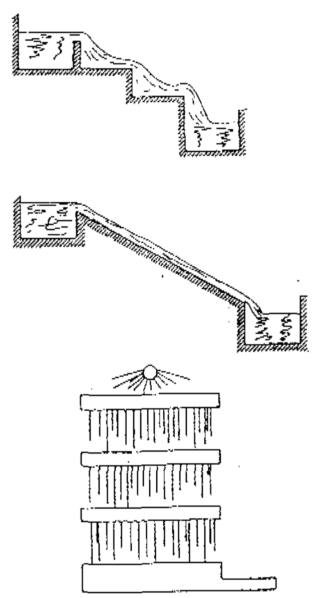


Figure 3.11 Cascade, inclined apron and tray aerators

Source: Pickford, (1983).

Coagulation and Flocculation

Turbidity and colour are most frequently removed by coagulation and flocculation, since the particles causing turbidity and colour are sufficiently small that their removal in a sedimentation tank is impossible at reasonable surface flow rates and detention times. The electrostatic repulsion between colloidal particles cancels out the mass attraction forces that would allow the particles to come together. Chemicals called coagulants have the ability to reduce the electrostatic repulsion between particles and thus enable them to come together, (i.e. flocculate), increase in size and then be removed by settling or filtration. According to the Chapman (1991), water treatment process involving chemicals are not suitable for small community water supplies and should be avoided if possible. They further state that chemical coagulation and flocculation should only be used when the required water quality cannot be achieved by other treatment processes which requires no chemical treatment, example slow sand filtration.

Coagulation and flocculation will usually be required when the suspended solid load would cause the filter to block or when the colloidal matter is to fine to be removed even by slow sand filtration.

There are a number of chemicals that can be used for **Coagulation**, viz.:

i. Alum (aluminium sulphate - $Al_2(SO_4)_3.nH_2O$), most widely used;

ii. ferric chloride - $FeCl_3$;

iii. ferric sulphate - $Fe_2(SO_4)_3$;

iv. ferrous sulphate - $FeSO_4.7H_2O$;

Although alum is widely used, iron salts have a number of advantages over alum. One significant advantage of iron salts over Alum is the broader range of pH over which ferric salts can be used. The pH zone for optimal coagulation using alum is between 6.5 to 7.5, whereas for ferric sulphate the pH zone for optimal coagulation ranges from 5.5 to 9.0 (Cox, 1964). Although ferric salts are not as widely available as alum (which may prevent their wide spread adoption as coagulants in developing countries), the possibility of using ferric salts should be investigated, especially when raw water pH is about 8 or higher (Schulz and Okun, 1984).

For optimal coagulation using a ch

be adjusted using alkalis. Three types of alkalis are suitable for use in developing countries (Schulz and Okun, 1984):

i. soda ash (sodium carbonate, Na_2CO_3);

ii. quicklime (calcium oxide, CaO);

iii. hydrated lime (calcium hydroxide, $Ca(OH)_2$;

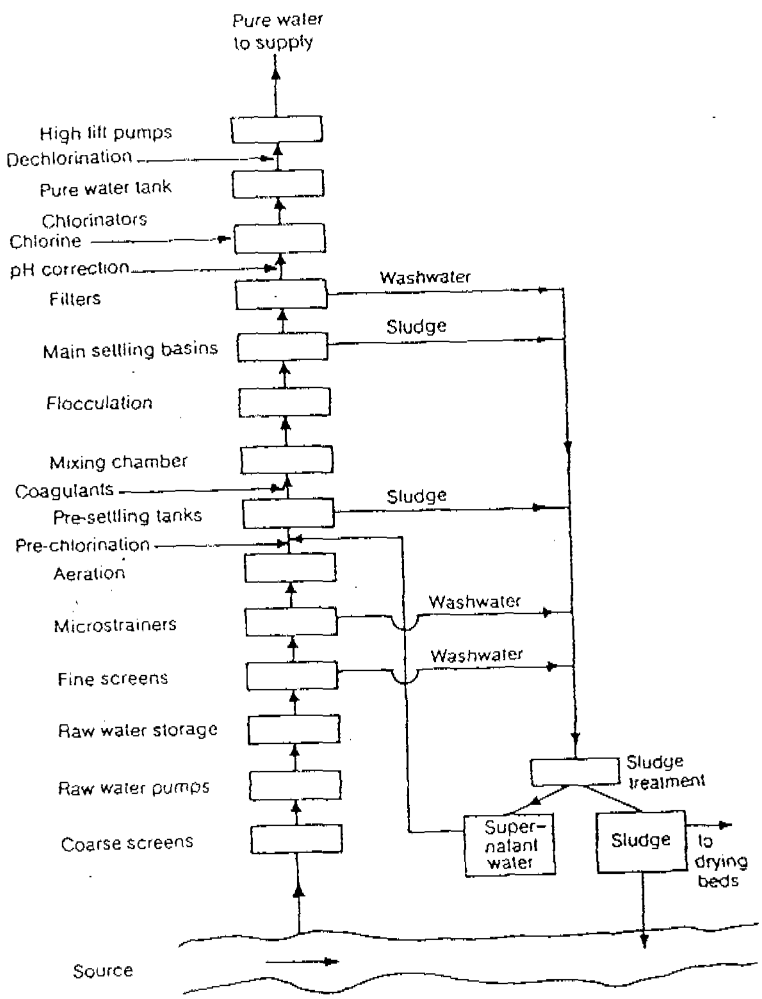


Figure 3.12 Flow diagram showing possible treatment stages

Source: Smethurst (1990).

Natural Coagulant Aids fall into two categories, viz., adsorbents or weighting agents and natural polyelectrolytes

Adsorptive clays, example bentonite and fullers earth assist coagulation by supplying additional suspended matter to the water upon which the flocs can form. Due to the high specific gravity of the clay, the flocs can settle rapidly. Practical experience has shown that doses of clay ranging from about 10 to 50 mg/l result in good floc formation, improved removal of colour and organic matter, and a broadening of the pH range for effective coagulation (American Water Works Association, 1971).

Natural polyelectrolytes have been used for many centuries in developing countries for clarifying water (Schulz and Okun, 1984). The National Environmental Engineering Research Institute (NEERI) in India conducted studies on several plant species to determine their effectiveness as coagulant aids. In some cases the use of natural coagulant aids has resulted in a saving in the amount of alum used for coagulation and a resultant decrease in costs of coagulation.

Rapid Mixing

Rapid mixing provides for the uniform dispersion of chemical additives in the raw water. This is achieved by agitating the water violently and adding the chemical in the most turbulent zone. Rapid mixing is necessary because the coagulation process, which comprises the hydrolysis of the coagulant and destabilisation of the colloidal material is completed almost instantaneously (less than 1 second) (Schulz and Okun, 1984). Schluz and Okun (1984), support the use of hydraulic rapid mixers rather than mechanical mixers in developing countries since they are capable of achieving high velocity gradients forrapid diffusion of coagulants and they require no imported equipment, are easily constructed, operated and maintained with local materials and personnel.

Typical hydraulic rapid mixing devices include the hydraulic jump mixers, partial flume rapid mixer, the Palmer-Bowlus Flume, various types of weirs, baffled mixing chambers etc. Utilisation of the a hydraulic jump downstream of a Parshall flume is one of the most practical methods used in developing areas since it provides the additional advantage of flow measurement in the Parshall flume (Chapman, 1991).

Flocculation

Flocculation is the process of gentle and continuous agitation, during which the suspended particles in the water coalesce into larger particles so that they may be removed from the water by subsequent treatment processes, particularly by sedimentation (Schulz and Okun, 1984). Flocculation follows rapid mixing and the agitation can be produced mechanically or hydraulically. In developing countries it is more practical to use hydraulic flocculators that do not require mechanical equipment or a continuous power supply. There a variety of hydraulic flocculators that are appropriate for use in developing countries. Namely, baffled channel flocculators, gravel-bed flocculators, surface-contact flocculators and hydraulic jet-action flocculators. The efficiency of the flocculation process is largely determined by the number of collisions which can be induced between the minute coagulated particles per unit of time (Chapman, 1991).

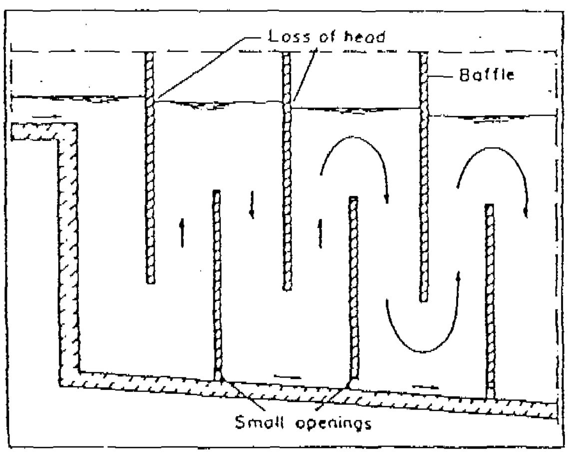


Figure 3.13 Baffled channel type hydraulic flocculator

Source: Chapman (1991).

Sedimentation

Sedimentation is the settling and removal of suspended particles which takes place in static or slow flowing basins (Chapman, 1991). Suspended particles with a density greater than that of water will settle to the bottom of the settling basin. Sedimentation usually follows flocculation and particles that are not removed in the settling basins are removed by filtration processes. There are basically two types of sedimentation basins, viz., the horizontal flow basins and upflow basins. The horizontal-flow sedimentation basin has performed admirably in numerous water treatment plants throughout the world and is still advocated by water treatment experts because of its simplicity and inherent simplicity (Hudson, 1981). A well-designed horizontal flow sedimentation basin can remove up to 95 % of raw water turbidity following effective coagulation and flocculation; the remaining turbidity is removed by filtration (Schulz and Okun, 1984). The advantage of horizontal flow sedimentation basins without mechanical sludge removal over upflow basins, especially for use in developing countries, is their simplicity and ability to adapt to various raw water conditions, example changes in turbidity and flow rates. In addition to this, horizontal flow sedimentation basins are cheaper to construct, their capacity can easily be increased and their operation and maintenance is simple. In developing countries manual sludge removal is preferred over mechanical equipment because of the difficulty of installing and maintaining mechanical equipment. Furthermore labour is freely available in developing countries and at a lower cost than operating mechanical equipment.

The design of sedimentation basins is governed by three basic criteria (Schulz and Okun, 1984):

i. the quantity of water to be treated;

ii. the selected detention time;

iii. the selected surface loading rate;

The principles governing the design and construction of horizontal-flow sedimentation basins are well documented in standard texts, example

American Water Works Association, 1971; Cox, 1964; Hudson, 1981; Smethurst, 1990.

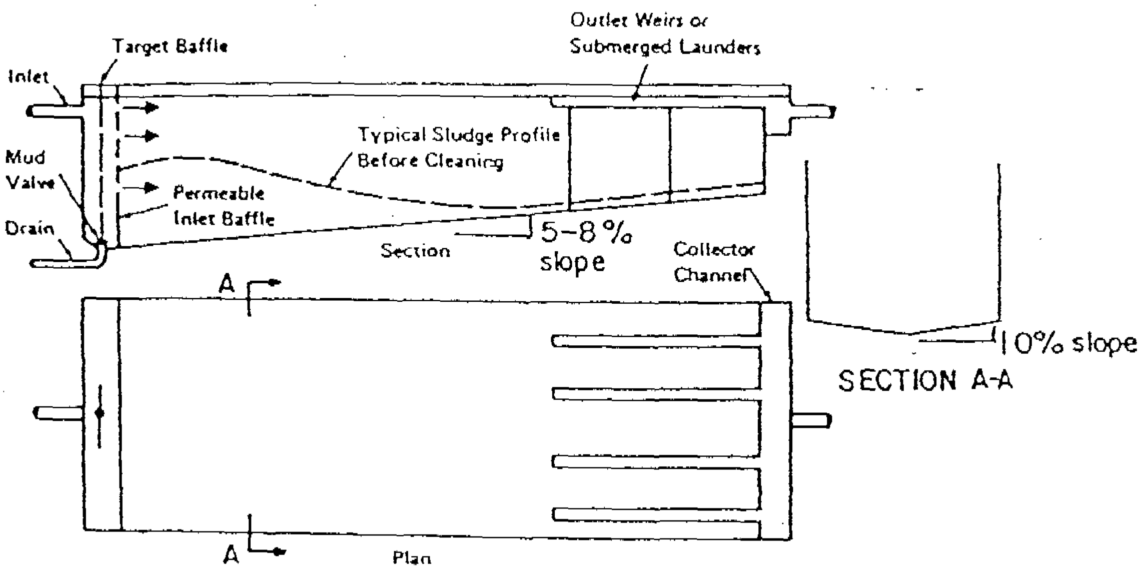


Figure 3.13 Conventional horizontal-flow settling basin

Source: Adapted from Hudson (1981).

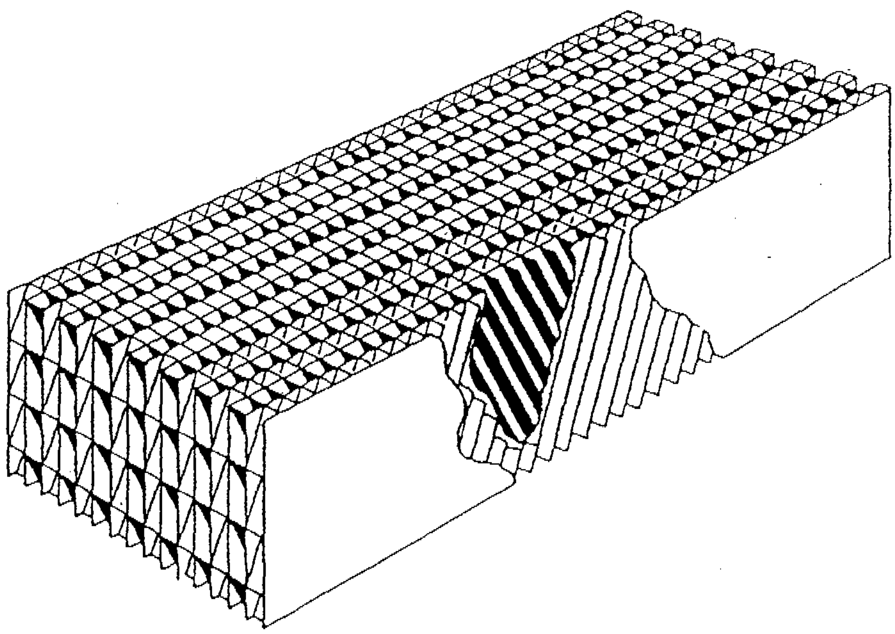


Figure 3.14 Tube Settler

Source: Steel and McGhee (1979).

The settling efficiency of a tank can be improved by the installation of trays or tubes in the settling tank. These units can improve settling performance and increase the capacity of conventional settlers by 50 to 150 % (Schulz and Okun, 1984). The trays or tubes can be self-cleaning if they are placed at steep angle to the horizontal. The most suitable angle will depend on the type of sludge which varies with different types of raw water.

Filtration

Filtration is the physical, chemical and (in some instances) biological process for separating suspended impurities from water by passage through a porous media (Schulz and Okun, 1984). Slow sand filtration has great advantages for developing countries although types of filtration is widely used (Pickford 1983).

Sand filters can be made in various sizes, from a family unit contained in a 200 l drum, to large units designed for cities.

A 200 l container is a convenient container in which to construct a family sand filter, although brick built containers, traditional pot or cement jars can also be used (Morgan, 1990). Figure 3.15 shows a sand filtration unit capable of serving up to 300 people, assuming a consumption rate of no more than 20 l/p/d (Morgan 1990).

The upward flow gravity filter is part of a pre-treatment process which removes as much sediment as possible. Sediment can also be removed in the storage reservoir which can act as a settling basin.

Slow Sand Filtration is one of the most effective, simplest, and least expensive water treatment process and is therefore particularly suitable for rural areas in developing countries (Chapman, 1991). For developing countries there are a number of special advantages (Pickford, 1983):

i. the cost of construction is low, especially where manual labour is used;

ii. simplicity of design and operation means that filters can be built and used with limited technical supervision. No special pipework, equipment or instrumentation is needed;

iii. the labour required for maintenance can be unskilled as the major job is cleaning the beds, which can be done by hand;

iv. imports of material and equipment can be negligible and no chemicals are required;

v. power is not required if a fall is available on site, as there are no moving parts or requirements for compressed air or high-pressure water;

vi. variations in raw water quality and temperature can be accommodated provided turbidity does not become excessive. Overloading for a short period does no harm;

vii. water is saved - an important matter in many areas - because large quantities of washwater are not required;

viii. sludge, which is often a major problem with water treatment by more sophisticated methods, is less troublesome. There is less of it and it is easily dewatered;

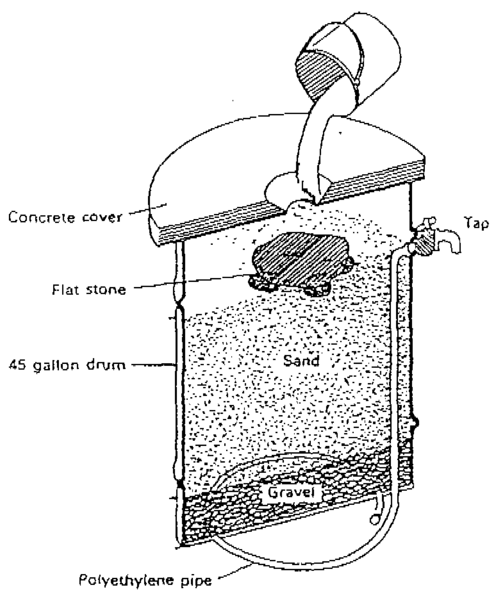


Figure 3.15 Section through a family sand filter made from a 200 l drum

Source: Morgan (1990).

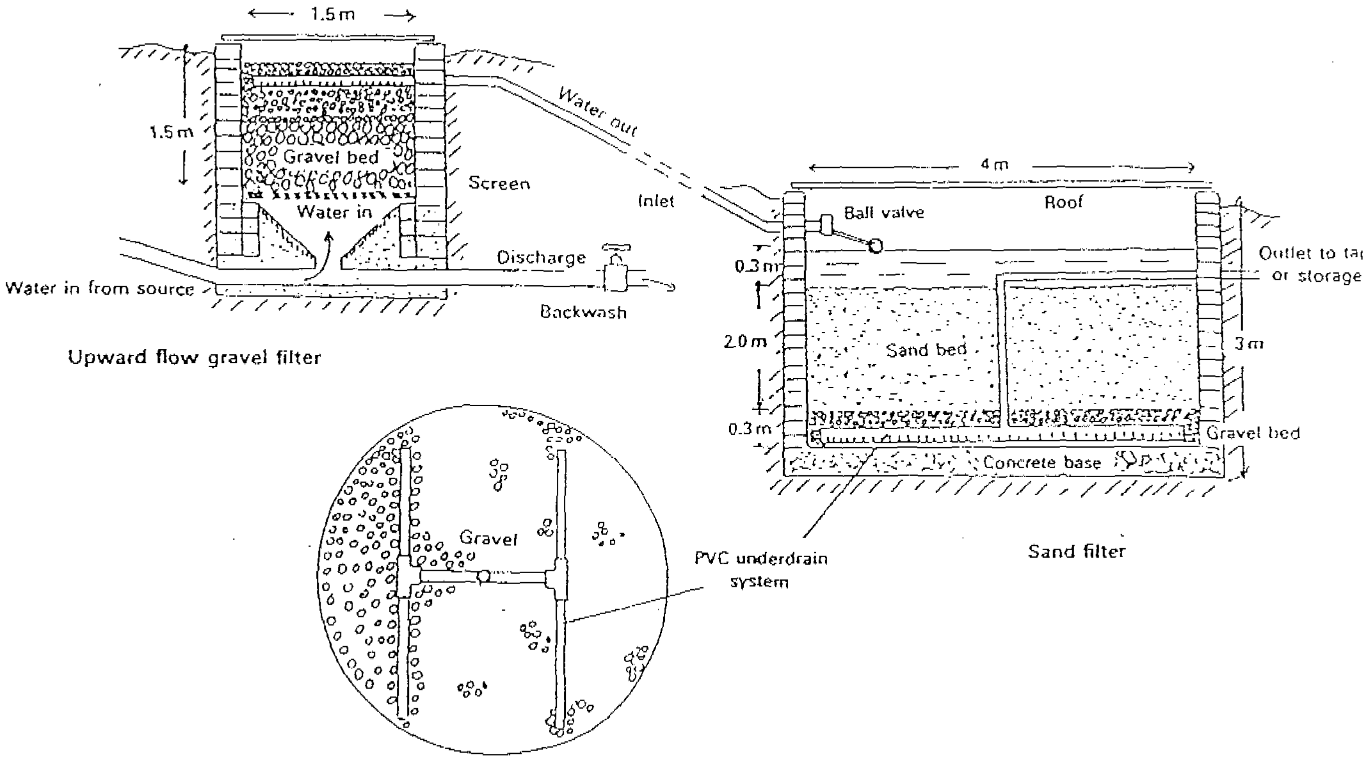


Figure 3.16 Section through a small community gravel and sand filter

Source: Morgan (1990).

