THE TESTING OF A MEMBRANE TECHNOLOGY UNIT FOR THE REMOVAL OF NITRATE, CHLORIDE, FLUORIDE, SULPHATE, CALCIUM AND MAGNESIUM POLLUTANTS FROM GROUNDWATER, AND THE MONITORING OF RURAL CONSUMER KNOWLEDGE AND ATTITUDE TO WATER PURIFICATION

Report to the

WATER RESEARCH COMMISSION

by

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WRC REPORT NO. 1529/1/09
ISBN 978-1-77005-839-2
SET No. 978-1-77005-832-3

April 2009

This report forms part of a series of two reports. The other report is Water Education and Training – Wet-programme (WRC Report No. 1529/2/09).

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GLOSSARY OF ABBREVIATIONS

AFM	Atomic Force Microscopy
AFS	Atomic Force Spectroscopy
AGEP	Average Groundwater Exploitation Potential
BPS	Batlhaping Primary School
DWAF	Department of Water Affairs and Forestry
ED	Electrodialysis
EDTA	Ethylenediamine tetra acetic acid
FBWP	Free Basic Water Policy
MF	Microfiltration
MWCO	Molecular Weight Cut-Off
NF	Nanofiltration
NWU	North-West University
RDP	Reconstruction and Development Policies
RO	Reverse Osmosis
RQS	Resource Quality Services
SABS	South African Bureau of Standards
SANS	South African National Standard
SEM	Scanning Electron Microscopy
STPP	Sodium tripoly phosphate
TDS	Total Dissolved Solids
UF	Ultrafiltration
WET	Water Education and Training
WRC	Water Research Commission
WSA	Water Service Authorities
WSP	Water Services Providers

EXECUTIVE SUMMARY

As a result of concern expressed by the Mmabatho Department of Water Affairs (in the early 1990s) for the high levels of nitrate ions in some water sources in North West Province, a research project, executed by the North-West University was funded by the Water Research Commission (WRC) to address this problem. Initially, the project aimed to survey the extent of nitrogenous pollution in the province. The survey involved the collection of water samples and the quantitative determination of nitrogenous pollutants (ammonium, nitrate, and nitrite ions) in these samples. The survey confirmed the pollution problem in some areas of the province. Nitrate pollution causes methaemoglobinemia (blue-baby syndrome) in infants from 0-6 months. The highly nitrate-polluted sources were also found to be salty and probably contained other ions like calcium, magnesium and phosphate. Apart from this, high fluoride levels, which can cause skeletal and dental fluorosis, were detected.

A follow-up study was funded by the Water Research Commission to investigate membrane technology to bring the concentrations of fluoride, nitrate, other salts and hardness to recommended and specified levels. This study aimed to apply suitable membrane methods for the removal of pollutants from boreholes; train local people to operate, monitor and maintain the water processing installation.

Madibogo is in one of the many villages in North West Province's rural areas that depend on ground water and are experiencing the problem of nitrogenous pollution. The Madibogo community was chosen as a study area among other communities because of its accessible location and very high concentrations of nitrate, chloride, calcium and magnesium ions in the water. Tests performed on groundwater from this community indicated high concentrations of nitrate, chloride, calcium and magnesium ions whose concentrations were respectively 23.6 ppm, 637 ppm, 176 ppm and 102 ppm. The high concentrations of calcium and magnesium result in water hardness. The concentrations of these determinands in the groundwater at Batlhaping Primary School (BPS) in Madibogo village are above the specifications of the South African National Standard (SANS-241) for drinking water. It can be argued that this pollution of groundwater at Madibogo is unacceptable in terms of South African consumer rights and the constitution that oblige municipalities and service providers to deliver services that are safe, healthy and friendly towards the environment which the human being is part of.

Consequently, the use of membrane technology (nanofiltration and reverse osmosis) was investigated for the removal of excess concentrations of these determinands in brackish groundwater Batlhaping Primary School in Madibogo village. Since membrane technology is relatively new in South Africa, it called for a thorough investigation of how the community would receive this type of water purifying methodology.

It is important not only to address the technical aspects of water provision but also the social and human aspects regarding the practical use of water.

AIM AND OBJECTIVES OF THE STUDY

The aim of the study was to reduce the concentrations of nitrate, fluoride, calcium and magnesium ions to recommended specific levels. The main aim of the social dimension of the project was to determine consumers' understanding of water and the use of water in general, water usage and water service provision in rural areas through setting the following objectives:

- determination and verification of the available data on the presence of nitrate, fluoride, salinity and water hardness in some areas in North West Province;
- application of low-cost membrane technology methods for the removal of pollutants from borehole waters;
- installation and testing of a pilot plant for on-site borehole water softening, desalination and the removal of nitrate and fluoride;
- training of the local people to operate and maintain the water treatment installation and monitor impurities on-site with field testing equipment;
- to explore the consumer's perceptions and knowledge regarding current and general water supply, general rural water household utilization and the Free Basic Water Policy;
- to establish whether there is a difference between the untreated borehole water and the purified water;
- to explore the consumer's attitude regarding current and general water supply, general rural water household utilization and the Free Basic Water Policy;
- to identify the aspects that need to be addressed in an educational programme on water purification and
- to develop, implement and evaluate a water purification education programme.

METHODOLOGY

The nanomembranes that were going to be tested for their separation efficiency of the pollutants initially had to be characterized. Six nanomembranes were selected for the study. The three nanofiltration (NF) membranes were Desal-DL, NF 90, and NF 270. The three reverse osmosis (RO) membranes were BW 30, GM and S5. These nanomembranes were characterized to determine which one would be most optimal for treating the brackish groundwater of Batlhaping Primary School in Madibogo village. A dead-end module reactor was used for this aspect of the study.

The next aspect of the study was setting up a cross-flow module reactor pilot water treatment plant at Madibogo village with Batlhaping Primary School as a research site. The groundwater source at this school was identified in a previous study on water quality to be particularly highly polluted with nitrate ions. The six nanomembranes, in spiral-wound configuration, were also used in the cross-flow brackish groundwater treatment. It was concluded from the study that the most optimal nanomembrane for the treatment of the brackish groundwater was the nanofiltration NF90 membrane.

Contact was made with the relevant stakeholders and the perceptions and attitudes of the consumers that use the water were investigated through means of a series of focus groups.

After the filtration apparatus for purification were installed, the consumers' understanding and satisfaction of the water purification system was investigated. Focus group meetings were held with the users to obtain their opinions regarding the use of treated water; sensory evaluation of the taste differences between the purified and unpurified water were done; the treated and untreated water were used to make tea to establish a difference between the two types of water; and different types of soaps were used with treated and untreated water.

An educational programme was developed based on the water users' perceptions, problems and knowledge regarding the water they receive. The programme consisted of educational outcomes, a training manual, creative training materials as well as evaluation and assessment material. The programme was implemented as a three-day course in Madibogo and attended by 17 participants.

In order to evaluate the success of the education programme, the outcomes of the learning programme must be assessed. Learning outcomes are assessed by quantitative and qualitative measurements. For the quantitative measurements, standardized attitude and knowledge scales were developed and applied before and after the education programme to measure any change in attitude and knowledge (impact of intervention). The results of the perception study were used to develop the attitude and knowledge scales.

Qualitatively, the attainment of skills regarding water usage was assessed by means of creative activities such as storytelling, role-play and practical demonstrations. Information days were held to involve and inform the community as well as different stakeholders such as the tribal authority, local municipality, provincial departments and other relevant provincial non-governmental organisations about water purification and ways to improve their water provision. A specific work-session with the key role players was held to plan ways and means to improve water delivery. A task team to address improvement of water provision to Madibogo was formed.

SUMMARY OF THE RESULTS

The results that were obtained from the treatment of the brackish groundwater at BPS using the nanomembrane cross-flow module reactor pilot water treatment plant (on the basis of SANS-241) were as follows:

- Nanomembranes Desal-DL and NF270 are not suitable for the treatment of the brackish groundwater at BPS because the concentrations of NO_3^- and Cl^- ions in their permeates are non-compliant to SANS-241 for drinking water;
- Nanomembrane BW30 had the highest retention coefficient (R) for all the determinands at 18 bars and 20 bars except for the SO_4^{2-} anion;
- The reverse osmosis (RO) nanomembranes produced permeates in which the concentrations of all the determinands were compliant to SANS-241 for drinking water;
- The retention coefficient (R) of nanofiltration membrane NF90 was intermediate between those of RO and the other NF nanomembranes (Desal-DL and NF270);
- The optimal nanomembrane for the treatment of the brackish groundwater at BPS in Madibogo village is NF90;

- The optimal pressure for the treatment of the brackish groundwater at BPS in Madibogo village is 16 bars;
- All the six nanomembranes produced permeates whose physical determinands all complied with the SANS-241 for drinking water.

The results from the social dimension of the project can be summarised as follow:

The study of the community of Madibogo‘s perceptions revealed many misconceptions regarding the use of water, especially regarding personal grooming and household utilization. They also knew very little about the latest legislation and implications thereof, such as the Free Basic Water Policy and the implications for them. They also did not understand what the water purification involves. Based on the above findings the need to develop a general water education programme was identified.

