Water and Environmental Sanitation for Urban Communities in Developing Countries: Information Server

by

Ndirangu Kibata

Submitted in partial fulfilment of the academic requirements for the award of the degree of Master of Science in Engineering , in the Department of Civil Engineering, University of Durban-Westville.

Department of Civil Engineering
University of Durban-Westville

July 1996

Declaration

I, Ndirangu Kibata declare that unless otherwise indicated, this dissertation is my work and has not been submitted for degree purposes at another University or Institution

Signed

Ndirangu Kibata	Chris A. Buckley	Fred A. O. Otieno
Candidate	**Supervisor**	**Co-Supervisor**

Abstract

In order to bring about a more efficient delivery of services in the Water and Sanitation sector in urban areas of developing countries, an information server based on the Internet was to be constructed. This server was to be designed to assist the users solve various institutional and technical challenges encountered in the sector.

A number of issues pertinent to provision of clean water and adequate sanitation were identified and the mechanism by which they affect the sector explored, as a first step toward the construction of the server.

A suitable design of the information server was made and the prototype was placed on the Internet. The prototype server was used to evaluate the potential usefulness of the information server's in meeting the objectives of facilitating a more efficient delivery of services in water and sanitation sector of developing countries.

Initial results indicated that the server has the potential assist users in solution of various technical and institutional challenges facing them in developing countries.

Acknowledgement

Prof. C. A. Buckley : Your guidance, advice, encouragement and friendship were invaluable to me.

Dr. F. A. O. Otieno : I owe my presence in the course to you.

Reinier De Vos and Simon Tyrrell

: Your knowledge of Unix is unbelievable. That you were readily let me into the club was sheer act of selfness.

Cort Dietervors, IRC The Hague

: Although I have never met you, your format for WENDY was where it all started.

James Voortman, Umgeni Water

: Thank you for your assistance in evaluation of this project. Your assistance can not be eulogised enough.

Staff at Pinetown Wastewater Works

: Thank you for you help with evaluation.

Dan Campbell, Environmental Health Project

: Your vision for WENDY has helped the shaping of this dissertation.

Ian Bailey, Umgeni Water

: Thank you for review the epidemiology section of my dissertation.

John Sternberg, Scott Wilson, Kirkpatrick Consulting Engineers

: Thanks for your assistance in evaluation.

The Local and International WENDY steering committees

: Your insight is second to none.

International Association on Water Quality

: Thank you for funding the project.

Table of Contents

List of Figures

List of Tables

Lists of Abbreviations

ARPA	Advanced Research Projects Agency
BOD	Bio-Chemical Oxygen Demand
CAD	Computer aided design
CD-ROM	Compact disc read only memory
EHP	Environmental Health Project
ESA	External support agency
FTP	File Transfer Protocol
HABITAT	Acronym for United Nations Centre for Human Settlement
HTML	Hyper Text Markup Language
HTTP	Hyper Text Transfer Protocol
IAB	Internet Architecture Board
IAWQ	International Association on Water Quality
IDRC	International Development and Research Council
IRC (a)	International Reference Centre now known as International Reference Centre for Water and Ssnitation.
IRC (b)	Internet Relay Chat
MCRT	Mean cell residence time
MLSS	Mixed Liquor Suspended Solids
NSF	National Science Foundation
POE	Point of Entry
SGML	Standardised General Markup Language
UN	United Nations
UNDP	United Nations Development Programme

URL	Uniform Resource Locator
USAID	United States Agency for International Development.
UV	Ultra-Violet rays
VIP	Ventilated Improved Pit Latrine
WASH	Water and Sanitation Health Project
WEDC	Water, Engineering Development Centre
WENDY	Water and Environmental Sanitation Electronic Network for Developing Country Needs.
WWW	World Wide Web

Glossary

Anaerobic ponds	Ponds used for treatment of wastewater through anaerobic digestion.
Appropriate technology	Innovative technology that fits the environment within which it is applied. Over time the has come to mean intermediate technology.
Artificial wetlands	Artificially engineered alternately wet and dry areas that are periodically sufficiently wet to create low oxygen conditions.
Barrios	Large quasi-legal settlements on the city fringes of Tegucigalpa, the capital city of the Honduras, resulting from migration from the rural areas to the City.
Constructed wetlands	Same as artificial wetlands.
Cost recovery	A projects ability to pay back the original capital invested.
E-mail	The direct transfer of typed messages to any computer to another linked computer or computer network.
Electronic conference	Simultaneous communication by more than three persons on the Internet whereby each of the parties can view what each other is typing in.
Epidemiology	Study of spread of diseases.
Facultative ponds	Types of waste stabilisation ponds that remove BOD through aerobic metabolism of various bacteria in the pond degrading the organic matter to simple gaseous and liquid molecules leaving behind an inert sludge.
Firewalling	Use of inactive computers on the Internet to prevent illegal access to secure information.

Fluorosis	Browning of teeth due to excess fluoride in drinking water.
Grey literature	Printed information that has not been published in mainstream scientific publications and usually held only by the publishing organisation as an in-house publication.
Host Computers	Computers that are permanently connected to the Internet and through which information flows to and from the Internet.
Information Poverty	Lack of access to information necessary for development in developing countries due to the absent communication infrastructure.
Information Superhighway	Euphemism for the Internet in reference to the Internet's potential to allow a vast flow of information.
Internet	Worldwide network of computers and computer networks which transmits data in digital form over normal telephone lines.
Listservers	Written exchanges over the Internet using e-mail which cover a common interest.
Local Internet Provider	Organisations that provide a gateway into the Internet for people in their vicinity at a fee.
Macrophytes	Higher order plants growing in wetlands.
Methaemo-globinaemia	Ailment in children related to high level of nitrates in water.
Maturation ponds	Aerobic waste stabilisation ponds with a primary purpose of pathogen removal.
Mean Cell Residence Time	Time spent by micro-organisms in a reactor in activated sludge process.
Mixed Liquor Suspended Solids	Suspended solids in wastewater after recycled sludge has completely mixed with influent wastewater in activated sludge process.

Pollution shadow	Drastic increase in levels of environmental pollution as one approaches urban areas.
Rhizosphere	Area sorrouding plant roots in aquatic environment.
Search Engines	Programs on the Internet that help in search for information in the Internet.
Sustainable development	Development policy that takes cognisance of the need for development to go hand in hand with environmental conservation.
Talk	An e-mail feature that enables two parties that are logged on to a computer network to communicate simultaneously.
Waste stabilisation ponds	Technology used mainly for domestic wastewater treatment employing purely biological mechanism for treatment with no mechanical devices.
World Wide Web (Web in short)	Advanced system for accessing documents containing styled text, images, and sound over the Internet

Chapter One

Introduction

Water is probably the most important resource at the disposal of mankind. However, water is a finite resource. Its contamination through improper sanitation can further render the resource unavailable by being of poor or unacceptable quality. In developing countries, a challenge posed to the water managers is a need to provide water of acceptable quality at minimum cost and to dispose of the wastewater in a sanitary manner so as to avoid contaminating the available water resources. In order for this challenge to be met, there is a need to apply technology that is appropriate to the prevailing conditions while at the same time maintaining the required standards for safe water supply and efficient disposal of wastewater. One way in which suitable technology can be tapped is through information exchange among developing countries in order to save on research costs by avoiding duplication of efforts.

1.1 Water Supply and Environmental Sanitation in Developing Countries: Overview

At the end of the century, 45 % of the world population - 2 250 million - will be living in urban areas and 75 % of them will be in developing nations (Urbanisation Working Group of Water Supply and Sanitation Collaborative Council, 1993). The challenge posed by this large urban population is to provide water and sanitation services at affordable costs and using the most practical technology. Effective management of urbanisation rather than attempts to reverse it has been suggested as a more practical approach (Urbanisation Working Group of Water Supply and Sanitation Collaborative Council, 1993). An element of such a management strategy is water supply and environmental sanitation. In 1990 it was estimated that 200 million people living in urban areas of developing countries did not have access to clean water. A further 1 000 million did not have facilities for sanitary disposal of wastewater. These figures demonstrate a large need for the provision of clean water and sanitary disposal facilities of the wastewater.

Investing in water supply and environmental sanitation is considered beneficial to a country's populace. Definite correlation between improved environmental sanitation and water supply on one hand and decrease in infant mortality has been found. Other studies suggest reduced morbidity from a host of water borne diseases with improved water supply and environmental sanitation (LaFond, 1986). Improper sanitation leads to excreta disposal that lacks privacy with attendant loss of human dignity.

Water supply and environmental sanitation in developing countries is limited by scarcity of resources, both fiscal and human. This shortfall in developing countries in resources has often compromised the sector's ability to deliver the benefits of clean water supply and enhanced environmental sanitation (Water and Sanitation for Health Project, 1993). It is thus necessary to study means by which benefits of improved water supply and environmental sanitation can be delivered taking cognisance of the resource constraints affecting the developing countries.

Due to almost similar conditions prevailing in developing countries, information exchange in the sector of water and environmental sanitation has been suggested as a way of reducing costs of delivering services while at the same time ensuring adequate standards are maintained. For various reasons e.g ignorance of the existence of information among developing countries, this has not always been possible. In most cases, water supply and environmental sanitation programmes are funded from the West and the Pacific Rim. The practice has been to transfer technology from the developed to the developing countries. Often, the technology so transferred has been unrealistically expensive and at times unsuitable. Thus, this project seeks to enhance information transfer among the developing nations in order to overcome these problems in this sector.

One possible network is an information server based on the Internet. This would have the advantage of portability, low transmission cost and a large and expanding coverage. The information server so created would have the potential of assisting users in formulating solutions for a number of water and environmental sanitation problems. This would be done by publicising technological and other related information that may be available among the developing countries.

1.2 Electronic Databases in Decision-making

Information forms an integral resource in consultation, planning, designing, constructing, operating and maintaning a successful water and environmental sanitation system. A database of any kind offers the user the advantage of fore knowledge. A wide variety of organisations, institutions and individuals are involved in the water supply and environmental sanitation sector, all generating information in one way or the other. All of them have a need for information on the degree of succes or failure of various undertaking in the sector in the past. In a world that is technologically advancing, it is desirable to keep up with the rate of change and at the same time preserving the lessons learnt in course of time (Myburgh, 1994). In other words, water and environmental sanitation managers can benefit from experiences of others faced with similar technological problems with comparable social implications.

1.3 Internet in Engineering

Increased use of the Internet in developed countries is changing engineering practices in those countries. Using various tools available on the Internet, engineers are being able to access data at a higher speed than has hitherto been the case. It has also become possible to pose technical questions to other engineers who have access to the Internet. Electronic mail (e-mail) has enabled a fast and efficient system of information transfer between the various branch offices of an engineering organisation. It has become possible thus say to have an engineering team on site doing the field work and another one in the head office doing the design simultaneously. This would have an effect of saving costs and time.

1.3.1 Definition

The Internet is a worldwide network of computers and computer networks which transmit data in digital form over normal telephone lines. Using the Internet costs about as much as a local telephone call and a subscription cost to the local Internet provider. These charges vary from country to country. In developing countries telecommunication and Internet services tend to be expensive but in developed countries the same services are cheap a reason being the higher number of subscribers in developed countries lowering the break-even price. The Internet is a decentralised network. No single organisation operates or owns it. It is essentially a network of networks governed only by a set of protocols which specify how messages must be formatted or routed. This task is accomplished by the Internet Architecture Board (IAB) (Smith, 1994).

Although the Internet is very extensive, it is not the only channel of electronic communication available. There are other international networks and electronic channels that work independently of the Internet. However, the Internet is the biggest of the networks (Parker, 1995).

1.3.2 History of the Internet

The Internet began in 1960 with the United States Department of Defence. The Advanced Research Projects Agency (ARPA) developed the first network of computers called appropriately ARPAnet. It was largely developed to support the space programme and its race with the Soviet Union. The USA government continued to experiment with this network for several years. Around 1980, two networks were developed at universities called Usenet and BITNET. These networks linked hundreds of computers but had nonstandard designs that restricted their growth to the general population (Wilson, 1995).

In 1986, the National Science Foundation (NSF) linked five supercomputer sites across USA to promote research work. With only five sites available, researchers would have to travel each time they needed access to the supercomputers. The NSF decided to create their own network, NSFNET, using regional networks that connected schools and research sites in the same area (Engst, 1994). The NSFNET was the springboard for the addition of networks that currently comprise the Internet (Wilson, 1995).

The USA is a leader in the development and use of the Internet and is playing an active role in planning the future of the Internet. Some US $ 1 150 million were allocated in 1991 over five years to develop the National Research and Education Network (NREN). This *information superhighway* will provide a high-speed network needed until the twenty first century (Smith, 1994).

1.3.3 Internet, Water Supply and Environmental Sanitation

The use of Internet in dissemination of information on water supply and environmental sanitation is not new. The publishers of the water bulletin *US Waternews* use the Internet to distribute electronic version of their technical publications. They also use it to make announcements of water related conferences and make available back copies of their magazine. Discussion forums on water related issues are also included.

The National Water Research Institute of Canada uses the Internet as a public relation tool to explain to the tax payers how their money is spent. Technical information from the institute including research findings is availed through the Internet.

The Asian Development Bank uses the Internet to explain to the various parties aspiring for bank funding on the standards and content of presentation expected in the motivation for such funding. A complete Environmental Impact Assessment report to be used as a guide in the bank funded projects is availed through the Internet. Such projects include those in water and environmental sanitation sector.

Appendix 11 gives a list of location address on the Internet of the above named water and environmental sanitation resources and other. Location address on the Internet is referred to as a URL (uniform resource locator).

1.4 Statement of Problem

Access to information in developing countries is limited. There are multiple reasons for this, ranging from economic, social, cultural and political factors to a lack of an adequate infrastructure that allow information flows within the country. In general, national governments have been in a privileged position in most developing countries when it comes to getting information on specific developmental issues. Even so, many key decision makers in government cannot obtain the up-to-date information they need to implement policies. Other sectors of civil society like non-governmental organisations (NGO's), academia and national businesses, who can and should also play a key role in development issues within their countries, have had an even more restricted access to information. For many years developing countries have been net exporters of information. It is common to find more information for a specific developing country on an Internet server located in Washington D.C., for example, than in the country itself. Moreover, within most countries the little information that exists is either on private hands and/or it does not flow out of government institutions. This lack of information impairs the ability of water managers in developing countries to make informed decisions. There is a need to equip water and environmental sanitation managers in these countries with information capable of assisting them in formulating solutions for a range of water and environmental sanitation challenges (Urbanisation Working Group of Water Supply and Sanitation Collaborative Council, 1993). On the other hand, while exchange of information between developing countries is low, the most practical solution to water and environmental sanitation challenges is to be found among the developing countries themselves. In the past, transferring first world technology to the realities of developing countries, has at times proved inappropriate, costly or both. Hence a mechanism for information exchange between developing nations ought to be investigated in order to overcome this problem.

1.5 Project and Dissertation Objectives

This dissertation forms the initial phase of a project codenamed WENDY standing for **W**ater and **E**nvironmental Sanitation Electronic **N**etwork for **D**eveloping Countr**y** Needs. The project hypothesis is that it is possible to solve a range of management and technical challenges in the water and environmental sanitation sector of developing countries by facilitating exchange of information. The mechanism through which this exchange is to take place is via an information server on the Internet.

The overall goal of WENDY is to contribute to the more effective delivery of services in the water supply and environmental sanitation sector in developing countries through improved information provision and to promote and facilitate the exchange of data, information, knowledge and experience among water and environmental sanitation institutions and professionals.

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.

These objectives are proposed to be achieved by the establishment of a WENDY home page on the Internet that will point the way to:
(i) information provided by various partner institutions that are on the Internet;
(ii) to sources of information, activities and contact outside the WENDY partner institutions;
(iii) to operate and maintain the network through the provision of protocols, guidelines, standards and manuals;
(iv) to maintain up-to-date links to other sources of information;
(v) to promote the use of WENDY by increasing the awareness of WENDY and;
(vi) by capacity building in the use of the network, promote its expansion through increasing the number of partner institutions and improving physical access to the network through promoting pilot projects.

The WENDY plan of action is in **Appendix 15** while **Appendix 14** is a breakdown of the members of WENDY steering comittee and their affiliations.

In view of the foregoing, the following have been identified as the objectives of the dissertation :-
(i) to design a suitable format in which the information server can be constructed on

the Internet.

(ii) to identify through a partial literature search issues that are pertinent to the provision of clean water and adequate sanitation in developing countries. These are the issues that need data and information to be generated and disseminated, and views exchanged among the sector professionals as stated in the objectives of WENDY.

(iii) to construct a prototype information server on the Internet that will be used as a pilot test for the complete information server.

(iv) evaluate the potential effectiveness of the information server in carrying out the objectives of WENDY.

1.6 Scope of the Dissertation

In view of the available time and resources, the scope of the dissertation was limited as follows:-

(i) The evaluation of the effectiveness of the WENDY was limited to Umgeni Water and Pinetown Wastewater Treatment Works representing water and environmental sanitation managers in a developing countries; Environmental Health Project (EHP) of United States Agency for International Development (USAID) representing donor organisations; Water Supply and Sanitation Collaborative Council (WSSCC) representing sector professionals; and Scott, Wilson, Kirkpatrick Consulting Engineers, representing consultants.

(ii) Only urban areas of developing countries were considered, with another parallel dissertation by Dindar (1996) dealing with rural areas of developing countries.

1.7 Organisation of the Dissertation

In **Chapter Two**, the literature is reviewed on selected issues involved in urban water supply and environmental sanitation in developing countries and how they impact on the decision making process in these countries. These issues are the potential topics that could be addressed on the proposed information server. Further, the use of Internet as a tool for the maintenance of a technical database is examined as well as Internet's ability to present these data. **Chapter Three** describes the procedures and methodologies followed in constructing the information server on the Internet. The Chapter further explains the methodologies used in evaluating the effectiveness of the sever. **Chapter Four** presents the results of evaluation of the server's effectiveness and an analysis of these results. **Chapter Five** discusses the extent to which the dissertation's objectives have been met and makes the appropriate conclusions and recommendations. The Chapter also identifies scope for further work on the project.

Chapter Two:

Selected Topics in Water and Environmental Sanitation for Developing Countries: Literature Survey

In order for the benefits of improved sanitation and clean water supply to be experienced by as large a section of the urban communities as possible, it is imperative that these resources are used as judiciously and as prudently as possible. Water supply and sanitation are basic needs. Satisfying them represents meeting basic requirements for survival. Thus, it is in water supply and sanitation, more than in any other sector, that issues of equity must be addressed. Equity requires that limited resources be used to meet basic needs including health needs as fully as possible. Thus, public funds should be allocated to serve most people with adequate, effective water supply and sanitation rather than a few with wasteful models based on inappropriate foreign standards (Institute of Water Engineers and Scientists, 1983).

A forum from which the available appropriate technologies can be exchanged between managers in developing countries is necessary if the above goal is to be efficiently achieved. The use of the Internet has been suggested as one such possible medium. This chapter makes a partial review of the available literature on water and sanitation in developing countries. Particular attention is paid to literature on the benefits of improved sanitation and clean water supply, obstacles to provisions of these benefits and information technology in the sector. This is done with a view to identifying possible information gaps that the use of an information server can possibly close. Literature on use of the Internet as a tool for maintaining a technical database is also briefly reviewed.

2.1 Improved Water Supply and Environmental Sanitation; Benefits, Global and Implied Costs

Reduction in cases of water related diseases, improvement of standards of life and enhanced human dignity have been identified among others as possible benefits of improved water supply and sanitation. Given these benefits, development of facilities associated with improved sanitation and water supply should receive first priority in developing countries. However, this has not been the case. Many reasons exist for this lack of improvement in the sector. This section reviews the available literature on benefits of improved water supply and sanitation, impediments and their cost implications.

2.1.1 Water Supply and Sanitation in Development and Sustainable Development

Water and Sanitation for Health Project (WASH) asserts that water supply and sanitation are fundamental building blocks in the development process (Water and Sanitation for Health Project, 1993). The sector influences economic development, employment, agriculture, housing and health. In this respect, the number of taps per 1 000 persons is deemed to be a better economic indicator of good health than the number of hospital beds per 1 000 persons. In recent times, various growth indicators have come to replace the per capita income method in assessing the level of development of a country. This includes life expectancy, calorific intake, human rights observance, gender equality, and the quality of the environment. The quality of the environment in turn is partly determined by access to clean water and sanitary disposal of the wastewater.

Water supply and sanitation takes place in a real world of scarce funds, competing priorities, human resource and other institutional limitations. All this is within the framework of social and political systems that both shape and determine the success of water supply and sanitation programmes. These limitation affect the extent to which a country can realistically address its needs in the sector (Water and Sanitation for Health Project, 1993). Population growth presents an example on how facility development can be out stripped even after many years of investment in water and sanitation. Table 2.1 indicates urban population that was unserved with water and sanitation at the beginning and the end of the water decade. Table 2.2 compares the coverage gain with population growth in developing countries over the same period. Coverage gain refers to the difference between the population served at the beginning and the end of the decade.

Table 2.1: Urban population unserved with water and/or sanitation at the beginning and the end of the water decade (1980 - 1990) in developing countries, in millions (WASH, 1993).

	1980	1990
water	235	204
sanitation	374	345

Serageldin (1995) suggests that The International Water Supply and Sanitation Decade has had mixed results in provision of clean water and adequate sanitation as shown in Table 2.3. From Tables 2.2 and 2.3, it can be discerned that 427 million people were provided with access to water of reasonable quality over the period. The number of urban dwellers with access to clean water increased by 80 % during this period. At the same time, the number with adequate sanitation facility increased by about 50 % (World Bank, 1992). However, despite these improvements, 1 000 million people still lack access to an adequate supply of water and 1 700 million do not have adequate sanitation facilities (Seregeldin, 1995).

Seregeldin further argues that while the aim of the International Drinking Water and Sanitation Decade was to provide water of reasonable quality and adequate sanitation, an emerging agenda that emphasises environmentally sustainable development has come to the fore. This concern extends to the quality of both surface and ground water. This has been in line with the thinking that the quality of an environment and in this case the aquatic environment is a global concern. However, cities in developing countries continue to have a low levels of sewage treatment. This is the case in middle income countries as well. For example, Buenos Aires, for instance treats only 2 % of its sewage. This fact is amplified by the fact that while environmental quality in industrial countries improved over the period 1980 to 1990, it declined in low income countries over the same period (World Bank, 1992). This fact is illustrated in Table 2.4.

Table 2.2: Overall growth in urban population compared with coverage gains in water and sanitation at the beginning and the end of the water decade (1980 - 1990) in developing countries in millions (WASH, 1993).

	Water coverage	Sanitation coverage
coverage	427	425
population growth	393	396
net gain	+34	+29

The cost of this lower quality of environment can be seen in terms of environmental degradation. Apart from aesthetics, the streams around most cities in developing countries constitute a reservoir for waterborne diseases. In such circumstances, the costs of relocating the water abstraction facilities can be enormous, impacting seriously on a country's overall economy. For example, Seregeldin (1995) reports that the Chinese city of Shanghai has had to relocate its water supply intake 40 km upstream at a cost of US $ 300 million (1993) because of the degradation of the river water quality around the city.

Table 2.3: Proportion of people with access to safe water and adequate sanitation in developing countries, 1980 and 1990 (Seregeldin, 1995).