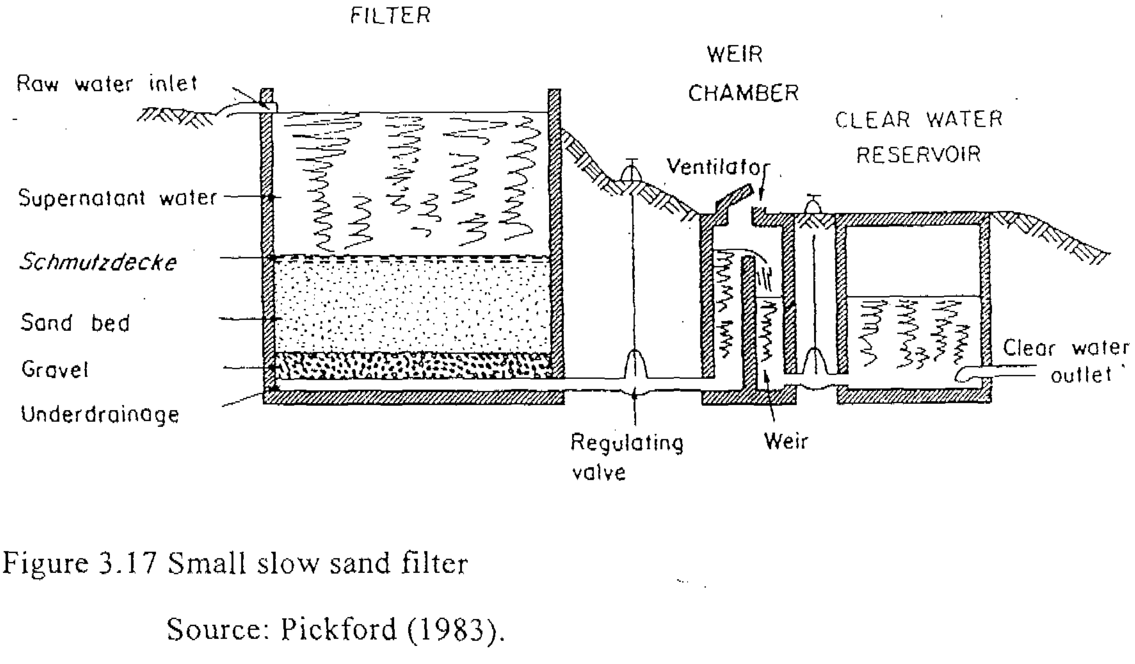


Figure 3.17 Small slow sand filter

Source: Pickford (1983).

The basic process of slow sand filtration is a follows:

i. water passes through a bed of fine sand at a rate of 0.1 to 0.3 $m^3/m^2/h$ (IRC 1987);

ii. The quality of water is improved considerably by the filtering of turbidity by the large reduction in the number of micro-organisms;

iii. in a mature bed a thin layer called the scmutzdecke forms on the surface of the bed, which consists of algae, plankton, bacteria and other forms of life that are very active in the purification process (Pickford, 1983). The biological purification process extends to a depth of 0.4 m. Due to the slow movement of water and long retention time, slow sand filtration resembles the percolation of water through the subsoil, and the process effectively produces water comparable in quality to groundwater (Chapman, 1991).

Table 3.1 Performance of Slow Sand Filters

Water Quality Parameter	**Purification Effect of Slow Sand Filtration**
Colour	30 to 100 % reduction
Turbidity	Reduced to < 1 NTU
Faecal coliforms	Between 95 to 100 % and often between 99 to 100 % reduction in faecal coliforms.
Cercariae	Virtual removal of cercariae of schistosoma cysts and ova.
Viruses	Virtually complete removal.
Organic matter	60 to 75 % reduction in COD
Iron and manganese	Largely removed
Heavy metals	30 to 95 % reduction

Table 3.2 Design Criteria for Slow Sand Filters in Rural Areas

Design Criteria	**Recommended Level**
Design period	10 to 15 years
Period of operation	24 h/d
Filtration rate in the filters	0.1 to 0.2 m/h
Filter bed area	5 to 200 m^2 per filter, minimum of 2 units.
Depth of sand layer: Initial Minimum	0.8 to 0.9 m 0.5 to 0.6 m
Specification of sand: Effective size Uniformity coefficient	 0.15 to 0.30 mm < 5 preferably below 3
Height of underdrains including gravel layer	0.3 to 0.5 m
Maximum height of supernatant water	1 m

(Source: Chapman, 1991).

Although raw water turbidities of 100 - 200 mg/l can be tolerated by a slow sand filter for 2 or 3 d, they work best with fairly clear raw water - an upper limit of 50 mg/l (Pickford, 1983). Sand filters can also be used to remove iron and manganese once the water has been aerated.

Disinfection

It is important that drinking water be free from any micro-organisms that can transmit diseases. In most cases raw water will have to be disinfected to remove bacteria. Disinfection of water provides for the destruction or the complete inactivation of harmful micro-organisms present in the water (CSIR, 1990). The following factors the efficiency of disinfection (IRC, 1981):

i. the nature and the number of organisms to be destroyed;

ii. the type and the concentration of disinfectant used;

iii. the temperature of the water to be disinfected (the higher the temperature the more rapidly will disinfection take place);

iv. the time of contact (the disinfection process becomes more complete when the disinfectant remains for a longer period in contact with the water);

v. the nature of the water to be disinfected (if the water contains particulate matter especially of the colloidal and organic nature, or other commercial components which react with the disinfectant used - i.e. exerts a demand, the disinfection process will be hampered);

vi. the pH of the water. If chlorine is used, it is considerably more effective at pH 7 than at pH 9;

vii. mixing. Good mixing ensures proper dispersal of the disinfectant throughout the water, and so promotes the disinfection process.

Raw water can be disinfected by either boiling or chlorination.

Boiling this does not provide complete sterilisation, but majority of bacteria and viruses are destroyed. It is necessary to boil contaminated water for 10 minutes to ensure its full safety (Mann and Williamson, 1983)

Chlorination

Although Cairncross, (1993) does not regard chlorination suitable for village systems except for the chlorination of wells. This involves hanging a pot below the surface of the water, which contains a mixture of coarse sand and bleaching powder.

The double pot is suitable for a well serving up to 20 people and need to be refilled with 1 kg of bleach and 2 kg of sand every 3 weeks, while the single pot will serve up to 60 people if it contains 50 % more bleach and sand and requires refilling every 2 weeks (Cairncross, 1991).

However pot chlorinators tend to make the water taste unpleasant for the first few days and this may drive people to use water of worse quality.

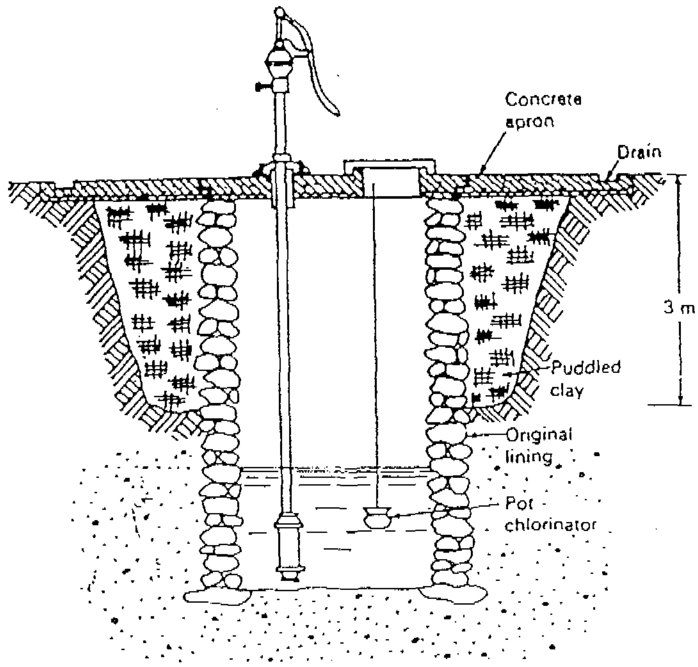


Figure 3.18 Pot chlorination of well water

Source Cairncross (1993)

Dangerfield (1983) regards chlorination in one form or another as the universal method used for disinfection of water supplies in developing countries. According to Schulz and Okun (1984), the ability of chlorine gas or chlorine compounds to kill pathogenic organisms as well as their wide availability and moderate cost in most regions of the world, make them well suited for disinfection. The decision to use chlorine gas or chlorine compounds should be based on several factors (Schulz and Okun, 1984):

i. quantity of water to be treated;

ii. cost and availability of chemicals;

iii. equipment needed for its application;

iv. skill required for its operation and control;

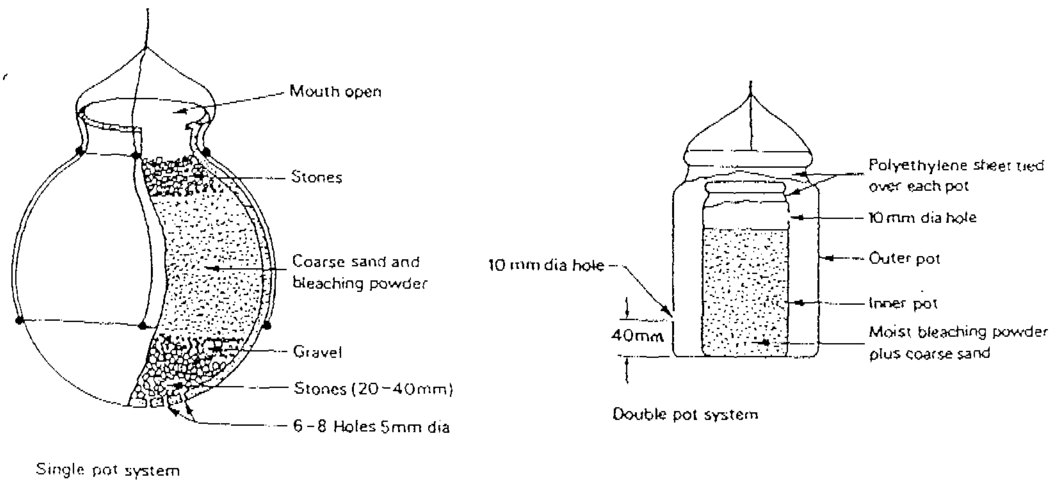


Figure 3.19 Pot chlorinators, two different designs.

Source: Cairncross (1993).

Chlorine Gas is normally used at water treatment works because it is cheaper than other chlorine products. However chlorine gas is not recommended for small water supplies unless appropriate safety measures are taken because any gas leaks will result in serious injury or death of people located close to the treatment plant (Chapman, 1991). Where chlorine gas is used staff should be adequately trained and appropriate safety measures taken.

Since chlorine is an oxidising agent it will immediately oxidise impurities and no longer be available for disinfection (Smethurst, 1988). Enough chlorine must therefore be applied for reaction with organic matter and micro-organisms (the *chlorine demand*). This chlorine demand will vary according to the quality of the water. Roughly speaking, 1 mg/l of chlorine is required to satisfy 2 mg/l of BOD (Cairncross, 1993).

Chlorine in water reacts according to the following reaction:

$$Cl_2 + H_20 = HOCl + HCl$$

The hypochlorous acid (HOCl), ionises of dissociates into hydrogen (H^+) ions and the hypochlorite (Ocl^-) ions in another reversible reaction:

$$HOCl = H^+ + Ocl^-$$

Disinfection is accomplished by the hypochlorous acid and the hypochlorite ions. Since the concentration of the two species is a function of the hydrogen ion concentration, the efficiency of disinfection is affected by pH. As a general rule chlorine is most effective at a pH of < 8

(WHO 1989).

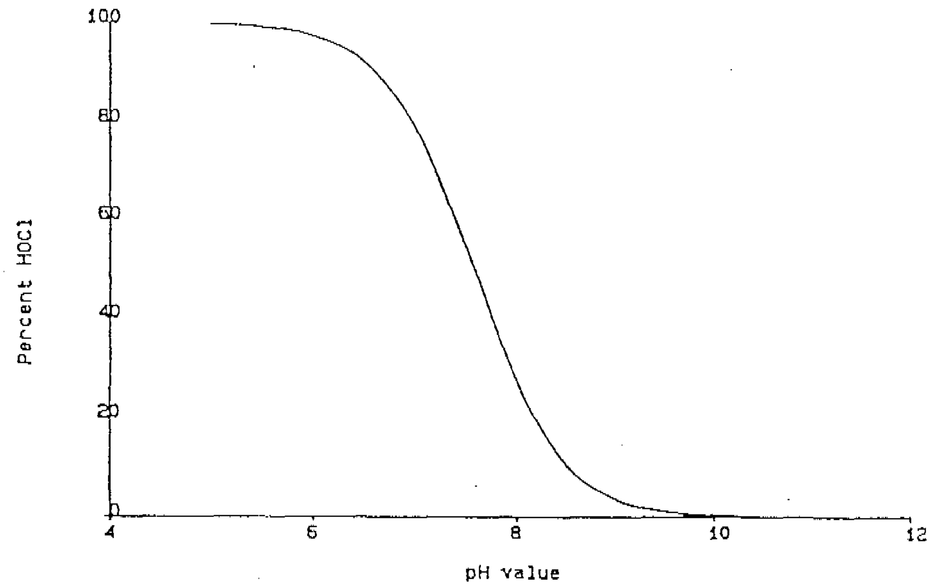


Figure 3.20 Dissociation of HOCL at 20°C (after Mara, 1976)

Hypochlorite Compounds such as calcium and sodium hypochlorite and chlorinated lime (bleaching powder) are the compounds commonly used. Sodium hypochlorite is supplied as a liquid. It contains 15 % chlorine (150 g/l chlorine) after manufacture, but can be reduced to 10 % after several months of storage (Chapman, 1991). Household bleaches containing about 3.5 % chlorine can also be used to disinfect drinking-water. Calcium hypochlorite is available in tablets or dry granules, normally containing 65 to 70 % chlorine by weight. It is favoured for use in rural areas since it is less hazardous and much more stable in storage. Rural communities collecting surface water in buckets and containers can use household bleach for disinfection. The recommended dosage is given in Table 3.3. The water should be allowed to stand for 2 h before drinking. About 10 g of granular chlorine per 1 000 l of water will give a chlorine dosage of 7 mg/l (CSIR 1990).

In larger operations chlorine needs 30 min in contact with water to disinfect it (WHO, 1969). Thus it is applied before water enters the storage tank. Chlorine would kill off the organisms in a slow sand filter and therefore should never be added before slow sand filtration (Cairncross, 1991).

Table 3.3 Quantity of household bleach recommended to chlorinate a container of water.

Container size	Quantity of bleach	Chlorine dosage (mg/l)
10 l bucket	1/2 teaspoon (2.5 ml)	8.7
20 l container	1 teaspoon (5 ml)	8.7
200 l drum (44 gallons)	1/4 cup (50 ml)	8.7
1000 l tank (1 m^3)	1 cup (200 ml)	7.0

TABLE 3.5 General Features of Construction and Operation of Conventional Slow and Rapid Sand Filters

(Source: Adapted from Fair, Geyer and Okun, 1968)

	Slow Sand Filters	**Rapid Sand Filters**
Rate of filtration	0.1 to 0.2 to 0.4 m/h	4 to 5 to 21 m/h
Size of bed	Large, 2 000 m^2	Small, 40 to 400 m^2
Depth of bed	300 mm of gravel, 900 to 1 100 mm of sand, usually reduced to no less than 500 to 800 mm by scraping	300 to 450 mm of gravel, 600 to 700 mm of sand; not reduced by washing.
Size of sand	Effective size 0.25 to 0.3 mm; uniformity coefficient 2 to 2.5 to 3	Effective sizes 0.55 mm and higher; uniformity coefficient 1.5 and lower, depending on underdrainage system.
Grain size distribution of sand in the filter	Unstratified	Stratified with smallest or lightest grains at the top and coarsest or heaviest at the bottom.
Underdrainage system	1. Split tile laterals laid in coarse stone and discharging in tile or concrete main drains. 2. Perforated pipe laterals discharging into pipe mains	1. Perforated pipe laterals discharging into pipe mains; 2. False floor type with orifices. 3. Many others, generally propriety.
Loss of head	60 mm initial to 1 200 mm final.	300 mm initial to 2 400 or 2 750 mm final.
Length of run between cleanings	20 to 30 to 60 d.	12 to 24 to 72 h.
Penetration of suspended matter	Superficial	Deep, particularly with dual or mixed media.
Method of cleaning	Scraping off surface layer of sand and washing and storing cleaned sand for period resanding of bed.	Dislodging and removing suspended matter by upward flow or backwashing which fluidizes the bed. Possible use of auxiliary scour systems.
Amount of water used in cleaning sand	0.2 to 0.6 % of water filtered	1 to 4 to 6 % of water filtered.
Preparatory treatment of water	Generally none when raw water turbidity is < 50 NTU	Coagulation, flocculation and sedimentation.
Supplementary treatment of water	Chlorination	Chlorination
Cost of construction	Relatively low.	Relatively high.
Cost of operation	Relatively low	Relatively high

3.2 Rural Sanitation

The World Health Organisation's (WHO) figures for 1988 showed that only 19 % of the world's rural population had adequate excreta disposal facilities (Cairncross, 1993). According to Black (1990), 1 740 million (43 %) of the rural population in developing countries do not have access to appropriate sanitation. Furthermore, WHO estimates that as much as 80% of all diseases may be due to inadequate and poor water quality supplies and sanitation (WHO 1989). Clearly, in order to improve the status of health in developing countries, the water supply and sanitation facilities would have to be improved.

The safe disposal of human wastes and waste waters is especially important in the control of infectious diseases. This can only be achieved by the building of appropriate sanitation systems. However, experience has shown that unless there is an effective primary health care education programme, the installation of improved sanitation facilities alone may not result in improved health (Chapman, 1991). Primary health care involves educating people of the importance of washing hands after defecation, washing food, keeping the household free from the excreta, and encouraging people to use toilets. Sanitation thus requires some change in the daily habits of people. As a result, sanitary changes take a longer time to implement and may not always be successful, especially when they are not marketed correctly. Cairncross, (1993) states that whereas water supplies are almost universally popular, sanitation facilities are unlikely to be used, still less maintained, unless people want them. Reasons for this include:

i. the link between improved health and proper sanitation is not clearly perceived;
ii. the costs involved in improving current sanitary facilities;
iii. cultural and socio-economic conditions with regard to sanitary practices;
iv. the lack of proper maintenance in the event of a breakdown;

Thus to implement a successful sanitation system the sanitary engineer should take into account the factors affecting the health and social organisation of the community. The technology to be used in a sanitary system should be assessed according to its reliability, appropriateness, acceptability and affordability to the community.

3.2.1 Sanitation Systems

According to the Chapman (1991), there are three main criteria for distinguishing between types of sanitation systems. These are:

i. need water or do not need water
ii. on-site or off-site treatment and disposal
iii. aerobic or anaerobic treatment of wastes

Unless there is a piped water supply, sanitation systems that do not require water are more appropriate for rural areas.

With regard to the site for treatment and disposal, it should be remembered that most rural communities do not have a central disposal facility or sewage system. Thus an on-site disposal system may be the viable choice in these circumstances.

3.2.2 Excreta Disposal Systems

Pit Latrines

The basic pit latrine comprises of a 2 to 3 m deep hole dug into the ground with a pedestal or a covering slab secured above the pit, located in a shelter. In many cases the shelter allows a lot of light to enter, may not be kept clean, and the cover plate may be missing. Such sites have an odour emerging from them and are a breeding place for flies and diseases.