The investigation of the community’s perceptions regarding their experience of the purified water was very positive and that they are satisfied with the purifying process at the school. They indicated that the purified water tasted better and there was a statically and practical significance difference between the sensory panel’s evaluation of the water.

The washing and cleaning characteristics of the water will improve with purification. When tea is made with the purified water there will also not be coagulants or scum and people will be able to serve nice and warm tea to their guests

A standardised attitude scale was developed but because attitude is an abstract concept and water and water provision are also something that ordinary water users do not think about or are able to verbalise, the quantitative results proved very valuable. Because of community members’ lack of knowledge about water and water provision, their attitudes are very often distorted and not clearly defined.

The Water Education and Training Programme (WET-programme) was developed, the standardised attitude and knowledge scale was completed before and after the presentation of the course. The WET-Programme is available in hard copy or disc from the researchers. The attitude and knowledge of consumers improved and therefore it can be suggested that education and training can play a role to improve a community’s water provision. If the community members have more knowledge and their attitude is positive, they can play an active role in improving their own water provision.

To conclude the research programme and to involve the community in the process, an open day was organized to exhibit the nanofiltration apparatus and to provide the necessary information to community members to ensure community participation.

Nanotechnology is an option to improve communities with water problems such as high nitrates and minerals in their water. However there must be an educational component together with the physical purification; cost implications must be explained to community members and the participation and approval of all stakeholders must be obtained.

ACKNOWLEDGEMENTS

The project leaders would like to thank the following people and instances, in no particular order, for their inputs and support of the project.

- The financial and other assistance of the Water Research Commission is acknowledged with great gratitude;
- Dr Gerhard Offringa is acknowledged for his tactical management of the project;
- Prof S.J. Modise of Vaal University of Technology (VUT) for his invaluable inputs and assistance, particularly during the initial stages of the project;
- Prof H. Neomagus, technicians and engineering students who were always available to troubleshoot engineering problems associated with the reverse osmosis pilot plant;
- Mr Nathan Herbert of Malutsa (Pty) Ltd for the design and construction of the cross-flow module reactor pilot water treatment plant and advice in its operation and maintenance;
- Hydra Engineering in Mafikeng for servicing and repairs to the cross-flow module reactor pilot water treatment plant;
- CHC (Cape Town), a subsidiary of FilmTec (USA), for supplying all the required nanomembranes;
- North-West University's (Mafikeng campus) Department of Chemistry who provided the laboratory floor space and infrastructure;
- Dr T. Duma of the Resource Quality Services (RQS), Department of Water Affairs and Forestry (DWAF), for the analysis of the numerous water samples;
- Members of the steering Committee WRC Project K5/1529 for their various invaluable contributions:
    - Dr G. Offringa — Water research commission
    - Prof J.J. Schoeman — University of Pretoria
    - Mr C. S. Crawford — Department of Water affairs and forestry
    - Mr H. Strohwald — VWS – Envig
    - Prof E. P. Jacobs — University of Stellenbosch
- Ms Tania Venter for the formatting and technical work.

SECTION A

THE TESTING OF A MEMBRANE TECHNOLOGY UNIT FOR THE REMOVAL OF NITRATE, CHLORIDE, FLUORIDE, SULPHATE, CALCIUM AND MAGNESIUM POLLUTANTS FROM GROUNDWATER

Report to the Water Research Commission

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January, 2009

CHAPTER 1 BACKGROUND

1.1 INTRODUCTION

The study was initially prompted by the concern of the Department of Water Affairs and Forestry (DWAF) in Mmabatho in the early 1990s for the anomalous levels of inorganic nitrogenous pollution in some naturally occurring water sources in North West Province. A research grant was subsequently received from the Water Research Commission (WRC) in 1996 to survey the extent of the nitrogenous pollution in the water sources in the province. Water samples were collected from rivers, lakes, dams and boreholes. The results of the survey confirmed the presence of nitrogenous pollution of water sources in some areas of the province. The areas in which the water sources were highly polluted were Molopo, Delareyville, Ganyesa, Kudumane and Vryburg1. The predominant inorganic nitrogenous pollutant was nitrate ion. These water sources which were highly polluted with nitrate ion were also found to be salty and probably contained other ions such as calcium and magnesium. Apart from this, high fluoride levels were also detected.

1.2 MOTIVATION

The concentrations of these pollutants in these naturally occurring water sources have to be reduced such that they comply with the accepted standard for drinking water, the South African National Standard (SANS 241) because they are a health risk. Nitrate ion is a health risk because it can be reduced to nitrite ion, which is toxic, by microbiological processes in the stomach. Nitrite ion causes methaemoglobinemia (blue-baby syndrome) in infants of 0 to 6 months of age. Nitrite ion can also react with amino compounds, in various media, to form nitrosamines which are strongly carcinogenic and are a cause of various cancers[1]. Calcium and magnesium ions cause water hardness, which in turn adversely affects body organs such kidneys, liver and eyes[2]. Fluoride ion affects health because they result in dental and skeletal fluorosis when its concentration exceeds the SANS-241 specification for drinking water[3]. It is therefore absolutely essential that the polluted, brackish groundwater should be treated.

CHAPTER 2 LITERATURE SURVEY

2.1 HISTORICAL OVERVIEW

The major focus in membrane technology in the past two and a half decades was the study of the mechanism of transport of determinands across the membrane. The research activity in this field was multidisciplinary. The major milestones in the scientific development of membranes may be divided into four areas. The phenomena of osmosis, electro-osmosis and dialysis were observed respectively by Nollet (1748), Reuss (1803) and Graham (1861). The relations between the transport of determinands from the feed across the membrane to the permeate side were described by, among others, Fick in 1855, Van`t Hoff in 1887, and Nernst and Planck in 1889. The theoretical basis of the membrane process was developed by various individuals from 1905 to 1964. Three major mass transfer models across the membrane were proposed. The mechanism of transport through ionic membranes was developed by Teorell in 1937, and Meyer and Sievers in 1936. The pore model was developed by Schmid (1950) and Meares (1956) and the solution-diffusion model by Lonsdale in 1965. [4]

The three countries that are accredited for the initial technical development of membranes are Germany, Netherlands and the United States of America (USA). The one factor that is responsible for the conversion of membrane processes into a technology was the development of asymmetric membranes which are characterized by higher water permeability's relative to their symmetric counterparts. Micro filtration (MF) membranes were the first membranes to be commercially produced and were prepared by Sartorius in Germany in 1920. Ultrafiltration (UF) membranes were also first developed in Germany in 1930 for laboratory use as were the MF ones. Haemodialysis membranes, which are used as artificial kidneys, were developed in the Netherlands on a small scale in 1950. Electro dialysis (ED) and reverse osmosis membranes were developed in the USA in 1955 and 1960, respectively, for industrial applications. The RO membranes were used for seawater desalination. The USA also developed UF membranes for the concentration of macromolecules. Nanofiltration membranes were the last to be developed. They were developed by Cadotte, Jonsson and Kurihara in the seventies and late eighties and were originally called open or low pressure reverse osmosis membranes. [4, 5]

Research on membranes in South Africa was begun in 1953 on electro dialysis at the Council for Scientific and Industrial Research (CSIR). Research and development on nanofiltration and reverse osmosis membranes began in 1973 at the Institute of Polymer Studies (IPS) at Stellenbosch University. This research resulted in the establishment of membrane manufacturing plant in 1979. Further noteworthy milestones in the research and development of membranes in the country are the following: the development of woven fibre micro filtration membranes at the University of KwaZulu-Natal in 1980; a cost-efficient method was developed by the Universities of Western Cape and Stellenbosch for the industrial preparation of ozone by membrane technology. North-West University (Potchefstroom campus) investigated a method for the removal of metals using encapsulated supported liquid membranes and is also currently engaged in the development of ceramic membranes [6].

Today, membrane research is conducted at several tertiary institutions and private companies. One of the major membrane companies that have been established through the advances that have been made in membrane technology is Malutsa (Pty) Ltd [7] which was started in 1997 in response to the Government's Policy of black economic empowerment. It broke away from a Scottish-owned company which was called Weir. The major operations of the company are contracting, consultation, manufacturing and operation and maintenance of water and wastewater plants. The water and wastewater plants are manufactured for both local and international markets. The plants are exported to Europe (Denmark, Netherlands and the United Kingdom), Asia (South Korea and Maldives), Indian Ocean Islands (Madagascar, Mauritius and Comores) and Southern African Development Countries (SADC). The main thrust of the research is in water treatment as South Africa is a water-stressed country. Accordingly, North-West University (Mafikeng campus) is actively involved in membrane research for water treatment [7].