	1980		1990	
	Urban (%)	Rural (%)	Urban (%)	Rural (%)
water	72	29	87	69
sanitation	67	33	73	48

The concept of sustainability is borrowed from the discipline of system analysis and often used as a measure for judging system performance. It refers to the ability of a system to continue performing its function at an acceptable level and for an indefinite period of time using only the inputs specified in the system's design. To be sustainable, the system must include all the resources, including financial resources required to sustain the flow of benefits. Water and sanitation programmes in developing countries are heavily funded by the donor communities. The concept of sustainability requires that financial resources are not dependent on donor funding indefinitely. Sustainability is increasingly being considered a guide to a wise investment by donor communities (WASH, 1993). Donor agencies are reluctant to put capital funds into programmes that fail to function before the end of their design period. It is thus imperative that any programme on water supply and sanitation be based on the concept of sustainablity and more so sustainable development if the full benefits of enhanced water supply and improved sanitation are to be realised.

Table 2.4: Average dissolved oxygen levels in rivers in developing and industrial countries in 1980 and 1990 (Seregeldin, 1995).

	Low-income	Middle-income	High-income
1980	7.3	7.0	10.0
1990	6.0	7.0	10.8

Dissolved oxygen (DO) is in mg/l. Depending on temperature, DO levels of above 6.4 mg/l are acceptable while below 5.2 mg/l are not acceptable.

One social benefit of the provision of a clean water supply is a marked reduction in terms of human suffering. Often, in urban areas that are not served, the urban poor have to rely on commercial vendors for their water supply. The charges for this is typically US $ 2 to 3 for a cubic metre of water using 1995 prices. This is about ten times the price paid by those served with water from a tap in their houses (Seregeldin 1995). This has dire social implications because it is those who can ill afford to that end up paying high charges for their water supply.

Okun (1987) lists other micro-economic and social benefits of improved water supply as follows:-

(i) Improved water supply reduces the amount of time required to collect and transport water. For example, in 1980 a third of the total work time of the female heads of family in Kenya was devoted to collecting water while only 17 and 21 % were devoted to cooking and economic activities respectively (World Bank 1980).

(ii) Improved opportunity for keeping livestock or growing subsistence crops as a result of time saved in transporting and collecting water.

(iii) Communities with adequate water supply attract small businesses reducing outward migration and improving on the micro-economy of the area.

(iv) In larger communities with buildings and other properties, water supply may be designed to provide improved fire fighting capacity hence reducing fire risk to property.

(v) Easier access to safe water can improve family and social development. When women are freed from water bearing, they have more time for income producing work, child care, household tasks as well as training and educational programmmes. The same applies to children's obligation to fetch water at the expense of school time.

Okun further provides Table 2.5 to show the relationship between water supply improvement and potential benefits

Table 2.5: Relationship between water supply improvements and potential benefits (Okun, 1987)

Benefit	Accessibility	Quantity	Quality	Reliability
time-saving	saving on water collection journey for each household	-	-	saving during season when unrealisable sources fail.
health improvement	water piped into the households may increase quantities used and reduce exposure to water-borne diseases.	potential improvements in hygiene if additional water is used.	eliminates an avenue of faecal-oral transmission	may avoid seasonal use of more polluted sources of water.
labour	labour released by time saving and indirectly by health improvement.	indirect through health improvement.	indirect through health improvement	seasonal time - saving.
agricultural advance	possible indirect benefits from labour release.	surplus or waste available for gardening	-	seasonally significant in some cases.
economic diversity	a prerequisite but not usually a major one.	a prerequisite but not usually a major one	-	permits permanent settlement.

2.1.2 Epidemiology of Water Supply and Environmental Sanitation

The foremost benefit expected from improved water supply and sanitation is improved health (Institute of Water Engineers and Scientists, 1983). The Institute (1983) defines water related diseases as those diseases which in some way are related to water in the environment (to water bodies not molecular water) or to impurities within the water. Water related diseases can further be categorised as water related infections and those caused by chemical substances in the water. The former category requires a pathogen for transmission and are the most important in developing countries. The second group may include conditions such as fluorosis (browning of teeth due high fluoride levels in water) and methaemo-globinaemia (condition in young children related to high nitrate levels). Water related infections overshadow the water chemistry related diseases in developing countries (by number of incidences and ensuing mortality rates).

The water related infections are so called because their transmission and prevention in part or whole depends on water. Both Okun (1987) and Institute of Water Engineers and Scientists (1983) give four possible routes of transmission of the water related infections. These are **water-borne, water-washed, water-based** and **water-related insect vector. Water-borne** infections occur when pathogens in water are ingested by a human being or an animal which subsequently becomes infected. Water borne diseases can also be transmitted via other means which allow faecal material to pass into the mouth. Examples of water-borne diseases are cholera and typhoid. **Water-washed transmission** route refers to the route that allows proliferation of infection due to absence of water in adequate quantities as opposed to quality. The relevance of water in this case is as an aid to hygiene. Most water-borne infections can also be water washed when transmitted through other routes due to lack of adequate washing. In this category falls most water-borne diarrheal diseases, water washed infections of the eye and the skin and those transmitted by other vectors such as flea, lice or mites. Infections in this latter category are seldom transmitted as water borne infections.

Table 2.6: The four routes of water related infection transmission and the preventive strategies appropriate to each route (Okun, 1987)

Transmission route	Preventive strategy
Water-borne	improve quality of drinking water prevent casual use of other unimproved sources
water-washed	increase water quantity used improve accessibility and reliability of domestic water supply improve hygiene
water-based	decrease need for contact with infected water control snail population[a] reduce contamination of surface water by excreta[b]
water related insect vector	improve surface water management destroy breeding sites of insects decrease need to visit breeding sites. use mosquito netting

a. Applies to schistosomiasis only
b. The preventive strategy for helminths is dependent on precise life cycle of the helminth.

Table 2.7: Classification of water related infections (Institute of Water Engineers and Scientists, 1983)

Category	Infection	Pathogenic agent
faecal-oral	Diarrheas and dysenteries	
	Amoebic dysentery	P
	Campylobacter enteritis	B
	Cholera	B
	E.Coli diarrhea	B
	Giardisiasis	P
	Rotavirus	V
	Enteric fevers	B
	Typhoid	B
	Paratyphoid	V
	Poliomyelitis	V
	Hepatitis A	S
	Leptospirosis	H
water washed		
- skin and eye infection	infectious skin diseases	M
	infectious eye diseases	M
- others	lice borne typhus	R
	lice borne relapsing fever	S
water based		
- penetrating skin	Schistosomiasis	H
- ingested	Guinea worm	H
	Clonorchiasis	H
	Diphyllobothriasis	H
	Fasciolopsiasis	H
	Paragonomiasis	H
	others	H
water related insect infection	Sleeping sickness	P
- biting insects	Filariasis	H
near water	Malaria	P
- insects breeding	River blindness	H
in water	mosquito-borne viruses	
	-Yellow fever	V
	- Dengue fever	V

B = bacterium H = helminth P = protozoa S = spirochaete
R = rickettsia V = virus M = miscellaneous

In **water based route**, a pathogen spends a part of its life in water snail or other aquatic animal. All the resulting infections are due to parasitic worms (helminths) that depend on aquatic host complete their life cycle. Examples are guinea worm and schistosomiasis. **Water-related insect vector** route depends on insects that breed or live near water for transmission. Malaria and yellow fever are typical examples in this category. It is noted that appropriate sanitation and drainage can reduce incidences of this latter category of diseases. A list of the transmission route is given in Table 2.6

Reduction of diarrhea diseases is the most marked health benefit of improved water supply and sanitation. About 2 million children die each year from diarrhea diseases resulting from contaminated water (Water and Sanitation for Health Project, 1993). Repeated bouts of diarrhea inhibit the body's ability to absorb food. This has an effect of putting children at risk of dying from diarrhea and at risk of dying from malnutrition. The combination of diarrhea and malnutrition have an effect of stunted growth on children. This is in spite of medical and nutritional intervention (Water and Sanitation for Health Project, 1993)

Incidences of other water and sanitation related diseases in developing countries are also as high. Table 2.8 indicates incidences and effects of selected diseases in 1986 in developing countries excluding China. From the table it can be seen that about 4.6 million fatalities from diarrhea occurred in the year occur making it by far the most important disease related to water and sanitation.

Table 2.8: Incidence and effects of selected diseases in developing countries, excluding China, for the year 1986 (WASH, 1993)

Disease	Incidence	Estimated Deaths /Year
Diarrhea	875 million[a]	4 600 000
Ascariasis	900 million	20 000
Guinea Worm	4 million	b
Schistosomiasis	200 million	b
Hookworm	800 million	b
Trachoma	500 million	c

a estimated cases per year
b effect is usually debilitation rather than death
c major disability associated with Trachoma is blindness

Precise relationship between incidence of diarrhea diseases and improved water supply and sanitation is difficult to model . However the statistical linkage is well supported. Table 2.9 (Esrey *et al.*,1990) shows expected reduction in morbidity from improved sanitation from different studies.

Table 2.9: Expected reduction in morbidity from improved water supply and sanitation (Esrey *et al.*, 1990).

	All Studies			Better studies		
	No.	Median (%)	Range (%)	No.	Median (%)	Range (%)
diarrhea diseases	49	22	9 - 100	19	26	0 - 68
ascariasis	11	28	0 - 70	4	29	15 - 70
guinea worm	7	76	37 - 98	2	78	75 - 81
hookworm	9	4	0 - 100	-	-	-
schistosomiasis	4	73	59 - 87	3	77	59 - 87
trachoma	13	50	0 - 91	7	27	0 - 79

Other surveys by Water and Sanitation for Health Project (1993), in Guatemala showed that stunting, as a measure of child health and nutritional status, is more than twice as likely to occur among children living in communities with poor sanitation than among those living in communities with high levels of sanitation. A total of 2 000 children were sampled.

The epidemiological importance of water and sanitation can be best be illustrated by return of cholera to a number of south and central American countries the most recent being the outbreak in Mexico. These outbreaks are attributable to a population growth that is not commensurate with provision of water and sanitation facilities. Cholera is also endemic in Asia and Africa (Water and Sanitation for Health Project, 1993)

Of the 37 major diseases in developing countries, 21 are water and sanitation related. In 10 out of these 21, provision of clean water and adequate sanitation is considered to be a useful primary intervention (Walsh, 1990). These are diarrhea, typhoid, schistosomiasis, hookworm, amoebiasis, giardisis, ascariasis, trichuriasis, hepatitis A, and drancunculiasis.

Outside the diarrhea spectrum, malaria is one of the most important diseases related to water and sanitation due to its high level of incidences and fatalities. Malaria is transmitted by the mosquito *anopheles*. The malarial control depends on the knowledge of ecology of the vector. Mosquitoes breed in warm marshy areas. Thus, provision of water without sanitation may under such cicumstances increase incidences of malaria. In some arid areas, malaria transmission is seasonal, peaking during the rainy season due to emergent breeding grounds formed by rain water. Development of water supply in such areas can easily lead to increased malaria incidences due to puddles formed from the water extending the vectors' breeding season.

With increased level of industrialisation in developing countries, cases of *modern* water related health problems are more likely to be encountered. The most likely health problem is that related to ingestion of water contaminated with organic or inorganic compounds. Though uncommon, cases of these health problems are prevalent in former Soviet Union, Eastern and Central Europe due to the relative level of industrialisation in those countries. Water and Sanitation for Health Project (1993) has documented various problems encountered in these republics as follows:

(i) Agricultural practices have caused extensive water contamination and salinisation of soils and groundwater

(ii) Minning and industry have caused localised contamination with industrial chemicals and metals

(iii) Chronic problems associated with consumption of unsafe waters. This is exebercated by discharge of untreated industrial effluent.

People in these regions have thus reported health problems like diarrheasis and acute poisoning.

2.2 Impediments to Improved Urban Water Supply and Sanitation in Developing Countries

Heavy investments in water supply and sanitation have been made since 1980. However, there has been no commensurate gains in health terms and economic upliftment of the communities in developing countries. To an extent, this poor performance can be attributed to emphasis being placed on water supply with little or none to sanitation. This has placed the aquatic environment in these countries at risk and threaten the very water resources they were being developed in the first place (Water Research Commission, 1995). The Water Supply and Sanitation Collaborative Council working group on the Promotion of Sanitation as reported by Water Research Commission (1995) identified several reasons as to why these benefits were not being delivered.

2.2.1 Low Emphasis on Appropriate Technology and Sanitation

In water supply and sanitation programmes, there has been an emphasis on water supply and neglect of sanitation. This fragmented approach has annulled possible benefits of improved water supply because sooner or later the raw water sources become so polluted that the water supplied ends up transmitting the diseases it was supposed to prevent in the first place. There are various reasons for this imbalance.

Inappropriate approaches have been cited as a problem with delivery of sanitary services. This is blamed on an attempt to seek simple universal solutions to localised problems. These solution have often failed after ignoring the diversity of needs and their context. For example, urban needs differ from rural needs. In some cases, the scope of aquatic environmental management becomes so broad that the focus on basic household excreta management is lost. On the other hand, the focus can be narrowed down to say installation of pit latrines ignoring the prevailing hydro-geological conditions. This may have an effect of amplifying disease transmission in case of floods and contaminating ground water resources. Another possible area where approach to problems in sanitation tends to wrong is in short term disaster relief. Long term sustainabililty fails to get developed due to inadequate attention being paid to treating transition as a goal. There is evidence that the current sanitation systems are stifling innovations and probably undermining confidence. This makes workers afraid to take risks essential for success (Water Research Commission, 1995).

Institutional arrangements as they are in developing countries do not seem to serve the promotion of effective environmental sanitation. The various reponsibilties are too fragmented within the government departments and quasi-governmental organisations. The needs of the most venerable are often neglected. The potential roles of non governmental organisations are also ignored. These factors make it necessary for a review of the existing institutional framework (Water Research Commission, 1995).

Iwugo (1995) lists the following as basic institutional requirements in with regard to a systems ability to deliver on environmental sanitation and environmental pollution control:-

(i) Strengthened environmental legislation and standards in developing countries.
(ii) The need for adequate sustainable infrastructure (regular water supply, vigourous town planning and urban renewal and laboratory facilities)
(iii) Appropriately trained and motivated technical staff.
(iv) Co-ordination of duties and responsibilities between different national agencies and organisations.
(v) Co-ordination of aid and assistance between different international development agencies and,
(vi) Vigourous research and development including field trials of appropriate water pollution control systems.

Lack of *Political Will* to deal with the difficult task of sanitation makes it hard for the government to sacrifice resources for use in sanitation. Rarely is provision of sanitation made an issue in political campaigns. This is in sharp contrast to the dire need for political commitment needed to create an environment in which political demand for sanitation can grow. Out of this demand, a political will to deliver can then arise. The situation is made worse by the fact that people in greatest need have the least political power (Water Research Commission, 1995).

Low prestige and recognition hinder provision of sanitation in some subtle ways. This is especially more so for low cost sanitation which is looked down upon. At the professional level, low cost sanitation is shunned due to its perceived low status and low pay. Among the consumers low cost sanitation is low in prestige when compared to the more expensive water borne sanitation (Water Research Commission, 1995).

Agencies involved at all levels in creating a supportive environment for water and sanitation tend to have ineffective and counter productive policies. One such policy is emphasis on water supply without at the expense of sanitation. Poor policy also takes the form of subsidies that favour middle and high income communities at the expense of the poor. A typical example is water supply subsidy in most developing countries ensuring that the cost of water is about US $ 2 to 3 per cubic metre for supply of water in taps running into homes compared to US $ 20 to 30 per cubic metre from commercial vendors where the poor get their water supply using 1993 costs (Seregeldin, 1995). Most importantly, on the theme of poor policy, is the lack of a philosophical approach to the problem on which sound policy can be based (Water Research Commission, 1995).

Neglect of consumer preferences tend to have a profound effect on the delivery of sanitation services. More often than not, promoters of sanitation services tend to sell the health benefits of sanitation while the consumer needs are privacy, status, and comfort offered by sanitation. Low cost technologies are often seen by the consumers as low status technology while more sophisticated technology is probably beyond their economic reach (Water Research Commission, 1995).

The passive role played by women and children in decision making effectively excludes the majority from making decisions that affect them directly. This is more so because women and children tend to be vulnerable victims of breakdowns in hygiene. Consequently, important considerations such as disposal of children's excrement are ignored despite their obvious potential to transmit diseases. Generally, women require more privacy and security in sanitation but their needs are usually not well articulated due to their lack of representation in decision making process (Water Research Commission, 1995) .

Water Research Commission, (1995) lists other points in failure of sanitation programmes as:

(i) Ineffective promotion and low public awareness.
(ii) Little effective demand for sanitation.
(iii) Widespread ignorance of cultural beliefs and taboos of communities being served.

Perhaps the linkage between water supply and sanitation is best illustrated by failure of water supply programmes in developing countries to deliver the benefits of improved health despite massive investments during the water decade and post water decade era (Seregeldin, 1995). Failure to consider sanitation issues when planning water supply projects has in no mean way contributed to the programmes' inability to deliver.

2.2.2 Economics of Water Supply and Sanitation

Seregeldin (1995) is of the opinion that the cost of water supply and sanitation is changing globally for two reasons:

(i) Population growth in developing countries is forcing citizens to reconsider their existing needs for better sanitation. Thus in some case, low cost appropriate technologies no longer suffices due to the upward mobility of the people in question. Experience of Orangi Pilot Scheme in Karachi, Pakistan as described by Hassan (1986) illustrates this upward mobility where slum dwellers would only agree to installation of traditional reticulated sewage.

(ii) Water like money, labour, etc., is an economic resource with a monetary value attached to it. There is an increasing recognition of this fact hence the tendency to treat water as *free* is changing and with it the whole pricing structure of provision of water and sanitation.

Table 2.10: Population, water availability and accessibility, and urbanisation data for selected countries (Engelman and LeRoy, 1993).

Country	Population (10^6)		Annual water availa-bility	Water/ area/ annum	Water/head/year (m^3/P/y)		Access to safe water	Urban-isation
	1990	2025	(10^9m^3)	(m^3/km^2/y)	1990	2025	(%)	(%)
Developing								
Lesotho	2	4	4	133	2 290	1 057	35	20
Malawi	9	22	9	96	939	361	55	12
Mozambique	14	35	58	74	4 085	1 598	14	27
Namibia	1.3	3.0	9	11	6 254	2 399	58	28
South Africa	37	71	50	42	1 317	683	66	60
Tanzania	26	62	76	81	2 924	1 025	49	33
Zimbabwe	10	19	23	59	2 312	1 005	54	28
India	850	1 300	2 085	659	2 464	1 496	72	27
Israel	4.7	7.8	2	95	429	246	95	92
DEVELOPED COUNTRIES								
France	56	61	185	340	3 262	3 044	100	74
Japan	123	121	547	1478	4 428	4 306	97	77
Sweden	85	97	180	400	21 013	18 890	98	84
Britain	57	61	120	490	2 090	1 992	100	89
Australia	16	24	343	45	20 007	13 606	93	86
USA	249	331	2 478	265	9 913	7 695	94	75

Rawlin (1995) reports that 22 countries have water resources of less 1 000 m^3/person/year - a level taken to indicate severe water shortage. A further 18 have resources of below 2 000 m^3/person/year. Table 2.10 illustrates the water resource availability profiles of selected countries from the developing world and some from the north for comparison. The data is for the year 1990 and the projected availability in the

year 2025.
The effect of the diminished water resources in developing countries has been to increasing mismanagement of the existing resources. One widespread mismanagement practice that has lead to water scarcity has been setting aside of large quantities of water at minimal or no cost at all for farming. In developing countries, cities have sourced their raw water supply from the cheapest sources. Usually, the cheapest sources have tended to be rivers and aquifers next to the cities. As these cities grow, their *pollution shadows* have followed them with the resulting polluting of the very source of the cities' water supply. In such cases, expensive relocation as in the case of Shanghai in **Section 2.1.1**. The net effect of these factors has been an increase in costs of supplying water. It can be said that high costs of supplying water and treating wastewater has impended provision of those facilities more than any other factor (Seregeldin 1995). The services seem to be out of reach to the urban poor in developing countries. Table 2.11(World Bank, 1992) shows typical costs of provision of water and sanitation in developing countries in 1991.

Table 2.11: Typical investment costs for provision of different levels of service in urban areas of developing countries in US $ (1991) per person (World Bank, 1992).

	Intermediate technology	High technology
water	100[a]	200[b]
sanitation	255[c]	3 506[d]

a public standpipe
b piped water house connection
c Pour flush or ventilated improved pit latrine
d Piped sewerage with treatment

Clearly provision of these services is out of reach of the vast majority of developing countries whose per capita income is below US $ 1 000 per year. Thus most developing countries resort to use of donor funding to provide for the services or neglect to provide them.

The paradox is that the neglect of provision of the services has increased the potential costs of providing them. As time goes on, the raw water sources become more polluted forcing the cities to either source their water further away or treat the water at greater cost. Table 2.12 from World Bank (1992) shows the present and future cost of water supply indices for selected number of cities in developing world.

From Table 2.12, it can be seen that except for Mexico City, the cost of supplying water services to all the cities will double over the next 20 years. In addition, Hyderabad, Dhaka and Sheyang will supply their water at three times their present costs.

Table 2.12: The cost water supply indices for a selected number of cities within the developing countries for 1992 and 2012 (World Bank, 1992).

	1992	2012	current/future indices
Algiers (Algeria)	0.19	0.49	2.58
Amman (Jordan)	0.35	1.33	3.80
Bangalore (India)	0.10	0.20	2.00
Dhaka (Bangladesh)	0.10	0.32	3.20
Hyderabad (Pakistan)	0.14	0.63	4.50
Lima (Peru)	0.25	0.58	2.32
Mexico City (Mexico)	0.51	0.83	1.62
Shenyang (China)	0.04	0.13	3.25

Financial inefficiency and irresponsibility have been cited by the World Bank (1994) as reasons for increasing costs of water supply and sanitation services. In a study conducted by the World Bank (1994) examining over 120 urban water projects initiated between 1967 and 1989, only 4 countries were found to have reached acceptable levels of performance in public water and sewerage utilities. These are Botswana, South Korea, Singapore and Tunisia. South Korea has since been reclassified as a newly industrialised nation. This poor performance is in spite of efforts at capacity building in public institutions of the countries concerned. The report cites the following as examples of the severity of the situation:-

(i) An estimated 30 % of connections in Caracas and Mexico City are not registered.
(ii) Unaccounted for water is 8 % of the total water supplied in Singapore, 8 % percent in Manila and about 40 % in most South American cities. It is estimated that water losses cost between 1 000 and 1 500 million US dollars in revenue forgone per annum.
(iii) The number of employees per one thousand connections is between two and three in Western Europe and about four in a well run developing country utility (Santiago, Chile). It is however between ten and twenty in most South American cities.

The water and sanitation sector as a whole does not fare well in its overall cost recovery. World Bank (1994) shows that public utilities seldom recovered their costs from users. These short falls are met by injection of public funds. Fig 2.1 (World Bank, 1994) shows the degree of cost recovery in various sectors of the economy. In Brazil, about US $ 1 000 million (using 1994 values) was invested annually between mid 1970s and mid

1980s. Mexico uses US $ 1000 million a year (0.6 % of the GDP) in federal subsidies to water and sewerage services. Overall, a conclusion can be made that the real cost of urban water supply and environmental sanitation tends to be hidden due to the use of subsidies. Further, the subsidies do not seem to benefit those in dire need i.e the urban poor but the middle class who can afford to pay the real cost. This distortion in cost profile tends to compromise a nation's ability to deliver the very services that it is endeavouring to provide.