Pit latrines can be built fairly easily by following some basic principles outlined below:

i. decide on an adequate location for the latrine, preferably downhill of groundwater sources (at least 30 m away), close to the dwelling and downwind (so that odours are not blown towards the dwelling);
ii. dig a pit at least 3 m deep and 1.5 m in diameter. The sides of the pit should be lined with bricks and mortar. The lining should extend 100 mm above the surface;
iii. the pit should not penetrate the water table;
iv. the coverslab of the pit, which must be smooth and sloping gently towards the pit

in order to facilitate drainage, should be placed onto the pit and sealed with mortar;

v. the pit may be fitted with a pedestal or a squatting slab. The opening should be fairly small to prevent children from falling into the pit.

vi. the superstructure of the latrine can be constructed from bricks of metal. A roof should always be fitted.

vii. the interior of the pit should be semi-dark for effective fly control.

viii. small amounts of water should be added to the pit to assist in decomposition of the wastes (should not exceed more than 1 l per user per day).

ix. the pit should be made accessible for external cleaning equipment.

Ventilated Improved Pit (VIP) Latrines were developed by the Blair Research Institute of Zimbabwe. The difference between a standard pit latrine and the VIP is that the latter contains a ventilation system to control flies and odours. The ventilation system consists of a vent pipe is fitted over the latrine slab. Any air movement over the top of the pipe causes an updraught in the pipe, which sucks out air from the pipe (Morgan, 1988). This creates a downdraught through the squatting hole as air is being replaced. Thus the squatting hole acts like an air inlet with the vent pipe acting like an exhaust, effectively removing odours emanating from the faecal material in the pit (Cairncross, 1993).

On hot days the sun heats the wall of the pipe which in turn heats the air in the pipe. This hot air raises and escapes through the top of the pipe while cool air enters through the squat hole. This mechanism enhances the ventilation of the latrine. Vent pipes are often painted black or grey to help this effect (Morgan, 1988).

The VIP also controls flies effectively. In the VIP, odours are sucked through the vent pipe and likewise light enters the pit through the vent pipe (Morgan, 1988). Flies are thus attracted to the head of the pipe by the odours, and flies in the pit are attracted up the pipe to the light. With a flyscreen placed over the top of the pipe, these two groups of flies cannot meet. The flies in the pit will eventually fall down and die. In controlled experiments in Zimbabwe, 13 953 flies were caught over 78 days from an unvented pit latrine, while only 146 flies were caught from a vented latrine (Morgan, 1977). In addition to this a simple insect trap shown in figure 3.21 can be placed over the drop hole, to control insects which emerge at dusk and escape through the drop hole (Ciarncross, 1993).

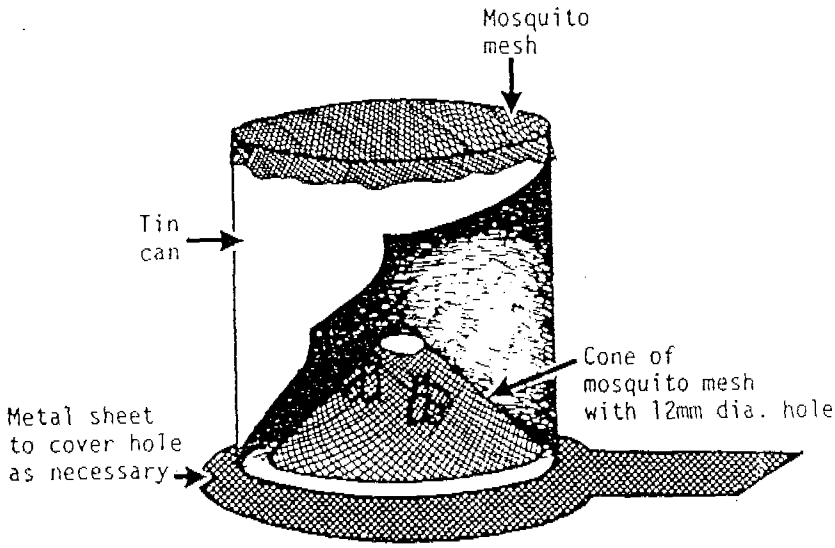


Figure 3.21 Cutaway view of a simple fly trap made from an old paint tin.

Source: Cairncross (1993).

It is important that the latrine should be kept semi-dark to prevent flies from escaping through the drop hole.

Septic Tanks

A septic tank is a watertight tank to which wastes are carried by water flushing down a short sewer (Ciarncross 1993). Similar to the pit latrine, the septic tank is an on-site sanitation system where the liquids are disposed of to a soakaway and the solids are partially digested in the tank. Septic tanks can be connected to the outlet of any water flush latrine (Chapman, 1991) and can accept sullage water from bathrooms and kitchens. The sludge in the tank must be removed periodically depending on the size of the tank. According to Drews (1986), the minimum practical volume is 1.5 m^3, at least 1 m deep and at least 0.65 m in any other direction.

According to Umgeni Water (1991), the use of septic tank systems depends on at least four prerequisites, apart from educating the user. They are:

i. availability of water for flushing toilets. Depending on the type of toilet and the frequency of use per day, the volume of water needed could range from 25 l/p/d to 140 l/p/d;

ii. availability of land adjacent to the toilet or dwelling with favourable drainage characteristics for the construction of a soakaway.

iii. availability of sufficient land for soakaway construction.

iv. availability of site for sludge disposal after septic tank emptying.

The advantage of a septic tank is that it gives the users the convenience of an indoor flushing toilet at low cost well below that of conventional waterborne sanitation (Umgeni Water, 1991). Figure 3.22 shows a two-compartment and a three-compartment septic tank.

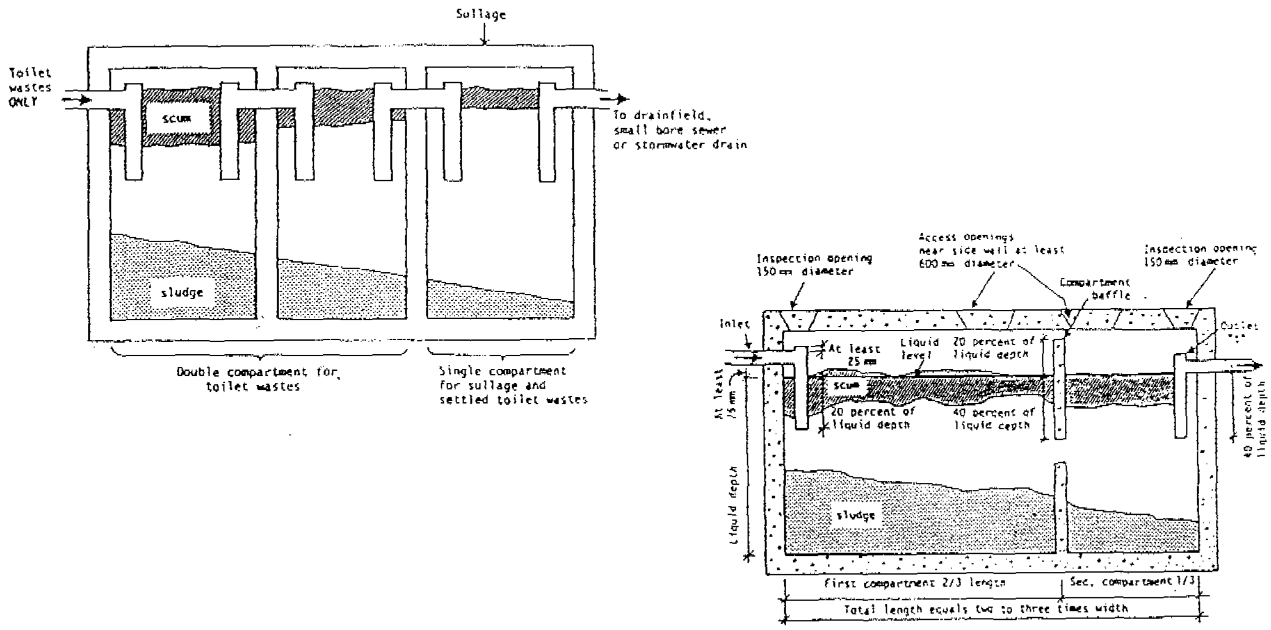


Figure 3.22 (a) A conventional two compartment septic tank.

(b) Three-compartment septic tank

Source: Kalbermatten *et al* (1982).

Aqua-privies

An aquaprivy is essentially a septic tank located directly underneath a squatting plate which has a vertical drop-pipe extending below the liquid level in the tank, thus forming a crude water seal (Ciarncross, 1993). The tank is also fitted with a vent pipe. The function of an aqua-privy is to provide settlement, stabilisation and anaerobic treatment of the solid wastes (Kalbermatten *et al*, 1980). An aqua privy can reduce the chemical oxygen demand (COD) of wastes by 50 to 75% (Chapman, 1991).

There are two principal disadvantages of the aqua-privy:

i. the difficulty of constructing a watertight tank in rural areas;

ii. the release of extremely offensive odours once the water level drops below the water seal of the inlet pipe.

This has lead to aqua-privies being banned in some countries, example Botswana.

Small-Bore Sewers

Unlike urban sewage systems which are designed to carry solid waste material, small bore sewers only carry effluent from on-site treatment systems, example septic tanks. Typically, the soakaway of a septic tank is replaced by a small bore sewer. Small-bore sewers can be successfully implemented where there is a high population density, the water table is high and where there is impermeable bedrock which prevents the construction of a VIP.

Pour-Flush Toilets

The pour-flush toilet consists of a water seal in the form of a U-shaped pipe filled with water below the squatting pan. The water seal provides an effective seal against odours and flies. The pour-flush toilet uses less water than the normal flush toilets (Chapman, 1991). An added advantage of the pour-flush toilet is that the toilet can be located within the household. The waste from such a system is deposited into a septic tank which can be located up to 8 m away.

3.2.3 Waste Water Disposal

Waste water or sullage is domestic waste that does not contain excreta. Sullage is also referred to as grey water. Sullage also contains pathogens and if it is not disposed of correctly it can pose a health risk.

In rural areas sullage may be disposed of by special sullage soakaways if the soil conditions are suitable, by stormwater drains, or by sewers if these are available (for example as part of a sewered pour-flush system) (Okun and Ponghis, 1975). Morgan, (1990) list three methods of waste water disposal in rural areas, viz.:

i. soakaway method;
ii. evapotransporation method;
iii. sump method;

Where there is a risk of groundwater contamination or where the seepage of sullage is inadequate, the sullage will have to be disposed off-site. This may either be by means of routine collections with a vacuum tanker, or by the installation of sewer pipes (Chapman, 1991). As a result of on-site sanitation the effluent contains only very fine suspended matter. This reduces the cost of the sewer system considerably, since only very fine suspended matter need to be transported.

Soakaway Method

This is a common method of waste water disposal in rural areas, but it has some disadvantages. In open soakaways around standpipes and wells, high amounts of silt is washed down the run-off channel, which may result in clogging the soakaway thus rendering it ineffective. The efficiency of open soakaways can be increased by planting bananas, trees, sugar cane or vegetables over the areas (Morgan, 1990). The covered or underground soakaway should be constructed with an open jointed brickwork and a layer of broken rocks or stones should be inserted between the brickwall and the earth wall to aid seepage. The cover, except the access hole, should ideally be buried to keep insects out.

A variation of the soakaway method is the soakaway trench. These are filled in trenches containing open-jointed pipes of 100 mm diameter, laid on rock fill, gravel, or broken bricks (Cairncross, 1993). This system provides for a larger infiltration area for a smaller volume of excavation than a pit (Okun and Ponghis, 1975). The trenches should be deep and narrow to obtain a larger side-wall infiltration area. In practice several trenches are dug in series between 15 to 30 m long

Evapotransporation Method

In the evapotransporation method, waste water is allowed to travel along a drainage furrow lined with plants. The plants extract the water from the saturated soil. According to Morgan (1990), banana plants, sugar cane, gum trees and even a garden of vegetables serve adequately for this purpose. An evaporation mound is a variation of this method where waste water is lead into a mound that is covered with vegetation. The waste water should preferably pass through a silt trap before draining out into the field or a mound of sand.

Sump Method

The sump method allows the waste water to drain into an unlined sump in the middle of a vegetable garden. Water in the sump is used to irrigate the vegetable field on a regular basis.

3.2.4 Waste Water Treatment

Often domestic waste water needs to be treated to prevent pollution of receiving water body. There are many methods of waste water treatment but the choice in rural areas will be limited by economic and technical considerations.

The aim of wastewater treatment is to enable sewage to be disposed off safely without risk to health, unacceptable pollution of receiving waters, or other environmental nuisance (Nicoll, 1988). The method of treatment will depend on the load of sewage, the conditions of the receiving waters and the climate.

In developing countries there are three ways in which wastewater can be treated effectively:

i. waste stabilisation ponds;

ii. aerated lagoons;

iii. oxidation ditches;

Waste Stabilisation Ponds

Waste stabilisation ponds are large shallow basins in which sewage is treated entirely by natural processes involving algae and bacteria. Since the process is entirely natural, the rate of oxidation is rather slow and as a result the retention times are usually long. However waste stabilisation ponds are without doubt the most important and effective method of sewage treatment in hot climates (Mara, 1983). There are four types of waste stabilisation ponds:

i. facultative ponds;

ii. maturation ponds

iii. anaerobic ponds;

iv. high-rate ponds;

Facultative Ponds refers to a mixture of anaerobic and aerobic conditions in the pond. Anaerobic conditions exist in and slightly above the sludge layer at the bottom of the pond, while aerobic conditions exist towards the surface of the water. The facultative pond is responsible for almost all BOD removal (Mara, 1983). In the upper layers of the pond waste is oxidised by bacteria. Most of the oxygen is supplied by the photosynthetic activities of the pond algae and the remainder is supplied by the atmosphere. The algae in turn need carbon dioxide for photosynthesis, which is supplied by the bacteria in the pond and a small amount is gained from the atmosphere. Thus there is a "*symbiosis*" between the bacteria and the algae which forms the main basis of waste stabilisation ponds (Mara, 1983). Figure 3.23 shows this symbiosis.

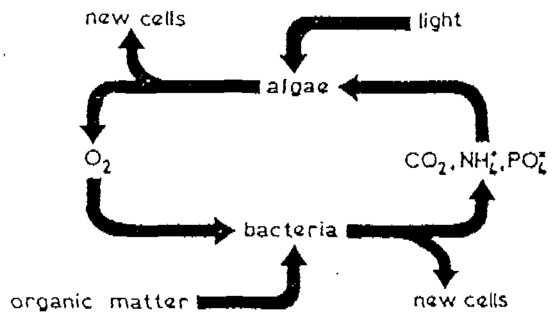


Figure 3.23 Symbiosis of algae and bacteria

Source: Mara (1983).

Anaerobic digestion of sewage takes place in the sludge layer which is formed over the entire pond bottom as the sewage settles under gravity. Some 30 % of the influent BOD is released from the pond as methane gas (Mara, 1983), which is produced under anaerobic conditions. The pathways of BOD removal are shown below.

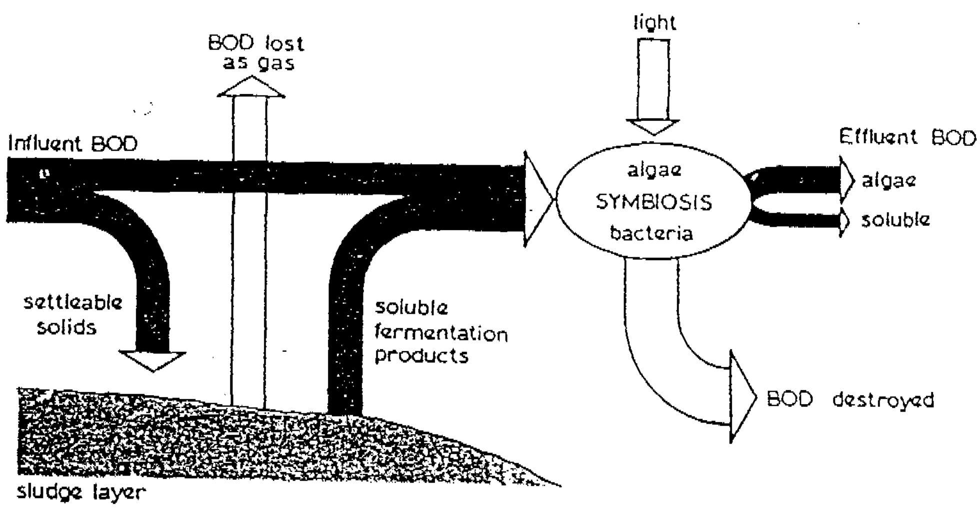


Figure 3.24 Pathways of BOD removal in facultative stabilisation ponds

Source: Marais (1974).

Photosynthesis is light dependent and as a result there is a diurnal variation of DO and pH in the level of the pond where aerobic conditions exist (Mara 1983). This variation is shown in figure 3.25.

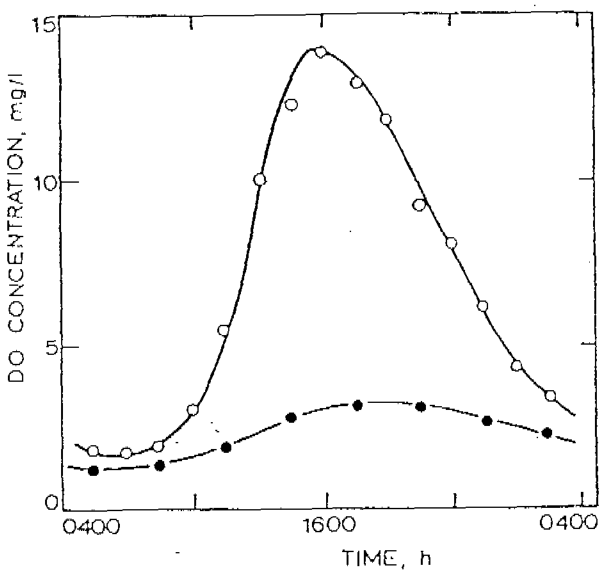


Figure 3.25 Diurnal variation in dissolved oxygen; O, top 200 ml of pond;

•, 800 ml below surface.

Source: Mara (1976).

The breakdown of bicarbonate to release carbon dioxide for algal growth occurs according to the following reaction:

$$HCO_3^- = CO_2 + OH^-$$

The release of hydroxyl ions results in an increase in pH.

To ensure a relatively uniform distribution of water, algae and dissolved oxygen (DO) in the pond, it is necessary for the pond to be mixed uniformly. Mixing also ensures that the algae is spread throughout the photic zone of the pond. The pond can be mixed either by wind action, by temperature inversion or by mechanical mixers. In the absence of effective mixing, thermal stratification occurs. About 300 to 500 mm below the pond surface a thin static layer of steep temperature change (the *thermocline*) forms, above which there is some mixing but none below

(Mara 1983). Mara (1983) further states that non-motile algae sink to the bottom of the pond where they exert an oxygen demand rather than supply it, while above the thermocline the temperature rises and the motile algae move away to a cooler depth. This results in a vast reduction in the number of algae in the photic zone, and a subsequent reduction in oxygen production and waste stabilisation.

A hot climate is ideal for pond operation, (Mara, 1983) but they are used at all latitudes, even as far north as Alaska (Mara, 1976).

The prime function of **Maturation Ponds** is the destruction of faecal bacteria (Mara, 1976). According to Mara (1983), maturation ponds are used as second and third stages to facultative ponds and are also responsible for the quality of the final effluent. The size and the number of maturation ponds control the effluent quality (both bacteriological and chemical) and hence the efficiency of the pond (Meiring et al, 1968).Whereas facultative ponds are both aerobic and anaerobic, maturation ponds are wholly aerobic. According to Marais and Shaw (1961) two maturation ponds in series with a retention time of 7 d are required to achieve an effluent with a BOD < 25 mg/l. Marais (1974), further states that a properly designed maturation pond is capable of removing 90 to 95 % of faecal coliforms.

The BOD loading capacity of **Anaerobic Pretreatment Ponds** is so high that these ponds are devoid of any DO. They are most advantageously used to pretreat strong wastes which have a high solids content (Mara, 1976). The solids settle to the bottom of the pond under gravity and are digested anaerobically. The partially clarified supernatant is discharged into a facultative pond for further treatment (Mara, 1976). Mara (1976) also stresses that a temperature of > 15° C and a pH > 6 is necessary for the successful operation of anaerobic ponds.