2.2 GROUNDWATER QUALITY OF MADIBOGO VILLAGE

Madibogo village is located in North West Province and is at least 100 kilometres south west of Mafikeng, the provincial capital. It is situated in the Ditsobotla district between longitudes 25 E and 26 E, and latitudes 25 S and 26 S. North West Province is situated on a semiarid region of South Africa where there are few surface water sources. The majority of people in the rural areas depend on groundwater for their livelihood which is taken directly from boreholes without any prior treatment [7].

The distribution of some determinands in the groundwater in Madibogo village in the current study can be deduced from the ten groundwater maps that are given in Figures 2.1 to 2.10.[8] The first groundwater map (Figure 2.1) shows that the average groundwater exploitation potential (AGEP) in Madibogo village extends from 10 000 to 15 000. The next figure, Figure 2.2, shows the level of total dissolved solids (TDS) in the groundwater in Madibogo village. The TDS is used to evaluate the quality of freshwater systems and it ranges from 500 to 700 mg/ℓ. The third groundwater map (Figure 2.3) indicates that the conductivity of groundwater lies between 70 to 300 micro Siemens/m. The remaining groundwater maps (Figures 2.4 to 2.10) show the concentrations of some determinands that were investigated in the current study. The concentration of sulphate ion ranges from 30 to 100 mg/ℓ in which range it does not exhibit any health or aesthetic effects. The concentrations of calcium, chloride, magnesium and sodium ions range respectively, from 30 to 80 mg/ℓ, 50 to 100 mg/ℓ, 50 to 70 mg/ℓ and 50 to 100 mg/ℓ. The concentration of the nitrate ion ranges from 10 to 20 mg/ℓ. The concentration of alkalinity, the measure of water to neutralize an acid, lies between 100 to 400 mg/ℓ.