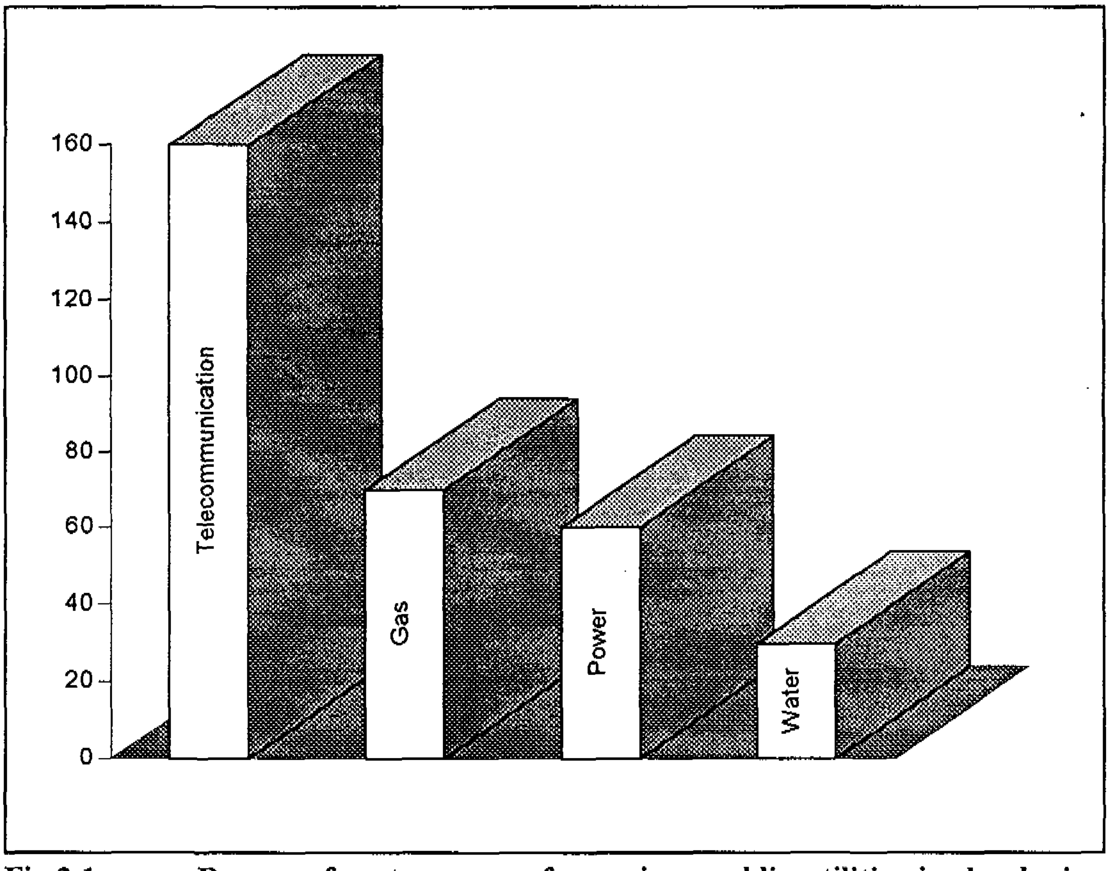


Fig 2.1: Degree of cost recovery for various public utilities in developing countries as a percentage. At 100 %cost recovery, a utility can operate with financial autonomy (World Bank, 1994).

The public financing profile of the water and sanitation sector as analysed by the World Bank (1994) indicates an increase in proportion of the GDP spent on water and sanitation in developing countries between 1960 and 1980 increasing from 0.25 to 0.45 %. In the 80's despite an overall decrease in public investment in developing countries, the proportion of GDP spent on water and sanitation remained constant at about 0.4 %. Seregeldin (1995) asserts that the performance and sustainability of water and sanitation services depend not only on level of financing in these services but also on the source of such financing. Projects that have performed well have been those in which the users have been closely involved in the financing thereof. Thus sector deficiencies as described earlier have been effectively overcome by user financial supervision borne out of the need to account for their (users) money. Given those facts, a question arises as to whether public expenditure on water and sanitation should be increased considering the level of water and sanitation infrastructure in developing countries. Comparison of experiences can answer such a question.

A feature that is common in many developing countries is the large hidden water economy due to inefficiencies in delivery by the formal institutions. Thus a private industry has arisen to meet the vacuum created by the inadequacies of the formal institutions (Seregeldin, 1995). Various studies of the water and sanitation sector have tended to ignore this aspect despite its considerable impact on the overall water economy. Jarkata, Indonesia provides an indication of the size of the hidden economy; only 14 % of the estimated eight million people receive piped water directly. About 32 % purchase from the street vendors while the rest rely on private wells (World Bank, 1994). With regard to sanitation, about 800 000 septic tanks serving about half the population are in operation. These septic tanks are installed by local contractors, fully financed by the households and maintained by a competitive private industrial sector.

The private water economy though free from the price distortions of the formal sector tends to have economic contradictions. For example, in the city of Onitsha in Nigeria, private water vendors collect about ten times the revenue collected by the formal water utilities (Seregeldin 1995). In Telgucigalpa, Honduras, households overcome problems of unreliable water supply by building storage tank, installing booster pumps, and sinking wells as it is the case in many other places. The amount of money spent on such investment annually in Tegulcigalpa is enough to double the number of wells currently supplying water to the city. The hidden water economy offers an avenue for broad and efficient delivery of services. However, the pricing tends to be high due to lack of advantages of economies of scale as illustrated by the case of Onitsha. However, a lot of study in the area is necessary in order to establish the underlying mechanisms of operation and the growth and diversification potential available.

Economics of water supply and environmental sanitation suggest that although growth in the sector has been hindered by lack of funds (and to a lesser extent other resources such as water and manpower) misuse, inefficiencies and poor policy and institutional frameworks are equally to blame for lack of delivery in this sector. A greater level of sector analysis is probably necessary in order to map strategies to overcome these inefficiencies.

2.3 Review of Selected Appropriate Technology Options for Developing Countries in Water and Sanitation

Cairncross (1993) defines appropriate technology as that technology that is innovative and fits the circumstances. Cairncross gives further requirements of areas appropriateness as follows:

(i) appropriate as to cost, i.e the technology must be affordable.

(ii) appropriate in terms of the job requirement. This means that the technology must perform the tasks it is intended to perform satisfactorily.

(iii) the technology must be reasonably simple such that it can be maintained and operated.

There are many instances of expensive and inappropriate technology having been used in the developing countries in the past. Cairncross (1993) attributes this to the first and second generation of engineers from developing countries having been trained in Europe and North America. Their designs have thus erroneously been based on the models from the north. However, Cairncross argues that this should not be the case because an engineer's training should encourage flexibility and ingenuity in producing solutions to novel engineering challenges.

Perhaps it is in the area of appropriate technology that water and sanitation managers in developing countries can benefit most from information exchange. This is because appropriate technology tends to be looked down upon such that it is given little international visibility. This section makes a partial review of the appropriate technologies available for use in developing countries. These technologies are the ones that would benefit developing countries if the known mechanisms of their operations are documented and the information exchanged possibly through the proposed information server.

2.3.1 Waste Stabilisation Ponds

Mara (1993) asserts that waste stabilisation ponds (WSP) are an extremely efficient and cost effective method for wastewater treatment especially in developing countries where sufficient land is available at low prices. Another essential prerequisite for reliable operation of WSP is a fairly warm climate all the year round. WSP's requirement for large tracts of land makes them initially expensive. Furthermore, the land required for WSP must flat and which implies that the land would have been suitable for agriculture. Thus, the opportunity cost of the land may be high.

Both Mara (1993) and Cairncross (1993) classify WSP into three types ie anaerobic, facultative and maturation ponds. These three types of WSP are arranged in series since each has different but complementary function. Anaerobic and facultative ponds are designed for BOD removal while maturation are designed for faecal coliform removal. A fair amount of BOD removal occurs in the maturation ponds and so does pathogen removal in anaerobic and maturation ponds (Mara, 1994).

Anaerobic ponds are in effect large open septic tanks used for treatment of large volumes of strong wastes. Anaerobic digestion and setttlement takes place and a thick scum layer develops at the top. This scum layer is partly responsible for the anaerobic conditions there under. Cairncross reports Mara (1976) as having given the data in Table 2.13 for anaerobic pond design.

Table 2.13: Some design parameters for anaerobic ponds (Cairncross, 1993).

Parameter	Limiting values
Retention time	1 to 4 d for optimum BOD and pathogen removal
Depth	2 to 4 m to ensure aerobic conditions
Volumetric Loading	Should not exceed 400 mg/l to avoid odour.
Sulphate concentration of the waste	Should not exceed 100 mg SO_4^{2-}/l to avoid odour release.
Sludge accumulation	0.03 - 0.04 m^3/person/year

Anaerobic ponds have been noted to be efficient in BOD removal. For example the results presented in Table 2.14 by Oragui *et al* (1987) were obtained after treatment in an anaerobic pond in north eastern Brazil. The strength of the waste water was between 230 and 290 mg of BOD /l, with inpond temperatures of 27 to 29 °C and retention times ranging between 0.8 and 6.8 d.

Table 2.14: BOD removal of an anaerobic pond in north eastern Brazil with inpond temperatures of 27 to 29 °C and retention times of between 0.8 and 6.8 d (Oragui *et al*, 1987).

Pond number	Retention time (days)	BOD loading (g/m^3day)	BOD removal (%)
1	0.8	306	76
2	1.0	215	76
3	2.0	116	75
4	4.0	72	68
5	6.8	35	74

Other performances data from anaerobic ponds have been documented by various researchers. Moshe *et al.* (1972) demonstrated that anaerobic ponds could receive a shock loading of 30 mg /l of heavy metals (introduced as 6 mg/l each of cadmium, chromium, copper, nickel and zinc) without reduction in performance. Overcash *et al* (1978) found high removals of copper (96 %), zinc (83 %), and lead (87%) from piggery wastes. A lower removal of cadmium (47 %) was reported by Parker (1979). An overloaded WSP at Beer Sheva, Israel reported removal rates below 30 % for for cadmium, copper, lead and zinc (Parker, 1979). Anaerobic ponds have also been found to be efficient in treating wastewater from industrial effluent. Alabaster *et al.* (1991) reports that anaerobic ponds have successfully treated agro based industrial waste water separately and in combination with domestic waste water satisfactorily

Sludge accumulation for anaerobic ponds have been determined to be around 0.04 m^3/person/y (Mara, 1994) and 0.03 to 0.04 m^3/person/y (Cairncross 1993). Typically, anaerobic ponds will require desludging every 3 to 5 y.

Odour release has made anaerobic treatment an unattractive form of waste water treatment. Mara (1994) attributes odour release in anaerobic ponds to anaerobic oxidation of sulphur containing amino acids and the reduction of sulphates to sulphides. This problem, Mara notes, can be eliminated with proper design practice of limiting the influent BOD load to below 400 g/m^3/day.

The facultative pond is usually the largest pond in the system (Cairncross, 1993). In absence of pretreatment by an anaerobic pond, it is the pond in which wastewater will first flow. The facultative ponds form the basic treatment unit in all pond system. The general theory of facultative pond is well documented (CSIR, 1968; Mara, 1976; Drews, 1983). In short it involves aerobic metabolism of various bacteria in the pond degrading the organic matter to simple gaseous and liquid molecules leaving behind an inert sludge that settles at the bottom of the pond. The design of the ponds is based on equations by Mara (1976) for determining the optimum pond sizes. The allowable BOD loading rate is treated as a function of the average ambient air temperature for a given month and per capita BOD contribution. Marks (1993) reports using values of BOD of 40 g of BOD per capita per day for for high density housing areas in Zimbabwe.

Maturation ponds are wholly aerobic and as pointed out earlier have as a primary purpose pathogen removal. Cairncross (1993) reports a faecal bacteria removal of up to 95 % in maturation pond. The ponds also provide a breeding ground for some hardy species of fish.

Other types of ponds include aerated lagoons and oxidation ditches.

2.3.2 Use of Natural and Artificial Wetlands for Water Quality Improvement.

Artificial wetlands are a viable waste water option for small to medium sized urban communities in developing countries. Woods and Hensman (1988) identified the following advantages of use of artificial wetlands over conventional wastewater treatment works:-

(i) wetlands have a low running costs.
(ii) low energy requirement.
(iii) wetlands can be easily established at the very location that the wastewater is being produced i.e point of entry.

(iv) the technology requires minimum level of skill and unskilled manpower once operational.

Woods and Pybus (1993) gives further advantages of using artificial wetlands as follows:-

(i) Wastewater treatment using artificial wetlands tends to be a robust process that can withstand a wide range of operating conditions. Zhenbin (1993) had also arrived at the same conclusion.

(ii) Artificial wetlands are environmentally acceptable since they offer considerable wildlife conservation opportunity.

These advantages make the use of wetlands particularly attractive for use in developing countries. However, Brix (1993) cautions againist the deliberate use of natural wetlands as treatment grounds because the fate of the pollutants removed from the waste water is not well understood. Thus, Brix recommends continued use of natural wetlands for nature conservation and constructed wetlands for deliberate waste water treatment.

Wetzel (1993) points out the complications involved in various definitions of wetlands both artificial and natural. Wetland hydrology has been used traditionally to define natural wetlands. Wetzel categorises the wetland hydrology based on definition of a permanent wet area including ground and surface water in most of the root zone and alternately wet and dry areas that are periodically sufficiently wet to create low oxygen conditions. A hydrology based definition is inadequate from a legal perspective because of seasonal and partial variation in hydrology. Wetland hydrology also tends to be difficult to evaluate quantitatively. Thus Wetzel (1993) found it more prudent to use a definition based on plants as indicators of the presence and functional efficacy of wetlands. He suggested the presence of well characterised indicator plants as a possible legal definition of wetlands. Such characterisation should extend to the prevailing soil and hydrological conditions.

Functionally, there should be no difference between natural and artificial wetlands. However, artificial wetlands do not posses or simulate natural wetland hydrology (Wetzel, 1993).

Water quality improvement through the use of wetlands has only come into vogue recently (Brix, 1993). The mechanisms by which nutrients, BOD, pathogens and suspended solids are removed are not well understood and more research needs to be done in ths regard. Brix (1993) contends that there are too little data to predict the extent of treatment by natural wetlands and says it would be erroneous to use the data obtained from constructed wetlands. The wetland's potential to absorb pollutants is largely unknown and unless more information becomes available, the natural wetlands' use in wastewater treatment could either go unexploited or be exploited with disastrous consequences. At the moment, it is not known what will happen when the wetlands cannot take any more pollutants. Worse still, the cost of remediation is unknown.

Brix (1993) suggests a variety of mechanism in which wetlands use to treat wastewater. These mechanisms are summarised in Table 2.15. Wetland treatment is also referred to as macrophyte based wastewater treatment systems. Macrophytes are the high plant life found in the wetland aquatic systems. In these macrophyte based treatment systems, the macrophytes have a key function in relation to cleaning of water. The macrophytes remove the pollutant by the following mechanisms:-

(i) directly assimilating them into their tissues

(ii) providing surfaces and a suitable environment for micro-organisms to transform pollutants and reduce their concentration. Oxygen transfer into rhizosphere (area surrounding the plant roots) is a prerequisite for certain microbial pollutant removing processes to function effectively.

Table 2.15: Removal mechanisms in wetland based wastewater treatment systems (Brix, 1993)

Wastewater Constituent	Removal Mechanism
suspended solids	sedimentation/filtration
BOD	microbial degradation (aerobic and anaerobic)
nitrogen	ammonification followed by microbial nitrification and denitrification plant uptake ammonia volatilisation
phosphorous	soil sorption (adsorption - precipitation reactions with aluminum, iron, calcium, and clay minerals in the soil) plant uptake (phosphine production)
pathogens	Sedimentation/filtration natural die off UV radiation excretion of antibiotics from roots of macrophtytes

Brix (1993) explains that suspended solids are removed in wetlands through filtration and sedimentation. The conditions in the wetlands are quiescent enough to allow for sedimentation of the wastewater. These two purely physical treatment processes also remove a significant amount of BOD, nutrients and pathogens.

Soluble organic compounds are aerobically degraded by bacteria attached to plant and sediment surfaces. The oxygen necessary for the aerobic process is supplied directly by diffusion from the atmosphere via the sediments or water atmosphere interface, by photosynthetic oxygen production from the macrophytes and leakage of the oxygen from the macrophytes' roots. In some cases, anaerobic degradation may be significant. The anaerobic process occur when there is oxygen depletion within the water column and the anaerobic sediments.

Brix (1993) quotes Reddy *et al.* (1985) having cited nitrification - denitrification as the most important mechanism for nitrogen removal in macrophyte based treatment. Ammonia is oxidised to nitrates by nitrifying bacteria in aerobic zones and nitrates are reduced to nitrogen gas in the anoxic zones. The oxygen required for the processes is obtained by the similar means as those used in aerobic processes above. Plant uptake of nitrates in macrophyte based treatment occurs but at a much lower extent is of less importance as a treatment mechanism in view of its magnitude. A limited amount of ammonia is also removed as gaseous ammonia if algal photosynthesis raises the pH of the aquatic system to above the pK_a for ammonia.

Mann and Bavour (1993) attribute phosphorous removal from wastewater to adsorption, complexation and precipitation reaction with aluminum, iron, calcium and clay minerals in the sediments. Alternate dry and wet spells enhance fixation of phosphorous in the sediments. Brix (1993) asserts that phosphorous plant uptake may be significant in systems where specific loading rate is low. Czinnki (1986) is reported by Brix (1993) as having indicated reduction of phosphates to gaseous hydrogen phosphide evolution under anaerobic conditions as a possible removal mechanism for phosphorous in macrophyte based treatment systems. Brix further reports that this assertion has since been queried by Nusch *et al* (1978) due to thermodynamic considerations.

Pathogens are removed in the wetlands during passage of wastewater through the system by sedimentation and filtration. Natural die off in an unfavourable environment also takes place. Root metabolites of some macrophytes have been reported by Wetzel (1993) to produce substances that are toxic to bacteria. In waters exposed to light, reduction of pathogens is thought to occur through UV irradiation (Brix, 1993).

Trace metals have beeen reported to complex with fulvic and humic substances that are formed from decaying macrophyte (Brix, 1993). This has an effect of complexing or fixing trace metals that are potentially harmful to the environment.

Results of treatment using macrophyte based wastewater treatment systems (from developing countries) have been encouraging. The results in Table 2.16 were from experiments conducted in Huangzou City, China between 1990 and 1993 (Zhenbin *et al*, 1993) with constructed wetlands. The table shows the extent of pollutant removal for various pond design parameters.

The full description of the experiment is beyond the scope of this dissertation and is documented elsewhere (Zhenbin, 1993). A summary only is presented. The experiment site pond 1 was lined with concrete but the rest were not. In all the ponds, there was presence of various macrophytes such as water hyacinths (*Eichhornia crassipes* Solms), large duckweed (*Spirodela polyrhiza* L. Schleid), water lettuce (*Pistia Stratiotes* L.), and water peanut (*Alternathera piloxeroides* Griseb). Some spaces in the ponds were left open. Algae and aquatic animals were present in pond 5. In phase 1 of the experiment, the pond system was operated in series. In phase II, pond 1 was taken out of service and operations continued as in phase I. In phase III, ponds 2 and 3 were run in parallel both discharging into pond 4 and subsequently pond 5.

Table 2.16: Removal of polluting substances from macrophyte based wastewater treatment systems in Huangzou City, China (Zhenbin *et al*, 1993).

		Ponds number and average % age removal				
Items	Phase	No. 1	No. 2	No. 3	No. 4	No. 5
BOD_5	I	66	76	79	80	77
	II		87	88	83	87
	III		85	81	77	78
COD	I	50	68	66	64	61
	II		78	79	73	76
	III		75	71	74	75
Total Suspended Solids	II		90	73	72	67
	III		94	85	78	76
Total Nitrogen	I	4.6	34	49	62	72
	II		42	60	69	75
	III		35	48	55	63
Total Phosphorous	I	24	50	39	48	72
	II		52	75	84	88
	III		63	73	81	84
Retention time (d)	I	5.5	9.1	12	16	20
	II		3.6	7.2	11	15
	III		4.3	4.3	6.5	8.9

Other conclusions by Zhenbin (1993) were as follows:

(i) in a macrophyte based waste water treatment system, several food chains are in existent and they have an effect of converting various water pollutants into useful biomass.

(ii) macrophyte harvesting did not significantly affect purification efficiencies of most pollutants. This seems to indicate that nutrient uptake as a removal mechanism is insigificant. However, biomass production was improved by harvesting.

(iii) the introduction of macrophytes in a pond system reduced the amount of algae present in the pond for various reasons. Beside competition for light, space and nutrients, the macrophytes seemed to excrete some organic substances from the rhizosphere that were harmful to algae.

(iv) the influent water quality varied greatly from time to time but the quality of the effluent remained stable.

Artificial and constructed wetlands present an opportunity for wastewater treatment that is largely unexploited. However little research in the field seems to have been undertaken. It is thus necessary that the little research that has been done be used on a global scale in order to exploit the opportunity offered by wetlands in water quality improvement.

2.3.3 Improved Pit Latrines

Palmer Development Group (1994) defines adequate sanitation in an urban area as an area with either full water-borne sewage system, septic tanks or ventilated improved pit latrine (VIPs). Bucket systems are not regarded as adequate. Although the feasibility VIPs in urban areas has been questioned (Seregeldin, 1995), the lack of resources associated with developing countries at times leave the use of VIPs as the only viable sanitation option.

Ventilated improved pit latrines (VIPs) were originally developed in Zimbabwe (Marks, 1993). This makes them ideal for use in other developing countries being an appropriate technology developed in a developing country. Cairncross (1993) points out that conventional pit latrines have the disadvantages of producing odours and flies. The VIP toilets overcome these disadvantages in a simple way. Mark (1993) explains that the VIPs have an extended vent pipe which extends well beyond the roof and covered with a gauze at the top. Wind blowing over the top of the pipe creates negative pressures in the toilet pit drawing in air through the toilet pedestal/squat hole. Marks (1993) also suggests that the mechanism of suction through the toilet hole is assisted by thermal effects. **Appendix 1** shows a construction of an improved pit latrine by Cairncross (1993). Removal of odour also helps to keep the flies off the toilet since they are attracted by odour. Thus the flies will only be attracted to the top of the vent where they are kept out by the gauze.

Cairncross (1993) explains that in looking for a suitable breeding grounds, the flies are attracted to odour. However, this is at the top of the vent rather than the drop hole. Some female flies may find their way into the drop hole though and lay the eggs. Once adult flies are hatched, they instinctively move towards the light which is at the opening of the vent. The gauze prevents them from going out and they eventually fall down into the pit and die. Cairncross (1993) reports Morgan (1977) as having counted 146 flies from an improved VIP over a 78 day compared with 13 953 from an unimproved pit latrine over the same period.

Cairncross (1993) recommends a programme for pit emptying in order to adapt of use of pit latrine in urban environmental sanitation. Among the recommended pit emptying techniques are vacuum tanker which have to wet the pit to a slurry or by use of hand if the pit contents are to be used as manure. Pit emptying operation can also be a municipal function.