High Rate Ponds are designed to receive high rates of settled sewage (for example the effluent from anaerobic ponds) (Mara, 1983). Their depth is shallow so that the photic zone extends to the bottom of the pond and thus the conversion of sewage to algae is very fast. Retention times of 1 to 3 days is necessary to convert 1 kg of BOD to 1 kg of algae (McGarry, 1971). One of the drawbacks of high rate ponds is that they require skilled personnel to operate and maintain the algae removal plant.

The disadvantages of ponds is that they require much larger areas of land than other forms of sewage treatment. However the advantages far outweigh the disadvantages. Mara (1976) lists the following advantages:

i. they can achieve any required degree of purification at the lowest cost and with the minimum maintenance by unskilled operators;

ii. the removal of pathogens is considerably greater than that in other methods of sewage treatment;

iii. they are well able to withstand both organic and hydraulic shock loads;

iv. they can effectively treat a wide variety of industrial and agricultural wastes;

v. they can easily be designed so that the degree of treatment is readily altered;

vi. the method of construction is such that, should at some future date the land be required for some other purpose, it is easily reclaimed;

vii. the algae produced in the pond are a potential source of high-protein food which can be conveniently exploited by fish farming.

The design features and expected performance of a few pond systems is shown in Table 3.4.

Aerated Lagoons

Aerated lagoons are mechanically aerated waste stabilisation ponds. The mechanical aerators are installed, particularly in temperate climates, to supplement the algae oxygen supply. Aerated lagoons achieve BOD removals of > 90 % at comparatively long retention times (2 to 6 days), but are not particularly effective in removing faecal bacteria (Mara, 1976). As a result further treatment in maturation ponds is necessary.

Table 3.4 Design Features and Expected Performance for Aquatic Treatment Units

Concepts	Treatment goals	Climate needs	Detention Time, (d)	Depth m	Organic loading, (kg/ha.d)	Effluent characteristics (mg/l)
Oxidation pond	Secondary	Warm	10 - 40	1 - 1.5	40 - 120	BOD 20 - 40; TSS 80 -140
Facultative pond	Secondary	None	25 - 180	1.5 - 2.5	22 - 67	BOD 30- 40; TSS 40-100
Aerated pond, partial mix	Secondary, polishing	None	7 - 20	2 - 6	50 - 200	BOD 30-40; TSS 30 - 60

Source: Adapted from Reed et al, (1988).

The sludge from the effluent of an aerated lagoon can be removed by conventional sedimentation processes. To avoid the breakdown of mechanical aerators the sewage should be screened to remove any objects that may clog the aerators. Aerated lagoons are best built 3 to 4 metres deep with embankment slopes of 1 in 2 (Mara, 1976). The embankments and lagoon bottoms should be adequately lined to prevent erosion and scour.

Oxidation Ditches

Oxidation ditches are similar to aerated lagoons in that the wastewater is oxidised by bacteria in flocculent suspension and the oxygen required for bio-oxidation is supplied by mechanical aerators (Mara, 1983). The difference between oxidation ditches and aerated lagoons lies in their shapes, the type of aerator and the recycling of sludge. Oxidation ditches are usually oval in shape with channels between 1.5 to 2 m deep. Horizontal cage rotors are used to aerate the water and also imparts a flow to the water. Sludge is removed from the effluent by sedimentation and fed back into the oxidation ditch. Sludge recycling oxidises the waste more rapidly and results in shorter retention times and a smaller quantity of sludge which is more mineralised.

Oxidation ditches require considerable maintenance. All electrical and mechanical equipment must be kept in perfect working order and the operator has to maintain the concentration of suspended solids in the ditch in the range of 3 000 to 5 000 mg/l (Mara, 1983). Oxidation ditches are usually used when there is insufficient land for an aerated lagoon system.

Wetland Systems

Wetlands can be defined as land where the water surface is near the ground surface long enough each year to maintain saturated ground conditions (Read et al, 1988). Suitably designed and operated wetlands have considerable potential for low-cost, efficient and self maintaining wastewater treatment systems (Chapman, 1991). Waste is stabilised by bacterial colonies which flourish on the roots and stems of plants as well as the soil or gravel media in which the plants grow. Wetland systems can reduce high levels of BOD, suspended solids and nitrogen as well as significant levels of metals, trace organics and pathogens (Read et al, 1988). The basic treatment mechanisms include sedimentation, chemical precipitation, adsorption and microbiological activity as well as evapotransporation. Both constructed and natural wetlands have been used as wastewater treatment systems. Brix (1993) lists the following advantages of wastewater treatment by constructed wetlands:

i. low cost of construction and, especially, maintenance;
ii. low energy requirements;
iii. being a "low-technology" they can be established and run by relatively untrained personnel;
iv. the systems are usually more flexible and less susceptible to variations in loading rate than conventional treatment systems;

Therefore, the disposal of wastewater into constructed wetland is an especially attractive alternative to conventional wastewater treatment technologies for small-to medium-sized communities, in sparsely populated areas, and in developing countries (Brix, 1993).

Table 3.5 Experimental Reed Bed treatment System at Prague Central Treatment Plant

Source: Vymazal (1993).

	Inflow (average) mg / l	Outflow (average) mg / l	Efficiency (%)
BOD	200	21	89.5
COD	380	64	83.1
Suspended Solids	240	5.7	97.6
Total P	6.5	3.3	49.2
Total N	48	26	45.8
Coliforms CFU / 100 ml	$107 * 10^5$	$3.6 * 10^3$	99.97
Faecal coliforms CFU / 100 ml	$79 * 10^5$	$2.1 * 10^3$	99.97
Enterobacteria CFU / 100 ml	$18 * 10^5$	700	99.96

away. Since flushing is done manually, multiple-tap connections are not required. Pour-flushed toilets are best used with a yard-tap level of water supply, although they can be used in conjunction with public standpipes if the standpipe density is such that the users can and will carry enough water home for their operation (Cairncross S. 1993).

Chapter Four

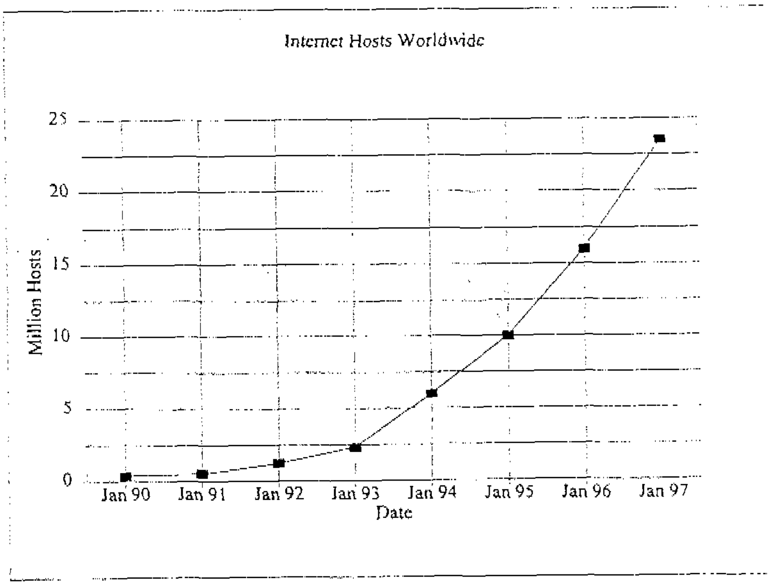
The Internet and the Construction of WENDY

The Internet can be described as a web of different, intercommunicating computers. The Internet began in early 1969 under the name *Advanced Research Projects Agency Network* (ARPANET). Later it became known as the *Defence Advanced Research Projects Agency* (DARPA) under the auspices of the United States Department of Defence. By 1972 the ARPANET was first publicly demonstrated and consisted of a network of 50 university research facilities (involved in military projects). The aim of ARPANET was to learn about and design networks that could withstand the loss of ordinary communications.

At the end of the 1970's numerous other networks, public and private, were created based on the same communications structure as ARPANET. Eventually all these networks combined to form the National Science Foundation Network (NSFNET). This formed the basis of the Internet. Today the Internet covers almost every country in the world, with an estimated 56 million end users by the end of 1995, (Bournellis, 1995). The expected growth of the Internet is shown in Figure 4.1.

Figure 4.1 Internet Hosts Worldwide

Source: , (Bournellis, 1997).



A recent development on the Internet has been the World-Wide Web (WWW), also known as the *Web*. The Web is a globally accepted standard for presenting hypertext documents. Under the

WWW, all information is arranged in documents with hypertext links (text or graphics coloured differently from ordinary text) scattered throughout the document. By simply clicking on the link the user is moved to another document that could be on the same computer, or on another computer at a remote site. Similarly, the new document may have links which can be followed. By following the links the end user is *surfing the Net*. Each link can be located via its address on the Internet, or its Uniform Resource Locator (URL). Hypertext documents contain text and graphic images, and can even contain sound and full-motion animation.

Gibbs and Smith (1993) divide Internet activities into 6 main areas:

(i) **Electronic Mail (e-mail)**. Probably the most widely used Internet facility in the world. E-mail is the direct transfer of textural information, graphic images and binary files from one Internet user to another. Audio and video data can also be transferred, but these processes are still in their development phases. The data is transferred almost instantaneously. The savings in terms of cost, time and paper has made e-mail an environmentally friendly alternative to the ordinary postal service.

(ii) **File Transfer Protocol (FTP)**. This is the tool used to transfer files between computers on the Internet. The file is transferred using a standard protocol which works even if files are transferred between computers with different hardware and software configurations. FTP can be used to download or send text files, program files, data files or graphic files.

(iii) **Telnet**. This tool is used to log onto and run programs on a remote computer, transferring the screen display to your machine while sending the keyboard data to the remote machine. This allows the end user to run programs on a remote computer or extract information from the remote computer.

(iv) **Search Engines**. Due to the enormous size of the Internet, user may not know where to find the information they require. Search engines can be described as the librarians of the Internet. They automatically and regularly search a large number of Internet servers and index their files to create a single, searchable database. Using search engines such as Archie or Lycos, the user can search files through keywords contained in the title or sometimes in the file itself.

(v) **Usenet Newsgroups**. This tool allows people on different computers to exchange messages and information in a way that allows discussions to develop around a certain topic. Information, requests, advertisements, arguments are all posted onto the Internet. These posting are followed by responses from the millions of end users subscribing to the specific newsgroup.

(vi) **Listservers**. This is a popular method of exchanging information over the Internet. Listservers are similar to newsgroups except that the users send and receive messages via e-mail rather than using a special news reading program. Listservers can also be described as electronic journals, where authors post their articles to the editor who then compiles these articles in the form of a booklet and posts it to the various subscribers. All this is done on the Internet.

4.1 The Importance of Communication and Information Exchange

During September 1993 the Global Forum of the Water Supply and Sanitation Collaborative Council reviewed reports on Information, Education and Communication (IEC) and on Information Management (IM).

The IEC report stated *only when men and women in communities are mobilised to participate fully as agents and managers of change, can programmes be developed which provide sustainable improvements in water and sanitation services. That mobilisation and participation depends crucially on the right information, education and, above all, communication* (WSSCC 1993). The above statement, made by experienced professionals in the water and sanitation sector, outlines the importance of communication in developing sustainable improvements in the sector. The IEC Working Group further urges that the communication approach be applied throughout any programme cycle to address a range of recognised WSS sector programming failures. In the light of these problems the Working Group formed a programming strategy. One of the key objectives of the programming strategy is to implement capacity-building at all levels using relevant participatory methods to stimulate interpersonal and two-way communication that respond to community requirements, cultures, and behaviour. As a result the IEC Working Group now has a network of 60 members who regularly share experiences.

Furthermore, WASH (1993) states that an active information service can expand the reach, as well as the visibility and credibility, of technical assistance. An important way to accomplish this is through the development and dissemination of written material (WASH, 1993). Information exchange also leads to the development of communications networks which are particularly important in providing information to researchers and practitioners in developing countries (WASH, 1993).

The goal of improving sector activities through communication and information exchange is also shared by the Swiss Development Co-operation. In their Sector Policy on Water Supply and Sanitation, they encourage the use of international exchanges of practical and scientific experience in order to improve sector activities (SDC, 1993).

Similar views are shared by the WHO, who cite the exchange of information between sectors as a key issue in their Operation and Maintenance Working Group Report to the WSSCC (WHO, 1995).

The dissemination of written material, the development of informal networks, and the exchange of information between sectors can easily and very effectively be accomplished by using Internet tools such as Listservers, Newsgroups, FTP and e-mail.
The most practical demonstration of the importance of communication and information exchange is the existence of INFOTERRA (see **Appendix 2**). INFOTERRA is the international information system designed by the UNEP to stimulate and support the exchange of international scientific and technical environmental information. INFOTERRA can also be accessed through the Internet.

An example of the way in which communication, information exchange and problem solving can be conducted via the *Web* is shown in **Appendix 3**.

4.2 The Construction of WENDY

In order to facilitate communication between sector professionals, a *Web site* had to be created to act as a link to various sources of information as well as serve as a clearing house to facilitate the dissemination of information to individuals involved in the water supply and sanitation sector. This site was named WENDY (Water Supply and Environmental Sanitation Electronic Network for Developing Country Needs). WENDY was to be a set of hypertext documents based mainly on the WWW. The homepage along with the first few links was to be stored at the University of Natal's Computing Centre for Water Research (CCWR) server at the Internet address *http://www.ccwr.ac.za/WENDY.*

Early on in the project it was realised that all the information could not be housed at one location, due to the costs of hardware requirements and costs of maintaining the information at one site. Rather, the organisers thought it more practical and feasible that WENDY act more like a *signpost* directing users to the relevant information. This information would be housed and maintained, preferably, at a server in the host county.

The type of information that was to be contained in WENDY was carefully chosen to suit the needs of individuals involved in water and sanitation in developing countries. They ranged from government bodies, municipal authorities, consultants, contractors and researchers.

The initial format of WENDY was divided into two catergories. One delt with issues relating to urban water supply and sanitation in developing countries while the other addressed issues relating to rural water supply and sanitation in developing countries. The former can be viewed in Kibata (1995).

A printout of the introductory page with all the subdivisions is given in **Appendix 4**. Level 1 is an introductory page with hypertext links leading to various subdivisions relating to rural water supply and sanitation. The following subdivisions were then further subdivided:

i. planning and policy making;

ii. technical information;

iii. equipment;

iv. wastewater treatment;

v. health and sanitation;

vi. community involvement;

vii. research;

viii. software;

ix. funding;

x. announcements and events;

This structure was presented to the WENDY steering committee members for comments, suggestions and discussion. The outcome of this meeting was a thoroughly revised structure of WENDY, formatted by the documentalist at IRC and converted to HTML by researchers at the University of Durban-Westville, under the supervision of Professor Chis Buckley from University of Natal, Durban. The flow of information through the revised structure of WENDY is illustrated in Figure 4.2. A printout of the information pages is given in **Appendix 5**

4.3 Data Collection

Organisations involved in the water supply and sanitation sector in developing countries were invited to form a partnership with WENDY. They included:

i. Water Supply and Sanitation Collaborative Council (WSSCC);

ii. International Reference Centre for Water and Sanitation (IRC);

iii. International Association on Water Quality (IAWQ) (project initiators);

iv. United Nations Centre for Human Settlements (HABITAT);

v. Environmental Health Project (EHP) (formally WASH);

vi. Water and Engineering Development Centre (WEDC);

vii. Water Research Commission (WRC);

viii. United States Aid Organisation (USAID);

These organisation have been active in the sector for a number of years. Many of them had a large amount of information in their libraries and were regularly distributing journals and articles. The plan was for each of these organisations to construct their own homepages on the Internet and for WENDY to index these homepages. Thus WENDY was to be constructed around this information with the aim of disseminating this information electronically.

In addition the Internet was searched for all relevant information relating to water supply and sanitation in developing countries. The searches were conducted using the various search engines, example, WWW Worm, Webcrawler, Lycos and Infoseek. However the results of the searches were not very useful as most of the information contained on the Internet was only applicable to developed countries. This exercise also revealed the need for an information server

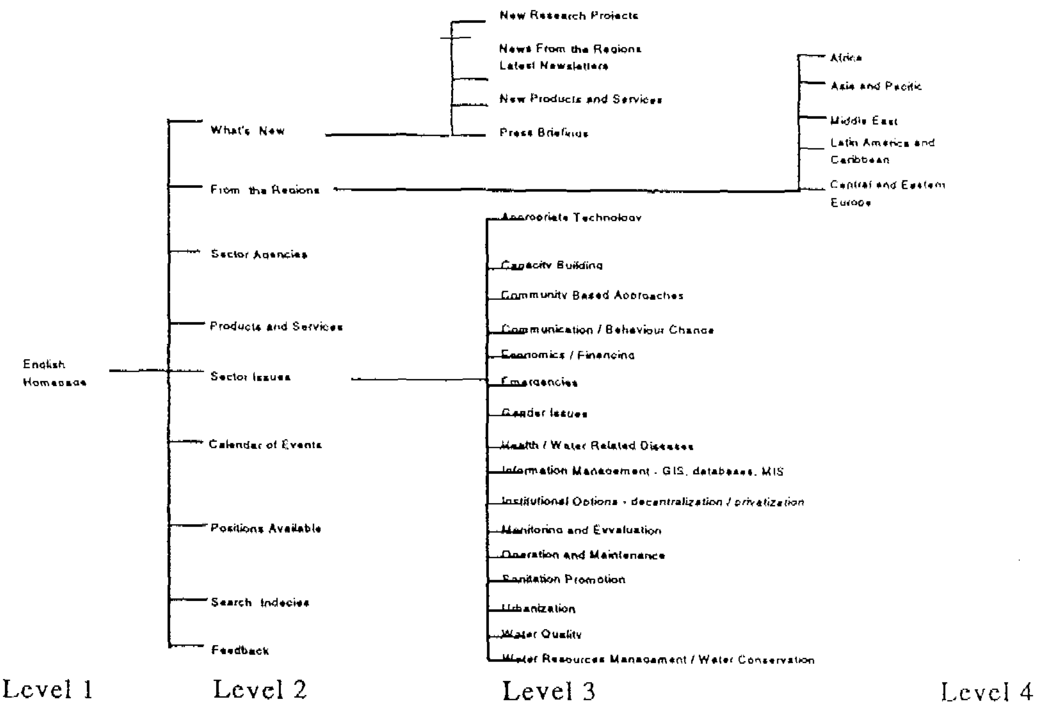


Figure 4.2 Flow of information through WENDY

on the Internet catering for the needs of the water supply and sanitation sector in developing countries, or the need for WENDY.

Requests were sent out via the various listservers on the Internet to people and organisations involved in the water and sanitation in developing countries. These people and organisations were invited to disseminate the information at their disposal on the Internet, through WENDY. WENDY was also advertised at the Water Supply and Sanitation Collaborative Council's Third Global Forum in Barbados. Organisations were offered assistance in setting up their own homepages, Web sites, and Internet facilities. The responsibility of maintaining and upgrading these sites would then rest with the respective organisations. WENDY would then direct end users to these sites through the WENDY homepage. A number of organisations showed a keen interest in forming *links* with WENDY.

Since many of the organisations involved in the water and sanitation sector in developing countries did not have the skills to set up their Internet facilities and create their own homepages, a team visit was made to various organisations in

Southern, Central and East Africa for this purpose. The objectives of the trip were to:

i. demonstrate and popularise the use of WENDY in the water supply and sanitation sector in the countries to be visited;
ii. review the Internet infrastructure available in these countries and to assess the extent to which the Internet could be used in information dissemination in these countries;
iii. link up the WaterAid country offices in these countries onto the Internet;
iv. assist organisations in setting up their Internet facilities and creating their own homepages;

The organisation that were visited on the trip include:

i. Mvuramanzi Trust (Zimbabwe);
ii. WaterAid Zambia
iii. Water Sector Development Group (Zambia);
iv. University of Zambia, Department of Civil Engineering;
v. WaterAid Tanzania;
vi. UNEP (Kenya);
vii. African Water Network (Kenya);
viii. NETWAS (Kenya);
ix. WaterAid Uganda;
x. WaterAid Ethiopia;
xi. UNICEF (Ethiopia);

By the end of this trip all the WaterAid offices listed above had full access to the Internet and its related activities. WENDY was also demonstrated to these organisations and they were keen to become partners with WENDY and share information at their disposal.