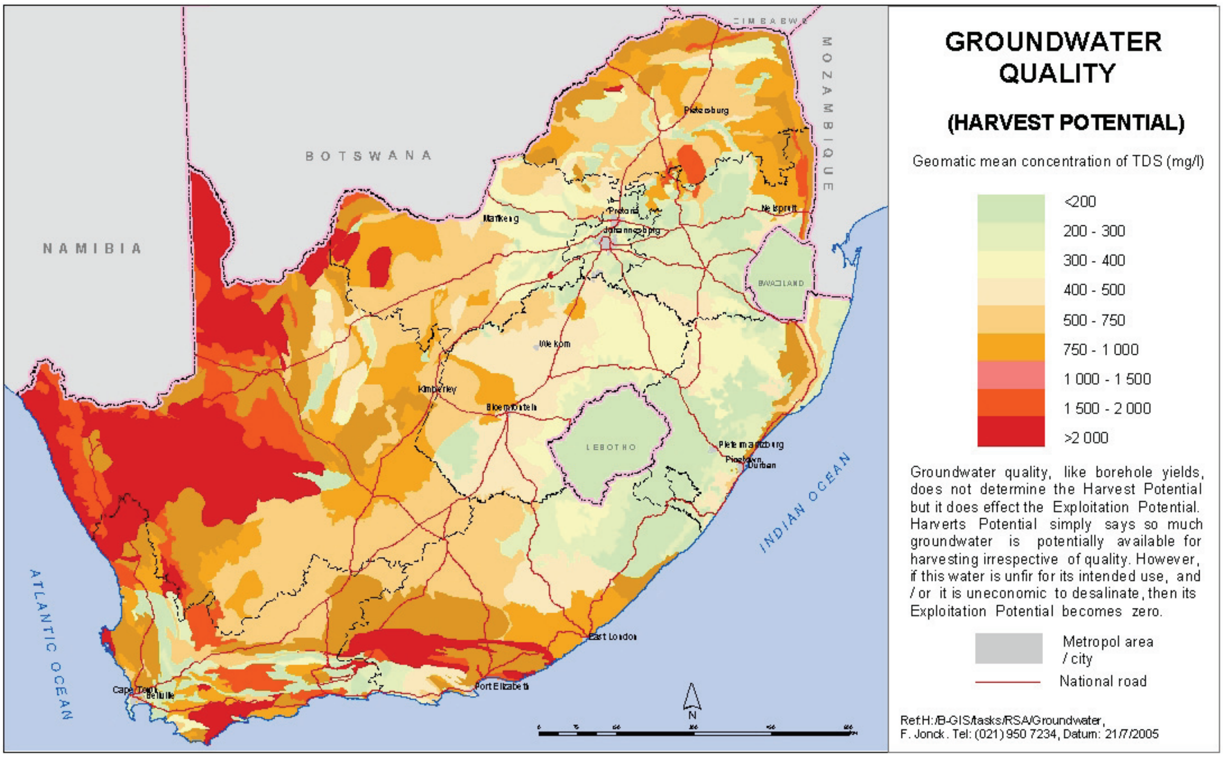


Figure 2.1 Groundwater exploitation potential

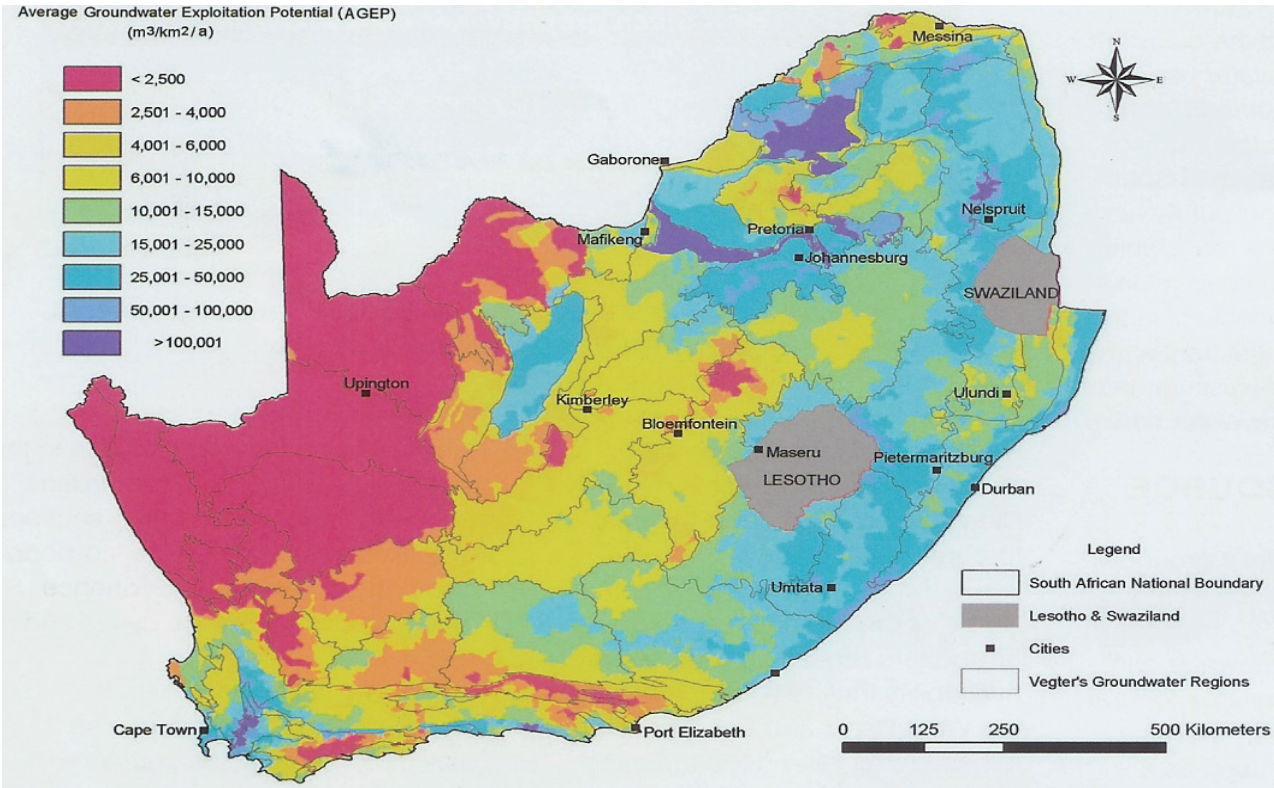


Figure 2.2 TDS

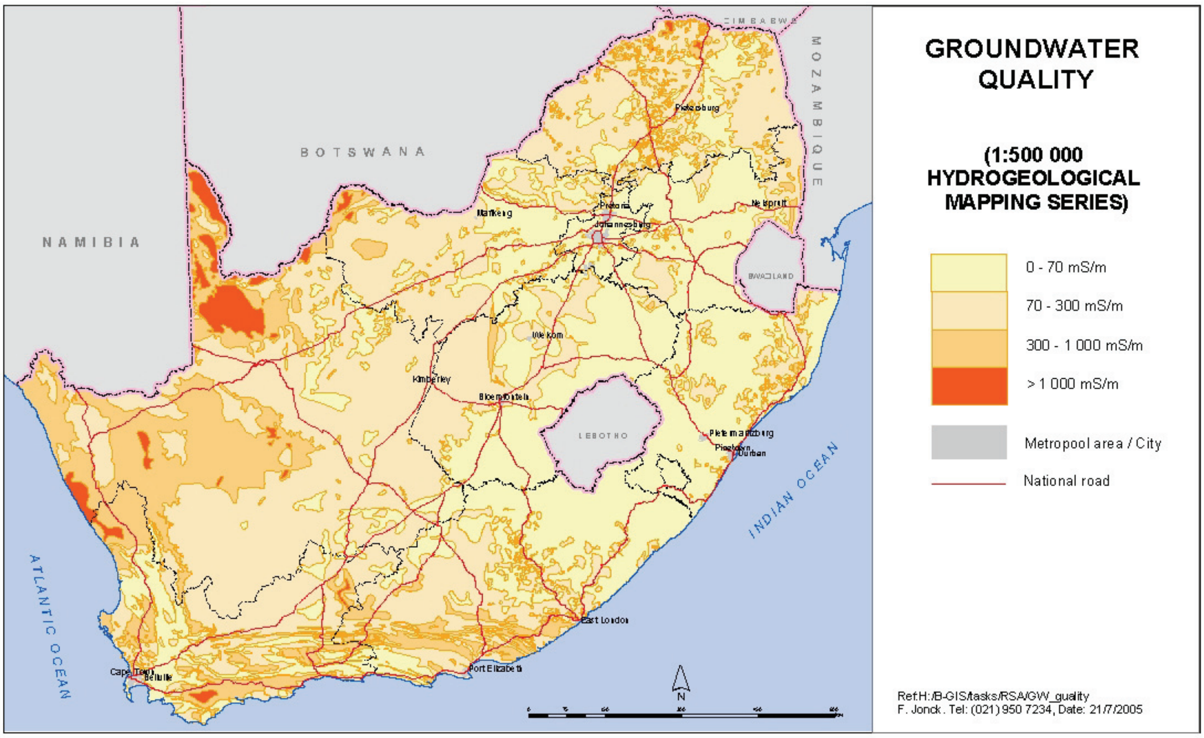


Figure 2.3 TDS

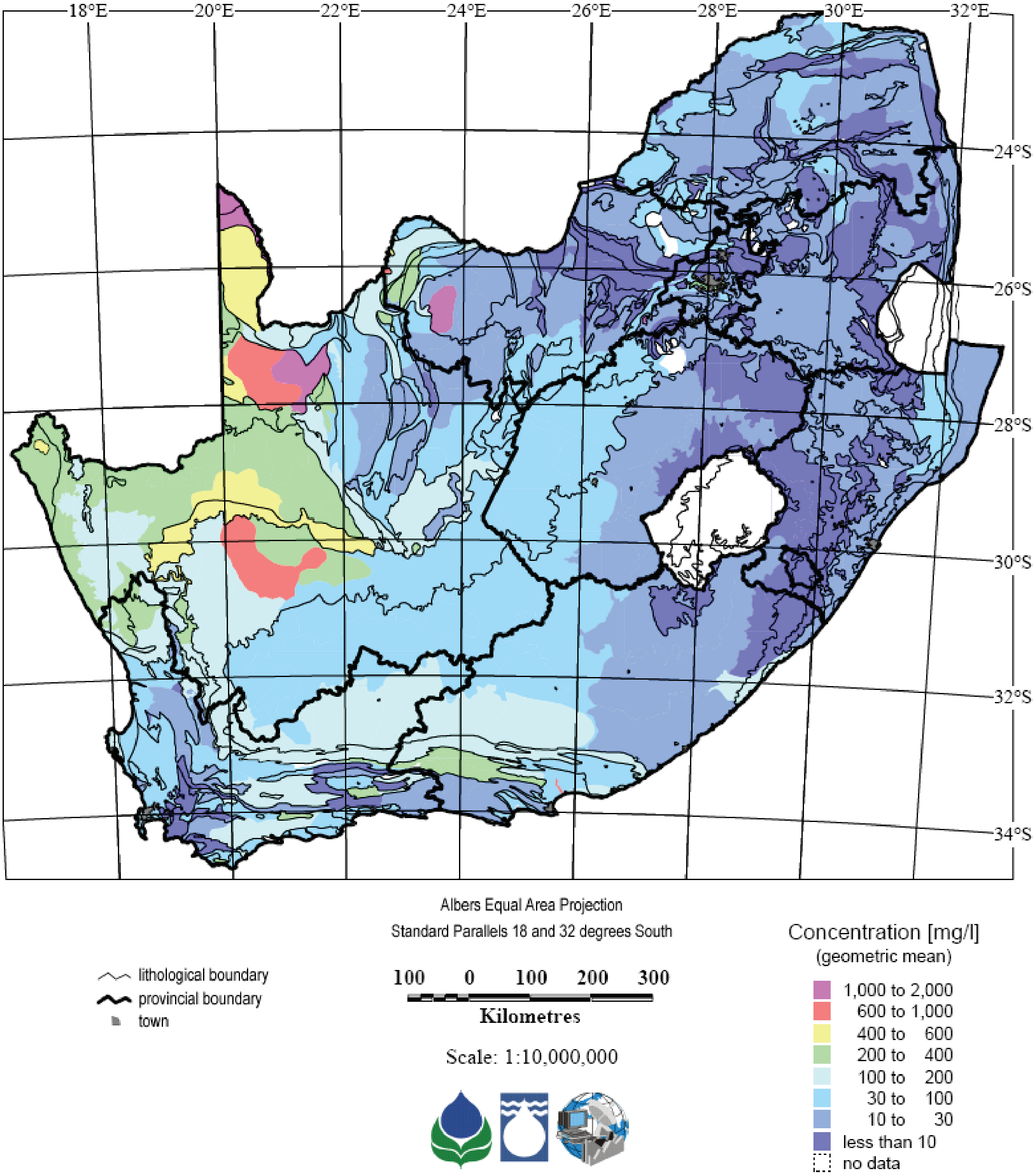


Figure 2.4 Sulphate

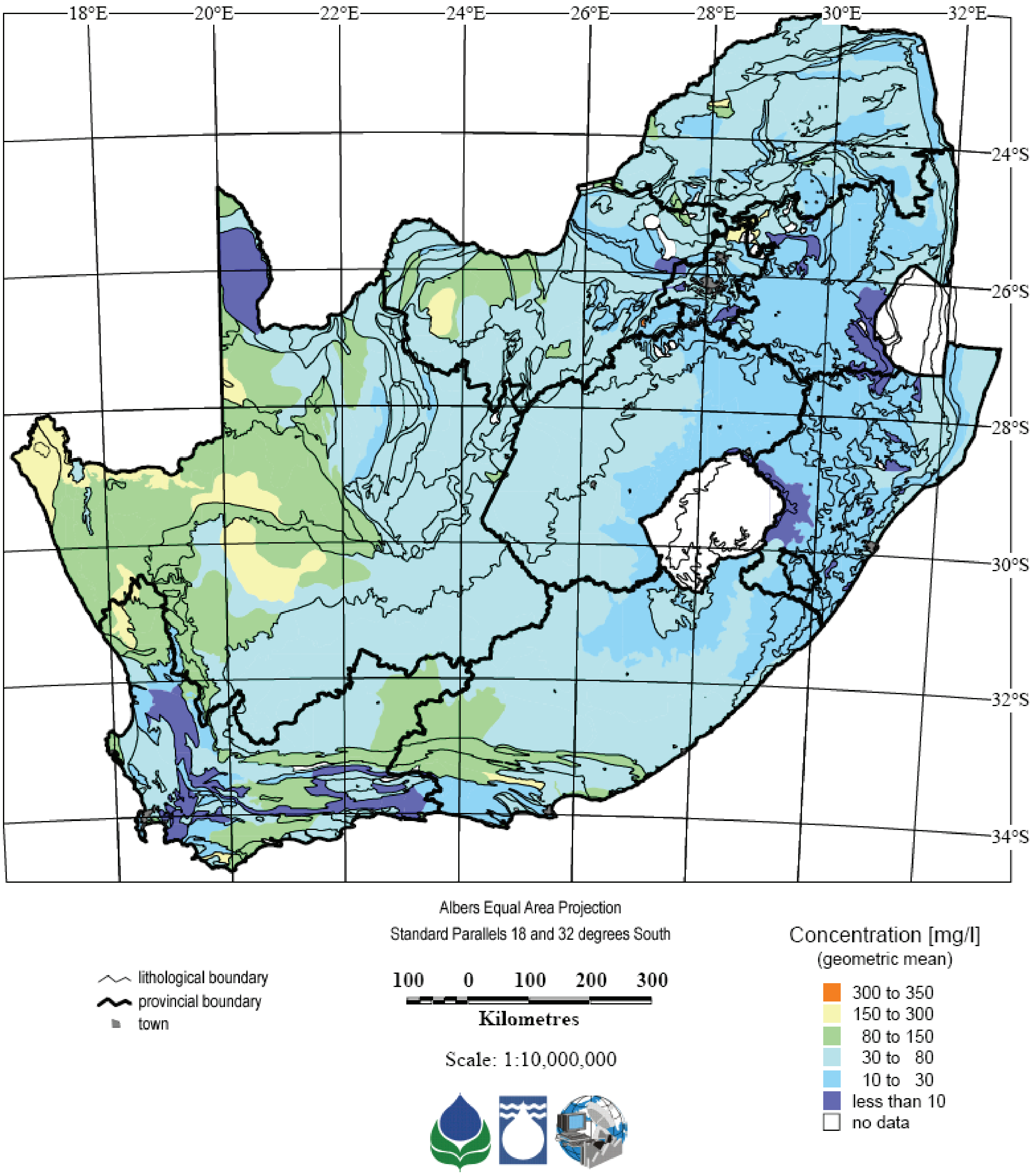


Figure 2.5 Calcium

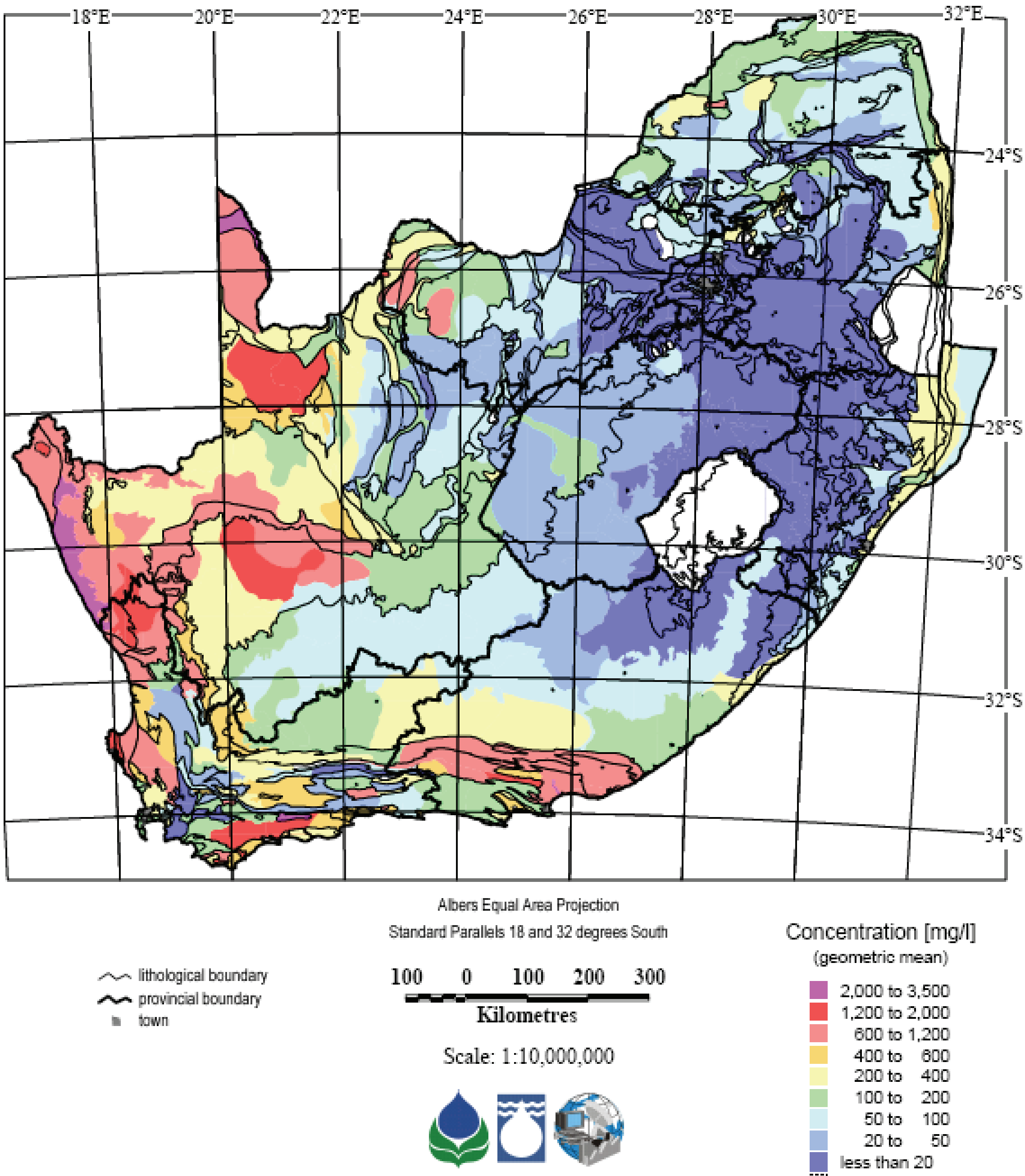


Figure 2.6 Chloride

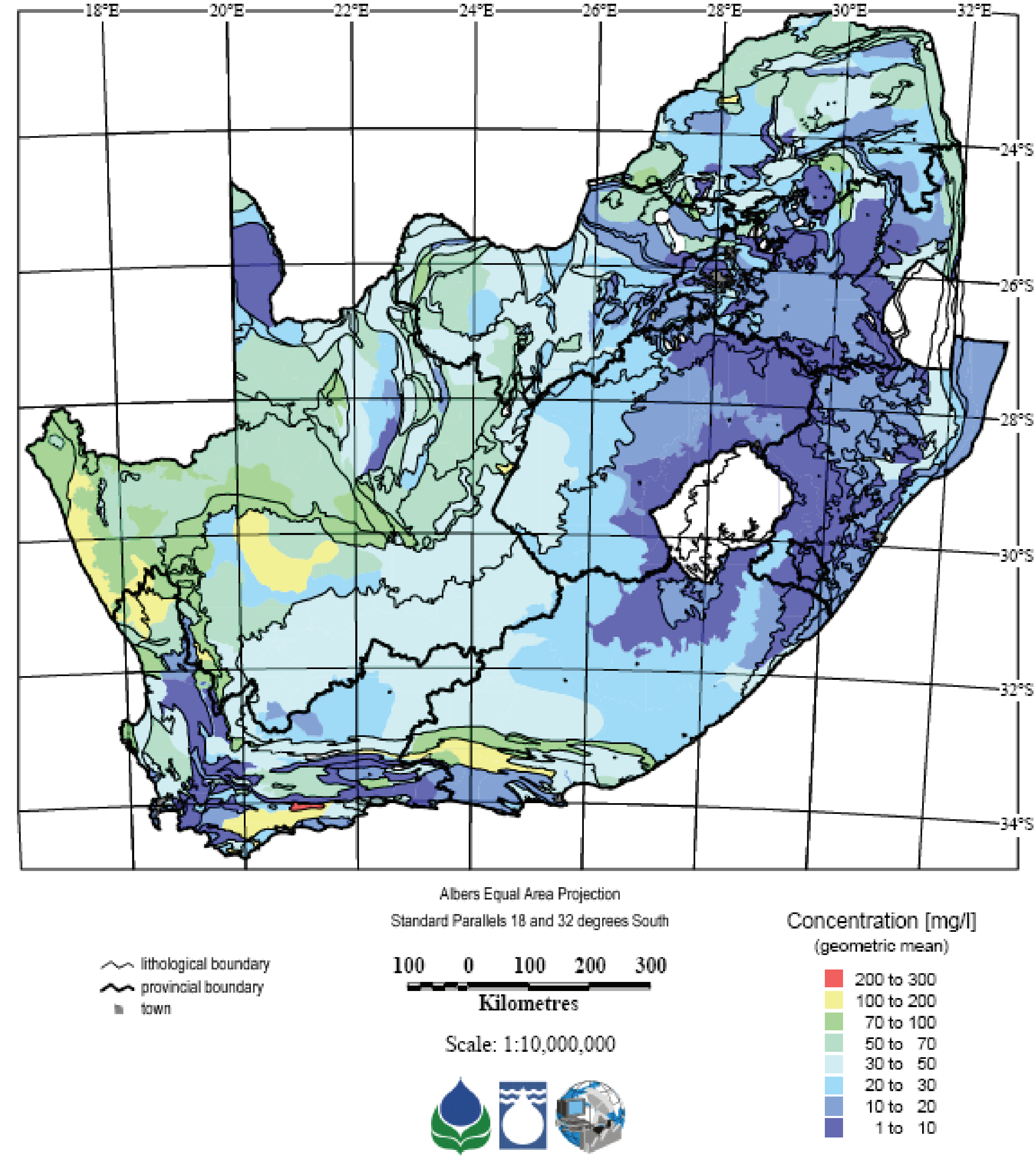


Figure 2.7 Magnesium

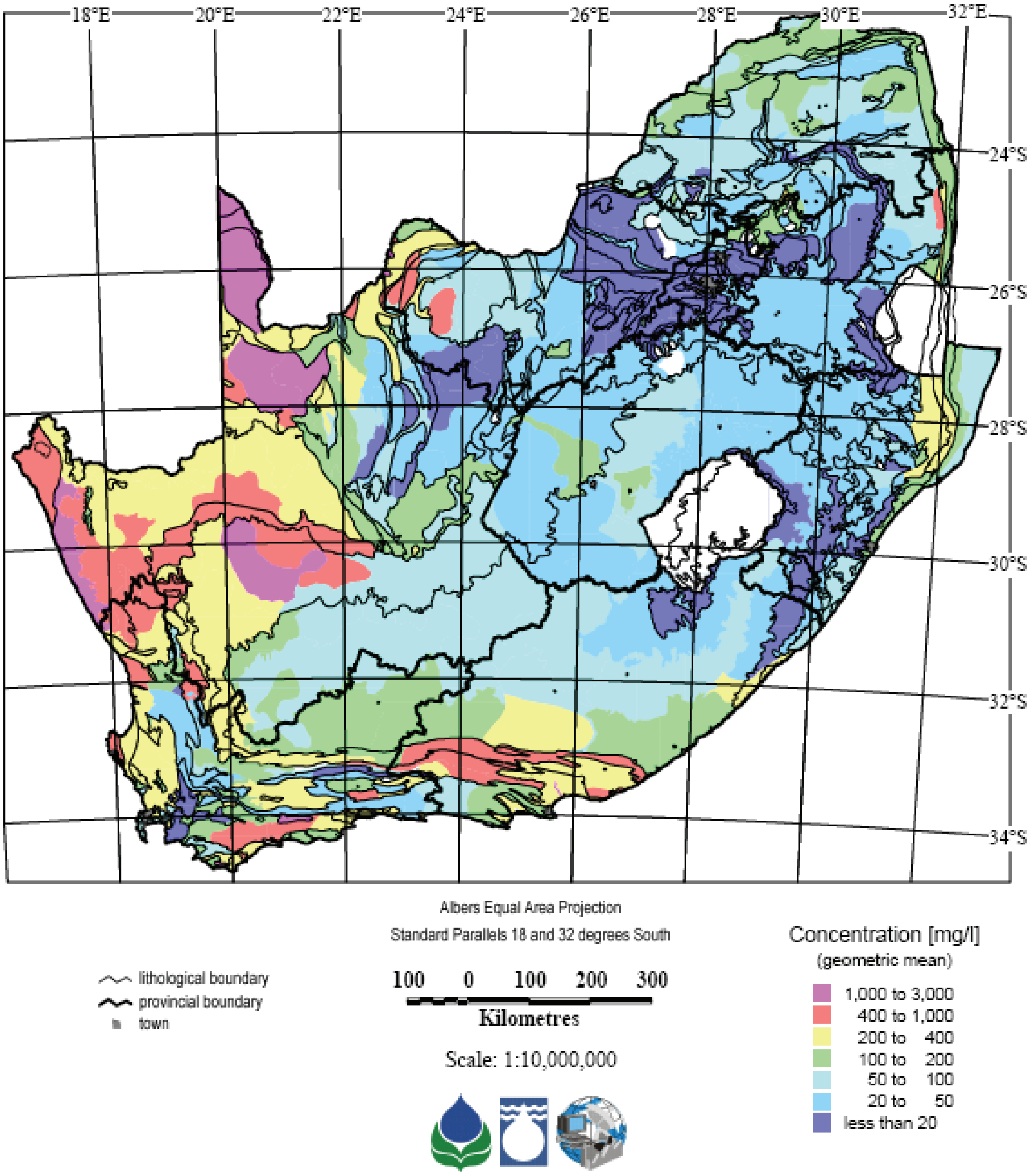


Figure 2.8 Sodium

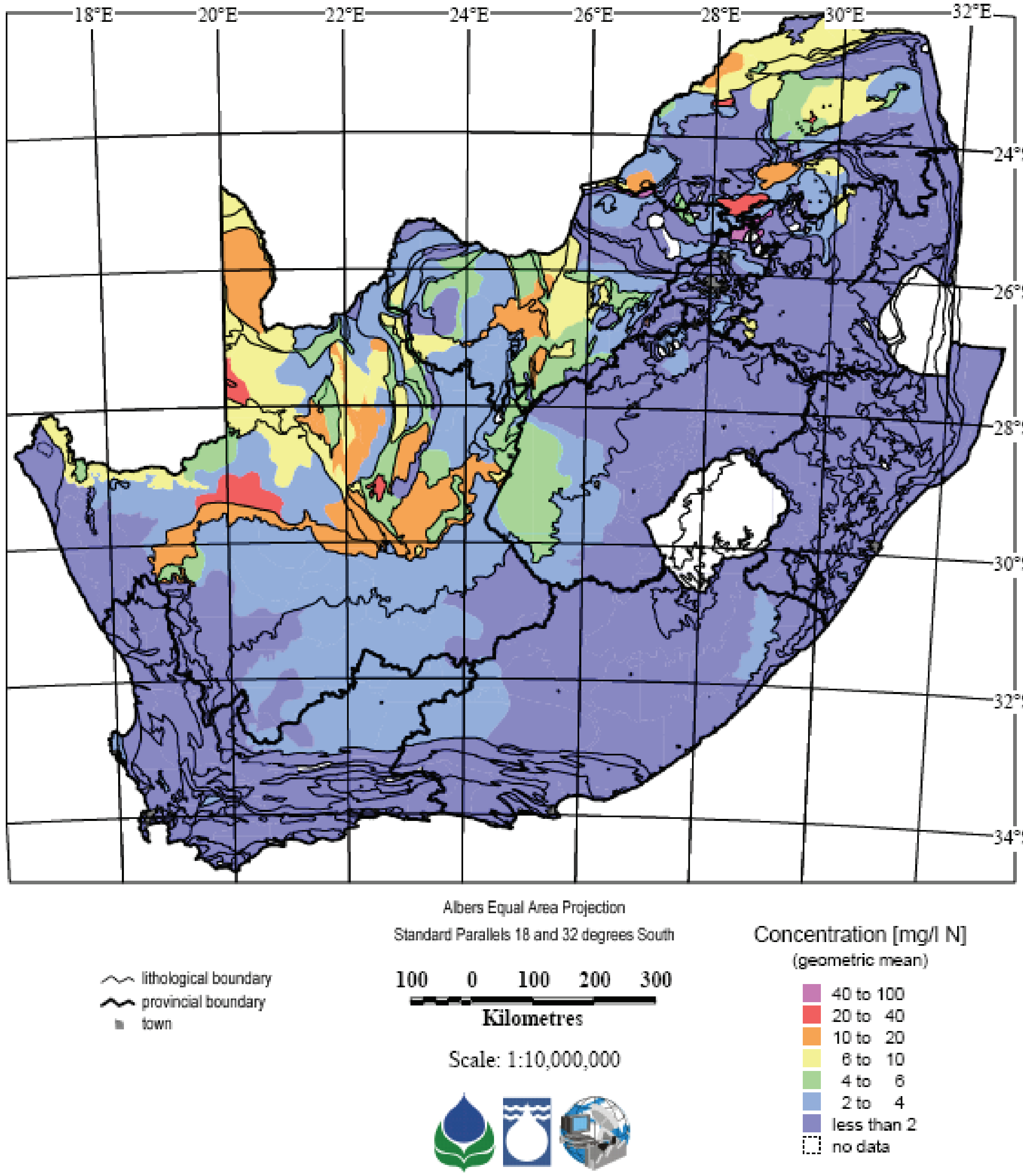


Figure 2.9 Nitrates

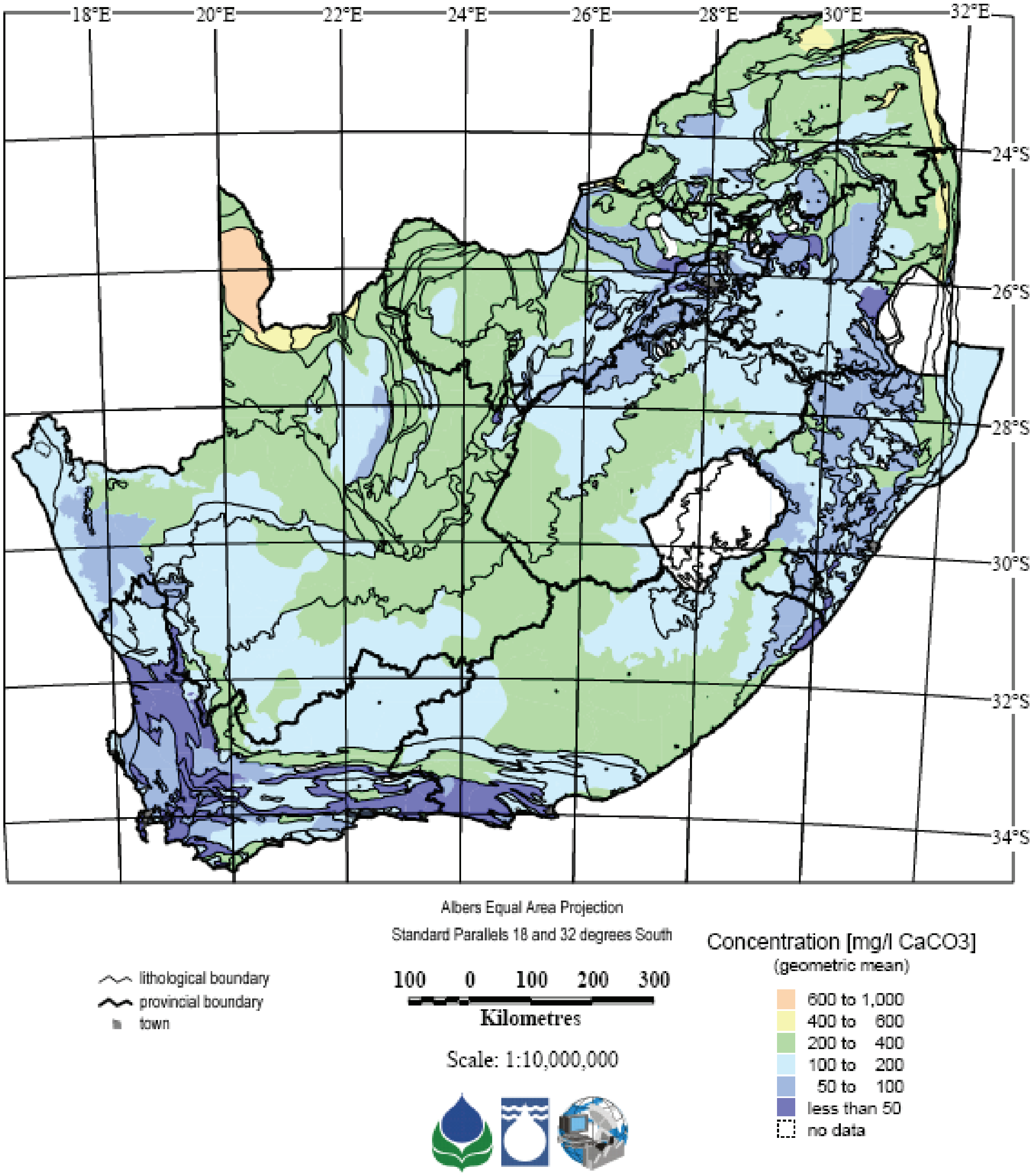


Figure 2.9 Nitrates

2.3 WATER QUALITY AND TREATMENT

Africa is the most water-stressed continent and it has already been predicted that there will be a water crisis by 2025 on the continent [9]. Two thirds of its surface is affected by aridity to some degree [10]. The scarcity of water results in competition for this finite entity which will in turn lead to conflict or cooperation among the various stakeholders as water is one of the core resources of life. Economic and social development and environmental sustainability depend on the availability of water. However, this resource is increasingly becoming a scarce commodity for a variety of reasons including, but not limited to, population growth, change of life style, water pollution and changes in climatic conditions. There could also be more frequent extreme events such as droughts and floods [9]. One of the greatest challenges of this century is ensuring access to the affordable and potable sources, particularly in developing countries.

A water source, the concentration of whose determinands do not comply with the specifications of the South African National Standard, SANS 241[11] for drinking water is said to be polluted. The pollution might originate from one or more of the following sources: domestic and industrial waste water; public and private sewage disposal; mine effluent; land