Cairncross (1993) outlines the following problems associated with construction and operations of pit latrines:

(i) Ground and surface water contamination is the greatest risk posed by the pit latrines especially nearby wells. Reticulation mains with low or intermittent pressures also run a risk of contamination. The risk is increased with fissured rock structure underlying the pit and when the pit is dug to below the water table. Cairncross (1993) suggests as a rule that construction of the pit latrine should not be within 10 m of a well or other drinking water sources. It is suggested that the distance be increased when large volumes of water are abstracted or abstraction is done using a motorised pump. Further, pit latrines should not be located uphill of drinking water sources. Cairncross (1993) establishes that bacteria travel between 1 and 2 m in an unsaturated soil. Bacterial contamination travels as far as the water travels in 10 d. Chemical contamination eg nitrates travels further. A soil layer of at least 2 m between the bottom of the pit and water table or rock surface is recommended in order to eliminate this pollution risk. Regular water quality monitoring for bacteria and nitrates is recommended in areas where toilets are unavoidably close to the drinking water resources. Nitrates leaching from pit latrines have been identified as a possible threat. In Botswana, the high level of nitrates in the drinking water is thought to be due to low level of rainfall whose infiltration is unable to dilute the latrine nitrate leachate to acceptable levels. Calculations by Cairncross (1993) show that it would require a rainfall infiltration of 630 mm per year to dilute the faecal leachate to acceptable WHO standards of 10 mg/l of nitrates in drinking water in Botswana. The area receives an annual average rainfall of about 500 mm per annum and has high reported nitrates level in the drinking waters.

(ii) Pit latrine construction in rocky ground tends to be a difficult and expensive operation due to high costs associated with cutting of rocks. There is a temptation to construct shallow pits which tend to fill quickly and would also be unhygienic.

(iii) Pits dug in loose sand tend to be unstable and the walls need to be lined. The lining creates a problem in that the faecal liquids are restrained from soaking into the surrounding grounds.

(iv) High water tables create a problem in construction of the pits. The pits tend to collapse in wet weather. The high water tables also act as breeding grounds for mosquitoes.

Pit latrines offer the advantage of low construction cost and a low demand for water. Other improvement to the pit latrines are pour flush latrines and vault toilets and cartage.

2.3.4 Septic Tanks and Other Small Wastewater Treatment Technologies

Ødegaard (1993) points out the importance of small solutions in the modern world as opposed to the perception that small works are only suitable for use in developing countries. He points out that more often than not, small treatment works perform to higher standards than large works since they discharge into small sensitive streams. Ødegaard (1993) makes out the following operational difficulties associated with small works:

- Small plants are very sensitive to varying pollutant and hydraulic loading.
- Small plant operators lack the necessary operation resources leading to impaired efficiency.
- Large municipal establishments hold small works in lower regard further impairing their resource allocation.

Septic tanks are used as a pretreatment option for domestic sewage. Among the common forms of treatment of waste from septic tanks, Ødegaard (1993) suggests earth treatment, macrophyte treatment and algae ponds as options available for low technology treatment. Activated sludge plant, biofilm plants, chemical treatment, and biological/chemical treatment are the high technology options suggested.

Novotny *et al* (ed.) (1989) asserts that septic tanks afford the luxury of house plumbing associated with communities with access to municipal sewers at a considerably lower expense and little or no attention. Cairncross (1993) offers some rule of the thumb designs. In order to ensure that the retention time in a septic tank is at least 3 d, the capacity of the tank should be at least three times the average volume of water consumed in household daily.

Conventionally designed septic tanks require low population densities in order to function optimally. This is because of the large areas of land required for use as drain fields. This makes the use of septic tanks in urban areas somehow difficult. Cairncross suggests a more robust design of septic tank with three compartments for separate disposal for sullage and excreta. A diagram of conventional two chamber septic tank and improved urban design with three chambers is attached in **Appendix 2**. This design introduces sullage only at the third compartment. The disturbances created in the first compartment are reduced and the quality of the final effluent improves meaning the lower areas of drain fields are required. Cairncross reports that this design can probably be implemented in urban areas with a population density of up to 300 persons per km^2 and suitable drainage conditions.

Other small waste water treatment works that have been used are aquaprivies cesspools and small bore sewers. Both Cairncross (1993) and Novotny *et al.* have covered these latter technologies.

2.3.5 Rainwater Harvesting

Rainwater harvesting is generally associated with rural areas. However presentation by Otieno (1992), on the quality of urban runoff from preliminary studies conducted in Nairobi, Kenya suggests that with diminishing fresh water resources globally, rain water as a source of urban water supply should be reassessed. In the studies, Otieno shows that the overall water quality of the runoff water after 30 min compares well with allowable quality of effluent discharge into water bodies. This gives rise to an argument that rain water can to an extent be used to supplement the raw water in municipal water supplies.

Brand and Bradford (1991) report that migration from the rural areas of the Honduras to Tegucigalpa, the capital city, has resulted in large quasi-legal settlements on the city fringes called *barrios*. The property titles are either non-existent or at best disputable. Thus the *barrios* cannot petition for public services such as water and sanitation services. Water vendors sell water in these low-income areas in excess of ten times the price charged by the municipal water supply. The *barrios* are dependent on rainwater as their primary water source. Brand and Bradford outline low-cost rainwater harvesting system to catch roof runoff, which is channelled through a gutter to a downpipe into a barrel. Different materials and methods are compared. Various problems such as pollution from animals and birds, open versus closed storage tanks, stagnant water pooling, and erosion potential from overflowing harvesting systems during exceptionally heavy rains are discussed.

Gurusamy-Naidu and Gould (1993) report that due to Botswana's flat topography and sandy pervious soils, the availability of surface water sources is limited and generally inappropriate for in water supplies. They consider the use of rainwater as a supplementary water source. Although the use of formalized rainwater catchment systems in Botswana, such as roof catchment tanks, supposedly dates back to the turn of the century, its capacity was limited because of poor design. Gurusamy-Naidu and Gould discuss the enormous potential of an improved and extended rainwater catchment system in urban Botswana. Estimates of roof runoff supply of housing stock and government buildings in Gaborone emphasize the need for rigorous implementation of a rainwater catchment programme. They also look at the problems of water quality and discuss computer-aided design (CAD) and the limitations of computer modelling.

Rain water would seem to have a potential to at least supplement existing water sources in urban areas. The technology involved thus need to be shared in the developing countries for successful implementation.

2.4 Urban Water Supply, Environmental Sanitation and Information Technology in Developing Countries

Myburg (1994) defines a database as an organised collection of related information that is stored. The database is made up of individual records which in turn hold individual files or folders each with a unique label. In an computer database, this label maybe in a form of a record number representing a unique item of information. Myburg further categorizes databases into four types i.e bibliographic, full text, numeric and referral.

Bibliographic databases are defined by Myburg as collection of related records that contain information about original information source such as articles, reports, books and conference proceedings. The database does not contain the article itself but such information as author, journal title, year and number of pages contained. It may also include a summary or abstract of the article itself and an indication of where the article may be found.

Table 2.17: Comparison between CD - ROM and online databases (Myburg, 1994)

Characteristic	CD - ROM	Online
capacity	600 megabytes of data. jukebox drives can offer more	hundreds of gigabytes
information currency	information on a CD-ROM is at least two weeks to a month old.	Information is as old as the database is updated.
costs	charged as annual subscription and cost of the disk.	Pricing is dependant on number of references retrieved, number of pages printed, viewed or downloaded, connection time and telecommunication cost
response time	related to type of data held and the hardware used.	related to type of data held and the hardware used.
operation time	unlimited	may be limited
equipment required	CD- ROM drive	terminal and hardware with communication capability. Appropriate software.

Myburg further defines **full text** database as a collection of complete texts of documents. The user has access to the complete document. **Numeric** databases contain figures and numbers which can be used directly or be manipulated within the database for the purpose of modelling. These are also known as databanks. **Referral** databases on the other hand provide information on people and their skills, companies and their activities, and at times properties of other databases. Such databases can for example be used to for names and backgrounds of experts in a particular field.

Modern electronic databases tend to be either on-line or off-line. The off-line versions are usually produced on CD-ROMS and are updated on regular intervals say annually, semi annually etc. Myburg compares online databases with CD-ROM based databases in Table 2.17. It may be noted that whereas one has to keep replicating information in a CD-ROM based database, it needs not be the case with online based systems. This has an effect of making CD-ROM based databases more expensive to run than their on-line counterparts.

The Internet as defined in **Chapter One** has come into vogue in the last four years. It is also increasing rapidly in size. In 1992, there were 10 000 networks that made up the Internet. By August 1995, the figure was estimated at around 30 000 and predicted to reach 100 000 in the year 2 000 (Wilson, 1995). One of the main reasons for the speed at which the Internet is growing is the ease of connection. In countries with Internet connectivity, entrepreneurs saw a business opportunity and established their own computer networks called *local providers*. Most cities in the USA now have local providers that charge a fee for unlimited access to the Internet (Engst, 1994). If there is no local provider available, long distance phone charges are the biggest cost element of Internet access.

The Internet has several applications. Wilson (1995) summarises the major applications of the Internet below:-

Electronic Mail (e-mail)- E-mail was one of the original applications created for networks. Very simply, it is the direct transfer of typed messages to any person with access to the Internet. E-mail allows almost instantaneous delivery of messages across the world. A further advantage of e-mail is that one can retrieve and reply to messages at leisure. Use of e-mail (and most of the other Internet based resources) has an environmental implication in that the amount of paper needed for information transfer is reduced. Different e-mail systems have various useful functions. Some systems have a *talk* feature allowing users to instantaneously see what the other person is writing and respond. Other systems can attach data or image files to the message. *See-you-see-me* feature of the E-mail enables instantaneous audio-visual communication between two persons. *Internet Relay Chat (IRC)* enables more than three people to hold an *electronic conference* where all the participants can view what each one of them is typing into the computer.

File Transfer Protocol (FTP) is one of the most useful applications in the future of the Internet. FTP is used to transfer files or programs from one computer to another relatively quickly. This application is particularly useful because it allows the transfer of files across machine and language barriers. Each network around the world usually has a list of files or programs available to the public. Using FTP, the user can copy any file to their computer or send files to a remote computer. Examples of the files that can be copied using FTP include executable programs, data files, or even image files.

Telnet is a simple application used exclusively for logging on to remote networks Telnet allows connection to any network around the world, however, each network usually has a security password that only permits guests limited access to its resources.

Usenet Newsgroups - are round tables of dialogue being discussed on over 11 000 topics. The exchanges of information, called strings, start with a *posting* being made and the multiple responses to it. Most discussions are completely interactive. Some newsgroups are not interactive, however, and only provide periodic updates to the related topic. Since there are over 11 000 newsgroups in existence, most users subscribe to only a few. As the need or desire arises, new groups are created almost daily.

Discussion Groups are often referred to as listservers or mailing lists. Discussion groups are written exchanges using e-mail which are either moderated or unmoderated. A list owner will invite people to join their list and any messages that are sent to the list will be copied to all subscribers across the world. This application allows for open discussions on many topics with people of varying backgrounds and experience. These discussion groups can keep the user up to date on certain practices or give the opportunity to capture ideas from experts in a particular field.

Search Engines - The Internet is so large that people do not know where to look for information. Networks around the world have vast quantities of files available for FTP but organization and indexing has been a problem. The engines allow for searches by keywords in the title or sometimes in the file itself. However, these searches have several drawbacks. Unless the keywords happen to be in the title, the search will not find the desired files. Also, the searches can take extraordinary amounts of time if the criteria is not specific enough.

Gophers are simple text based information browsers. They do not support formatted text or images. However, gophers have been in operation for a long time thus the most comprehensive sites on the Internet are gopher sites. They are precursors to the present WWW (see below).

World Wide Web -The World Wide Web (WWW) is an advanced system for accessing documents containing styled text, images, and sound over the Internet (Engst, 1994). The most distinct feature of the WWW is its use of hypertext and hyperlinks. Some words in a document are marked, and each marked word has a link to another document or resource - which may physically be located thousands of kilometres away at another computer. Yet, the user can smoothly move between these documents without concern about their physical location. The new document will also have links which will lead to another document. The term *surfing the Net* refers to following paths of links information through the WWW. The advent of the WWW makes it possible to provide easy access to a common pool of information. WWW documents contain information that includes photographic images from weather satellites, music, real time movies, or simple text files. The WWW allows a user to access the *home page* of a network which is the starting point to access other hypertext documents. By following different paths, desired information of all sorts may be found.

The proposed information server was mainly but not exclusively based on the World Wide Web.

Austin (1995) has identified three problems associated with the use of the Internet. The access of information on the Internet can be slow in some countries and more so if the hardware in use is outdated. Hardware in this case may include overloaded communication line. Computer viruses can easily be transmitted via the Internet. This happens when files are downloaded from the Internet. By far the most compelling problem on the Internet has been that related to security of information in the computer networks. Internet has made it easier for computer hackers to breach the security of computers that are connected on the Internet. A temporary measure being undertaken is to use *firewalling* computers to ensure information security. However, these measures are thought to be inadequate.

Table 2.18: Number of host computers in different regions of the world as of October 1995 (Reuters, 1995)

Region/ Country	No. of *host* computers
USA	3 400 000
Western Europe	500 000
Asia and Pacific Rim	400 000
Africa	27 100
Middle East	13 800
Central & South America	16 000

Austin (1995) asserts that most Internet users are in developed countries. Reuters (1995) reports the low number of Internet *host computers* in developing countries. Table 2.18 shows the estimated number of Internet *host computers* in the world. Reuters (1995) attributes the low level of Internet related activities in developing countries to low income and high level of illiteracy. High cost of computers is also to blame. This high cost is partly attributable to governments' high taxes on imports. Reuters warn that this lack of access to the Internet by developing countries could lead to a new form of poverty referred to as *information poverty*. This form of poverty is likely to deprive developing nations access to a large reservoir of information accessible through the Internet and necessary for the development of these countries.

In recognition of the dangers inherent in the developing countries' inability to link on to the Internet, the international community is in various ways attempting to help developing countries to link up. Parker (1995) reports of the initiative by a group of potential donors such as UNDP and USAID to channel about US $ 60 million to help improve Internet access in developing countries especially in Africa. International Development Research Council (IDRC) is currently undertaking a similar project in poor Asian countries by the name Pan Asia Networking programme. A pilot project has been started in Mongolia.

Chapter Three

Construction and evaluation of the Prototype information server on the Internet.

This chapter describes the methodologies used to create a prototype information server on the Internet. This prototype information server was intended to simulate on a lower scale the operation of the complete information server when fully operational. The prototype was evaluated to test its potential ability to carry out its objectives as outlined in **Chapter One**.

3.1 Construction of The Information Server

The proposed information server was mostly but not exclusively to be based on the WWW. The server was proposed to form a database that was a mixture of full text, data base and a referral system. However, all the information was to be held by different computer networks around the world. The WWW offered a form of electronic publishing in which all the networked information could be retrieved. The WWW offered the advantage of the fact that grahical representations and diagrams could be used. Other character styles associated with wordprocessors such as bolding, Italicizing, etc could also included on the server.

In order to evaluate the usefulness of the proposed server, a prototype information server was constructed on the Internet containing a microcosm of the expected information on the complete server.

3.1.1 Data Collection

In order to construct the information server, consideration had to be given to the type, quantity and quality of information neccesary. The information specific to the needs of various end users was surveyed in assessing the type of information for inclusion in the proposed server. This information was assumed to be found within the developing countries. The likely end users were identified to be consulting engineers, water authorities, municipal authorities, engineering contractors, government bodies, urban communities, non governmental organisations, researchers and research agencies, and aid organisations. Due to time limitation, only one kind of each identified end user was interviewed. **Appendix 3** gives the breakdown of organisations surveyed. The survey was done through e-mail, face-to-face and telephonic interviews. These percieved needs were summarised in the Table 3.1.

Table 3.1: Information needs of various end users in water and sanitation sectors of developing countries as determined by interview.

End user	Information needs
consulting engineers	- design standards for projects in various countries - design methodologies adopted in various projects. - approach to feasibility studies in the water and sanitation sector - effluent disposal criteria and standards in different countries - applicable drinking water standards in developing countries - raw water quality in different countries - new methods, chemicals, equipment and techniques in water and waste water treatment.
water authorities	- policy and institutional issues. - project funding sources. - regulatory legislations on water quality in force internationally. - international trends in water treatment
municipal authorities	- policy issues in urban water supply and wastewater disposal. - policy issues on water and sanitation in peri- urban areas and informal settlements.
engineering contractors	- information on innovations in water supply construction technology. - pre-qualification requirements for international tendering processes - details of upcoming contracts with a view to bidding
government bodies	- potential sources of funds for new projects in water and sanitation sector. - impact of water and sanitation projects on development.
urban communities	- information on the state of their environment - information of conformity of their aquatic environment with the international standards e.g WHO guidelines for drinking water qualities.
non governmental organisations	- social implications of presence/absence of adequate water supply and sanitation.

Table 3.1: Information needs of various end users in water and sanitation sectors of developing countries as determined by interview.

End user	Information needs
researchers and research agencies	- researchers need to be kept abreast of developments in the field. Thus new findings, papers etc would be in need - there is a need to be informed of conferences and other forua in which researchers can present their findings. - a neccesity to bridge the *grey literature* coming out of the field with the research that is in the mainstream scientific publications.
aid organisations	- identification of potential needs of communities in developing countries in water and sanitation sector - comparison of parallel technologies in order to assess whether they are getting the best/most out of their money. - need to secure the cheapest and the most appropriate technology for the projects may be funded by these organisations.

Various options for data collection use in the information server were considered and briefly tested as follows:-

1. A request was circulated in water and environmental listservers on the Internet. People/organisations with information on water supply and sanitation in developing countries were requested to volunteer the information. A copy of the original information request is attached as **Appendix 4**. A list of the listservers contacted is also included. Information on the following areas was sought:-

   (i) research
   (ii) case studies (successful and unsuccessful)
   (iii) reports from funding agencies
   (iv) sociological issues
   (v) evaluation of treatment processes
   (vi) training resources
   (vii) bulletins
   (viii) equipment
   (ix) aquatic environmental quality
   (x) water quality legislations

   The results of this blanket call for information were mixed. Generally, members of the particular mailing lists (listservers) were willing to provide the information required.

However, the information sources were not in electronic form. This information also tended to be scattered such that making links to each of the bit of information would make the proposed information server unwieldly with many link to sources that do not contain extensive amounts of information. This approach was also found to be unrealistic because in practice, the manager of the information server would not have any control over the information entered in the linked pages.

2. A search on the WWW was conducted in November 1995 using four search engines namely *Alta Vista*, *Lycos*, *Infoseek*, *Webcrawler* and *WWW worm*. None of the search engines yielded information that was considered to be of value to the water and sanitation sector in developing countries. Moreover, the search terms used such as water, sanitation, and developing countries yielded a large number of irrelevant sites and articles. Search results are summarised in Table 3.2 .

Table 3.2: Results of information search using search engines

	Search engine and number of hits				
Search Term	Alta Vista	Lycos	Infoseek	Webcrawler	WWW Worm
Sanitation	10 000	800	< 100	30	6
water + sanitation	10 000	700	< 100	9	0
water + developing countries	10 000	300	< 100	0	0
sanitation + developing countries	10 000	400	< 100	0	0
water + sanitation + developing countries	30 000	400	< 100	0	0
total number of relevant hits	0	0	0	0	0

An interim conclusion could be made that either very little information was available on the WWW or had not been indexed efficiently. It may be pointed out that once a site has been set up on the Internet, the onus is on the person maintaining the site to notify the administrators of the search engine in order for the information contained in the site to be reflected by their search engines. However, a few search engines including *Alta Vista* do not need to be notified of the web page in order to reflect it. Thus a situation arises whereby the information may be held in the WWW but may not be located using the search engines because its location has not been indexed yet hence the conclusion that possibly the information was present but had not been indexed.

3. Eight organisations with working experience in water and sanitation sector in developing countries were invited to form a collaborative partnership in which each of the organisation was to maintain its own WWW pages. All these pages were to be indexed from the proposed information server. The organisations involved were The Water Supply and Sanitation Collaborative Council (WSSCC) based in Geneva, International Association on Water Quality (IAWQ), London, International Water and Sanitation Centre (IRC) from The Hague, Netherlands, United Nations Centre for Human Settlements (Habitat), U.S.Agency for International Development (USAID) through its Environmental Health Program (EHP), The Water Research Commission (WRC) of South Africa and The Water, Engineering and Development Centre (WEDC), Loughborough, UK. A brief profile of these organisations is in **Appendix 12**.

This approach seemed feasible and was the one that was eventually adopted for data collection. Between these organisations, a large amount of *grey literature* is available. For example, in its library, the International Reference Centre has over ten thousand documents mostly *grey literature* on water and sanitation in developing countries. Thus pooled together, the information held by these organisations could be used to form a nucleus around which the information server would be created.

3.1.2 The Hyper Text Markup Language

The Hyper Text Markup Language is an encoding system which allows text, graphics and sound to be linked by hyperlinks in the document for display on the World Wide Web (WWW) (Smith and Gibbs, 1994). The HTML falls within a category of languages collectively known as Standardised General Markup Language (SGML). The SGMLs describe a set of protocols within which a particular language is to operate on the Internet. In order for any document to be set up on the WWW, it has to be set in the HTML language for compatibility with publishing on the Internet through the WWW. Thus all the documents containing information on water and sanitation plus all the other auxillary documents created to aid navigation had to be formatted in the HTML format.

3.1.3 Logic Flow and Structuring of Information in the Prototype Server

In forming the basis for a decision tree, two approaches were adopted. Originally, it was assumed that the issues affecting the water and sanitation sector could be divided into those of the rural areas and those peculiar to urban areas. This will be described as the binary approach. Eventually, this approach was dropped in favour of an approach that assumed equal applicability of issues in both urban and rural areas. This will be described as the multifaceted approach.

The scope of this project is limited to urban areas hence description of the decision tree in the binary approach will be limited to the one that applied to urban areas. The work done on rural areas is described in a parallel dissertation by Dindar (1996).

3.1.3.1 The Binary Approach

Figure 3.1 illustrates the structure of the information in the binary approach. Level 1 of the information server in the binary approach contained an introductory page with hypertext links leading to technical issues, case studies, research, software library, organisations involved in the water and sanitation sector in developing countries, online water magazines and bulletins, unindexed articles and a forum for feedback. A printout of level 1 entries is given in **Appendix 5**. Of these sections, only Technical Issues, Organisations involved in water and sanitation sector in Developing Countries, announcements, unindexed articles and the feedback forum were developed further. Level 2 on technical issues were broken down to Planning including feasiblity study, Design and Construction - Water reticulation, water treatment, wastewater treatment facilities, Process evaluation for water supply and wastewater treatment systems, Sociological issues, Environmental issues, and Environmental Impact Assessments. Level 2 under organisations was tentatively broken into various organisations coming under the headings of goernmental donor agencies, development banks and UN bodies. Level 2 under announcements had announcements on available corses on water and sanitation in developing countries at Water, Engineering and Development Centre (WEDC) through Loughbourough University of Technology in Loughbourough, UK. Under unindexed articles, a collection of various articles retrieved from the Internet through an Internet search was put. A brief description of the article was done. The feedback forum on level 2 was a self addressed form on which comments on the site could be sent. It should be noted that no feedback was ever received because the site was never made public. **Appendix 6** contains a printout of level 2 pages from the binary approach. Most of the logic branches were developed to only to the second level. It was considered unnecessary to develop this approach further. Thus, most of the branches terminates at either level 2 or 3.