The result of promoting WENDY in this manner was the creation of a homepage for Mvuramanzi Trust which could be accessed through WENDY. Manuals of the VIP latrines developed by Mvramanzi Trust were available to all those connected to the Internet. The Mvramanzi Homepage and a manual of the 3 Bag Model of the VIP, that is available on the Internet is given in **Appendix 6**.

The field trip also exposed the researchers to the various activities of sector professionals in these countries. Of particular importance were the field trips to various rural communities where appropriate technology was implemented to overcome the problem of water supply and sanitation. The institutional and technical methods implemented by these organisations were demonstrated to the researchers as a possible means of overcoming sector related issues within South Africa. The field trip also helped establish communication links between sector professionals in Southern Africa.

4.4 Converting Text to Hyper-Text

The Hyper Text Markup Language is used to convert ordinary text, graphics and sound to text which can be read on the Internet by a number of different computer systems, example Unix, PCMS and Macintosh. Software packages such as HTML Editor, Hot Java and Ant Demo can be used to convert text to hyper-text. Wordprocessing packages are being upgraded to include this conversion feature.

Using HTML Editor the information received from the various organisations as well as the WENDY homepages was converted to hyper-text. This information was sent to researchers at the university via e-mail. Graphic images were scanned and added to the documents to enhance the appearance of WENDY.

The success with which WENDY was received at the WSSCC's global forum, as well as the number of organisations wanting to become partners with WENDY, is an indication of the initial success of WENDY. As the Internet spreads in developing countries, the number of partners and the number of users should increase. WENDY has already been used to solve a few problems in developing countries (see Kibata, 1995).

4.5 Evaluating the Server

The server was evaluated by seeking solutions to problems experienced by organisations in the water supply and sanitation sector in KwaZulu-Natal. The problems experienced by a consultant (Groundwater Development Services) and an aid organisation (Mvula Trust) involved in the sector were *put out* onto the Internet. The effectiveness of the server was judged on the speed at which
information was received, the quality of the information received and the cost of seeking solutions through the Internet.

The server was also evaluated by the responses received to a demonstration of the server at the Third Global Forum On Water Supply and Sanitation. The forum was hosted by the Water Supply and Sanitation Collaborative Council (WSSCC), during November 1995 in Bridgetown, Barbados.

Groundwater Development Services

This consultant experienced the problem of groundwater pollution from pit latrines and septic tanks. The extensive use of on-site sanitation in certain rural areas in KwaZulu-Natal has lead to elevated concentrations of nitrate in the underlying groundwater resources. Communities in these areas use groundwater extensively for domestic purposes and this has lead to the spread of diseases like methaemoglobinaemia (infantile cyanosis) and carcinogenesis. In addition to this faecal pollution of groundwater resources by individuals suffering from infections such as typhoid and cholera (both water borne diseases) has resulted in the spread of these infections to individuals who drink the polluted water.

To overcome these problems the consultant needed information. The information he was looking for included:

i. factors which affect the movement of contaminants in groundwater;
ii. factors which can be used to assess the risk of groundwater pollution from pit latrines and septic tanks;
iii. methods of preventing or minimising groundwater pollution from sanitation

systems;

iv. water purification techniques to be implemented in these situations;

Mvula Trust

Mvula Trust is an aid organisation involved in water supply and sanitation in rural areas of South Africa. The KwaZulu-Natal regional office was experiencing the problem of photo-voltaic cells being stolen. These cells are installed to power solar pumps used for water supply purposes. The project manager was open for comments and suggestions from sector professionals on how to overcome this problem. In addition to this the project manager wanted to know of appropriate alternatives to solar powered pumps that could be implemented in the rural areas of KwaZulu-Natal.

Both these problems were e-mailed to various listservers as well as organisations such as IRC, requesting information and guidance on how to overcome the problems.

Chapter Five

Results and Analysis

This chapter describes and analyses the results of the evaluation of WENDY which was used to solve two problems experienced by professionals involved in the sector in KwaZulu-Natal.

5.1 Groundwater Development Services

The problem of groundwater pollution from pit latrines and septic tanks occurred in various rural areas in KwaZulu-Natal. The problem was circulated on the Internet with the aim of gaining information on the following:

i. factors which affect the movements of contaminants in groundwater;

ii. factors that can be used to assess the pollution risk to groundwater in various hydrogeological environments;

iii. methods of preventing / minimizing groundwater pollution from on-site sanitation;

Solutions to the problems were sought through the Internet by sending direct e-mails messages to WENDY partner organisations as well as circulating the problem through the various listservers. Within 12 h, there were 7 responses and a further 13 responses within the next 12 h. After 24 h it was established that similar problems had been experienced in India, Bangladesh, Zambia, Botswana, Ghana, United States and Australia. However the problems experienced in United States of America and Australia related specifically to groundwater pollution from septic tanks. The responses received are summarised below under each of the questions posed.

5.1.1 Factors Which Affect the Movement of Contaminants in Groundwater

The responses received to this question concentrated mainly on the movement of bacteria and viruses in saturated and unsaturated soil columns. These factors include:

i. improper design, construction, operation and maintenance of sanitation systems;

ii. soil type and soil pH;

iii. groundwater flow rate and flow velocities;

iv. rate of groundwater abstraction;

v. filtration capacity of the soil;

Improper design of pit latrines leads to the spread of odours from the pit into the latrine. The odours also attract flies which in turn spread diseases. The end result is that the pit is abandoned and other unhygienic forms of defecating are used.

Improper design and construction of septic tanks, especially with regard to the soakaway, frequently results in the pollution of both surface and groundwater resources.

The movement of the pollution plume is also influenced by soil composition. Bacteria and viruses are readily adsorbed onto clays. Thus soils with higher clay contents have a greater ability to remove bacteria and viruses than soils with low clay contents.

Since viruses are almost entirely removed by adsorption, soil pH plays an important role in the movement of viruses. Low soil pH values favour virus adsorption while high soil pH values result in elution of adsorbed viruses.

Groundwater flow rate has a direct influence on the movement of contaminants. As the flow rate increases, the spread of contaminants increases both vertically and horizontally. The rate of groundwater abstraction, particularly for water supply purposes, affects the spread of contaminants, since a high rate of abstraction (> 5 l/s) induces a high groundwater flow rate. This has a significant impact on the area immediately surrounding the borehole (within a radius of 10m)

5.1.2 Factors Which can be Used to Assess the Risk of Groundwater Pollution from Pit Latrines and Septic Tanks

These factors include:

i. the number of individuals using on-site sanitation systems and the density of these units;

ii. details of existing water supply arrangements, especially those of boreholes, springs and wells;

iii. aquifer characteristics, including geology, soil type, thickness of aquifer, degree of confinement, depth of groundwater, thickness of the unsaturated and saturated zones;

iv. design of sanitation units, including depth of excavation, characteristics of effluent and maximum hydraulic loading;

v. topographic characteristics of the site and surrounding area;

vi. annual rainfall data, including monthly and annual averages as well as rainfall intensities;

vii. efficiency of nitrogen removal processes beneath the latrine or soakaway of a septic tank.

The aquifer hydraulic gradient and groundwater oxygen levels are also significant, but in many instances it is not possible to easily determine these parameters precisely. Therefore they are not listed above.

5.1.3 Methods of Preventing or Minimising Groundwater Pollution from Sanitation Systems

The suggested methods include:

i. ensuring that all pit latrines are lined;

ii. the careful design, siting and construction of water supply and sanitary installations;

iii. proper design and construction of septic tank soakaways;

iv. minimising the hydraulic loading of latrines and septic tanks;

v. increasing the soakaway area and excluding the addition of any household waste water;

In many rural areas groundwater is polluted by unhygienic sanitary habits. These habits may not change until the benefits of improved sanitation are realised. This can be achieved by educating the communities on the benefits of improved sanitation. Thus groundwater pollution can be prevented by conducting a through hygiene education programme.

5.1.4 Analysis of Results

The first two questions posed through WENDY were answered comprehensively. They provided a good understanding of the problem, which is essential in order to solve the problem effectively. The responses also provided a beginning from which the consultant could further conduct his research.

The responses to the third question were fairly brief, but gave the consultant some idea on how to prevent groundwater pollution. The importance of hygiene education was highlighted to the consultant, who had previously only sought technical solutions to the problem of groundwater pollution.

The question about water purification techniques that could be implemented in these situations was not answered satisfactorily. This may have been the result of insufficient information given to adequately answer the question.

In addition to the answers received, the consultant was also given names and contact addresses of professionals who were willing to communicate further to overcome the problems experienced. The short space of time within which the responses were received as well as the convenience of receiving all the information without having to leave of the office resulted in the immediate implementation of a solution, i.e., the lining of all pit latrines and minimising the hydraulic loading of latrines and septic tanks in the project area. Communication between the consultant and various sector professionals introduced to the consultant via the *Web* and e-mail is still continuing as further problems are experienced.

5.2 Mvula Trust

Mvula Trust had installed a number of solar powered pumps for water supply purposes in various rural areas of KwaZulu-Natal. These pumps are powered by photovoltaic cells. The cells are used to convert sunlight directly into electrical current. In order to capture sunlight throughout the day, the cells are installed on masts above any obstruction. However these cells are frequently stolen and as a result costly water supply projects are often abandoned. The net result of this theft is a decrease in the health status of the community as they revert to using abandoned sources of water which are usually polluted.

Solutions to these problems were sought through WENDY and various listservers. Within 24 h of posting the problem onto the Internet, 8 responses were received from individuals involved in the sector. The responses received are summarised below.

5.2.1 Protecting the Photovoltaic Cells

The theft of photovoltaic cells was also experienced by sector professionals in Brazil and India. In India the problem was overcome by actively engaging the community in the installation and protection of the photovoltaic cells. The cost of purchasing and installing photovoltaic cells was shared with the community, with the community contributing 1 / 3 of the costs. In this manner the ownership of the cells and the masts was transferred to the community. This sense of ownership within the community transferred the responsibility of protecting the equipment from the donors to the community.

Furthermore, instead of siting the equipment on a remote hill, the equipment was installed on or near the property of a prominent member of the community. In some villages cells were stolen but were soon recovered by

community members who could not afford to contribute to the cost of installing a new cell.

In Brazil the problem of stolen cells was overcome by changing the design of the cells to render them ineffective as soon as they were tampered with. However this solution was not immediately effective since the cells were still being stolen for some time until the thieves realised that the design had changed.

5.2.2 Alternative Sources of Power

The only appropriate alternative suggested was the use of windpumps. However advanced windpump technology is limited in KwaZulu-Natal. The other suggested alternatives, example, the use of methane gas from landfills, were not applicable to rural areas.

5.2.3 Analysis of Results

With regard to the question of protecting the photovoltaic cells, the project manager at Mvula Trust was satisfied with the answered received. The organisation had considered consulting the community on such matters but were unsure on how to approach the problem. Sector professionals who had experienced similar problems provided clear guidelines on how to actively involve the community in the protection of water supply installations.

The question of appropriate alternatives to solar powered pumps was not fully answered. However the project manager was given information of companies manufacturing windpumps. These companies also had WWW sites and could thus be contacted through the Internet. Unfortunately they were all international companies.

5.3 Water Supply and Sanitation Collaborative Council (WSSCC)

After a live demonstration of WENDY to the members of the WSSCC, the members deliberated on the advantages of transferring information via the Internet. The Council realised the ease as well as the reduced cost with which large amounts of information could be transferred quickly and efficiently via the Internet. Sector professionals also realised the ease of communicating with other individuals via the Internet. At the end of the conference, WENDY was accepted as an official mandated activity of the WSSC under the Information and Communication Working Group.

Chapter Six

Conclusion and Recommendations

This chapter firstly discusses whether the objective of designing and creating an information server on the Internet to facilitate the transfer of information and communication between professionals involved in water and sanitation, was achieved. This is followed by a discussion on evaluating the effectiveness of the information server as a tool in solving problems experienced by sector professionals. The chapter concludes by making recommendations for the sustainable development of WENDY as a source of information transfer.

6.1 Conclusions

The delivery of water and sanitation services to the population of a country forms an integral part in the overall development of the country. Therefore it is necessary that comprehensive policies and strategies for the delivery of these services be drawn up at the highest level of government. The lack of political will at these levels of government has often hindered the efforts of donor organisations and non-governmental organisations.

In order to effectively deliver water and sanitation services to isolated rural communities in developing countries, a number of issues have to be taken into account. These issues are highlighted in the literature survey section of the dissertation. However particular attention has to be paid to the use of technologies which are cost effective, sustainable and designed for the local rural conditions, i.e. appropriate technologies. Although these technologies may be outdated, they will be more successful in the delivery of services than modern technology. Often designers and engineers planning rural water supply schemes are not aware of these technologies since they do not form part of mainstream tertiary education. Thus there is a need to transfer this information to the relevant authorities and planners. The dissemination of this information can be facilitated through WENDY.

The importance of formal and informal communication between sector professionals in developing sustainable improvements in the sector has been outlined. This processes can be conducted efficiently and cost effectively through the use of Internet facilities such as e-mail, listservers and discussion groups. These facilities can also be used for the distribution of reports, newsletters and software at a fraction of the cost of distributing printed material.

Two test were conducted to evaluate the effectiveness of WENDY as a tool in the solution of problems encountered in water and sanitation in developing countries. The first problem was that of groundwater pollution from pit latrines and septic tanks encountered by Groundwater Development Services. The problem was circulated to various organisations and listservers through the Internet. Although the problem was not fully solved, the responses received via the Internet provided sufficient information for some immediate precautions to be taken in the field. In addition to this further discussions were being conducted between Groundwater Development Services and a host of professionals regarding specific issues of groundwater pollution that were unique to KwaZulu-Natal. All these discussions were being conducted through the Internet.

The second problem was the theft of photovoltaic cells from Mvula Trust as well as seeking appropriate alternatives to solar powered pumps for water supply purposes. The problem was circulated through the Internet and within 24 h 8 responses were received. Although the latter part of the problem was not adequately answered, valuable suggestions were received on how to combat the theft of photovoltaic cells. The information was received from sector professionals who had practical experience of similar problems in other parts of the world.

These tests show that the server can be used as one of many tools in solving problems experienced by sector professionals. As more information becomes available electronically via the Internet, the server will play a greater role in solving sector issues.

6.2 Recommendations

The problems of water supply and sanitation in rural areas is not given sufficient attention at research institutions. The reason for this may be because water and sanitation encompasses a wide variety of faculties including among others, health science, engineering, social science and economics. Many scientists and engineers emerging from research institutions are not given sufficient training in this field. As a result these professionals are not adequately equipped to deal with the problems experienced in rural areas. To overcome this problem research institutions need to develop specialised courses or degrees that will provide adequate training to individuals involved in water supply and sanitation. This will also encourage research in the sector. In addition to this, research institutions in collaboration with experienced sector professionals should conduct intensive training courses and workshops for individuals involved in the sector who may not have the necessary skills.

The advantages of speed and cost with which electronic data can be disseminated means that this medium must be used to its full potential. In this regard, organisations and sector professionals should be encouraged to collect store, and disseminate data electronically. The aim of these organisations and sector professionals should be to gradually move away from printed data dissemination to electronic data dissemination. This data can then be made available world wide through the Internet.

The hardware and software used by WENDY and its partner organisations should be standardized in order to maximize the speed and format in which data is disseminated. Although this has partly been achieved through the Internet, it should also be implemented in the types of databases and indexing systems used to catalogue large libraries of information. Standard hardware and software will also prevent the problem of a breakdown in communication due to the inability of certain computers to communicate with others.

The language base of WENDY should be increased to include French, Spanish, Portuguese, Arabic and Chinese. The responsibility of maintaining WENDY in the various languages should be given to organisations proficient in these languages. This will also enhance the globalisation of WENDY rather than confining it as an English speaking activity.

The information available through WENDY and its partner organisations should be indexed in a standard format. This will simplify the task of searching and finding information which will attract rather than discourage individuals from using WENDY repeatedly.

WENDY should be advertised in sector related journals to encourage organisations and individuals to become partners with WENDY.

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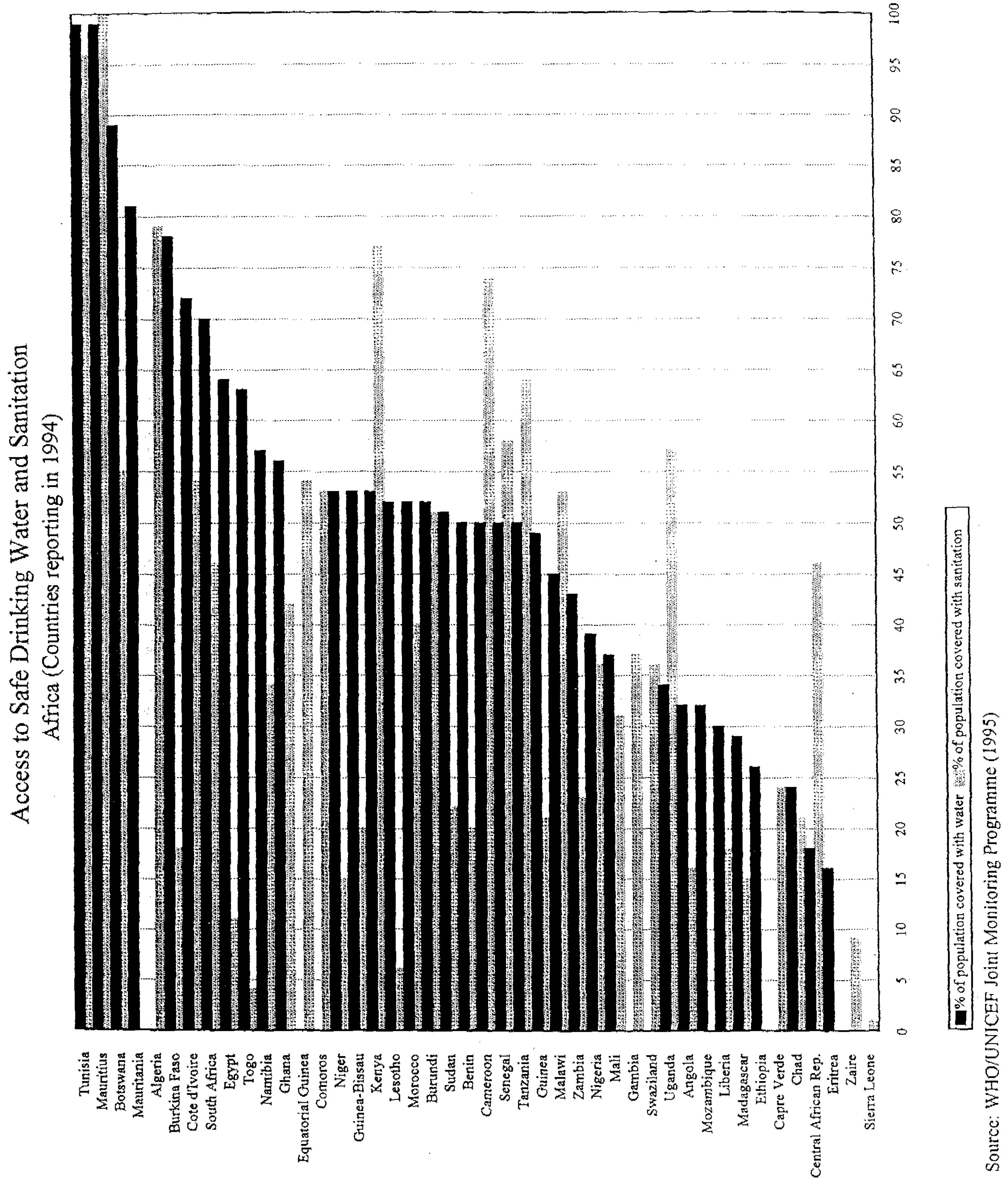
APPENDICES