run-off [12]. Since some of the pollutants are invariably toxic, the water should be treated to ensure that the health of the community is not compromised. Polluted water is often treated by conventional sand filtration or pressure-driven membrane processes. The typical unit processes in conventional sand filtration are pre-treatment, coagulation, flocculation, sedimentation, disinfection, aeration and filtration [13]. The four types of pressure-driven membrane processes are micro filtration, ultra filtration, nanofiltration and reverse osmosis [4]. Nanofiltration (NF) and reverse osmosis (RO) membranes are used for treatment (removal of pollutant concentrations of determinands) of polluted water. Since the pores of these membranes are less than 2 nanometres, they are thus called nanomembranes.

2.4 ADVANTAGES OF NANOMEMBRANE TECHNOLOGY

The major disadvantages of conventional water treatment or sand filtration are twofold: it cannot remove dissolved salts and some soluble organic and inorganic substances from the feed water; it cannot produce potable water from seawater or brackish water [14]. There are many advantages of membrane filtration methods. It can be used for the production of water of any desired quality [15, 16]. This can be achieved by connecting the different membrane processes in series such that the one acts as a pre-treatment step for the next. It can be used for the desalination (removal of salts) of seawater or brackish water; RO membranes can reject almost all soluble salts and fine soluble or insoluble inorganic or organic species in the feed water. RO membranes are used for the production of ultra pure water. NF membranes, on the other hand, are used for the partial desalination of brackish water and seawater, removal of micro pollutants, water softening and wastewater treatment [17]. A major impediment to wider application of membrane technology is high production costs. A third of costs are required for supplying the energy that forces the water