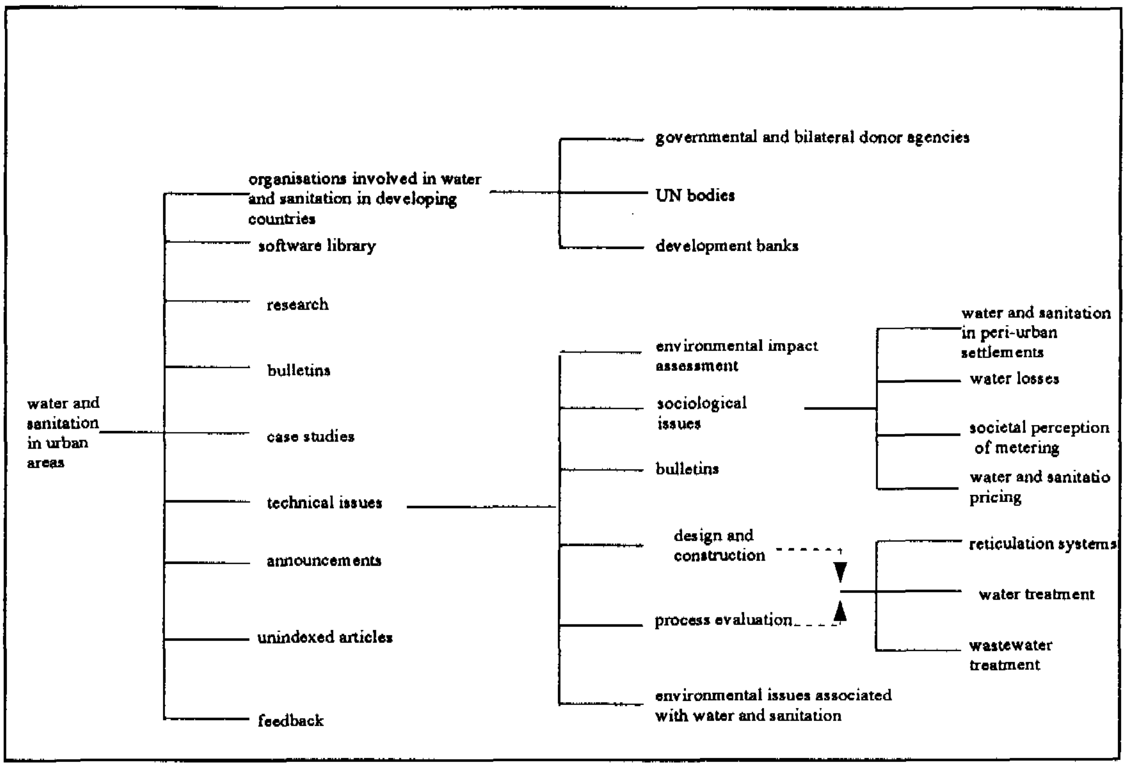


Fig 3.1: Logic flow in the binary approach of the prototype information server

3.1.3.2 The Multi Faceted Approach

The binary approach was considered to be cumbersome and inexhaustive. This was because it took several mouse clicks to follow a link before one could come to substantive information. If a person is logged on from a remote location, moving from one document to another could be very slow. Thus the Intenational Reference Centre (IRC) was contacted for professional advice. The documentalists at the centre drew up the information logic flow in a way that was considered to be more comprehensive and with a wider scope for sector issues.

Level 1 contained the main home page in English, Spanish, Portuguese and French these being some of the main languages of communication in developing countries. The translation resources at disposal also limited the number of languages that could be translated. The pages in foreign languages were not developed further due to lack of knowledge of the languages. However with time, these pages will be fully developed to accomodate the other languages. A printout of level 1 from the multi faceted approach is in **Appendix 8**. The underlined text in **Appendix 8** is the hypertext which forms a link to a document with the underlined information.

The pointers in level 2 of the English page contained recent additions to the server. This was given the acronym *what's new*. However, the addition would also be cross posted to its appropriate section. This was placed in order to guide those who would be visiting the site regularly in search of additions or developments in the sector. *From the regions* was a pointer to sector developments classified in various regions. The regions were Africa, Asia and Pacific, Central and Eastern Europe, Latin America and Caribbean, and the Middle East. Western Europe, North America and Australasia were considered to be out of the scope of developing countries. The section on *sector agencies* contained a link to various agencies working in the sector. This would include development banks, UN agencies, bilateral donors, NGOs, professional organisations, training institutes, information centres, networks and research centres. These latter categories were drawn up in level 3 of the information server. *Funding sources* was a section in level 2 dedicated to information on sources of funds in the sector. *Calendar of events* included such events as training courses, conferences, etc. *Positions available* was intended to be a listing of international positions available in the sector. *Search Indices* were tools developed to help in searching the various documents under the information server given the key search words. The logic flow in the level 2 was developed further down to lower levels as shown in Fig 3.2(a) and Fig 3.2(b).

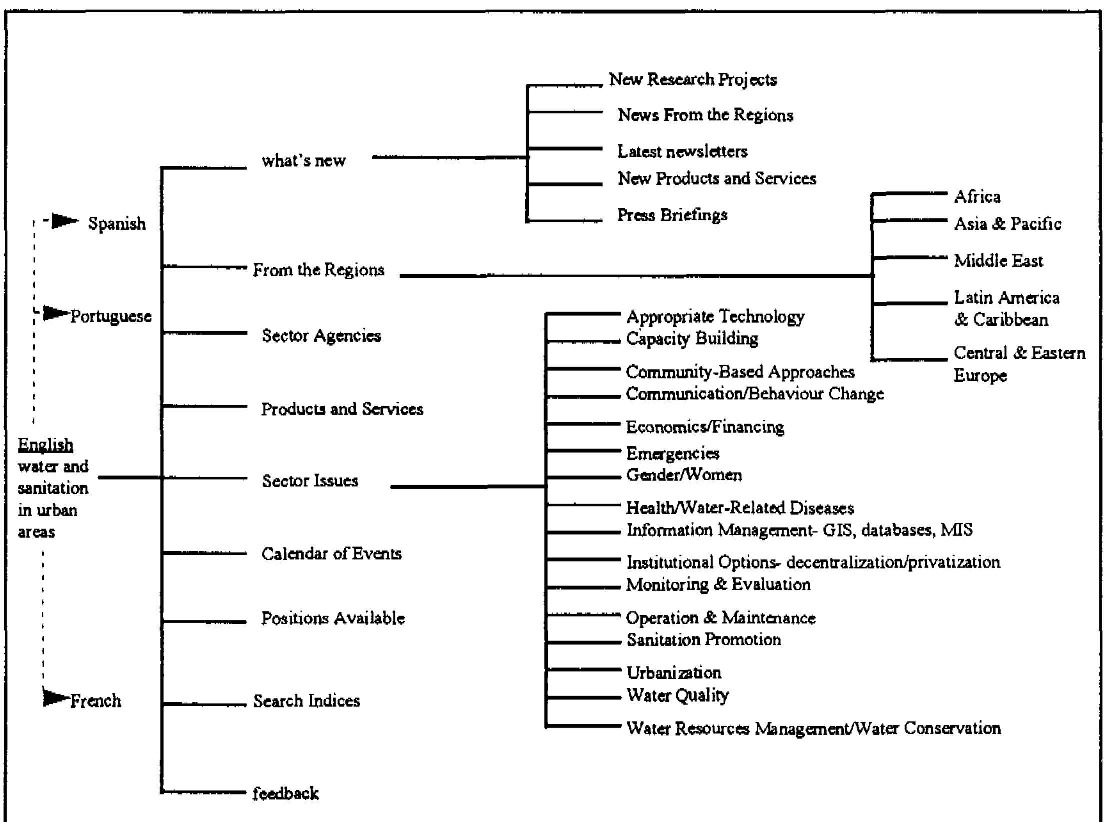


Figure 3.2(a) : Logic flow in the multifaceted approach to the prototype information server

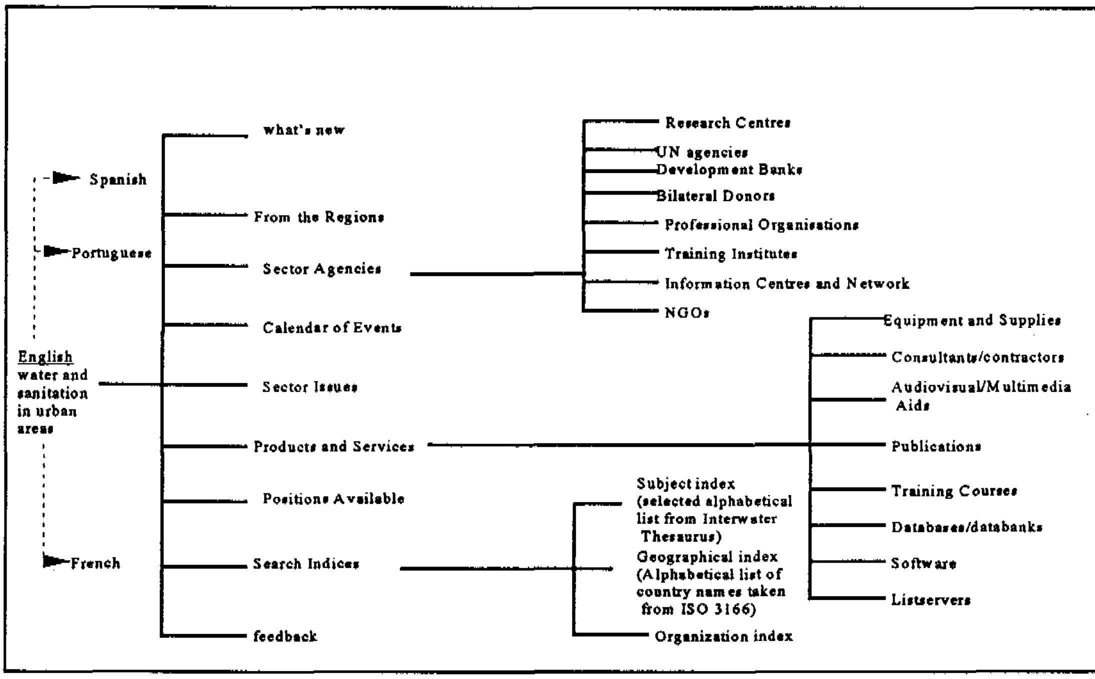


Figure 3.2(b) : Logic flow in the multifaceted approach of the prototype information server

3.2 Evaluation of the Server's Effectiveness

In order to evaluate the potential effectiveness of the server, 5 techniques were used. These techniques were considered appropriate given time limitations. Two practical problems from Umgeni Water in Durban, South Africa, and Pinetown Wastewater Works were presented through the Internet. Among the parameters sought was the speed at which feedback was received and the appropriateness of the solutions offered. Other techniques used in evaluation were facial interviews conducted with various role players in the water and sanitation sector. The use of the information server was also demonstrated at the third Global Forum of the Water Supply and Sanitation Collaborative Council in Bridgetown, Barbados in November 1995 from where a feedback from sector professionals involved with developing countries was obtained.

3.2.1 Umgeni Water: manganese and iron removal problem

Figure 3.3 shows a typical terrain encountered in design of water supply schemes in KwaZulu Natal province of South Africa. Water is to be abstracted from borehole B and pumped to the service reservoir at point A. At the bottom of the valley, power is available from the powerlines at P but not at the top of the hill on point A. Road communication is possible at the bottom but not at the top of the hill. Thus if treatment requiring power is neccesary, it is only feasible at the point indicated as PTP in Figure 3.3. Hydraulic/economic calculations indicated that construction of two pumping stations would be too expensive. Thus any possible treatment at PTP had to be under pressure if only one pump was to be used.

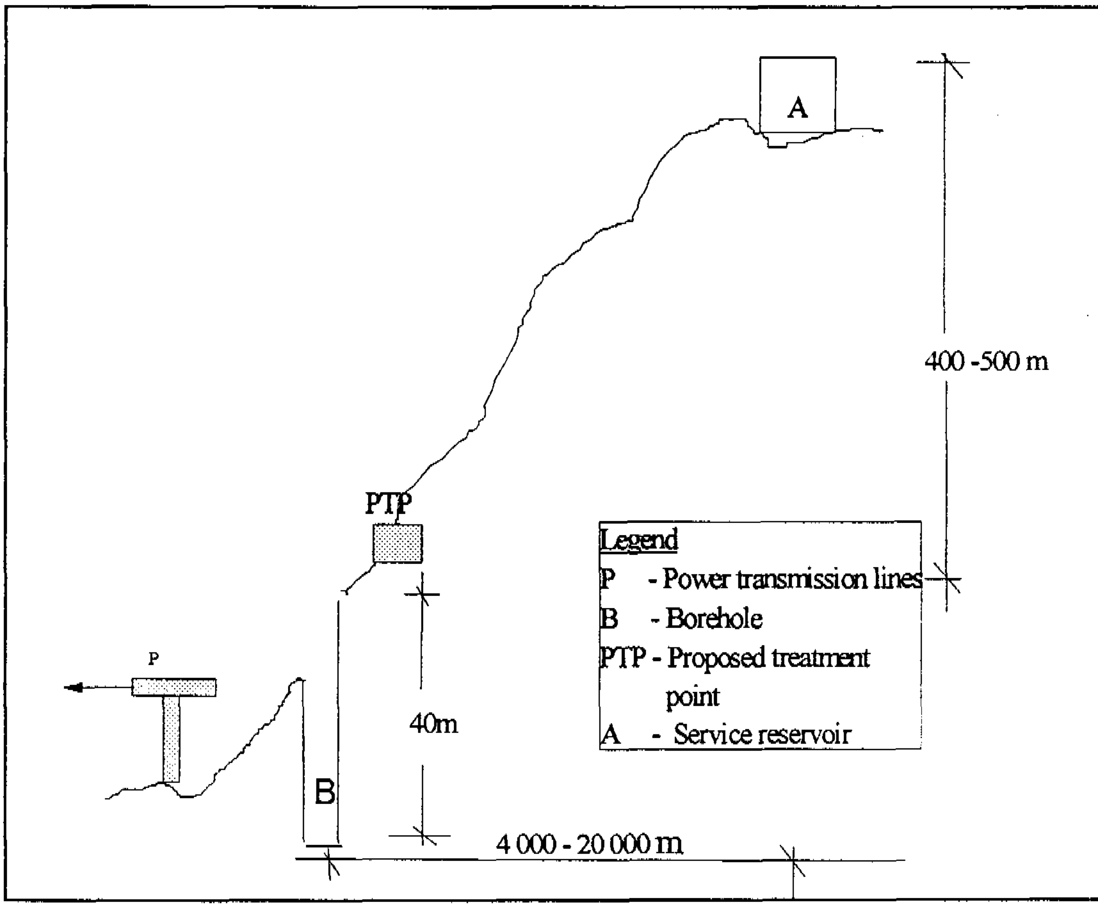


Figure 3.3: Typical terrain encountered in KwaZulu Natal, South Africa, in design of water supply projects

The Efaye - Mt. Elias water supply scheme and the Swayimana water supply scheme are two such schemes in which Umgeni Water was involved. The Efaye scheme consisted of 3 boreholes codenamed 1A, R2, and 1F in addition to surface water from Makeni river. These boreholes were projected to have a safe yield of 15, 6 and 8 m^3/h respectively. The Swayimana project was sourcing its raw water mainly from surface water sources. A borehole at Mazinganya was also to be used with a projected safe yield of 26 m^3/h with a daily pumping period of 10 h. Both projects were sampled at various times between 1993 and 1995. Table 3.2 gives a summary of the results of tests conducted on the boreholes and the corresponding Umgeni Water and WHO drinking water standards.

Table 3.3: Iron and manganese levels in waters sampled at Mazinganya borehole and Efaye - Mt. Elias water supply scheme in Kwa Zulu Natal, South Africa between May 1993 and July 1995 (Umgeni Water(a), (b), 1995).

	1st test	2nd test	3rd test	4th test	5th test
manganese levels in mg/l					
Umgeni Water standards	**0.05**				
WHO standards	**0.50[a]**				
Maziganya borehole	0.30	0.06	0.37	0.52	-
borehole 1A	0.54	0.51	0.47	0.48	0.52
borehole R2	0.06	0.01	-	-	-
borehole 1F	<0.01	0.01	<0.01	<0.01	-
iron levels in mg/l					
Umgeni Water standards	**0.20**				
WHO standards	**nc**				
Maziganya borehole	1.21	0.29	-	0.39	-
borehole 1A	0.86	0.82	0.78	0.84	0.39
borehole R2	0.59	0.19	-	-	-
borehole 1F	0.11	0.04	0.20	0.22	-

a - WHO recommends a maximum level of 0.5 mg/l for health reasons and a level of 0.01 mg/l for aesthetic reasons

nc - no criteria is available for health grounds. Otherwise a maximum level of 0.3 mg/l is recommended for aesthetic reasons.

Bacteriological examination revealed no faecal coliform present while other tests indicated low levels of various inorganic metal ions. Full results are given in **Appendix 10**. From these tests, it was found that iron and manganese were in excess of the maximum allowable levels using the Umgeni Water drinking water standards. Ideally, it would have been possible to aerate the water in order to oxidise iron II to iron III which is more insoluble, then precipitate. Alternatively, the pH value of water could be increased to precipitate iron. The same principles could be used for manganese removal. This aeration would have necessitated pressure break at point PTP in Fig 3.3 and hence impractical. Bleeding in air through the pump's impeller was not possible because the pump could be submerged up to 20 m in water. Given the high pressure through which the water was being pumped, the flow into the reservoir could be adversely affected because air under pressure would expand on release at the reservoir inlet.

Whereas the raw water quality of the boreholes was within the recomended levels using the WHO standards, the more stringent Umgeni Water standards required some form of treatment for the water to remove iron and manganese. The treatment options available all required either pressure breaks or supply of power at the top of the hill ie point A in Fig 3.3.

A message was sent through the Internet to WENDY partner institutions. The message requested for information on simple methods of pH correction that can be used on the rising mains under pressure, information on dosing systems that do not require electricity, and information on greensand filters and other simple methods of iron and manganese removal in the field. From the level of response to the query, an interim conclusion on the effectiveness of the use of the Internet in the sector could be made. The original message is given as **Appendix 13**.

3.2.2 Water Supply and Sanitation Collaborative Council: The role of the Internet in dissemination of sector information in developing countries

Given the nature of the Water Supply and Sanitation Collaborative Council (see **Appendix 12**), it was thought to be an ideal forum at which the potential effectiveness of the server could in principle be put to test. The council's Third Global Forum on water and sanitation was held in Bridgetown, Barbados in November 1995. An audio-visual presentation to the councils plenary session on the project was done. A live demonstration of the prototype information server was given throughout the length of the conference. From the presentations and demonstration, a feedback from sector professionals involved in developing countries was obtained.

3.2.3 Environmental Health Project

Of those organisations chosen as partners in the WENDY project, EHP was unique because it is a quasi bilateral donor agency and at the same time an organisation that was providing technical services in the water and sanitation sector of developing countries. Due to its unique nature, EHP was chosen from the partner institution to give a feedback on what the organisation perceived to be the role of the Internet in the sector in general and the role of the proposed information server in view of the capabilities of the prototype. The comments from this organisation were used in the evaluation of the information server.

3.2.4 Pinetown Wastewater Treatment Works: Problem of *Norcadia spp* Bacteria Disinfection

Pinetown Wastewater Treatment Works is a medium wastewater treatment works in Durban, South Africa. About 20 000 m^3 of waste water is treated per day. The effluent received consists of approximately 60 % domestic waste water and 40 % industrial effluent. The industrial effluent received is mainly from textile, electroplating and dairy industry. The treatment uses biological trickling filters for its secondary treatment in one plant and activated sludge process in the other. Anaerobic sludge digestors are used for sludge stabilisation. The digestors use methane produced as a fuel to keep the temperatures at around 37 ° C at which optimum degree of digestion occurs.

The staff at the plant have access to the Internet and have used it previously to compare the threshold levels of methane emission allowed internationally for comparison with the emissions from their anaerobic processes. The staff had also downloaded a copy of the South African government's white paper on sanitation. The paper was accessed through the WENDY prototype information server. E-mail is also used by the staff at the treatment works.

The treatment plant has been having a problem with flocs formed by *norcadia spp* bacteria. The influent waste water from dairy industry creates conditions that encourage the growth of *nocardia spp* bacteria. These bacteria form a scum that occasionally clogs the system. In order to overcome the problem, the staff at the water works have been disinfecting the waste water with chlorine before treatment. However, of late, chlorine does not seem to remove the bacteria completely. Moreover, the dosages of chlorine required to obtain a certain level of disinfection seems to have increased although there has been no change in the quality of the influent raw sewage. This has had an effect of increasing the cost of treatment.

The prototype information server had a list of various water and environmental related electronic mailing lists *(listservers)*. An environmental engineering listserver was picked from the *products and services* section of the prototype information server. A request for information on alternative means of disinfection the *nocardia spp* bacteria was sought from subscribers in the list. From the response, a conclusion on the effectiveness of the information server was made.

3.2.5 Scott Wilson, Kirkpatrick Consulting Engineers

Scott Wilson Kirkpatrick Consulting Engineers is an international firm of Civil Engineers with offices in Durban. A live demonstration of the prototype information server was performed to the consultants in the firm. It was noted that the only Internet facility used by the firm was e-mail which was limited to the computer staff. It was also noted that the firm was not involved in low cost to intermediate technology although there was a desire by the firm to consult in that direction.

Chapter Four

Results and Analysis of Review of the Information Server's Effectiveness.

Five approaches described in **Chapter Three** were used to evaluate the effectiveness of the information server on water and sanitation in developing countries. This chapter describes the results of these approaches to the evaluation. In all, solution to two problems encountered in the field were attempted using the server as a means of acquiring the necessary information. Theoretical solution to one of the problems was compared with the solution found through the information server. One facial interview and one over the Internet were conducted with role players in the sector. Another approach was an exhibition at an international conference on water and sanitation in developing countries. The chapter also analyses the results of the various results obtained.

4.1 Umgeni Water: manganese and iron removal problem

Umgeni Water had encountered various problems with manganese and iron during the course of their operations as described in **section 3.2.1**. The problem was circulated to the partner institutions participating in the information server project. Within 24 h, it had been established that the problem of excess iron in drinking water had been experienced in India, Sri Lanka and Bangladesh. However, in those countries, manganese was not experienced as a problem. The lessons though learnt using iron have a scope for adaptation for use in manganese removal. The rest of this section describes the pathology of the Sri Lanka/Bangladesh problem and the recommended solutions. Unless otherwise stated, all the information was obtained from the WENDY partners in response to the request in mentioned in **Section 3.2.1**.

4.1.1 Background to the problem

The WHO standards for portable water quality state that an iron level of 0.3 mg/l is the highest desirable level and that 1.0 mg/l is the maximum permissible level. The Umgeni Water potable water quality standards allow a maximum iron level of 0.2 mg/l. There are no direct health risks associated with the iron content levels usually found in groundwater, and the human body appears to require between 5 and 6 mg of iron per day. It should, however, be noted that iron bearing waters, particularly from shallow wells or reservoirs, can be carriers of micro-organisms, e.g. *Crenothrix*, which apart from clogging well screens and other equipment can have a detrimental health impact. Iron in water becomes objectionable because of its taste, clogging in taps, pipes and staining on clothes and stickiness in the hair. This clearly has an effect on the users' acceptance of the water. Badly affected supplies can have the effect of forcing the users to abandon an otherwise good and safe supply for a heavily contaminated and unsafe one (CarlbroInternational Consulting Engineers, 1986).

Most groundwaters contain some iron, usually at a level below 5 mg/l, but concentrations up to and above 15 mg/l are common. High concentrations of iron are associated with deep well waters from shale, sandstone and other rocks. The iron is dissolved by groundwater containing carbon dioxide but not oxygen (Domenico and Shwartz 1990).

4.1.2 Chemistry of iron bearing water

Two kinds of iron commonly occur. One type is the ferrous ion (Fe^{2+}) and the other is the ferric ion (Fe^{3+}). Iron in the ferrous state is colourless, highly soluble and unstable in air. When iron in the ferrous state is exposed to air it changes to the reddish coloured, insoluble ferric state. It is this reaction which causes the problem of iron in water because the ferric iron (commonly known as rust) is precipitated out and onto clothing, valves and pipelines.