Appendix 1

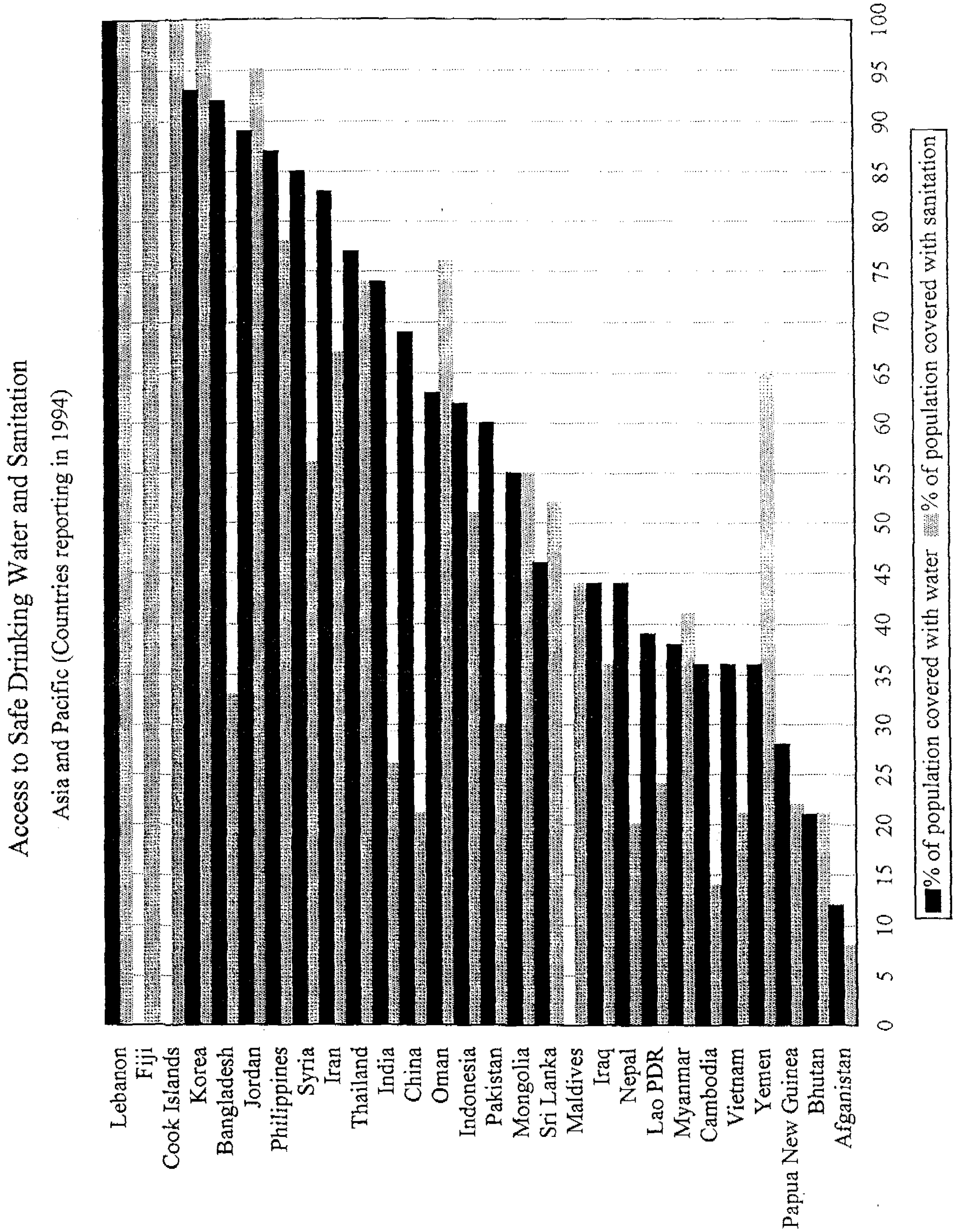
Level of water supply and sanitation services in developing countries



Source: WHO/UNICEF Joint Monitoring Programme (1995)

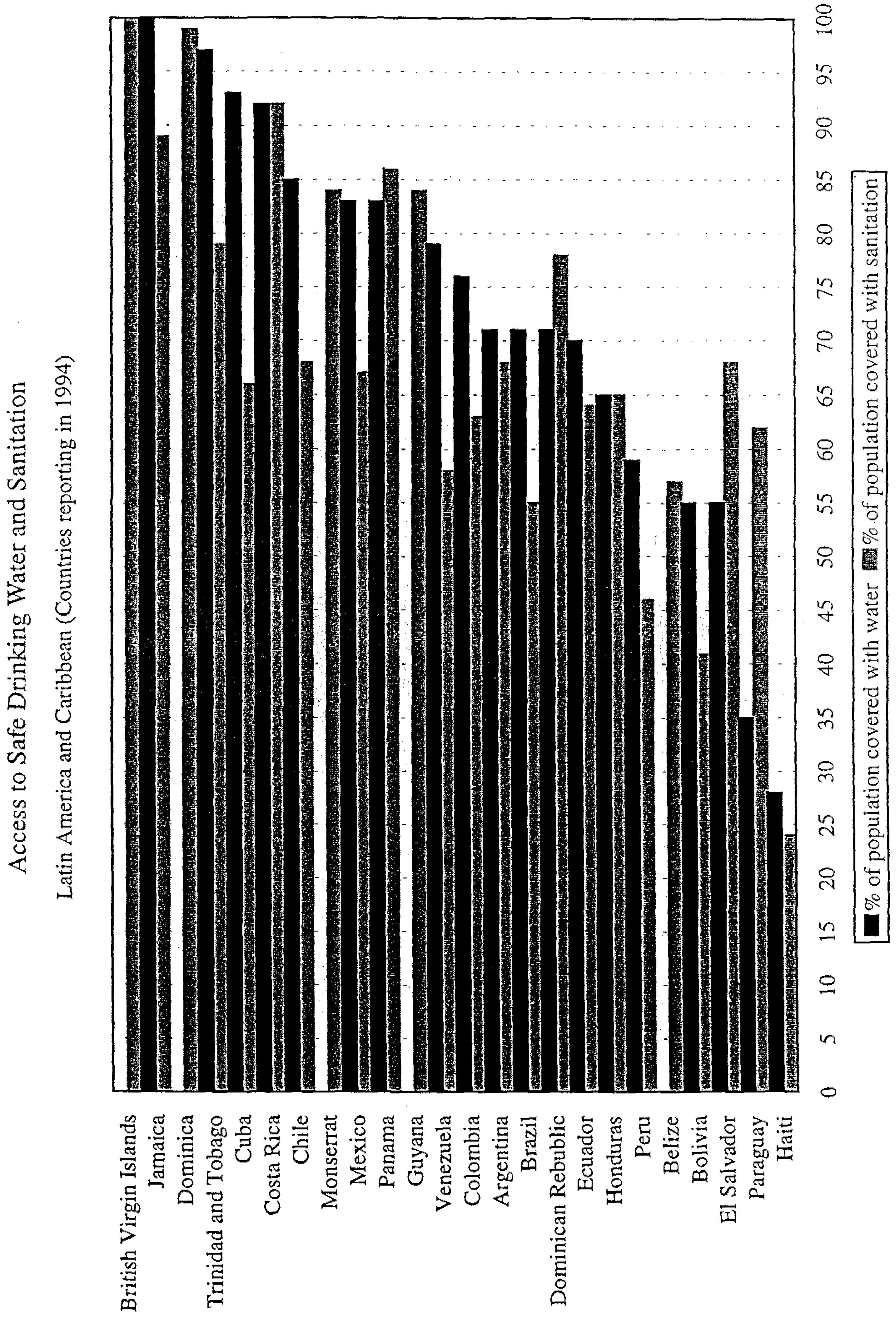
Appendix 1

Level of water supply and sanitation services in developing countries



Source: WHO/UNICEF Joint Monitoring Programme (1995)

Appendix 1



Source: WHO/UNICEF Joint Monitoring Programme

Appendix 2

The role of INFOTERRA in facilitating communication and information exchange.

Forwarded by: "Chris Buckley" <BUCKLEY@che.und.ac.za>
Forwarded to: dindar@pixie.udw.ac.za, kibata@pixie.udw.ac.za
Date forwarded: Sat, 25 May 1996 17:21:46 SAST
Date sent: Fri, 24 May 1996 09:02:30 +0200
Send reply to: d.eckstein@unsw.edu.au
From: d.eckstein@unsw.edu.au (David Eckstein)
To: Multiple recipients of list <infoterra@cedar.univie.ac.at>
Subject: Compilation of responses on: internet/developing countries and Science

Here is a collection of responses to my original question about the role of email/internet regarding 'proliferation' of science and technical info. in developing countries.

Many thanks to all respondents.
Regards
DAvid Eckstein

==

Your query was passed on to me and I would love to answer at length but I am up to my eyeballs in deadlines so please take a look at the bellanet web page listed below. It is just a start in this direction but you will get some ideas. - Sam Lanfranco

==

^ Prof Sam Lanfranco, Distributed Knowledge Project (DKProj)
^ Centre for Research on Latin America & the Caribbean (CERLAC)
^ Centre for Health Studies (YCHS), Bellanet at IDRC (Ottawa)
^ Sam Lanfranco, YCHS ^ York: lanfran@yorku.ca Pager 816-2852
^ York Univ. (214YL) ^ Tel (416) 736-5941 Fax (416) 736-5737
^ 4700 Keele Street
^ North York, Ontario ^ Bellanet: lanfran@internet.idrc.ca
^ CANADA M3J 1P3o ^ Tel (613) 236-6163 Fax (613) 563-3858
^ •http://www.yorku.ca/• ^ •http://www.bellanet.org/•

You might note that after about the 21st of June there will be additional material at:
•http://www.worldbank.org/html/fpd/technet/•
It will be the product of a more-or-less closed on-line discussion on the subject that is taking place at the moment. The technet page is there now with other stuff.

- Sam Lanfranco

Dear Kerry and David,
I too am interested in this issue vis-a-vis the use of scientific and technical information on environmental issues and I would be grateful if you could share your findings with me when you eventually compile them. Meanwhile I will give you both my 2 cents:

When we speak of the Internet, it is useful to separate out information received via e-mail, gopher, WWW, etc. My gut feeling is that very little info on the Web is reaching developing countries for the simple reason that they don't have either the connectivity or the bandwidth. The use of the Web is very much a long term goal for many African countries. The situation is not as bad in Asia and LAC. CIS region is somewhere in between. I tried the Web from Accra, Ghana recently and it took about 45 minutes to download the UNESCO logo (at 2400 baud). Nobody has time to use the Web at such slow speeds.

For developing countries, I see e-mail (and listservers) as the best and cheapest option in the short term. This is why I created this **INFOTERRA** subscription list. The poorest Fidonet user can still receive info within 12 hours of asking for it. We did a survey about a year ago and the feedback was most encouraging. I remember one case of somebody in Australia supplying vital info to Mozambique on waste management. This North-South transfer of info is the beauty of the list. It happens automatically through the goodwill of the subscribers. The Eritrean Env Agency became a subscriber recently and they told me it was as if someone switched a light on! The info suddenly flowed in and they were in touch with the world and envtl events. The same applies to places like Vanuatu and Samoa.

There will still be a need for printed 'traditional' info for a long time in developing countries because users simply won't have the connectivity.

I have to rush, but those are my initial thoughts anyway. However, you have raised an intersting issue and one in which **INFOTERRA** is very much interested in given that 77% of our clients are from developing countries.

Best regards
Gerry Cunningham
UNEP/INFOTERRA

==

From: IBTUSA@aol.com
Date: Tue, 21 May 1996 11:08:59 -0400
To: d.eckstein@unsw.edu.au
Subject: Re: Science communication, developing countries and internet

Regarding your message dated 96-05-21 07:25:24 EDT:

Mr. Eckstein,
I do not know about most of the rest of the world, but over the last month we have communicated with more than ten developing countries and several developed countries (I just sent a E-Mail to Perth moments ago). This is more and more the trend for IBT and the way we do an increasing amount of our business. Previously, we used E-Mail to exchange messages between our offices (Denver, Washington, New York, Dublin, Bombay and Betty's Bay South Africa). Now however, we receive more than 60 messages per day from developed and developing countries off of our home page (www.infi.net/~msenski) and from other related sources.
It would be my estimate that we will continue this trend, building upon our internet exchanges in the years to come for IBT (this week we are adding color pictures to our web site). Currently our practice (as in Ghana and India this week) we communicate via E-Mail, provided imediate answers to questions, and follow the information up with a detailed booklet or brochure regarding our technology or services.

Good luck on your research. If I can be of any assistance please let me know.

Best Regards,

Richard L. Stephens Jr. CHMS
Senior Partner, Manager of Technology
International Business & Technologies
Technical Service Center
Post Office Box 414
Kiowa, Colorado 80117-0414 USA
Telephone: 1-303-621-2580
Telefax: 1-303-621-2674
E-Mail: IBTUSA@aol.com

==

You may want to check out the Environment in Latin America Network (ELAN), a very active listserver based at Communications for a Sustainable Future at the University of Colorado:

ENVIRONMENT IN LATIN AMERICA NETWORK <elan@csf.colorado.edu>

The glaring difference is speed in disseminating the information plus its expanded audience. Networking with **INFOTERRA** has helped me a lot in my work on the environment. Through the internet, I have been able to pass on information to our group of companies in the Philippines, a third-world country. The environment covers a broad area and holds a wealth of knowledge.

I hope the above will be of some help to you.

- David Eckstein
- Institute of Environmental Studies
- University of New South Wales
- SYDNEY
- NSW 2052
- AUSTRALIA

- Fax: + 61 2 663 1015
- Phone: + 61 2 385 5707
-Email: D.Eckstein@unsw.edu.au

Appendix 3

Date sent: Mon, 19 Aug 1996 16:13:09 -0400
From: owner-groundwater-digest@IAS.champlain.edu
To: groundwater-digest@ias.champlain.edu
Subject: groundwater-digest V1 #175
Send reply to: groundwater@ias.champlain.edu

groundwater-digest Monday, 19 August 1996 Volume 01 : Number 175

Ground Water Contamination From Dead Animals

From: MARTHA SABOL <SABOL.MARTHA@EPAMAIL.EPA.GOV>
Date: Mon, 19 Aug 1996 09:57:51 -0700
Subject: Ground Water Contamination From Dead Animals

Hi, Folks. I work for EPA, and have received a question from a private citizen concerning contamination of a spring with E. coli. bacteria. Seems that a couple of their neighbors have detected the bacteria in their drinking water springs. They think that the only potential source of the contamination is an upgradient field where a property owner eledgedly buried up to 600 dead/starving pigs (he had operated a pig farm).
Question: Anyone know of the potential bacterial, viral, etc.. forms that could be generated from dead animals, then transported via the ground water? Any studies known?

Thanks----Martha

- -----Groundwater Mailing List-------www.groundwater.com--------
For information, including how to unsubscribe, send a message to
majordomo@ias.champlain.edu with "info groundwater" in the body.
Administrative problems: e-mail kenbannister@groundwater.com

Date sent: Tue, 20 Aug 1996 09:44:41 -0400
From: owner-groundwater-digest@IAS.champlain.edu
To: groundwater-digest@ias.champlain.edu
Subject: groundwater-digest V1 #176
Send reply to: groundwater@ias.champlain.edu

groundwater-digest Tuesday, 20 August 1996 Volume 01 : Number 176

Re: RE: DNA Ground Water contamination from dead animals
RE: DNA Ground Water contamination from dead animals
RE: DNA Ground Water contamination from dead animals

Appendix 3

From: Artifaxi@aol.com
Date: Mon, 19 Aug 1996 20:39:38 -0400
Subject: Re: RE: DNA Ground Water contamination from dead animals

Mike_Cochran wrote:
>Conceivably, you may be able to identify the source of the E. coli. bacteria as pig >bacteria, or human, etc. This study used DNA patterns from collected bacteria to >discriminate between sources.

How is the DNA from bacteria matched to source animals? Are these DNA patterns from animal tissue shed with the bacteria or actually inside the bacteria? Or is it used to identify a particular strain of bacteria associated with particular animals. I'll send for the referenced study, but I thought someone could give some educated remarks.

Thanks
Bud Hixson Louisville KY

From: edurek@iafrica.com (Hendrik J Bosman)
Date: Tue, 20 Aug 96 05:40:38 GMT
Subject: RE: DNA Ground Water contamination from dead animals

Dear Bud,

> How is the DNA from bacteria matched to source animals? Are these DNA
> patterns from animal tissue shed with the bacteria or actually inside the
> bacteria? Or is it used to identify a particular strain of bacteria
> associated with particular animals. I'll send for the referenced study, but I
> thought someone could give some educated remarks.

In many cases it is so that certain strains of bacteria, fungi, etc., have specific hosts. Although I don't know in the case of E.coli I know of other cases where a slight modification in the micro-organism require that the specific "sub-species" need a different host. There are also cases where the life cycle require different hosts at different stages in the cycle.

I hope that this has helped.

Hendrik J Bosman Pr.Sci.Nat
Consulting Environmental Geologist
GeoEnviron CC
Environmental & Related Software Distribution Centre
Private bag X01
Betty's Bay 7141
South Africa

Tel/Fax: +27-2823-28571
E-Mail: edurek@iafrica.com

Appendix 3

From: Simon Toze <Simon.Toze@per.dwr.CSIRO.AU>
Date: Tue, 20 Aug 1996 16:06:54 +0800 (WST)
Subject: RE: DNA Ground Water contamination from dead animals

>How is the DNA from bacteria matched to source animals? Are these DNA
>patterns from animal tissue shed with the bacteria or actually inside the
> bacteria? Or is it used to identify a particular strain of bacteria
> associated with particular animals. I'll send for the referenced study,
> but I thought someone could give some educated remarks.

What is acually being refered to here is DNA finger printing. It is a method commonly used in medical microbiology/epidemiology and forensic sciences. It has been used (but less commonly) in environmental microbiology to trace sources of microbes in soil, and waters.
The basic principle is extracting DNA from two different microbial isolates which are suspected of being from the same source, in this case, E. coli isolates from a pig carcass and from the downstream wells (the microbial strains must first be isolated using common microbial techniques). The extracted DNA from each isolate is then cut into fragments using a series of restriction enzymes (enzymes which cut DNA at specific recognition sites). The cut DNA samples are then run on an agarose gel (electrophoresis) which separates the cut DNA fragments in each sample depending on size. If the patterns of the sizes of DNA fragments produced by using the different restriction enzymes are the same for the two different isolates then the two isolates are considered to be from the same source, in the example given from the pig carcasses.

I hope I have made this clear enough (i.e instead of totally confusing
you) in such small detail

Simon Toze
****
Simon Toze Phone : (61) 9 387 0130
Environmental Microbiologist Fax : (61) 9 387 8211
Centre for Groundwater Studies e-mail: simon@per.dwr.csiro.au
CSIRO Division of Water Resources www: •http://www.dwr.csiro.au•
Private Bag PO Wembley, Perth
Western Australia, AUSTRALIA 6014
****

End of groundwater-digest V1 #176
****

Appendix 3

Date sent: Wed, 21 Aug 1996 21:39:17 -0400
From: owner-groundwater-digest@IAS.champlain.edu
To: groundwater-digest@ias.champlain.edu
Subject: groundwater-digest V1 #179
Send reply to: groundwater@ias.champlain.edu

groundwater-digest Wednesday, 21 August 1996 Volume 01 : Number 179

Re: Ground Water Contamination From Dead Animals

From: "Janusz A. Szpaczynski" <janusz@sparky.inasec.ca>
Date: Wed, 21 Aug 1996 15:12:25 -0400
Subject: Re: Ground Water Contamination From Dead Animals

Dear Martha,
Migration of bacteria in the subsurface can be find in:
M.V. Yates , S.R. Yates, CRC Crit. Rev. Environ. Control 17, 307, 1987
or in:
Conrad P. Straub, Practical Handbook of Environmental Control.

For example:
Escherichia Coli can migrate in fine/coarse sand, vertical direction- 4 m, horizontal- 24 m, in fine sand, vertical direction 0.3 m, horizontal 70 m in medium sandy gravel in horizontal direction 125 m
Fecal Coliforms in stony silt loam can migrate in horizontal direction 900 m.