through the membrane. Although significant advancements in technology have extended membrane life while lowering energy requirements, overall energy consumption remains extremely high [14, 17]. Desalination costs are about USD 0.60 per m^3 of brackish water. It is expected that nanotechnology will contribute to the improvement in membrane technology that will reduce the cost of brackish water treatment.

2.5 APPLICATIONS OF NANOMEMBRANE TREATMENT

Membrane technology is now used as an alternative method for water treatment with a wide range of applications [15]. It is used in the treatment of naturally occurring water (including the desalination of sea water), industrial and municipal wastewaters. There are currently more than 15 000 membrane water treatment plants which produce more than 35 000 million gallons of water per day in more than 120 countries. Desalination water accounts for 70% of the water supplies of each one of these countries, Spain, Saudi Arabia and the United Arab Emirates [14]. Nanomembrane water treatment is used in Israel for the desalination of saline waters. The Grand Water Institute of Israel Institute of Technology is working with corporate and other partners to treat salt water by reverse osmosis and create fresh water sources for drinking water and irrigation. Filmtec is a company from the United States which supplies NF and RO membranes for the purification of public drinking water supplies. These membranes remove excess calcium and magnesium ions from municipal water and also pesticides and other dissolved organics. One of the advantages of NF over RO membrane processes is the lower energy consumption [18]. Some specific examples of nanomembrane filtration treatment of water are given in Table 2.1.

Table 2.1 Examples of application of nanomembrane treatment of water

Organisation	Country	Type of technology
Filmtec Corporation	United States of America	Nanomembrane filtration technologies
North-West University	South Africa	