The following reactions occur in ground waters:-

In low oxygen conditions as experienced in ground waters, insoluble ferric oxide (from iron bearing rocks) is reduced to the more soluble ferrous oxide.

$$2\,Fe_2O_3 = 4\,FeO + O_2$$

Ferrous oxide is dissolved by carbon dioxide containing water.

$$FeO + CO_{2(aq)} = FeCO_3$$

On exposure to air, the soluble carbonate is then oxidised to form ferric hydroxide.

$$2FeCO_3 + 3H_2O + \frac{1}{2}O_2 = 2\,Fe(OH)_3 + 2CO_2$$

The above reactions are typical although the actual reactions will depend on the exact nature of the iron compounds and the particular method of oxidation. The chemical characteristics of the water and the varying nature of the iron compounds can complicate the removal of iron. Ferrous bicarbonate, for example, can be precipitated by aeration alone as long as the pH of the water is 7 or above. If the pH of the water is below this and is later used with soap for washing clothes, the higher pH caused by the soap will precipitate the remaining iron and stain the clothes. If the iron is combined with e.g. manganese or organic matter, it is more difficult to remove and may require a catalytic oxidation action or a pH adjustment of the water to bring the iron levels to within WHO standard. Biological activity, for example supported by humic acid, has been found to interfere with iron removal by creating reducing conditions in a slime layer at the surface or in the filter medium itself. These reducing conditions can lead to re-absorption of precipitated iron into the water and the consequent reduction in removal efficiency.

4.1.3 Suggested solutions

Carlbro (1986) suggests there are three basic methods of iron removal i.e ion exchange, chlorination-filtration and aeration-filtration. Several highly specific methods, such as the

Variate method which involves the in-ground treatment of the water by pumping compressed air into the aquifer, have also been used.

(i) Ion exchange requires a high level of skills in operation and maintenance. It can thus not be classified as a simple treatment method. It is most suitable for water with an iron concentration below 5 mg/l.

(ii) Chlorination-filtration involves the oxidation of the iron from ferrous state to the ferric state by chlorine.

$$2Fe^{2+} + Cl_2 = Fe^{3+} + 2Cl^-$$

Chlorine can be fed into the water in much the same way as is done in conventional units and the ferric precipitate and dead iron bacteria are then filtered out by gravel beds. Chlorination is an effective means of eliminating groundwater bacteria and has the advantage of disinfecting the water supply and providing bacteriologically safe water. If the iron content is well above the 20 mg/l level, chlorination-filtration is usually considered the most effective and dependable method. It should be note that regardless of the bacteriological quality of the raw water, Umgeni Water drinking water requires that all the portable water be dosed with a minimum level chlorine to produce a residual chlorine level of up to 1 mg/l.

(iii) Oxidation-filtration is probably the most suitable method where simple removal technologies are required. Simple iron removal plants of the oxidation-filtration type generally involve a spray or slotted screen type aeration followed by a succession of gravel beds which serve to filter out the iron precipitate. A sedimentation chamber is sometimes used between aeration and filtration to trap some of the iron and thereby reduce the loading on the filter. For effective sedimentation, a retention time of at least 1 to 2 h is required. For the Mazinganya borehole, this would translate to a sedimentation tank of between 26 and 52 m^3 in volume (diameters of between 2.5 and 4 m assuming a height of 2 m). This retention time can be obtained by suitably modifying the service reservoirs to work as clarifiers. Boreholes 1A, R2 and 1F would require smaller sizes of sedimentation tanks (Carlbro International Consulting Engineers, 1986).

The aeration, oxidation and filtration option was thought to be most suitable for simple iron removal and is developed further here.

4.1.3.1 Aeration and Oxidation

The oxidation is achieved either by aeration alone or in combination with catalytic contact bed action. The method chosen depends on the degree of iron removal required and the chemical characteristics of the water and iron compounds. Aeration alone is particularly suitable for water with a pH of 7 or above provided that the iron is free of organic matter and without a significant presence of manganese. However, this was not the case with the waters sampled by Umgeni Water because there was significant amount of manganese present and the pH was below 7 (see **Appendix 10**).

As relatively little oxygen is required to oxide the iron (only 0.14 mg/l of oxygen is needed to oxidise 1.0 mg/l iron), convenient and enclosed units can be used. Spray and slotted screen type aerators are commonly incorporated into such units. Further aeration takes place if the water is allowed to trickle down gravel filtration beds designed to retain and filter out the iron precipitate.

The purpose of contact beds is to facilitate the oxidation of iron through the catalytic action of previously precipitated oxides on the gravel or specialized filter medium. The conditions for this process occur spontaneously as the iron precipitate is filtered out and coats the gravel. To speed up the oxidation of the iron or manganese, chemicals such as potassium permanganate are often are dosed so as to initially coat the media. These types of beds have the advantage over non-regenerative filters in that backwashing and the removal of accumulated iron deposits is considerably easier. However, the extra complication and provision of chemicals precludes them from use as simple solutions. Many non chemically regenerative filter materials require very vigorous backwashing to *shake* the iron deposits loose from filter material.

4.1.3.2 Iron Bacteria

Iron bacteria are present in almost all groundwater that contain iron. They can be defined as that group of bacteria which appear to utilize the oxidation or reduction of ferrous and/or manganese ions as an essential component of their metabolic functioning. The resultant production of ferric salts (usually hydroxides) within the cell or cell coatings give the bacteria their typical brown colouring. It is known that iron bacteria have the potential to oxidize and filter iron from groundwater.

As a result of full-scale tests on bacteriological removal of iron described by Domenico and Schwartz (1990), it was found that iron bacteria could oxidize as much as 17 mg/l of iron at flow rates of 10 $m^3/m^2/h$. The oxidation is influenced by the oxidation-reduction potential of the water and the flow rates. In a downward flow filter it was found that large improvements in the iron level takes place initially in the first portion of the bed. As deposits grow in the top layers, the flow rates, i.e. the pore-water movement, exceeds the bacterial capacity for consumption and the process moves into lower portions of the bed.

4.1.3.3 Filtration

In filtration, the following factors act in combination:- straining, flocculation, sedimentation, inert compaction, diffusion, Brownian movement, Van der Waal forces, electro-kinetic effects and bio-chemical action. Filter performance is best quantified through testing the filter medium. In the case of iron, the temperature and chemical nature of the water, the size and strength of the iron flocs and the particular type of filter media readily available on site makes in-situ, controlled pilot testing essential.

The major parameters that need to be determined in order to predict the performance of filters are the direction of flow, the size and grading of media, the depth of bed and the flow rates or area of filter. The choice of these parameters should be such as to satisfy the following requirements:

(i) The quality of effluent during the filter run should not fall below the design criteria adopted.
(ii) The head loss or reduction in discharge should not rise above the design limit, e.g. the level at which users start to reject the supply because of the delay or effort required.
(iii) A filter run interval satisfying the above constraints should also be appropriate to the maintenance system adopted.
(iv) long term filter media rejuvenation should not impose undue constraints on the maintenance system.

Iron removal units can operate with either upward or downward flow systems. The advantages and disadvantages are similar to the considerations for simple rapid gravity filters.

Filtration rates for iron removal plants vary depending on the performance required, the level of sophistication applied, the filter parameters, the nature of the water and the strength and size of the iron flocs. Filter rates cannot be theoretically predicted, only pilot studies can indicate the filter rates to be adopted in differing conditions. The results of the pilot studies for low technology plants are very limited and flow rates of between 1 and 50 $m^3/m^2/h$ are actually used or suggested for differing units and locations.

4.1.3.4 Low technology iron removal plant development

Low technology iron removal plants developed for application in developing countries have depended on aeration-filtration techniques. Early models generally depended on removal and cleaning of filter media, either in bulk or as a top layer, for rejuvenation.

One model used in Orissa, India developed for use in rural areas with hand operated pumps is described in Fig 4.1 which illustrates the prototype model as developed in Denmark.

The filter unit is designed to operate at a hand pump capacity of 0.8 to 1.2 m^3/h. The prototype is constructed in steel and is 600 mm diameter by 1 000 mm long. The unit is approximately half filled with filter media and flow is downward through the tank, and outlet water is collected via a perforated pipe under the media. The unit is thus operating as a filter with a surface area of approximately 0.6 m^2 and a surface loading of 1.3 to 2 $m^3/m^2/h$.

When cleaning is required, the filter is disconnected from the inlet and outlet pipes and rotated on the bearings shown, thus agitating the filter media and releasing the trapped

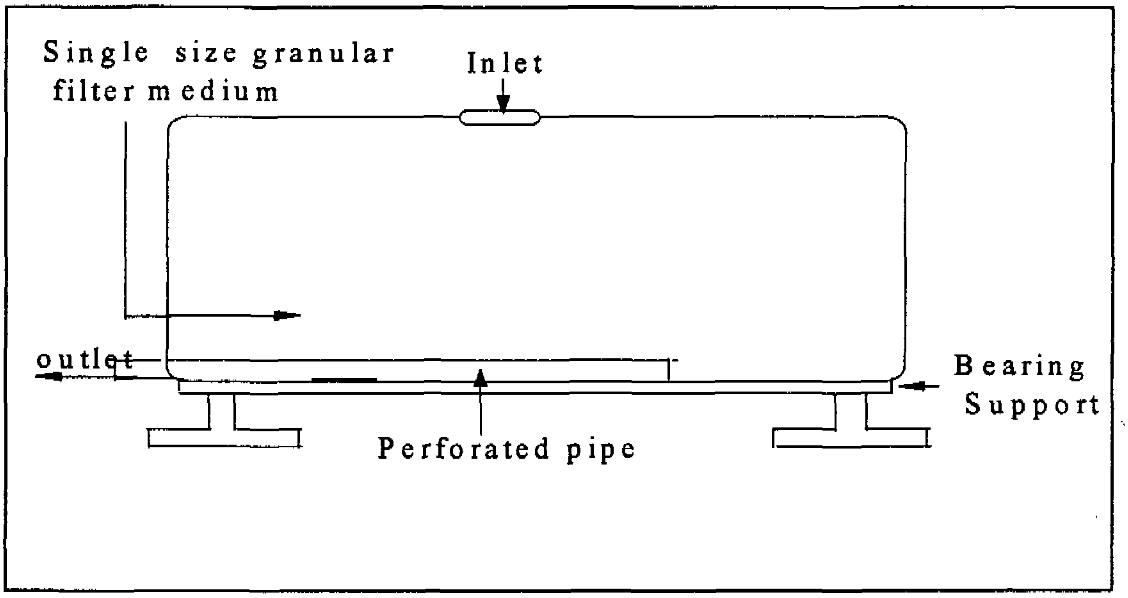


Figure 4.1: Prototype iron removal plant developed in Denmark and used in Orissa, India

iron particles into suspension. After several rotations, the *dirty water* in the filter is discharged to waste, the filter is refilled with water and the cleaning operation is repeated. Three or four such washes have been shown to remove 85 to 95 % of the theoretically retained solids without removing media or entering the unit. This mode of operation has benefits from both effort and hygiene standpoint.

The principal on which the filter operates requires use of a single size media. Various trials have been carried out with differing size media and it has been found that a media of 0.4 to 0.8 mm size results in good effluent quality and filter runs. Effluent quality of 0.01 to 0.05 mg/l of iron was obtained from a raw water level of 3.55 to 8 mg/l. Filter runs of up to 300 m^3, or 30 d equivalent hand pump supply, have been found to be possible before filtrate quality starts to deteriorate. After this length of filter run, the head loss through the unit was recorded as 0.1 m.

The unit as operated in Orissa, India was connected to an existing public water supply treatment plant in which cascade aeration was included. Some type of aeration unit would need to be connected to the filter unit to provide a complete treatment system for iron removal.

4.1.4 Extent of solution of the problem

To a large extent, the basic questions posed were not answered i.e. search for simple methods of iron and manganese removal, simple methods of pH correction and simple methods of chlorine dosing that do not require power. However, the documents provided produced a starting point in the search for solutions to this problem. Aeration combined with filtration was developed as a possible means by which the desired removal could be achieved. This is a feasible solution because aeration can be achieved at point of entry into the reservoir if the water is cascaded into the reservoir. However, filtration as suggested in Fig 4.1 would require an occasional power supply to agitate the filter unit and remove the filtrate as well as personnel possibly on a part time basis.

This problem had an initial effect of proving that in some instances, various problems encountered in the field are likely to have been encountered elsewhere. Although a complete solution was not proffered, a starting point for further development was made. An example would be development of methods of filtrate removal that do not require power or are powered by the water pressure in the pipe.

4.2 Water Supply and Sanitation Collaborative Council: The Role of the Internet in the Dissemination of Sector Information in Developing Countries

After the information sever was presented to the WSSCC plenary session (see **section 3.2.2**), the Council deliberated on the potential of the Internet in general and the information server in particular in the water and sanitation sector. Given the informal nature of the council, the Council saw an opportunity whereby its large pool of information could be shared at a much reduced cost because multiple copies need not be made. The Council recommended the information server be accepted as an official mandated activity of the council under its Information and Communication working group.

The objective of the Information and Communication working group is mobilisation for improved programme development in the water and sanitation sector through communication. It addresses social mobilisation for partnership among all stakeholders based on interest and needs of people. It implies changes in behaviour including communities and decision-makers. Communication processes which assist and stimulate behavioural changes are thus an integral part of the mobilization that is recommended. The group achieves these objectives globally through advocacy policy development and nationally through situation analysis of the country, joint programme strategy for improved programming, capacity building, learning projects on the ground, and evaluation. Thus in assigning the project to this working group, the council was defining the role of Internet in sector advocacy.

The technical publications from the meeting were to be officially located in the information server. This defined another role in which the server in particular and Internet in general could be used to report on the activities of the sector from the field and transmit it onwards to sector professionals worldwide.

4.3 Environmental Health Project

Environmental Health Project (EHP) had been consulted on their perception of the information server and use of the Internet in the water and sanitation sector. The description of the approach is in **section 3.2.3**

The EHP thought that information server initiative does have the potential to make important contributions to the sector. One role that EHP saw for the server was in the coordination and sharing of information resources among partner institutions. According to EHP, each partner institution has some unique and important information resources. It was thought that the sever could serve as a focal point for the sharing and dissemination of these resources.

A possibility exists developing home pages for organisations from developing country in EHP's opinion. This could alleviate the isolation faced by researchers and organisations in developing countries.

EHP suggested that the server be expanded to include a listserver of water and sanitation in developing countries as an alternative to the Web in countries or regions, such as the former Soviet republics, that do not have Web access. It should also be noted that in Africa, only 12 countries have full Internet connectivity although majority of them are on e-mail (Reuters, 1995).

EHP thought a marketing effort is one factor that is essential for the success of information server. Use of the Internet in general and the WWW in particular is increasing fast in Latin America, Asia and other regions. The information sever is likely to become more important as Internet access increases.

4.4 Pinetown Wastewater Treatment Works: Problem of *Nocardia spp* bacteria disinfection

Pinetown wastewater treatment works was having a problem with scum caused by *Nocardia spp* forming in their plants that operate activated sludge processes during (winter months). This was thought to be due to presence of dairy waste in the influent wastewater. This problem was referred to a listserver which was to be found in ***products and services*** section of the prototype information server. This approach is described in **section 3.2.4**. This section describes the results obtained. The results are compared with solution of the problem from standard text.

4.4.1 Background information

Nocardia spp are branched filamentous bacteria belonging to the order of actinomycetes of the procaryotae kingdom. They are saprophytes commonly found in soil and possess several characteristics that make them well suited for growth in treatment plant environment. They grow on a wide range of organic compounds including recalcitrant substrates such as long chain hydrocarbons, pesticides, complex aromatic compounds and dead microbial compound. Gerardi (1990) suggests that they may be important in removal of these compounds in wastewater. The bacteria can also grow on readily degradable compounds such as sugars, amino acids and low molecular weight organic acids. They however grow more slowly on these compound than other wastewater bacteria.

Pinetown Wastewater Works were experiencing a thick layer of scum on their clarifiers during the winter months. The scum layers had been identified as *Nocardia spp* flocs. Such a scum layer interferes with normal gas exchange at the water- air interface. The scum can cover catwalks requiring additional time and expense in cleanup costs. Odour problems may also develop.

Available literature has not found any correlation between plant operating conditions and the *Nocardia spp* population. Correlations have also not been made between scum formation and pH, influent BOD, influent suspended solids, mixed liquor suspended solids, DO, organic loading or detention time in secondary clarifiers. However, *Nocardia spp* scum formation could be correlated with treatment of dairy wastes but not the influent oil and fat. *Nocardia spp* appeared after mean cell residence time in activated sludge processes exceeded 1.5 d. Another important characteristic of *Nocardia spp* is that it has a very high saturation co-efficient for heterotrophic growth (K_s) that makes it unable to compete for food with other micro-organisms. (Gerardi, 1990).

4.4.2 Response from listservers

Response was received from 4 respondents within 48 h.

(i) The first respondent suggested that ozone was a better disinfectant than chlorine. However this option was negated by the high capital and operating costs involved. It was also thought not to be feasible to put up an ozone production plant for a plant treating only 20 000 m^3 of waste a day.

(ii) The second respondent had had previous experience dealing with the bacteria. The respondent said that chlorine does not work because the bacteria float. Some type of liquid bleaches were also recommended. However, Pinetown wastewater works had been using sprays without success. It was said that vacuum trucks have been used to suck off the scum and send it to a holding pond. The respondent cautioned that the scum must not reintroduced to the mixed liquor suspended solids. Complete removal of scum was thought to be the only long term cure. He also advised to keep the mean cell resident time as low as possible. Use of vacuum trucks was thought to be practical by the plant staff in view of the volumes of wastewater treated and the fact that the problem was encountered only during the winter months requiring only temporary solution.

(iii) The third respondent had spent 7 y working in the wastewater treatment department of a large Wisconsin, USA cheese factory. He stated that *Nocardia spp* is a filamentous bacteria common to dairy wastes as it is strictly aerobic and thrives in the foam layer of an aeration tank. He volunteered to list reference material regarding *Nocardia* causes and control.

(iv) The fourth respondent suggested that application of ultrasonics on the clogged point could help unclog the system. This option was not considered further because the basic problem that was being addressed was that of *Nocardia spp* production and not the problems caused by the production.

4.4.3 Theoretical *Nocardia spp* scum control methods

Gerardi (1990) gives the following guidelines for avoiding *Nocardia spp* scum production in activated sludge processes. The control is based on the theory that unable to compete for food with other micro-organisms, *Nocardia spp* uses scum production as a means of improving on its mean cell residence time

(i) Some plants whose scum layer was sprayed with coarse water sprayers seemed to have a reduced scum production. This was not successful in all cases.

(ii) Bioaugmentation could be used. This would involve introduction of a microorganism that out competes the *Nocardia spp* for food. The bacteria should also survive the treatment environment. Additional measure would be the introduction of a micro-organism that digests the lipids excreted by the *Nocardia spp* which are responsible for scum formation. So far, this method has not been employed.

(iii) chlorination of returned sludge has been used with varying degree of success. Adequate care need to taken in order not to kill the rest of the microbial population necessary for wastewater treatment. This is complicated by the fact that actinomycetes tend to be more resistant to chlorination than most micro-organisms.

(iv) Use of defoaming agents has been found to be useful in some cases. However, the actinomycete is not eliminated in this control method.

(v) Many actinomycetes use recalcitrant hydrocarbons as a source of carbon as noted in **section 4.4.1**. These hydrocarbons are found in petroleum, fats, oils and greases. Termination of this preferred food source has been suggested a possible mean of prevention of scum formation. However, scum formation has also been reported in facilities treating wastewater lacking the recalcitrant hydrocarbons.

(vi) Reduction of pH to below 5 reduces the growth rate *Nocardia spp* to 1 % of their growth rate at pH 7. Thus, pH reduction can be used a scum control measure. It has the disadvantage of reducing the overall micro-organism population

(vii) Physical scum removal can help reduce the problem if the scum is wasted rather than recirculated.

(viii) Reduced aeration rate can also reduce the scum formation due to the aerobic nature of *Nocardia spp* bacteria. Care should be taken so as not to compromise the overall plant treatment efficiency.

(ix) Reduction of mixed liquor suspended solids has been reported in some instances to control sum production. Concentrations of between 2 000 and 2 500 mg/l have been determined to be suitable for reduced scum production. The theory assumes that the low growth rate of *Nocardia spp* puts them at a disadvantage when the substrate level is reduced. This theory seems to be negated by the fact that scum growth has been observed.

When the theoretical control methods are compared with solutions given from the listserver, it can be seen that while some are novel (use of ultrasonics and ozonation) scum removal and lowering of mean cell residence time have been suggested. However, the response from the listserver was more practical and did describe the mechanism by which the scum was to be removed.

4.5 Scott Wilson, Kirkpatrick Consulting Engineers

A demonstration of the web pages of the prototype information server was performed in the offices of Scott Wilson, Kirkpatrick consulting engineers. They engineers were asked to comment on the web page in terms of its capabilities, actual and potential as described in **section 3.2.5.**

The consultants felt that the information server was capable of providing background information on a project they had been awarded on water and sanitation situation analysis in KwaZulu Natal province of South Africa. This was likely because the server carried a section on sector developments in various developing countries of the world including South Africa. The information sever would thus be useful in comparative study of water and sanitation infrastructure.

There was a feeling that other products of the server such as downloadable software and listservers were useful. The engineers expressed a desire to have the software developed by the US Army Corps of Engineers accessible through the server. Such an effort would require liaison with US Army corps of engineers.

The consultants felt that the server could be underutilised due to lack of interest on the part of engineers in the field to use the Internet which in turn could be due to ignorance. They felt that this was a new idea and was likely to take time before its full capabilities and potential could be realised.

Chapter Five

Discussions, Conclusions and Recommendations.

This Chapter discusses the extent to which the objectives of the dissertation as set in **Chapter One** were achieved and draws appropriate conclusions. The following steps had been set out as the objectives:

(i) design of a suitable format.
(ii) identification of pertinent issues through a partial literature survey.
(iii) construction of a prototype information server.
(iv) evaluation of the server.

The corresponding recommendations for each of the conclusions are made. Scope for further work in order to achieve the overall goals and objectives of WENDY is set out.

5.1 Discussions and Conclusions

The following points are noted from the work undertaken in the dissertation:

(v) An attempt was made to identify the various issues affecting delivery of services in the water and sanitation sector in developing countries. The mechanism by which they affect the provision of clean water and adequate sanitation was explored through a literature search. These are some of the issues that are likely to improve the delivery of services in water supply and sanitation sector in developing countries if approached the right way. Information held in developing countries on these issues seems to be useful and there is a need for this information to be disseminated for the benefit of sector role players. The understanding of the role of clean water supply and improved sanitation in a country's sustainable development is important if the policy planners are to put the necessary emphasis on the sector. On the other hand, this role tends to be ambiguous and little understood. This is the type of information that would need to be disseminated through the information server and WENDY project for sector development.

(vi) Appropriate technology offers an alternative means of provision of clean water supply and adequate sanitation at reduced costs in developing countries. However, the perception in these countries is that the technology being low cost is of lower standards. Further, there is a reluctance on the part of sector professionals to pay enough attention to appropriate technology hence lower level of research in the field. The information server can play a role in disseminating the available information and level of research in appropriate technology. This might have an effect of stimulating research and development in the sector in general and appropriate technology in particular. Examples of these appropriate technology are waste stabilisation ponds, constructed and natural wetlands, improved pit latrines, septic tanks and rain water harvesting.