Regards,
Janusz A. Szpaczynski, PhD
Delta Engineering Ltd.
Ottawa, Ontario

End of groundwater-digest V1 #179
****

Appendix 3

To: Amy Simpson <AmyJeanElizabeth@msn.com>
Copies to: GROUNDWATER <GROUNDWATER@IAS.champlain.edu>
From: Jan Baxter <Baxter.Jan@EPAMAIL.EPA.GOV>
Date sent: 27 Jul 96 12:01:29
Subject: Re: Coliform
Send reply to: Jan Baxter <Baxter.Jan@EPAMAIL.EPA.GOV>

Amy Simpson wrote:
>
> Hello-
> I am about to buy a house in Armonk, New York I had the well water tested and the test came back >positive for "choloform" or "coloform" (I'm not sure of the spelling). Can anyone tell me what this >means, how serious is it, can it be fixed, and how much will it cost to fix?
>
> Thank you very much!
>
> Amy

Amy;

The spelling is coliform. This bacterial is group, which includes a number of species including Escherichia coli and Klebsiella pneumoniae, is associated with the mammalian intestinal tract and, consequently, is regarded as an indicator organism in water quality analyis. Because each mammalian species has a typical coliform distribution, it is possible to establish the identity of the polluter. Also, because members of the coliform group have known life expectancies (depending on conditions) outside the intestine, it is sometimes possible to identify the location of the pollution source.

As for seriousness... From a health perspective the consequences range from none through intestinal upsets (cramps, diarhea, etc) to kidney damage/failure and, in extreme cases, death. It all depands on the level of contamination coupled with an individual's sensitivity to coliform bacteria.

On another front, many mortgage institutions will not supply mortgage money until the water well has tested negative for coliform. This leads to an interesting 'solution' in some jurisdictions - a gallon or so of Javex is dumped into the well. This will get you a negative coliform test and some aesthically objectionable water but IT WILL NOT SOLVE THE PROBLEM of coliform contamination.

There are a number of causes and solutions, the details of which are too extensive to discuss here. An over-simplified version is:

1. A leaky well-seal may be allowing surface water into the well, in which case repair/replace the well seal.
2. A septic system may be defective or is too close to the well.
3. Livestock may have access to the area immediately surrounding the well.

4. A typical solution is the installation of your own water treatment system; chlorination or treatment with ultra-violet radiation are popular.

The costs of solutions vary widely but usually are not prohibitive.

Regards,
Dennis

-----Groundwater Mailing List-------www.groundwater.com--------
For information, including how to unsubscribe, send a message to majordomo@ias.champlain.edu with "info groundwater" in the body.

Date sent: Sat, 27 Jul 1996 09:39:39 -0800
From: "Jim O'Neil" <joneil@polarnet.com>
Organization: Env. Consult
To: Amy Simpson <AmyJeanElizabeth@msn.com>
Copies to: Groundwater <GROUNDWATER@IAS.champlain.edu>
Subject: Re:
Send reply to: "Jim O'Neil" <joneil@polarnet.com>

Amy Simpson wrote:
>
> Hello-
> I am about to buy a house in Armonk, New York I had the well water tested and the test came back >positive for "choloform" or "coloform" (I'm not sure of the spelling). Can anyone tell me what this >ans, how serious is it, can it be fixed, and how much will it cost to fix?

> Thank you very much!
Amy:

The way you phrase the result:"the test came back positive" I suspect it's coloform. Coloform bacteria live in the intestines of all warm blooded anamals, including humans, and is therefore used as an indicatior that water may be contaminated by sewage.

Is the test result is correct (I ssay that because it is easy to contaminate the sample bottle while collecting the sample and thus get a false positive) a possible fix is to disinfect your water with chlorine using a small proportional feed pump. You can also have a new, perhaps deeper, well installed. The well may not really be contaminated though.

If I were you & I really liked the house, first thing I would try is sterilizing the well (by perhaps dumping a gallon of chlorine bleach down it) let it sit over night and then flush it and all the household fixtures by letting the water run to waste for a few hours. Then I'd re-sample being very careful not to contaminate the bottle.

Regards;
Jim

--

Jim O'Neil, Environmental Consultant
Box 55591
North Pole, Alaska 99705
phone/fax: 1-907-488-6661
e-mail: joneil@polarnet.com
joneil@polarnet.fnsb.ak.us
70252.2163@compuserve.com
Home Page: •http://www2.polarnet.com/~joneil/jon.html•

Date sent: Wed, 29 May 96 08:34 WET
To: dindar@iafrica.com
From: wsdg@zamnet.zm (wsdg)
Subject: Re: Internet and WSS

I hope this is not too late. I had completely forgotten you asked me a question on the use of internet practically. As you might know we have just began and have not had much use of the network. However recently we had a national water and sanitation fair. Through your efforts we recieved a lot of enquiries on the fair. I can say that the facility is very helpful. It has made us link up with a gentleman in Canada who works for an NGO and would like to establish a branch in Zambia. It is a good facility for information exchange. As mentioned above we have only started using the facility so I do not have much in terms of experience.

Regards, Dennis Mwanza
-- Dennis D.
Mwanza Water Sector Development Group, 11th Floor Indeco House,
Cairo Road, P/Bag RW 291X, LUSAKA, ZAMBIA telephone:
+260-1-226941/2 (work) +260-1-292408 (home) Fax:
+260-1-226904 +260-1-292408 (fax at home)

"Towards a better and improved water supply service to
Zambians!"

Date sent: Tue, 9 Jul 96 16:56:12 +0200
From: ENRM-Admin@jrc.it
Subject: G7 ENRM Environment project
Send reply to: ENRM-Admin@jrc.it
Send reply to: ENRM-Admin@jrc.it

G7 Environment and Natural Resources Management
(ENRM)

•http://enrm.ceo.org•

The ENRM prototype information server allows _free_ online registration and interactive editing of records for global environmental information resources. In addition to this, it provides an international directory of Environmentalists. to which all ENRM users belong.

You are invited to visit the site at the above URL and register your information on the system. Should you wish to contribute information about complete datasets held on other servers (of course, you retain control over all of the entries), or if you have any queries regarding the service please contact us by email at enrm admin@jrc.it. The success of the ENRM iniciative relies on your contribution.

THE ENRM MISSION

The objective of this G7 joint project is to increase the electronic linkage and integration of sources of data and information relevant to the environment and natural resources. A group of experts, representing each participating body, will build on existing international efforts to create a prototype for a Global Information Locator Service (GILS), to further interconnect catalogues and directories around the world and ensure their accessibility to developed and developing countries, and to facilitate the exchange and integration of data and information about the Earth for use in a variety of applications. The project will demonstrate the breadth of data and information already existing internationally, and show the mutual benefits of improved accessibility for all levels of policy makers, researchers, non-governmental organizations and the general public.

THE ENRM PARTICIPATORS

The G7 ENRM project is an iniciative of the G7 nations. As such, it involves the collaboration of organisations from these nations amongst others: Canada, France, Germany, Italy, Japan, Switzerland, United Kingdom, United States and the European Community. The following are _some_ of the organisations directly involved in the G7 ENRM MetaInformation Working Group:

CEO - European Commission / Centre for Earth
Observation DLR - German Aerospace Research
Establishment EEA - European Environment Agency ESA
European Space Agency ERIN - Environment Resources and
Information Network of Australia GCOS - Global Climate
Observing System NASA - the US National Aeronautics and
Space Administration NASDA - National Space Development
Agency of Japan NOAA - US National Oceanic and
Atmospheric Administration UNEP - United Nations
Environment Programme USGS - US Geological Survey WMO

World Meteorological Organisation

THE ENRM PROTOTYPE

1. This prototype system has been developed by the European Commission's Centre for Earth Observation on behalf of the G7-ENRM project. The current service provides the following features:

2. Searchable database of Worldwide Environmental resources on the internet. The ENRM server allows searches using free text, geographical and keyword searching and Z39.50 protocol searches. This makes it compatible with other initiatives and will allow distributed searching of ENRM resources.

3. Dynamically updatable entries: once you have registered you can contribute data into the ENRM database. Furthermore any of your entries can be edited and updated by yourself. All this can be done through any standard web browser.

4. The service is entirely free and will remain so.

You are encouraged to register youself, your organisation or datasets on the system, and to use the database for inquiries relating to environment, natural resources, climate change and biodiversity. For further information please contact the ENRM helpdesk by email at enrm-admin@jrc.it

The ENRM Development team.
9th July 1996

G7 Environment and Natural Resources Management (ENRM)
•http://enrm.ceo.org/•
Developed by the Centre for Earth Observation on behalf of the G7-ENRM Project.
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Date sent: Fri, 26 Jul 1996 14:27 +1200
From: Russel Sanders <Russels@CRC.GOVT.NZ>
Subject: Low Values of Specific Yield (Summary of
To: groundwater <GROUNDWATER@ias.champlain.EDU>
Send reply to: Russel Sanders <Russels@CRC.GOVT.NZ>

Thank you to all those people who responded to our question. I include here a summary of the responses, papers referred to (particularly those supplied by Dr Akindunni), and our conclusions relating to this topic. Sorry for the length of this letter.

Original Question Posed By Canterbury Regional Council

We have been undertaking pump tests on what, from geological logs, we interpret as unconfined alluvial gravel aquifers. These are typically tapped by shallow (up to 15 metres) irrigation wells. Transmissivities are commonly in the range 2000 to 7000 m2/day (say 20000 to 75000 sq. ft/day), but the pump test results often give specific yield results in the .01 to .001range which we would think was much too low for unconfined gravels. The aquifers are reworked glacial outwash gravels close to rivers (on the Canterbury Plains of New Zealand) and the data is to be used for calculation of stream depletion effects.

The question is, has anybody else come across similar specific yield anomalies, and is there an explanation. The aquifers are heterogeneous, but in most cases considered they would seem to be unconfined rather than semi confined. Pump test duration has been between 1000 and 3000 minutes.

Conclusions

It appears that unrealistically low specific yields derived from pump tests, and subsequent curve fitting analyses, have been encountered by numerous practitioners throughout the world. The letters, references, and discussions suggest several possible explanations.

1. Because of aquifer heterogeneity and anisotropy we may in some cases be dealing with semi - confined rather than unconfined conditions. If this were the case the derived storativity figures would be reasonable (we have used Neuman (unconfined) and Hantush or Moench (semi confined) to give good fits).

2. If the aquifer is in fact unconfined then it seems very important that late time data is used for a curve match assessment of specific yield. We have assumed in our tests performed in high permeability gravels that the early Theis drawdown occurs within the first few minutes and that most of the subsequent drawdown that we see is post - delayed yield. We are redoing one of our tests and will look at running it for between 3 days and a week, with a view to ensuring we are in fact in the late time phase. As to what is late time, refer to van der Kamp (1985). He reports that late time for Theis begins at times greater than Syb/Kv.

Alternative methods of assessing specific yield are included in the reference list below, and comprise small scale laboratory drainage, or field scale volume - balance, tests. It has also been suggested that if the aquifer is clearly unconfined then it may be simply a matter of using an appropriate textbook specific yield value instead of the curve fit figure.

Glen Carleton states that Êthe USGS has some good model preprocessors (i.e. RADMOD) that use MODFLOW to simulate pumping tests and might provide a better estimate of specific yieldË.

References

1. Nwankwor et al (1984), A comparative study of specific yield determinations for a shallow sand aquifer. GW, vol 22, pp 764-772.

- conducted a 65 hour pump test in unconfined medium sand aquifer.

- concluded that although the Boulton and Neuman type-curve methods gave reasonable transmissivity values, the values of specific yield are about one third (for the tested case) of the late time values obtained from volume - balance and laboratory methods.

- suggested that type - curve models provide values of specific yield that are not suitable for use in the context of long - term aquifer yield analysis, and that using the volume - balance method at late time or the laboratory method provides a more reasonable estimate of the long - term specific yield for this aquifer.

2. Nwankwor et al (1992), Unsaturated and saturated flow in response to pumping of an unconfined aquifer: Field evidence of delayed drainage. GW, vol 30, pp 690-700.

- detailed drawdown and monitoring of soil moisture during a pump test provided an explanation for the characteristic time - drawdown behaviour of unconfined sand aquifers.

- describes variation in horizontal and vertical flow in aquifer during pump testing.

- late time (beyond the delayed yield phase) flow is predominantly horizontal, and in this region the decline of water table can be represented by a specific yield value similar to the value that would be measured in a laboratory drainage experiment.

- figures derived for a specific site showed these variations in Sy derived using different methods
Neuman type curve .05
Boulton type curve .08 Laboratory/in situ drainage
.30 Volume balance .25

- concluded that for practical purposes specific yield can be determined by fitting late time - drawdown data to type curves. This procedure may require pump tests of very long duration and is further frustrated by the low sensitivity to specific yield in this region of the type curves. Alternatively the small scale laboratory or volume balance test (Nwankwor et al, 1984) may give reasonable results.

3. Akindunni and Gillham (1992), Unsaturated and saturated flow in response to pumping of an unconfined aquifer: Numerical investigation of delayed drainage. GW, vol 30 pp 873-884.

- simulated the field observations of Nwankwor et al (1992) using a numerical model (SUNFLOW).

- results confirm that the ultimate specific yield of an unconfined aquifer is more related to the drainable porosity than the low values often obtained from type curve analysis.

- because both the Boulton and Neuman models make simplifying assumptions about the complex processes at the water table, a possible explanation of the apparent discrepancies in specific yield values is the inadequate representation of the drainage process.

- modeling confirms that time - drawdown behaviour of the unconfined aquifer is mainly the result of the variation of vertical and horizontal hydraulic gradients during a test, leading to an extension and contraction of the capillary fringe.

- at late times vertical hydraulic gradients are negligible, the effect of the capillary fringe becomes minimal, and the effective specific yield approaches the drainable porosity.

- agreement between the late time results of the numerical simulations and the Neuman model suggests that a value close to the drainable porosity would be obtained from a type curve analysis if pumping tests were conducted for a sufficiently long period.

4. van der Kamp (1985), Brief quantitative guidelines for the design and analysis of pumping tests. In Hydrology in the Service of Man, Mem. 18th Congress Intern. Assoc. of Hydrogeologists, Cambridge, p. 197 - 206.

5. Price, M., (1985), Introducing Groundwater, p. 140 - 141, George Allen and Unwin Ltd, London. ú excellent coverage of unconfined aquifer response.

6. Kruseman, G.P. and De Ridder, N.A. Analysis and Evaluation of Pumping Test Data, Inst. Land and Water Manag. Res., Wageningen, Publication 47, 1990.

7. Neuman, S.P. 1975.Analysis of pumping test data from anisotropic unconfined aquifers considering delayed gravity response. Water Res., Vol. 11 pp. 329-342.

Summary of Responses (except for the Other Examples the brief statements are key statements drawn from respondentsÉ letters)

1. Other Examples

We have been studying a shallow water table aquifer in South Australia. The aquifer is essentially comprised of a uniform fine, well-sorted sand underlain by a clay aquitard. The aquifer is about 8 m in depth (ground surface to clay) and is bounded on one side by a virtually linear river. There is a thin (30 cm) clay layer running through the aquifer horizontally in the vicinity of the water table. There are also various this layers of peaty material occurring at different elevations in the aquifer.

We have performed pump tests on the aquifer in an attempt to determine saturated hydraulic conductivities, storativities etc. These pump tests were in the range of 5-24 hours in duration. Interestingly, we observed that the measured type curves indicated K values of the order of 5-10 m/d and storativities of the order of 0.002. Such low values of S are usually reserved for confined aquifers. We had an independent check of this result by means of correlating tidal water table oscillations in the aquifer with tidal amplitudes in the nearby river. The tidal analysis indicated values for K and S similar to those fitted in the pump test analysis. I am in the process of simulating this result, using inverse means to determine aquifer properties from the observed tidal fluctuations in the aquifer monitoring wells.

I don't have any firm conclusions about this so far, but it appears that delayed water table response was not observed in our pump tests. It may be that the aquifer was confined for the duration of our tests - seasonal water table fluctuations are of the order of 30 cm. It is also possible that confining layers of limited spatial extent are present in the study region. The jury is still out here.

--

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It sounds similar to a phenomenon I encountered in the UK when looking at certain "river gravels". The key word you used is "re-worked" The cause of the lower yield is often caused by the formation of hard pans in the gravel. This may be due to iron or silt etc. Results have not been well documented but if large enough excavations are made the pans can be found.
Also when using the gravels for an emergency water supply we found the abstraction tubes clogged with fine silts often very rapidly especially when we were abstracting from close to the river bank..

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....

I am working on hydrogeological studies around pumping wells in the alluvial plain of the river Meuse (south part of Belgium). We realize tracer tests and mathematical models to delineate protection zones around the wells.

I have also observed such strange specific yields deduced from the pumping tests datas (around 0.01). The tracer tests often confirm that the specific yields are bigger (around 5 to 10 percent).

So, I believe that you cannot rely on the values obtained trough the pumping test results. My explanation is that in the river Meuse alluvial plain, one often finds a vertical succession composed (from the top to the bottom) of -a surface layer (loess), a sandy gravel layer and a 'pure' gravel layer. Most of the time, the piezometric levels lie in the second layer (sandy gravel). That layer has a lower permeability, which is probably enough to turn the third layer into a semi-confined layer. That is why the specific yield is 'between' the porosity of a unconfined layer and the storage coefficient.

Regards, Serge Brouyer

....

2. Semi - Confined?

The values are certainly too low for the 'traditional' unconfined aquifers, which leads you to ask just how unconfined they really are. My own view is that there are hardly any text book style unconfined aquifers on the Canterbury Plains. Semi confined or semi unconfined I think is a better description, especially with the transmissivities you mention.

From memory, when I was well drilling many years ago in Canterbury, I think the drillers logs gave a poor representation of what was really down there. I remember many areas where there were tight, probably nearly impermeable layers intermingled with lenses of more open material. Can you really tell from a drillers log whether a well is unconfined or semi confined. A drillers log is quite a subjective assessment. Perhaps if you use the analysis for semi-confined aquifers, you might get better results.

Ian McIndoe.
Canterbury, NZ

....

3. Pump Test Duration / Curve Fitting Analysis

My guess is even at 3000 minutes, you did not run the tests long enough for the aquifers to come to equilibrium, you were still getting delayed yield due to drainage. I would expect 10-15%.

Jim Skipper, Senior Geologist, ERD/MDEQ
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When you plot the time-drawdown data from your observation wells, do the data plots exhibit the typical "Snoopy-nose" shape that one sees with unconfined aquifers? If so, has the drainage portion of each curve stopped and reverted back to the Theis curve? It might be that drainage is still taking place from finer grained materials near the water table.

Adrian Visocky, Senior Hydrologist
Illinois State Water Survey
2204 Griffith Drive
Champaign, IL 61820 USA Email:
avisocky@sun.sws.uiuc.edu

....

I have also had difficulty obtaining "reasonable" specific yield values from pumping test data. But I prefer to interpret this as problems with the pumping test: . . such as testing duration, not enough stress (flow rate) to cause a good response in the monitoring wells, etc. I haven't tried the more exotic analysis methods, but have used the Neuman method (type A and type B curve matching to account for delayed yield).

In general, we often find anomalies in our specific yield values and usually suspect that our testing is the root of this problem.

The key for my struggles has mainly been -too short pumping time- for development of the delayed gravity response. And when I saw your pumping time of 1000-3000 minutes. My gut feeling is the same for you. Even if you only dewatered a small volume (your cone), the field studies suggest that the drainage can take from 3-days to one-week.

This next thing may not be an issue for your test, but the other problems we have seen are issues of scale for the drawdown at the monitoring wells. Most of the time we have not pumped hard enough on the pumping well, so that the drawdown at the observ. pt. is on the order of a few inches. Even though we could match a curve to this, the noise from other noisy aquifer fluctuations (even a one-inch fluctuation) can tempt you to try a match the type B to it. This may not be an issue for your test.

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....

Only later time data can be used to estimate a specific yield; early to middle time data will yield confined to semi-confined storativities. Check how long your aquifer tests were, and use only the late time data for specific yield estimates. To answer the obvious question of "how late is late time data?" you should look at water levels in wells screened across the water table. When the water level drops in a well screened across the water table, you will be measuring the drainable porosity (specific yield) of the aquifer. This does not happen instantly in an aquifer test of an unconfined aquifer. Additionally, it happens at different times at different distances from the pumping well.

>From DerrikW

....

Water Supply and Environmental Sanitation Electronic Network for Developing Country Needs (WENDY)

Rural Areas

By the turn of the century the majority of the worlds population will still be living in rural areas. At present less than half of the population in developing countries have an acceptable water supply and only one in five has satisfactory sanitation. The provision of effective water supply and sanitation, especially in rural areas, has become the goal of many governments as well as aid organisations. The problems associated with rural water supply and sanitation are varied and require a different approach to that of urban areas.