University of Stellenbosch (Institute of Polymer Science)	South Africa	Nanomembrane filtration technologies
The Stephen and Nancy	Israel	Reverse osmosis
Long Beach Water Department	United States of America	Nanofiltration
Rensselaer Polytechnic Institute	United States of America	Devised a simple method to produce carbon nanotubes filters that efficiently remove pollutants from water.
Banaras Hindu University	India	Devised a simple method to produce carbon nanotube filters that efficiently remove pollutants from water.

Table adapted from reference [7].

Nanomembrane technology is also applied in industrial processes, for instance, retention of dyes, concentration of food juices, sugars and milk [1].

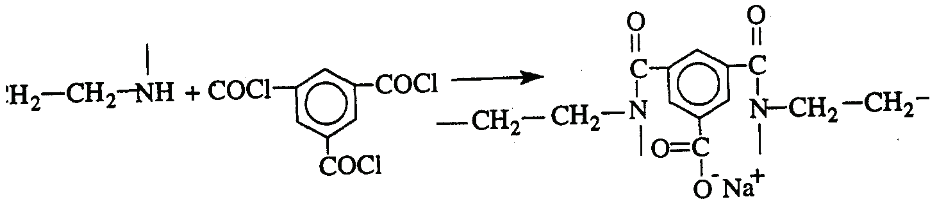
Schoeman *et al*.[19] used a nanofiltration membrane process to treat industrial solid waste leachate (ISWL) from Holfontein. The rejection of the organics in the leachate ranged from 42% to 59% using AFC 40, MPT 31 and MPT 36 NF membranes. Monovalent ions such as Na^+ and Cl^- had lower rejections relative to divalent ions such as Ca^{2+} and SO_4^{2-}. A higher proportion (52%) of Cl^- ions was found in the AFC 40 membrane permeates compared to the 18% of SO_4^{2-} ions. Higher concentrations of monovalent cat ions were also found in the permeate compared to those of divalent cat ions. The concentrations of the monovalent Na^+ and the divalent Ca^{2+} and Mg^{2+} ions in the permeate were respectively 70%, 14.6% and 15%. The remaining NF membranes (MPT 31 and MPT 36) gave rejections that were similar to those of the AFC 40 membrane. The researchers also used cellulose acetate and polyamide tubular reverse osmosis membranes for the treatment of municipal solid waste leachate (MSWL). A 96.1% removal of TDS was obtained. Good rejections were obtained for some determinands including Cl^- (92.4%), SO_4^{2-} (99.5%), Ca^{2+} (98.8%), Mg^{2+} (99.7%), K^+ (94.9%), Na^+ (96.4%) and COD (97.7%). However, the rejection for NH_3 was poor (90.7%).