(vii) Two formats for use as the information server were constructed on the WWW in the Internet. Of the two, one (referred to as the multifaceted approach) was eventually adopted because it was considered to be more exhaustive. Among the features that made it more exhaustive was a subject search index based on the Interwater thesaurus and a country/regional search index based on the country listing of ISO 3166. The use of four languages though not giving total coverage, increased the geographical reach of the information server. An attempt was made whenever possible to include the information needed by various sector role players as gathered in a survey on the information needs.

(viii) Two tests were conducted to test the potential effectiveness of the information server in solution of technical problems encountered in the sector in developing countries. The first was seeking simple methods of removal of iron and manganese from drinking water encountered by Umgeni Water. The problem was circulated to partner institutions in the WENDY project. From the answer given on the problem, it transpired that the problem had been encountered before in India, Bangladesh and Pakistan. The solution offered was not complete and could not be used without modification by Umgeni Water. However, useful background information on the removal of iron was provided. Further, the report received from WENDY partners ruled out the use of compressed air in the borehole, chlorination, and use of iron bacteria as possible simple treatment options. The decision was arrived by considering the technology that was simplest, cheapest and most realistic in the field. This possibly saved Umgeni Water some resources that would have been used investigating the options further. Most importantly, the hypothesis that problems encountered in the sector in developing countries can be solved using technology that has been tested elsewhere as long as there is a mechanism for information exchange was underscored.

(ix) The second problem used to test the potential effectiveness of the information server was removal of scum caused by *Nocardia spp* bacteria in an activated sludge process at Pinetown wastewater treatment works. This problem was investigated with one of the products of the information server (listsevers) and was circulated among the sector professionals. Within 24 h, four suggestions on the ways which the problem could be solved were received. Three of these suggestions were compared with theoretical solutions and were found to be based on sound theory. Moreover, the solutions were practical and based on experience. The fourth suggestion was beyond the scope of the problem.

(x) The potential effectiveness of the server was also sought from the views of the sector professionals. The Water Supply and Sanitation Collaborative Council designated the server as a potential tool for disseminating sector news, views and information at reduced costs. Its role in sector advocacy was also stressed. Sector advocacy is a powerful method of bringing about benefits of clean water supply and adequate sanitation. However, for the WENDY project to fulfill this role more effectively, greater access to the Internet for developing countries and higher profile of the project has to be ensured.

(xi) The Environmental Health Project (EHP) saw a role of the server in co-ordination of information among partner institutions. This would ensure greater spread of the information and prevent duplication of efforts. WENDY project being located in a developing country would also be useful in developing neighbouring countries disseminate important information held through the medium of the Internet possibly through WWW pages.

5.2 Recommendations and Scope for Further Work

(i) In order for WENDY to successfully carry out its functions, it is important that it reaches a wide population as possible. This can be carried out at three levels i.e access to the Internet, use of popular languages and creation of awareness of WENDY's presence. Improving of access to the Internet in developing countries is beyond the scope of WENDY project. The prototype information server was constructed using four languages i.e English, French, Spanish and Portuguese. These were the languages for which translation resources were available. Other choice language whose use would improve the access to information held by WENDY would be Chinese, Hindi, Arabic and Russian. EHP had suggested *marketing* of WENDY as a starting point in realising the awareness about WENDY's presence. The *marketing* would be through both the print and electronic media. Further, the information server should be registered with all the known search engines on the Internet.

(ii) Priority should be given to the inclusion of available information on appropriate technology. This may stimulate research in this direction by documenting the state-of-the-art in research on the technology. The server could also be used to reach out to the sector professionals and convince them that low technology solutions require as much research and engineering as high technology solutions.

(iii) Circulation of technical problems among sector professionals through listservers proved to be an effective means of solving these problems. However, the listservers used were not specific to water and sanitation in developing countries although solutions did to related problems existed. It is recommended that such a listserver be established to discuss various issues on water and sanitation in developing countries. This could be part of the WENDY project.

(iv) Internet access in developing countries is crucial in the realisation of the objectives of WENDY. Although provision of this access is beyond the scope of WENDY, the partner institutions in the project could be used to motivate on a long term basis for donors to avail funds to increase access to the Internet in developing countries.

(v) For the information server to operate effectively as clearing house on information in water and sanitation in developing countries, the information held by the partner institutions has to be indexed in a standard manner. This would ensure a logical and uniform information flow and ultimately have an effect on the quality of information held.

References

Alabaster, G. P., Mill, S.W., Osebe, S.A, Thitai, W.N., Pearson, H.W, Mara, D. D., and Muiruri, P., Combined treatment of domestic and industrial wastewater in Kenya, *Water Science and Technology vol.* 24, 1991. pp 43 - 52

Austin, T., Engineering a place in cyberspace, *Civil Engineering,* June 1995.

Brand, A. and Bradford B., Rainwater harvesting and water use in the barrios of Tegucigalpa, UNICEF, Agua el Pueblo 1991.

Brix H., Wastewater treatment in: constructed wetlands: System design, removal process and treatment performance in Constructed Wetlands for Water Quality Improvement, Moshiri G. A, (ed), Lewis Publishers, Boca Raton, 1991. pp 9 - 23

Cairncross S. and Feachem R., Environmental Health Engineering in the Tropics, John Wiley and Sons, London 1993.

Carlbro International Consulting Engineers, Technical report on mission to assess iron removal technology in DANIDA sponsored water supply projects in Sri Lanka, Bangladesh and Orissa, India, DANIDA, Copenhagen 1986.

CSIR, A guide to the use of pond system in South Africa for Purification of raw and partially treated sewage. Special report WAT 34, Council for Scientific and Industrial Research, Pretoria, 1968.

Czinki, L., Nitrat- und phosphateliminierung mit, *Korrespondence Abwasser,* pp 440

DeKam, J., A guide for sections, councils, divisions, and committees conducting AWWA activities on compuserve or the internet, American Water Works Association, *AWWA On-Line,* Denver, 1995.

Dindar C. M., Rural Water Supply and Sanitation: Transfer of Technology through the Internet, MscEng dissertation, Department of Civil Engineering,University of Durban-Westville, 1996.

Domenico, P. A. and Schwartz, F. W., Physical and Chemical Hydrogeology, John Wiley and Sons, London 1990

Drew, R. J. C., Pond Systems for the disposal of domestic wastewater from small communities. Report No. K69, National Institute for Water Research, CSIR, Pretoria 1983.

Engelman, R. and Leroy, P., Sustaining Water - Population and the Future of Renewable Water Supplies, Population Action International, New York 1993.

Engst, A., Internet Starter Kit, Hayden Books, Indianapolis, 1994.

Ersrey, S. A., Health Benefits from Improvements in Water Supply and Sanitation: Survey and Analysis of the Literature on Selected diseases, WASH Technical Report No. 66, Norfolk 1990.

Gerardi (ed.), Wastewater Biology: The Microlife, *Water Pollution Control Federation*, 1990.

Gurusamy-Naidu K. and Gould J. E., Rainwater Catchment : Possibilities in Urban and peri-urban areas, Proceedings of the Sixth International Conference on Rainwater Catchment Systems, International Rainwater Catchment Systems ASsociation, Nairobi, 1993

Hassan A., Innovative Sewerage in a Karachi Squatter Settlement: The low cost Sanitation Programme of the Orangi Pilot Project and the process of change in Orangi, Orangi Pilot Projects, World Bank, Washington D.C. 1986.

Institute of Water Engineers and Scientists, Water Practice Manuals Volume 3: Water Supply and Sanitation in Developing Countries, Institute of Water Engineers and Scientists, London 1983.

Iwugo K., Sustainable water pollution control technology in the south - issues and options, *Waterlines*, July 1995 pp 16 -20.

LaFond, A., A Review of Sanitation Program Evaluations in Developing Countries, US Agency for International Development, 1993.

Mann, R. A. and Bavour H. J., Phosphorous Removal in Constructed Wetlands Using Gravel and Industrial Waste Substrata, IAWQ; Proceedings of the International Conference on Appropriate Waste Management Technologies, 1993 pp 107 - 114.

Mara D. D., Sewage Treatment in Hot Climates, John Wiley and Sons, Chichester 1976.

Mara, D. D. and Mills S.W., Who's afraid of anaerobic ponds? *Water Quality International, No 2,* 1993 *pp 14 - 17.*

Marks R. F., Sanitation options for Southern Africa, Proceedings of the International Conference on Appropriate Waste Management Technologies, IAWQ 1993 pp 1 - 10.

Morgan, P. R., The Pit latrine revived, *Central African Journal of Medicine*, 1977. pp 418 - 456.

Moshe, M., Betzer, N. and Kott Y., Effect of Industrial Wastes on Oxidation Pond

Performance, *Water Research No 6, 1972.* pp 1165 - 1171.

Myburgh F., An introduction to electronically available water and related information, personal communication, 1994.

Novotny V. (Ed.), Imhoff, K. R., Olthof, M. and Krenkel P., Karl Imhoff Handbook of Urban Drainage and Wastewater Disposal, John Wiley and Sons, New York, 1989.

Nusch, E. A., Poltz J., Bucksteeg, K. "Eutrostop"-eine neue alternative zur gewässersanierung? K*orrespondence Abwasser*, 1987 pp 33.

Ødegaard H., Small Solutions gaining credibility, IAWQ, *Water Quality International, 1993.* pp 20 -24.

Okun, D. A. and Ernst, W. R., Community Piped Water Supply Systems in Developing Countries; A Planning Manual, World Bank Technical Paper No.60, Washington, 1987.

Oragui, J. I., Arridge, H., Mara, D. D., Pearson, H. W. and Silva, S.A., *Vibrio Chorelae* (El Tor) Removal in Waste Stabilisation Ponds in Northeast Brazil, *Water Research No 27,* 1987. pp 569 - 573.

Otieno, F. A. O., Quality of urban runoff in Nairobi, Proceedings of the Second National Conference on Rainwater Catchment Systems in Kenya, Rainwater Catchment Systems Association, Nairobi, 1992

Overcash, M. R., Gilliam, J. W., Humenik, F. J., and Westerman, P. W., Lagoon pretreatment :heavy metal and cation removal., *Journal of Water Pollution Control Federation* No. 50, 1978. pp 2029 -2036.

Palmer Development Group, Water Supply and Sanitation in Urban Areas - Financial and Institutional Review, Water Research Commission report no. 571/1/94, Pretoria, 1994

Parker, C. D., Biological mechanisms in lagoons. *Progress in water technology* II, 1979 pp 71-85

Parker, S., The Internet and the water sector, Internal Working Paper, IRC, The Hague, 1995

Rawlin, B. K., South African water resources in perspective: a discussion on availability of safe water and sanitation facilities in the country, South African National Committe for the International Association of Hydrological Sciences, Proceedings of the Seventh South African Hydrology Conference, 1995. Disk 6.

Reddy, K. R. and Debusk, W.F., Nutrient removal potential of selected aquatic macrophytes, *J. Environ Qual*, 1985

Reddy, K. R., Patrick, W. H. and Lindau, C. W., Nitrification - denitrification at the plant root sediment interface in Wetland, *Limonol. Oceanogr.* 34, 1990 pp 1004 - 1012.

Reuters, Third World Faces Information Poverty, 12th October 1995.

Serageldin, I., Water Supply, Sanitation and Environmental Sustainability; the Financing Challenge,The World Bank Washington D.C., August 1995.

Smith, R. and Gibbs, M., Navigating the Internet, Sams, Indianapolis, 1994.

Taylor, K., Training resources on the internet, *Environmental Protection,* May 1995.

Walsh, J. A., Estimating the Burden of Illness in the Tropics, McGraw Hill, 1990

Water and Sanitation For Health Project, Lessons Learned in Water, Sanitation and Health, US Agency for International Development, Washington D.C., 1993.

Water Research Commission, experts discuss poor progress of sanitation in developing world, *SA Waterbulletin, May/June 1995* pp 10 - 13.

Wetzel R. G., Constructed Wetlands: Scientific Foundations Are Critical in: constructed wetlands: System design, removal process and treatment performance in Constructed Wetlands for Water Quality Improvement, Moshiri G. A, (ed), Lewis Publishers, Boca Raton, 1991. pp 3 - 7.

Wilson, C., Engineers on the Internet: A New World of Information At Your Fingertips, Proceedings of Inet '95, Honolulu, August 1995.

Wood A. W. and Hensman L., Treating Effluents Nature's Way, *SA Waterbulletin,* Oct/Nov 1988. pp 18 - 21

Wood A. W. and Pybus P., Artificial wetland use for wastewater treatment; theory, practice and economic review, Water Research Commission, Report no. 232/1/93, Pretoria,1993.

World Bank, Water Supply and Waste disposal, World Bank and Basic Needs Series, Washington 1980.

World Bank, World Development Report 1992: Development and the Environment,Oxford University Press, New York 1992.

World Bank, World development Report 1994: Investing in Infrastructure, Oxford University

Press, New York 1994.

Umgeni Water (a), Efaye-Mt Elias Rural Water Supply Scheme: Water Treatment Design Specifications, Umgeni Water, Pietermaritzburg, 1995.

Umgeni Water (b), Swayimana Rural Water Supply Scheme: Recommendations for Treatment: Mazinganya borehole, Umgeni Water, Pietermaritzburg, 1995.

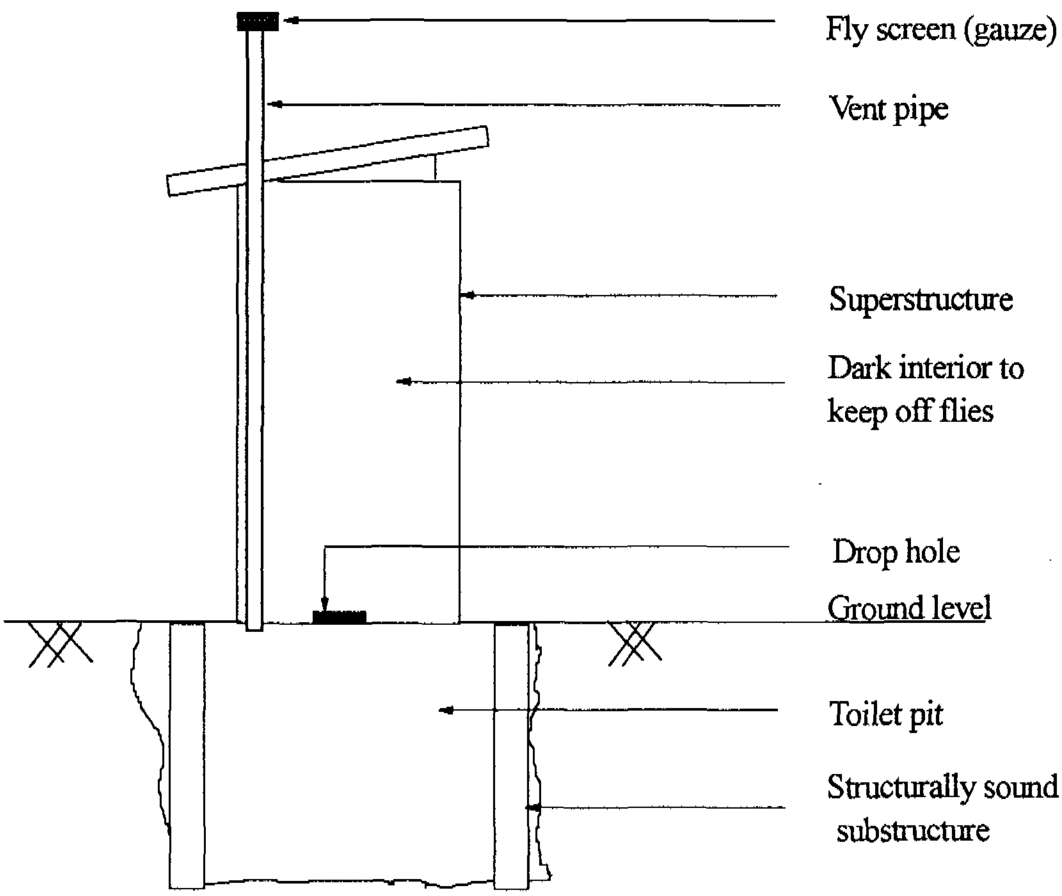
Urbanisation Working Group of Water Supply and Sanitation Collaborative Council, Report adopted at the Rabat Meeting of the Council 7-10 September 1993, Water Supply and Sanitation Collaborative Council 1993.

Zambrano, R. and Daudpota, I., The Sustainable Development Networking Programme: Concept and Implementation, Proceedings of INET ' 95 August 1995, Honolulu. pp 68 - 75.

Zhenbin W., Studies on wastewater treatment by means of integrated biological pond system: Design and function of macrophytes, IAWQ; Proceedings of the International Conference on Appropriate Waste Management Technologies, Oxford, 1993. pp 97 - 105.

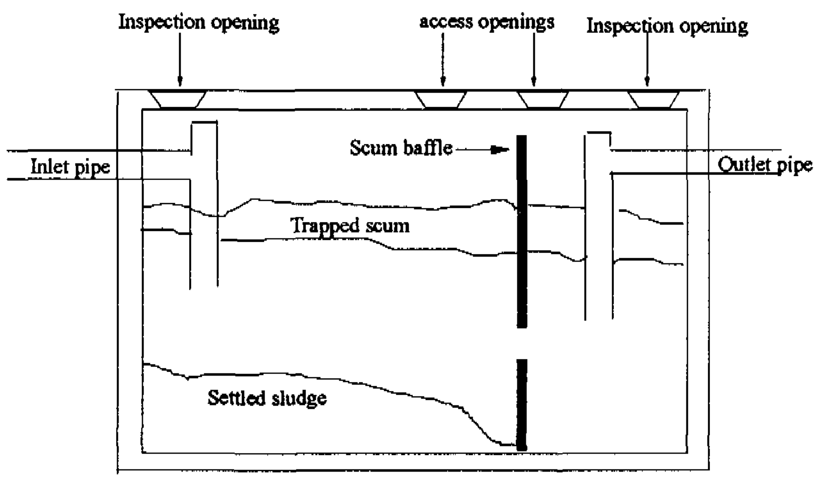
Appendix 1

Typical construction of a VIP toilet.

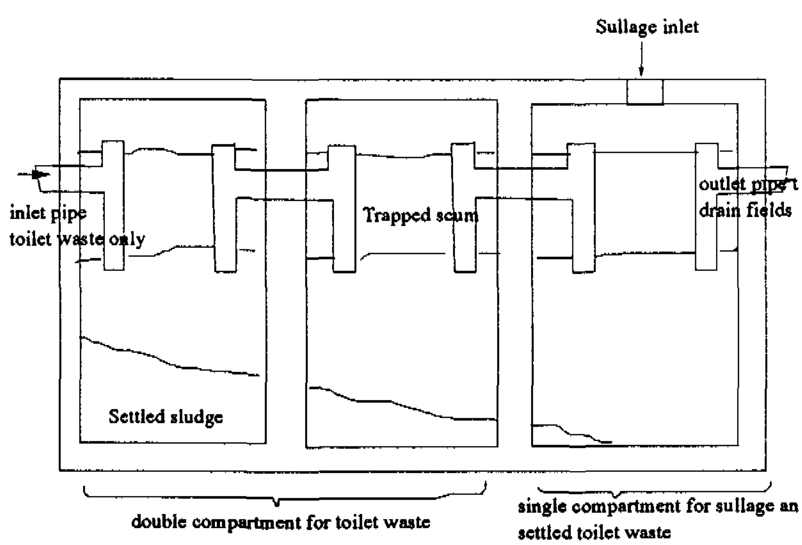


Appendix 2

Typical conventional septic tank and three chamber design.



conventional septic tank



3 chamber septic tank design suitable for use in urban areas

Appendix 3

List of organisations that contributed to information needs survey.

Category	Name of organisation
consulting engineers	Scott Wilson, Kirkpatrick International consulting engineers
water authorities	Umgeni Water
municipal authorities	Durban Corporation
engineering contractors	Falcon Engineering Contractors
government bodies	Department of Water Affairs and Forestry
urban communities	individuals
non-govermental organisations	Mvula Trust
researchers	Pollution Research Group, University of Natal, Durban.
aid organisations	US Agency for International Development.

Appendix 4

Original information request to list servers

From: Ndirangu Kibata <kibata@pixie.udw.ac.za>
To: Multiple recipients of list <enveng-l@cedar.univie.ac.at>

The International Association of Water Quality (IAWQ) through the Pollution Research Group of University of Natal Durban, Department of Civil Engineering, University of Durban Westville and Computing Centre for Water Research of South Africa intend to network the existing information on water and sanitation in developing nations via the internet. If you have any information on the above, please contact the undersigned.

Typically, areas of interest would be:-

* Research
* Case studies (successful and unsuccessful)
* Reports from funding agencies
* Socialogical issues
* Evaluation of treatment processes
* Training resources
* Bulletins
* Equipments
* etc

Any information received will be appreciated.

Ndirangu Kibata
Department of Civil Engineering
University of Durban Westville
P/bag x54001
Durban 4000
South Africa

Internet Kibata@pixie.udw.ac.za

This request was circulated to ENVENG-L, Infoterra, EIA, Aqua-dialogue and S-Asia-environment listservers

Appendix 5

Printout of Level 1 of the binary approach.

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

At the end of the century, 45% of the world population - 2.25 billion will be living in urban areas. Majority of them will be in developing nations.A challenge is posed by this large urban population to provide water and sanitation at affordable costs and using the most practicable technology. This server is borne out of the realisation that transferring first world technology to the realities of the developing countries will not work. Thus the server aims at encouraging information exchange between various developing countries in the sector of water and sanitation. This, it is hoped will foster informed decision making.

Contained in this site are

- TECHNICAL ISSUES IN WATER AND SANITATION - This section covers Planning, Design, Construction, Process Evaluation, Sociological and environmental issues associated with provision of water and sanitation in developing countries.

- CASE STUDIES - A comprehensive evaluation of ten municipal water supply and wastewater disposal projects showing typical problems in planning, design, implementation, operations and maintenance encountered in developing nations and solutions suggested by experts in these nations who experienced these problems.

- RESEARCH - Current abstracts on research in urban water and sanitation in developing countries from journals and conferences.

- SOFTWARE LIBARY - This library offers downloadable software developed to assist the user in solving various water supply and sanitation problems. Users are encouraged to donate any software they may have developed for use by other communities who may be experiencing similar problems.

- ORGANISATIONS INVOLVED IN URBAN WATER SUPPLY AND SANITATION IN DEVELOPING COUNTRIES - A brief profile of funding agencies, UN bodies,bilateral agencies

Appendix 5(cont)

Printout of Level 1 of the binary approach.

and NGO's involved in provision of water and sanitation in developing countries

- **BULLETINS** - Our online water magazine and bulletins
- **ANNOUNCEMENTS** - Annnouncements of conferences, workshops, call for contract bids,call for papers, trainning opportunities etc.
- **UNINDEXED ARTICLES** - This site contains various articles on Water and Sanitation that have not been indexed.
- **FEEDBACK** - The users are enouraged to get back to us. Please tell us what you think of the site and suggestions for improvements. We welcome all relevant articles and links for inclusion in WENDY pages.