Topics discussed in this Server:

- Planning and Policy Making:
  National, regional and local plans and policies. Water resource development. Population demographics

- Technical Information
  Data collection. Sources of water. Water quality. Environmental impacts. Rain and stormwater harvesting.

- Equipment
  An updated database of water supply and sanitation equipment. International manufacturers and suppliers.

- Construction and Maintenance
  Costs and labour requirements for operation and maintainence.

- Wastewater Treatment
  Technologies. Treatment and reuse of wastewater.

- Health and Sanitary Requirments
  Water quality guidelines. Water chemistry. Water borne diseases. Disposal systems.

- Community Involvement
  Sociological issues. Government community relations.

- Case Studies
  International experiences. UN reports.

- Research
  Articles and research papers on the latest developments in water science and sanitation in developing countries.

- Software

Computer software, books and references.

- **Funding**
  Agancies and Organisations involved in water resources development funding. Organisations providing technical support.

- **Announcements and Events**
  Conferences and conventions.

Return to WENDY Home Page

INTERWATER

Water Supply and Environmental Sanitation Electronic

Network for Developing Country Needs

English Français Español Português

In accordance with the aims of the Water Supply and Sanitation Collaborative Council (WSSCC), INTERWATER is a project of the International Association on Water Quality (IAWQ), International Water and Sanitation Centre (IRC), The Hague, in collaboration with the United Nations Centre for Human Settlements (Habitat), U.S.Agency for International Development, Environmental Health Program (EHP), The Water Research Commission (WRC) of South Africa, The Water and Engineering and Development Centre (WEDC), Loughborough, UK. The project is undertaken by the Pollution Research Group of University of Natal, Durban, together with the Department of Civil Engineering, of University of Durban Westville. INTERWATER is located at the Computing Centre for Water Research (CCWR)

Click here to go to INTERWATER English page.

This page was last updated on the 23rd Jun 1996

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Mvuramanzi Trust

EXECUTIVE SUMMARY

The Mvuramanzi Trust was established in 1993 with the aim of supporting and strengthening the Zimbabwe government's rural water supply and sanitation programme. By employing an innovative approach which brings a new perspective to "decade activities", the Trust hopes to help stimulate renewed vigour in the national programme.

There have been several highlights during the past year. By 31st December over 14,000 upgraded family wells had been completed since the start of the programme. In addition, almost 2,500 Blair latrines had also been completed and demonstration hand-washing facilities had been provided at 21 schools. The "user friendly" Bush Pump was continuing to be installed on a pilot basis and the trials so far over the past 18 months are looking very promising. The family well programme has now expanded into a total of 15 Districts which is six more than last year. It certainly looks likely to continue to expand into many new areas in response to the "demand driven" nature of this programme.

It was particularly reassuring when the National Action Committee, at their Annual Review last November, for the first time officially endorsed the work of the Trust by accepting the upgraded family well, the domestic and school hand-washing facilites and the Extractable Bush Pump as technologies that should be actively pursued in the National Rural Water Supply and Sanitation programme.

Apart from good progress as far as programme implementation and ongoing research into lower cost technologies is concerned, the Trust has also made very good progress in expanding its Donor support base. Up to December 1994 over 95% of the Trust's funds had been provided by WaterAid. An attempt was made to greatly expand the number of partners in support of the Trust. A detailed two year budget for 1995/96 was prepared and all funds requested have now been agreed to. In addition to WaterAid who continues to fund 20% of the programme costs, the balance is now being provided by UNICEF, SIDA, NORAD, ODA (through WaterAid), the Oak Zimbabwe Foundation and the Rotary Club of Harare

We feel that this is a healthy situation and makes the Trust far more robust and less dependent on any one partner.
By 1990 it was becoming obvious that the original targets set for the rural sanitation programmes were not being reached. Subsidy levels were high and cement became increasingly difficult to procure. In many circles doubts were being expressed about the sustainability of such a sanitation programme. However, the results of the Trust's activities prove beyond doubt that where the method of procurement and delivery of hardware is effective, and where the communities have accepted a much reduced level of subsidy, the outputs in terms of the number of latrines completed per million dollars spent can be increased by over three times that of former levels. This can only be seen as a very

positive step in the right direction.

The creation of the Trust has also given great impetus to the Ministry of Health and Child Welfare's Family Well Programme. This programme began about four years ago, as a logical but little tried concept which did not fit into any existing national strategy of rural water development. It has become clear over this period that the concept is eagerly accepted by the Ministry of Health staff, but more importantly, by the householders themselves, who are prepared to invest large sums of money on improving "their own" facilities. Here again, the effective method of procurement and delivery of hardware and the implementation technique employed by Trust leads to an output of Family Wells that can only be described as remarkable.

Of great concern to us all is the decreasing capacity of the DDF to maintain its ever increasing compliment of handpumps throughout Zimbabwe. With 25,000 Bush Pumps to service and maintain and an annual budget of less than five million dollars, the DDF's task is simply impossible. The Community Based Maintenance approach is being tried in some areas where the communities are expected to maintain their own pumps and thereby save the Government money. In practice however the Bush Pump in its standard form does not lend itself to simple community maintenance and management.

After several years of development work in order to address this most serious problem, a number of "user friendly" Bush Pumps have been introduced by the Trust. These have now been successfully field tested by both the DDF and several communities. The fruits of these field trials have shown some very encouraging results. It is hoped that now that this well researched but little used "model" will become more familiar in Zimbabwe in order to add a new perspective to "community assisted management" of Zimbabwe's hand pumped water supply.

It has been well established that the provision of hardware alone may achieve little in terms of improved health, unless it is matched by distinct behavioral changes relating to personal hygiene. The simple change in habit away from the use of a communal washing bowl to one in which fresh water is poured from a jug over the hands, has already proved remarkably effective in improving personal hygiene. The Trust has focused on improving the habit of handwashing and this now forms a central theme in all its work. Of interest therefore has been the Trust's recent innovative introduction of a handwashing facility which is constructed as part of the Blair Latrine. This is backed-up by health education in order to support the trend towards improved personal hygiene. The importance of health education, especially that education applied in a practical way, cannot be overemphasised. It is gratifying that the Trust is playing its part in this movement.

The Trust also plays a major part in practical training in areas where it operates. Very large numbers of builders are trained every year (599 in 1993), and Ministry staff are updated on practical techniques and improved methods of implementing programmes (112 VCW's and 46 EHT's in 1993). Such training initiatives are seen as important contributions to national development as they enhance skills at village, ward and district levels.

The staff of the Trust have long and practical experience, and this can easily be seen in the impressive achievements made over the last year alone. I compliment them all for their hard work and dedication which can so easily be seen in the field.

Peter Morgan
Chairman of the Board of Trustees,
Mvuramanzi Trust.

THE BLAIR LATRINE

A BUILDERS MANUAL FOR THE 3 BAG MODEL

MVURAMANZI TRUST

INTRODUCTION

The "low cost" series of Blair Latrines were developed by the Blair Research Laboratory in 1989 and 1990 as a response to the situation where cement prices were rising and cement supplies for the national latrine programme were becoming increasingly more difficult to procure.

The standard Blair Latrine consumes between 5 and 6 bags of cement, and provides a sturdy structure that will in most cases outlast the pit, which for most family latrines lies between 12-15 years. The simplest model of the low cost Blair Latrine uses one bag of cement, a commercial vent pipe, normally made of asbestos or PVC, a concrete slab placed over a brick collar and a structure and roof made of grass or reeds. The two bag model can be made in the same way as the one bag model, but with the addition of a fully brick lined pit. It can also be made with a brick ventilation pipe. These models, however, are less durable than the standard model.

The most acceptable "low cost" model uses three bags of cement. The "3 bag" model described in this manual has a fully brick lined pit, a concrete slab, a brick vent pipe and brick superstructure. The roof is made of asbestos or tin and is supplied by the owner, but as a first step, can be made of grass. A ferrocement roof can be made by the addition of one extra bag of cement. Less cement is used in the pit lining because the pit diameter (internal) has been reduced from 1.2m to 1.1m, a modification which reduces pit life by about 3 years. Cement is also saved with the concrete slab, which is 1.3m in diameter, compared to 1.5m in the standard Blair Latrine. This slab uses one half bag of cement. With great care at the curing stage, it is possible to make a concrete slab without reinforcing wire, although this will not normally be the standard practice. The brick pipe is made with 4 bricks per course compared to 6 bricks per course for the standard model. Where 4 bricks are used per cours e , very great care is required to ensure that the internal surface of the brick pipe is smooth and not obstructed with cement mortar. When the pipe is made correctly, the ventilation effect is maintained. The screen for the smaller brick pipe measures 22 5mm X 225mm which also saves on screen material - the standard screen measures 300mm X 300mm. The superstructure foundation and the first course of brickwork for the superstructure is made with cement mortared brickwork. From then on, traditional mortar, using anthill soil, often combined with sand, is used to bond the fired brick walls of the structure. The internal walls of the structure are plastered with cement mortar and a hard surface latrine floor is also built.

It is therefore possible to make a sound Blair Latrine with less than half the subsidy required for the standard model, (which also includes reinforcing wire and chicken mesh), but greater skill is required in measuring cement and at all constructional st ages. The material contribution by the owner is also greater. Such models have been on trial for several years and are durable and effective, provided they are built according to the instructions in this manual.

From the users point of view any technique which saves on cost is welcome, provided that the durability of the unit is not seriously affected. Models which use less cement and more traditional material are cheaper to construct and this may have important implications in the future. However it is not a wise practice to build a cheap latrine which lasts only a few years. It is far wiser to build a durable latrine which will last for the length of life of the pit. A well built 3 bag model will certainly last the life of the pit, and is a good investment. This will be particularly important in the future when the usres will be expected to provide far more of the total value of the latrine and eventually the entire cost. This makes the technique more sustainab le in the long term. The high levels of subsidy, currently provided by donor organisations through the Ministry of Health, cannot be sustained for ever, and now is the time to introduce options which retain all the properties of a standard Blair Latrine, but provide it at lower cost. In any event, only the first Blair Latrine can be subsidised for any household. The second must be built and paid for by the family itself.

I wish to acknowledge the full support of the Ministry of Health in this venture, and the Department of Environmental Health in particular. The drawings used in this manual are those of Kors de Waard, whose contribution has been invaluable. Much credit is also due to the Field Teams who have played an important part in building and testing these lower cost structures. In particular the efforts of Ephraim Chimbunde, Nason Mtakwa, Cornelius Mukandi, Fambi Gono, Philimon Kademetema, Joshua Mazanza and their supporting staff are to be commended.

I also wish to acknowledge the support of the Swiss Federal Institute for Water Resources and Water Pollution Control. I also wish to thank SIDA who have encouraged the wider use of lower cost options in water and sanitation projects in Zimbabwe. Thanks are also due to UNICEF who have kindly funded the printing of this manual.

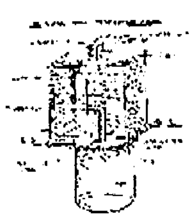
Peter Morgan
Harare.
september 1992.

HOW THW BLAIR LATRINE WORKS

The latrine slab is made with two holes, one for the squatting hole and one for the vent pipe. The vent pipe sucks air from the pit and fresh air is drawn down through the squat hole. The latrine itself is therefore odourless.

Flies approacing the latine are attracted to odours coming from the pipe but cannot pass the screen to enter the pit. Flies escaping from the latrine are attracted to the light coming down the pipe but are trapped by the screen and cannot escape.

THIS IS A CUT OPEN VIEW OF A BLAIR LATRINE



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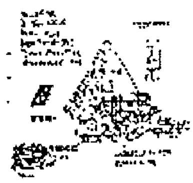
MATERIALS REQUIRED TO BUILD A 3 BAG BLAIR LATRINE

Cement (3 bags)
River Sand (1/4 cu.m.)
Pit Sand (3/4 cu.m.)

Reinforcing wire(20m X 3mm)
Flyscreen (225mm X 225mm) Aluminium or Stainless Steel
Fired Bricks (1100)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SITING THE BALIR LATRINE

The site should be chosen by the family with assistance from an Environmental Health Technician a nd should be at least 30 meters from a well.

The site should be:

Down hill from a well or borehole - so that the waste from the latrine does not drain into the water supply

Where the soil is firm - so that the latrine will not collapse

On slightly raised ground - so that rainwater can drain awa y

Near the house - so that the latrine can be used easily

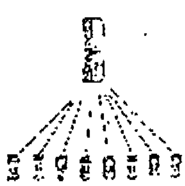
Away from trees - so that air can flow easily over the pipe

Facing the wind - so that air blows into the entrance

MEASUREMENT OF CEMENT

Where a limited number of bags of cement are being used for the construction of a Blair Latrine it is important to measure the cement accuratelyso that the maximum benefit can be made of the cement.

One bag of cement can be divided into 8X 4.5 litre tins of cement, with a little left over. A 5 litre tin makes a convenient measure. 4.5 litres measures just short of the full tin.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The following amounts of cement should be used to make different parts of the 3 bag model of the Blair Latrine

PART OF LATRINE	CEMENT USED (4.5 l TINS)	SAND USED	MIX
PIT LINING	8	80 PIT SAND*	10:1
FOUNDATIONS	2	16 PIT SAND	8:1
SLAB	4	20 RIVER SAND	5:1
BRICK VENT PIPE	2.5	20 PIT SAND*	8:1
LATRINE FLOOR	3.5	14 RIVER SAND	4:1
INTERNAL PLASTER	4	32 PIT SAND	4:1
FERROCEMENT ROOF	8	32 RIVER SAND	3:1

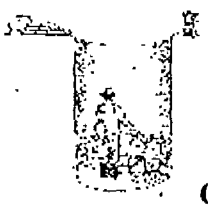
THE CONSTRUCTION

STAGE 1. DIG THE PIT


Click here to view larger image.

Dig a round pit 1.3metres in diameter and 2.9 metres deep.
Dig the pit wi th straight sides.
NOTE:If half bricks are used more cement will be required for each metre depth. In this case the pit should be dug to 2.5m depth

STAGE 2. LINE THE PIT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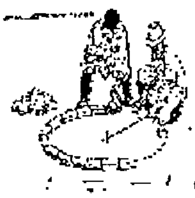
Line the pit with cement motared brickwork using a cement motar mix of 10 parts pit sand & 1 part cement.
The insi de diameter should be 1.1m
Use wet bricks if possible.

STAGE 3. FINISH THE LINING


Click here to view larger image.

Continue the pit lining to one course above ground level.

STAGE 4. MAKE THECOVERSLAB MOULD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Make a circle of bricks with internal diameter of 1.3 metres. lay cement bag, paper, or palstic under the mould site.

STAGE 5. MAKE THE COVERSLAB


Click here to view larger image.

Arrange bricks to form vent pipe hol and squat hole as shown.
Vent pipe hole is 140mm X 140mm. Squat hole is 280mm X 140mm.
Concrete mixture is 5 parts washed river sand 1 part cement.
Add half the mixture first (full mixture uses half bag cement). Add 3mm reinforcing wire with 150mm spaces. Add remaining mixture until slab is 75mm thick.
Leave for at least 5 days to cure - keep wet.


Click here to view larger image.

NOTE:The slab can be made without reinforcing if the sand is well chosen (clean and sharp) and the concre te is allowed to cure for at least 7 days and kept wet.

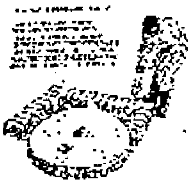
STAGE 6. PLACE COVERSLAB ON PIT


Click here to view larger image.

Bed down the coverslab on cement motar laid over the bricks. Ensure the orientation of the coverslab is cor rect. This is normally towards the homestead and towards the wind. The vent

pipe will be built on the same side as the doorway.
Make sure the vent pipe hole is over the pit.
A good seal between the coverslab and the collar prevents flies from enter ing and leaving the pit other than through the squat and vent pipe holes.

STAGE 7. MAKE THE SUPERSTRUCTURE FOUNDATION



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The foundation is laid out as shown in the plan provided later in this manual. The foundation is made up of fired bricks bonded together with cement motar (8:1). The brick course is 225mm wide. The surface soil is dug out first and the foundation laid on firm ground. The foundation is built up to salb level.

STAGE 8. THE FIRST COURSE OF BRICKS FOR THE VENT PIPE AND SUPERSTRUCTURE

Click here to view larger image.

The first course of bricks is built up on the foundation with ceme nt motar (8 parts pit sand & 1 part cement.) The measurements should be taken from the plan in this manual. The ventilation pipe is made with four bricks per course arranged as shown in the diagram. It is very important that the internal measurement of 14 0mm X 140mm is maintained throughout the length of the pipe.

STAGE 9. MAKE THE BRICK VENTILATION PIPE

Click here to view larger image.

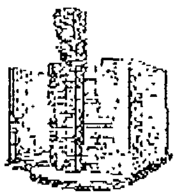
The brick ventilation pipe is now built up to 28 courses as shown in the diagram. The cement motar is used to bond the bricks. The internal measurement of 140mm X 140mm must be maintained at every course and the internal walls kept smooth. At every fourth course the brickwork is modified to include a "tooth" which will later form the connection betwee n the vent pipe and the wall of the superstructure. These are shown in the diagram.
Backfill the space between the foundation and the coverslab with half bricks, stones or well rammed soil. Level of to height of the slab.

STAGE 10. BUILDING THE SUPERSTRUCTURE

Click here to view larger image.

This is made with fired bricks bonded with anthill motar. The anthill motar may be mixed with sand o r cowdug to make more suitable for motar work. The superstructure wall is bonded to the vent pipe through the teeth previously made on the vent pipe.
The wall is built up to a height of 1.8m (which is about 21 courses of bricks).
When the superstr ucture is finished the inside wall is plastered with cement motar using a mixture of 8 parts pit sand & 1 part cement. This protects the wall from the washing water used in the latrine.

STAGE 11. MAKING THE LATRINE FLOOR



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Once the brick walls have been built and plastered the latrine floor can be made. The concrete for the f loor is made with 4 parts river sand & 1 part cement. The concrete is made so that it slopes down from the brick step at the entrance to the squat hole. It is finally smoothed down with a steel float.

STAGE 12. ADDING A ROOF

Click here to view larger image.

A permanent roof must now be added. This can be made of corrugated tin sheet or asbestos and supported by wooden b eams and attached to the structure with wire and nails.

STAGE 11. FITTING THE FLYSCREEN

Click here to view larger image.

This is a very important part of the latrine and controls flies. It also reduces erosion on the inside of t he anthill pipe. The screen should be made of stainless steel or aluminium mesh. The screen size is 225mm X 225mm. It si fitted to the head of the vent pipe in cement motar.

ADDING A FERROCEMENT ROOF

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The 3 bag Blair Latrine can be upgraded with another bag of cement so that it is fitted with a permanent ferrocem ent roof. This is made to the measurements shown below with a mixture of 3 parts washed river sand & 1 part cement. It is cured for 7 days and kept wet during that time.

Click here to view larger image.

THE THATCHED ROOF

Click here to view larger image.

If more permanent roofing material is not available a thatched roof can be used as a temporary measure. The thatched roof is made with poles and thatching grass so that a good overhang is made around the superstructure.

FINISHING OFF

Click here to view larger image.

Build up soil around the latrine. Plant grass in the built up soil. Tidy around the area of the latrine.

OTHER METHODS OF UPGRADING THE 3 BAG MODEL

Click here to view larger image.

1. Point the anthill motared brickwork with cement motar to a depth of 1 cm;

OR

2. Plaster the external walls of the latrine with cement motar;

OR

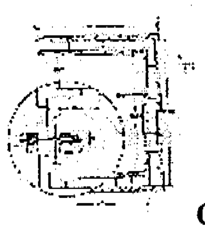
3. Replace anthill motated structure with cement motared structure.

4. Plant grass around the latrine to reduce erosion.

MAINTENANCE

THE MOST IMPORTANT MAINTENANCE OF THE BLAIR LATRINE IS TO KEEP IT CLEAN WITH WATER. WASH DOWN THE LATRINE SLAB EVERYDAY

DIMENSIONS OF SLAB AND STRUCTURE



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The diameter of the concrete slab is 1.3m and is placed over a brick lined pit with an internal diameter o f 1.1m. The pit is 3 m deep. The foundation shown above as the dotted area is 225mm wide. The brick walls are a single brick thickness. The squat hole is approximately 125mm wide and 275 - 300 mm long. The vent pipe hole measures 140mm X 140mm. The brick vent has the same internal size.