Return to WENDY home page

This page was last updated on 26th sep 1995, 18:45 GMT

Appendix 6

Printouts of Level 2 of the binary approach

Technical issues in urban water supply and environmental sanitation in developing countries

- **Planning including feasiblity study**
- **Design and Construction - Water reticulation, water treatment, wastewater treatment facilities**
- **Process evaluation for portable water supply and wastewater treatment systems.**
- **Sociological issues**
- **Environmental issues**
- **Environmental Impact Assessments**

Return to WENDY home page

Return to Technical issues

This page was last updated on 18 th sep 1995, 10:45 GMT

Organisations involved in water and sanitation in developing countries

Governmental funding agencies

- British Overseas Development Authority (ODA)-The ODA information page summarises the functions of the ODA. Navigation is possible to other ODA lin ks.
- Finnish International Development Agency (Finida) home page - Finida funds projects in water and sanitation at bilateral and multilateral levels. Currently, they are involved in projects in Afria, S o uth America, Asia and the Meditrenean region
- Japanese International cooperation agency - JICA - Japan is the largest donor nation in the world. Most of her development assistance under which water and sanitation fall is channeled through JI CA.
- United States Agency For International development - USAID Most of funding in water and environmental Sanitation by USAID through its Environment Health Project (EHP) formerly known as water and sanitary health (WASH)

Development Banks

- The World Bank - Access to this site is limited in some countries for security reasons
- Asian Development Bank - The Asian development Ba nk web site explains prerequisites in order for project to qualify for funding. It also sets out the procedure for environmental impact assessment including a sample EIA
- African Development Bank
- Inter American Bank - The page is both in english and spanish. It contains varous procedures followed before a proj ect is finally funded. Some sample EIA's are accessible from the site.

UN Bodies

- United Nations development programme (UNDP) - The UNDP provides technical support in implementing water and sanitation projects among others. Of particular intrest is the UNDP's SU/TCDC programme that seeks to enhance technical co-operation among developing countries.
- World Health Organisation (WHO) is concerned with the state of the world's health hence its role in water and environmental sanitation in developing countries.

Announcements

This site is still under construction

- Trainning opportunities at Wedc
-
-
-

Related unindexed articles

An essay by American Public Works Association on Water resources management in the development phase of a nation

World Game Institute's View of prefered state of Water and Sanitation in the world

Post Graduate Courses in Water and Sanitation for developing countries at University of Cranfield , UK

Post Graduate Courses in Water and Sanitation at University of Durban Westville, South Africa

US Food and Drug Administration's classification of *E.Coli*

Appropriate Waste Water Treatment for peri -urban areas of Bangkok, Thailand as documented by the Asian Institute of technology

Potential Funding for Jordan - Israel Water Project as reported by US Water news online

Phosphorous pollution and effect on raw water quality

ISO Standards for Water Quality testing. This is a searchable index.

This page was last updated on 21st Sep 1995, 18:45 GMT

Return to WENDY home page

Appendix 7

Printouts of Level 3 of the binary approach

Sociological issues in urban Water supply and sanitation

- **Water supply in informal settlements - constraints and issues**
- **Sanitation in informal settlements - constraints and issues**
- **Water pricing and effective revenue collection**
- **Societal perception of water metering**
- **Waterlosses and illegal connections**

Other links

South Africa's Ruling Party, ANC, has its policy document on health on this gopher site. Reference to water supply and sanitation is made.

Return to WENDY home page

Return to Technical issues

This page was last updated on 18 th Sep 1995, 10:45 GMT

Appendix 7(cont)

Printouts of Level 3 of the binary approach

- **Wedc's overview of urban water supply design considerations**

Return to WENDY home page

Return to Technical issues

This page was last updated on 17 th Aug 1995, 10:45 GMT

Appendix 7(cont)

Printouts of Level 3 of the binary approach

- **Low cost water disinfection**

Return to WENDY home page

Return to Technical issues

This page was last updated on 20 th Aug 1995, 13:45 GMT

Appendix 7(cont)

Printouts of Level 3 of the binary approach

- **WEDC overview on design of low cost wastewater treatment and disposal facilities**
- **Water borne sanitation in a reticulation system may not always be possible due to prevailing site conditions,resources availabble, etc. In such circumstances, septic tanks offer a good alternative. Click here for a lead to page on septic tanks, defination, design criteria and operations.**

Return to WENDY home page

Return to Technical issues

This page was last updated on 31st Aug 1995, 13:45 GMT

Appendix 8

Printout of Level 1 of the multi faceted approach

WENDY

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), WENDY 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. WENDY is located at the Computing Centre for Water Research (CCWR)

Click here to go to WENDY English page.

Appendix 9

Printout of Level 2 of the multi faceted approach

INTERWATER - ENGLISH HOME PAGE

- What's New
- From the Regions
  - Africa
  - Asia & Pacific
  - Central & Eastern Europe
  - Latin America & Caribbean
  - Middle East
- Sector Agencies
- Funding Sources
- Products and Services
- Sector Issues
- Calendar of Events
- Positions Available
- Search Indices
  - Subject index
  - Geographical index
  - Organization index

return to Main INTERWATER Page

Appendix 10

Results of Mt. Elias and Mazinganya boreholes water quality tests

Mazinganya Borehole

Determinand	Units	1st Test	2nd test	3rd test	4th test
Aluminium	µg/ℓ	-	-	-	81
Alkalinity	mg $CaCO_3$/ℓ	43.0	29.7	5.59	33.5
Arsenic	µg/ℓ	-	-	-	<2
Calcium	mg/ℓ	9.20	4.28	7	6.33
Chloride	mg/ℓ	6.53	8.93	6.68	5.88
Coliforms (total)	cells/100 mℓ	-	-	3.22	0
Colour	°H	3.59	5.85	9.73	-
Conductivity	mS/cm	12.7	9.34	0	9.94
Faecal Coliform	cells/100 mℓ	-	-	0	0
Fluoride	mg/ℓ	<0.075	<0.075	<0.075	<0.075
Hardness (Total)	mg $CaCO_3$/ℓ	38.3	0.29	-	27.6
Iron	mg/ℓ	1.21	2.53	2.89	0.39
Magnesium	mg/ℓ	3.69	0.06	0.37	2.83
Nitrates	mg/ℓ	<0.05	0.71	0.94	0.69
pH	pH Units	6.8	8.7	7.96	6.41
Potassium	mg/ℓ	2.46	2.08	1.98	6.41
Selenium	mg/ℓ	-	-	-	<0.5
Sodium	mg/ℓ	9.27	8.39	9.37	9.15
Sulphate	mg SO_4/ℓ	11.0	4.06	5.11	4.72
Suspended Solids	mg/ℓ	-	-	-	6.8
Turbidity	NTU	11.7	1.20	0.96	22.5
Zinc	mg/ℓ	-	-	-	1

Appendix 10(cont)

Results of Mt. Elias and Mazinganya boreholes water quality tests

Borehole 1A

Determinand	1st Test	2nd test	3rd test	5th test	5th test
Coliforms	-	Broken	0	0	-
E. Coli	0	bottle	0	0	-
pH	6.97	6.07	6.33	6.41	6.4
Turbidity	-	2.84	0.4	22.5	0.75
Conductivity	16.0	15.6	15.9	9.94	15.4
Aluminum	28	14	17	81	48
Alkalinity	48.8	47.1	47.7	33.5	47.5
Total Hardness	50.7	45.3	43.4	27.6	45.3
Calcium	15	13.3	12.8	6.33	13.5
Magnesium	3.16	2.88	2.73	2.83	2.76
Sodium	13.9	13.0	12.5	9.15	17.6
Potassium	3.31	3.18	3.03	2.22	3.47
Iron	0.86	0.82	0.78	0.39	0.84
Manganese	0.54	0.51	0.47	0.52	0.48
Silica	18.5	18.1	16.8	25	-
Nitrates	<0.05	<0.05	<0.05	0.69	<0.05
Chloride	9.73	11.1	10.5	5.88	10.7
Fluoride	156	157	<75	<75	165
Sulphates	15.4	14.7	14.6	4.73	14.4
Total dissolved solids	82	114	121	-	84.7
Suspended solids	-	7.2	<4	6.8	<4

Appendix 10 (cont)

Results of Mt. Elias and Mazinganya boreholes water quality tests

Borehole 1F

Determinand	1st Test	2nd test	3rd test	4th test
Coliforms	-	2	-	8
E. Coli	0	0	2	0
pH	6.60	6.00	5.88	5.56
Turbidity	-	-	17.5	15.7
Conductivity	12.8	12.8	13.3	12.9
Aluminum	36	14.0	28	<10
Alkalinity	27.8	28.1	26.6	27.6
Total Hardness	21.1	20.6	20.9	20.4
Calcium	4.46	4.23	4.45	4.34
Magnesium	2.39	2.41	2.34	2.31
Sodium	16.7	17.3	17.5	17.5
Potassium	3.24	3.22	3.20	3.23
Iron	0.11	0.04	0.20	0.22
Manganese	<0.11	0.01	<0.01	<0.01
Silica	23.7	23.8	20.7	25
Nitrates	<0.05	0.69	0.62	0.60
Chloride	14.7	19.0	17.9	18
Fluoride	96.7	75	-	87
Sulphates	11.6	6.99	6.87	6.94
Total dissolved solids	68	235	91	116
Suspended solids	-	-	49.7	30.8

Appendix 10 (cont)

Results of Mt. Elias and Mazinganya boreholes water quality tests

Borehole R2

Determinand	1st Test	2nd test
Coliforms	-	2
E. Coli	-	2
pH	0	1
Turbidity	7.20	6.32
Conductivity	-	8.54
Aluminum	29.8	29.3
Alkalinity	533	96
Total Hardness	80.2	79.7
Calcium	79.2	82.9
Magnesium	17	17.3
Sodium	8.80	9.52
Potassium	2.97	31.4
Iron	2.92	2.91
Manganese	0.59	0.19
Silica	0.06	0.01
Nitrates	32.0	31.1
Chloride	6.48	7.16
Fluoride	31.8	32.7
Sulphates	115	95.1
Total dissolved solids	3.85	<0.16
Suspended solids	181	223

Appendix 11

URLs for selected water related sites on the Internet

Organisation/Institution	URL
American Public Works Association	http://www.pubworks.org/apwa
Garnet	http://info.lut.ac.uk/departments/cv/wedc/garnet/grntover.html
American Waterworks Association	http://www.law.cornell.edu/topics/environmental.html
Ground Water Institute (USA)	http://141.225.68.41
Perdue Univerisity Water Quality	gopher://hermes.ecn.purdue.edu:70/11/Extension/Environment/Water%20Quality
South African Water Information Centre	http://africa.cis.co.za/wna/html/env/sawic/main.html
US Waternews	http://www.mother.com/uswaternews/
US Geological Society water resources information	http://h2o.er.usgs.gov/
Wastewater Engineering	http://www.halcyon.com/wastewater/
Water Network	http://www.uwin.siu.edu
Water Online	http://resources.agency.ca.gov/ceres/WOL/home.html
Water Web	http://www.waterweb.com
Watertek	http://crux.csir.co.za/csir/watertek.html
WEDC	http://info.lut.ac.uk/departments/cv/wedc/
World Wide Water	http://pubweb.ucdavis.edu/Documents/GWS/EnvIssues/George_Fink/MASTERW.HTM
Water Resources Centre	http://www.maxey.dri.edu/WRC/
River Danube System	http://www.cedar.univie.ac.at/danis
Water Wiser	http://www.waterwiser.org/

Appendix 12

Profiles of WENDY partner organisations

The Water Supply and Sanitation Collaborative Council is a group of professionals from developing countries, external support agencies (ESAs), non-governmental organizations, and documentation and research organizations all working in the water, sanitation, and waste management sectors.The precursor of the present Collaborative Council was an ESA Collaborative Council established at the International Drinking Water and Sanitation Decade Consultation held in 1988. The Council met for the first time in 1989. In 1990 it met for the second time. At that meeting it was agreed that a new council involving sector professionals from both ESAs and developing countries would play a useful role. The first meeting of the newly constituted Water Supply and Sanitation Collaborative Council was held in Oslo, Norway, in September 1991. The Council's second meeting was held in Rabat, Morocco 1993, the third one in Barbados, in 1995.

The council was formed at the end of the United Nations International Drinking Water and Sanitation Decade (1981-1990) to keep the momentum of the Decade alive by providing a framework for global collaboration within which sector agencies of both developed and developing countries could work together in partnership. Principally, this was to apply lessons learned during 1981-1990 decade in order to keep the momentum of the Decade alive by providing a framework for global collaboration within which sector agencies of both developed and developing countries could work together in partnership.

The Mission of the Council is to enhance collaboration among developing countries and ESAs so as to accelerate the achievement of sustainable water, sanitation, and waste management, with special attention to the poor.The Council provides a forum for the discussion of key issues, alerts members to opportunities for more efficient use of resources, increases awareness of the need to expand water, sanitation and waste management coverage, promotes collaboration at the country level, and stimulates the adoption of harmonious policies and programmes.

IRC is an independent, non-profit organization working for change towards more people-oriented water and environmental sanitation programmes. It receives support from the Netherlands Government and a number of international organizations, and is an active contributor to the work of the Water Supply and Sanitation Collaborative Council (WSSCC)

The Water Research Commission of South Africa is a statutory organization instituted according to the Water Research Act (Act 34 of 1971)- to stimulate and coordinate water research activities, to determine water research needs and priorities, to fund research in high priority areas and to promote the dissemination and application of research results. The Water Research Commission itself does not undertake any research but it provides funding for research undertaken by institutions like universities, the CSIR, AECI, HSRC, Eskom, Chamber of Mines, local authorities, government departments, consultants, water boards and industry. The Water Research Commission obtains funds from levies charged on water consumption. Areas of research addressed by the Water Research Commission include Rainfall stimulation, Urban water conservation, Surface Hydrology , Sewage water treatment, Mineralization, Hydrometeorology, Potable water, Groundwater, Conservation of water ecosystems, Dry cooling, Marine dumping of waste, Membrane technology Agricultural water utilization, Industrial water, Eutrophication and Sewage sludge.

International Association on Water Quality (IAWQ) is a professional membership association dedicated to the advancement of the science and practice of water pollution control and water quality management worldwide. The main focus of the International Association on Water Quality is water quality. The causes of water quality deterioration are of primary concern to the Association as well as the means by which these may be prevented or alleviated, through control of pollution at source, improvements to existing treatment processes and development of new ones. Through its activities in Conferences, Publications and Specialist Groups, IAWQ is deeply involved with the many aspects of water quality in the water cycle. Among the topics covered by the Association are the sources and causes of pollution: the problems of increased urbanisation and the consequences of the domestic wastewater and urban drainage water generated; industrial processes, including energy, agriculture and transport, which generatewastes of many diffuse types including nutrients, acid air emissions and persistent toxic substances. Also covered are the effects of pollution: eutrophication of rivers, lakes, groundwaters and seas; acidification of waters; health problems from polluted waters; impacts of pollution on the flora and fauna of marine and freshwaters. On the collection and treatment side there is a large body of knowledge about treatment processes of all kinds, advanced and low technology, for both domestic and industrial wastewaters, including residuals management and disposal and wastewater reuse. Management considerations are covered in activities such as river basin management; instrumentation, control and automation; and management and institutional affairs.IAWQ is an international Membership organisation.

The United States Agency for International Development (USAID) in response to demands from USAID missions and bureaus for a comprehensive and integrated response to the increase in the magnitude of environment-related health problems, inaugurated an **Environmental Health Project** (EHP) to provide both long- and short-term technical assistance to developing or newly democratising countries. EHP seeks to help developing countries create conditions in which harm from environmental hazards is kept to a minimum. EHP is active, through in the areas of tropical diseases, water supply and sanitation, solid waste and wastewater EHP was created to respond to changing conditions in the developing world. Many countries are undergoing a transition to industrialisation and urbanisation accompanied by health problems not previously encountered, EHP helps these USAID-assisted countries develop new paradigms for prioritising their urgent public health problems and for recognising the linkages among these problems.

Environmental Health Project (EHP) is a United States Agency for International development (USAID) centrally funded project that helps missions and bureaus and other development organizations to address both pre- and post-industrial transition environment-related health problems. The familiar pre-transitional health problems result from vector-borne diseases (some of which are re-emerging), water pollution, and lack of sanitation. Post-transitional problems result from human exposure to air pollution from industry and automobiles, hazardous and toxic wastes, pesticides, and dangerous workplace conditions. To achieve the most significant health impact, EHP concentrates on interventions that address three major causes of infant and child illness and death in USAID-assisted developing countries ie diarrhea, acute respiratory diseases, and malaria. Of these malaria and diarrhea are water realted diseases. EHP offers Technical assistance in both technical and cross- cutting areas water and sanitation and wastewater treatment.

The Water, Engineering and Development Centre (WEDC) is one of the leading European institutions concerned with the planning, provision and management of water, sanitation and other physical infrastructure fordevelopment in low- and middle-income countries. It is a self-funded centre based at Loughborough University of Technology in the UK.

For over twenty years, WEDC has been devoted to education and training and research and consultancy related to activities that improve the health and well-being of people living in rural areas and urban communities. The integration of technological, environmental, social, economic and management inputs for effective and sustainable development are encouraged.

WEDC operates within the Department of Civil and Building Engineering. The WEDC team consists of professional academic staff (engineers, biochemists, geographers, sociologists, economists and managers) and support staff including information, research, publications, publicity and secretarial assistants. In addition, they call on the services of associates and others with specialist expertise with considerable experience in low- and middle-income countries, which is continually updated by new assignments. Most of them have worked professionally in developing countries for government departments, local government, international agencies, non-governmental organizations and consultants.

Appendix 13

Original request for information on iron and manganese removal

From: Chris Buckley <BUCKLEY@che.und.ac.za>
Organization: University of Natal - Durban
To: CAMPBELLDB@cdm.com, IRC-I.VANDIETEN@GEO2.poptel.org.uk
Date sent: Thu, 26 Oct 1995 09:47:20 +0200 (SAST)
Subject: Information on Iron and Mn removal
Send reply to: Buckley@che.und.ac.za
Copies to: pryor@iaccess.za, kibata@pixie.udw.ac.za
Priority: normal

Dan and Stephen,

This is a real request but possibly is an indication of the type of requests in the future.

I was at the Umgeni Water Process Services section this morning. James Voortman, who is responsible for the design of rural water treatment plants had a number of questions.
I am sure that there are some solutions in your vast libraries.

1. Many of Umgnei Water's rural water supply schemes utilisegroundwaters by means of boreholes. Much of the groundwater has iron up to 10 ppm and manganese up to 2 ppm. Information on greensand filters and other simple methods of iron and manganese removal is required.

2. Many of these groundwaters also have low pH (6,0 to 6,5) which hampers Fe and Mn removal. Application of lime to pressurised systems is problematic, caustic soda is both costly and hazardous to use. Electicity is not always available. Information on simple methods of pH correction suitable forapplication to pressurised rising mains is required.

3. Any information on dosing systems that do not require electricity will be welcome especially where information on the reliability of these systems in the field is available.
Could you reply directly to
pryor@iaccess.za
It will also help to justify to Umgeni the need to give all
their engineers access to Internet.

Thanks

Chris Buckley
Pollution Research Group
Department of Chemical Engineering
University of Natal

Appendix 14

Members of WENDY steering comittee and their affiliation

Name	Organisation
Prof. C. A. Buckley	Pollution Research Group, University of Natal, Durban.
Mr. P. Odendaal	Water Research Commission.
Mr. S. Parker	International Reference Centre for Water and Sanitation.
Mr. T. Milburn	International Association on Water Quality (IAWQ)
Dr. M. Dent	Computing Centre for Water Research.
Dr. A. Cotton	Water, Engineering and Development Centre (WEDC)
Dr. F. A. Otieno	Department of Civil Engineering, University of Durban-Westville.
Dr. M. Van Rynveld	University of Witwatersrand
Mr. I. Imparato	United Nations Centre for Human Settlement (Habitat)
Mr. R. Lith	Internet Africa
Mr. B. Pfaff	Durban Water and Waste
Mr. D. Campbell	Evironmental Health Project (EHP)
Ms. J. Donaldson	Umgeni Water
Ms. F. Myburg	South Africa Water InformationCentre.

Appendix 15 *The WENDY plan of action*

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

Preamble

The Water Supply and Environmental Sanitation Services Electronic Network for Developing Country Needs **(WENDY)** is a collaborative electronic network of partner institutions in the water and sanitation sector.

Goal

In accordance with the aims and objectives of the Water Supply and Sanitation Collaborative Council which are,

To enhance collaboration among developing countries and external support agencies so as to accelerate the achievement of sustainable water, sanitation and waste management services to all people, with special attention to the poor.

the overall goal of **WENDY** is to contribute to more effective delivery of services in the water supply and sanitation sector in developing countries through improved information provision.

General objectives

To promote and facilitate the exchange of data, information, knowledge and experience among water and sanitation institutions and professionals.

Specific objectives

The specific objectives of **WENDY** are to promote and facilitate, through the medium of the Internet :

- the awareness and access to sources of information,
- the generation and dissemination of information,
- the establishment of effective networking among sector institutions and professionals.

Key activities

These objectives will be achieved by :

- the creation of a Water Supply and Environmental Sanitation Services Electronic Network for Developing CountrY Needs **(WENDY)**,
- to establish **WENDY** as a collaborative network of partner institutions in the WSS sector,

- the establishment of a **WENDY** home page that will point the way to :
  - ☐ information provided by partner institutions in the network, and to the activities of the Collaborative Council.
  - ☐ to sources of information, activities and contact outside the **WENDY** partner institutions.
- to operate and maintain the network through the provision of protocols, guidelines, standards and manuals,
- to maintain up-to-date links to other sources of information,
- to promote the use of **WENDY** by increasing the awareness of **WENDY** and by capacity building in the use of the network,
- promote its expansion through increasing the number of partner institutions and improving physical access to the network through promoting pilot projects.

Scope and functions

In accordance with its overall goal, **WENDY** is concerned primarily with water supply and environmental sanitation in developing countries. It aims to guide users to sources of information, professional contact etc., which are of potential relevance and value to those involved in this field, rather than itself providing substantive information on these subjects. Responsibility for providing substantive information to **WENDY** users rests mainly with the partner institutions, through the medium of their own homepages.

The principal functions of **WENDY** are :

- to provide an up-to-date, structured and user-friendly guide or pointer to sources of information on water supply and sanitation available both from partner institutions and from other sources which are accessible through the Internet.
- to provide an effective mechanism for the dissemination of information by sector institutions.
- to provide an effective channel of electronic communication between sector institutions and professionals in all parts of the world.
- to develop and distribute protocols, guidelines, standards and manuals defining the rules, procedures and methods of operation of **WENDY.**
- to promote the use of **WENDY** through awareness raising, capacity building and training activities.
- to promote the expansion of **WENDY** by encouraging and assisting sector institutions to become partners.
- to promote and propose pilot projects designed to provide selected institutions in developing countries with the equipment, materials, training, etc., required to help them to provide and obtain information through **WENDY** (and other channels).

Organisation and membership

WENDY will operate as a collaborative network of equal partner institutions under the guidance of an International Steering Committee on which each partner will be represented. The Steering Committee will formulate its own rules of procedure and th ose for operation and management of the network as a whole.

Any institution wishing to become a partner in **WENDY** must :

- ☐ accept and agree to support the goal and objectives of **WENDY.**
- ☐ maintain its own home page on the World Wide Web and agree to link this page to **WENDY.**
- ☐ be willing and able to participate in the **WENDY** steering committee.
- ☐ agree to abide by the protocols, guidelines, standards and manuals defining the rules, procedures and methods of operation of **WENDY**.

Implementation

In order for the goals of **WENDY** to be achieved the following roles have been defined :

- ☐ the central management and maintenance of **WENDY** will be undertaken by the Pollution Research Group of the University of Natal, Durban, South Africa.
- ☐ All the partners will be members of the Steering Committee and hence determine the policy, formulation of rules, protocols, etc. of **WENDY**.
- ☐ The individual partners will have the responsibility for the maintenance of their own homepages.

Financial implications

In order for the WENDY initiative to be sustainable it may be necessary for :

- ☐ individual partners to charge for information and services provided through their own home pages.
- ☐ to charge a subscription or membership fee to partners to cover the services of the central maintenance team and the work of the Steering Committee.

☐