Comstock [18] used a NF membrane whose molecular weight cut-off (MWCO) was between 150 and 200 (Desal-5) for neutral molecules for water treatment. The membrane had a high rejection for multivalent anions and divalent cat ions. It had a low rejection for monovalent ions. This characteristic made the membrane to be suitable for the removal hardness (Ca^{2+} and Mg^{2+}) and sulphate from natural waters. Eriksson [20] described NF as a membrane process whose properties lie between those of ultra filtration and reverse osmosis. He also noted its low rejection for salts with monovalent anion and neutral organic compounds with a molecular weight cut-off which is below 150. It has a high rejection for salts with divalent and multivalent anions and organics with molecular weight cut off above 300. The rejections for $MgSO_4$ and NaCl for all NF membranes were respectively 90- 98% and 50% or lower. Since NF membranes are negatively charged, their rejection characteristics are largely determined by anion repulsion. Thus they have high rejection for divalent and multivalent anions.

2.6 STRUCTURES OF NANOFILTRATION AND REVERSE OSMOSIS NANOMEMBRANES

Nanofiltration and reverse osmosis membranes have asymmetric structures which comprise of two layers[20]: the top layer is thin and dense and is less than 1 micrometer thick; the underlying layer (sub layer) consists of pores and its thickness ranges between 50 to 150 micrometers. The rate of mass transfer across the membrane (flux, J) depends on the thickness of the top layer with which it varies inversely. There are two types of asymmetric membranes. The first type is integral asymmetric membranes which consist of two layers that are prepared from the same material by phase inversion. This type can further be divided into three classes. Cellulose ester membranes are a widely used class of nanomembranes and examples include cellulose diacetate and triacetate. Their advantages include high water flux and high salt retention. However, they are unstable at temperatures greater than 30ºC and are also prone to bacterial decomposition. They have a pH operating range of 5-7. Although aromatic polyamides have good retention for solutes, they have a poor water flux. Their pH operation range extends from 5-9. A major shortcoming of these membranes is that the amide group (-NH–CO) reacts with free chlorine which results in poor membrane performance.

The last group comprises polybenzimidazoles, polybenzimidazolones, polymidehydrazides and polymides. The second type of asymmetric membranes is composite membranes in which the top layer and sub layer are made from different materials. Interfacial polymerization is one of the means by which the thin dense top layer is immobilized onto the porous sub layer. An example of a composite membrane is the synthesis of a polyamide by reaction of two monomers, thus



The separation characteristics of NF and RO membrane processes arise from their membrane structures. Both processes separate low molecular weight solutes such as inorganic salts and small organic molecules. These processes are essentially the same because they are based on the same principles. The major differences between them include the type of the network structure of the membrane and the operating pressure. The relatively more open network structure of a NF membrane results in a lower rejection of monovalent ions (such as Cl^- and Na^+) than a RO membrane [4]. The denser network structure of RO membranes results in lower selectivity for solutes. For example, RO removes a significant proportion of nitrate ions [20] and can reject more than 90% of fluoride ions in one operation [21]. Furthermore, RO membranes can retain all dissolved salts but water [17]. The denser network structure of RO membranes necessitates higher transmembrane pressure for the separation of the solutes from the solvent [20].

Recent developments in membrane technology have made it possible to produce various qualities of water from different water sources, for instance brackish water and seawater [15,16]. One of the developments that have advanced membrane technology is membrane element configuration. The most widely used configuration is the spiral-wound configuration which is used in all four types of pressure-driven membrane processes. It consists of two membrane sheets that are separated with a permeate carrier. A feed channel spacer is inserted between opposing membrane surfaces. Figure 2.11 shows the design of a spiral-wound element configuration.

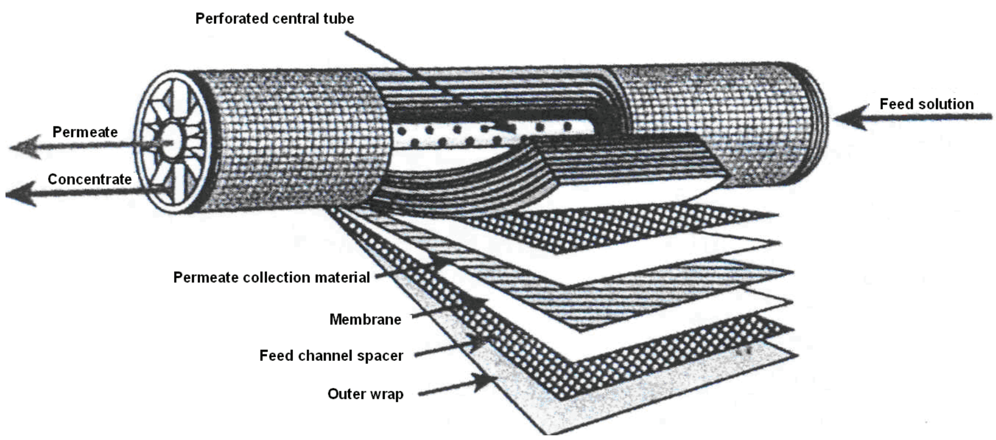


Figure 2.11 The spiral-wound element configuration

The membrane sheets, permeate carrier and the feed channel spacer are wound around a perforated central tube through which the permeate is eluted. The membrane element is covered with a protective outer wrap. The properties of the constituents of the membrane element are determined by the operating conditions. Some operating parameters for a typical RO application for water treatment are as follows: a temperature of 45ºC; a pH value of between 2 and 10; the silt density index should be less than 3; chlorine should be absent or removed. The advances in technology have resulted in the reuse of water to compensate for its scarcity in water stressed environments.

2.7 MEMBRANE CHARACTERIZATION

An appropriate membrane has to be chosen for the treatment of a given type of water. This choice is done via a process called characterization. This is the determination of structural and morphological properties of the membrane. It relates structural properties such as pore size distribution, free volume and crystallinity to membrane separation [4]. The separation characteristics of a membrane can then be predicted once its morphology and structure has been determined. The separation is based on size and charge effects. NF membranes can be classified as porous and nonporous. Porous membranes have pores which are distributed throughout the membrane. Nonporous membranes have a swollen network structure. NF membranes can also be classified as charged or neutral. However, no neutral porous membranes have been reported. The separation efficiencies of both porous and nonporous membranes are similar but the mechanisms are different. Uncharged solutes are separated through a sieving mechanism in porous membranes whereas they are separated by a solution-diffusion mechanism in nonporous, swollen network membranes. Charged solutes or ions are separated by a charged membrane through both repulsion the between membrane and the solute, and also by sieving. The separation of ions through a charged swollen network is through solution – diffusion and charge – interaction effects mechanisms. The characterization of NF membranes resembles that of both ultra filtration and RO membranes because of its place in the membrane domain [5].

There are several methods by which NF membranes can be characterized. These include solvent flux and retention measurements, scanning electron microscopy (SEM) atomic force microscopy (AFM), permporometry, gas adsorption/desorption and charge determination. Both NF and RO membranes are generally characterized by performance related properties, that is, permeation measurements. The separation efficiency of a membrane largely depends on flux and retention. An ideal membrane would have a high retention coefficient (R) and flux (J). However, the two variables are antagonistic: high flux values correspond to low flux values. The separation efficiency of a membrane is also determined by the sterical hindrance of solutes through the membrane pores which is governed by molecular weight and ionic charge of the determinands. This implies that the separation efficiency of a membrane is higher for low molecular weight determinands than for higher molecular weight ones [4].

Deionised water is used in the determination of water flux (J_w). The gradient of the plot of water flux versus the pressure applied on the membrane (ΔP) is called the water permeability (A_w or L_p) and is a constant for a given membrane. The relationship between J_w and ΔP is expressed by the Hagen-Poisseuille equation:

$$J_W = \frac{\varepsilon . r^2}{8 . \eta \cdot \tau} \cdot \frac{\Delta P}{\Delta x} \qquad (2.1)$$

where ε is porosity, r is pore radius, τ is tortuosity which expresses the geometry of the pores, η is the viscosity of water and Δx is the membrane thickness. Darcy derived J_w in terms of A_w and pressure,

$$J_W = A_W (\Delta P - \Delta \pi) \qquad (2.2)$$

where $\Delta\pi$ is the osmotic pressure difference.

Darcy's equation simplifies to Equation (2.3) as the osmotic pressure difference across the membrane is zero:

$$J_W = A_W \cdot \Delta P \qquad (2.3)$$

A combination of equations (3.1) and (3.3) and rearranging yields an expression for A_w, thus

$$A_W = \frac{\varepsilon . r^2}{8 \cdot \eta \cdot \tau \cdot \Delta x} \qquad (2.4)$$

Equation (2.4) shows that A_w is proportional to porosity and pore radius but inversely proportional to membrane thickness.

Retention measurements are one of the most reliable methods for the characterization of these membranes. Retention is the capacity of a membrane to reject a given solute and is expressed as rejection or retention coefficient (R):

$$R = 1 - c_P/c_f \qquad (2.5)$$

where c_p is the concentration of the solute in the permeate and c_f is the concentration of the solute in the feed.

Bowen *et al.* [21] characterized an NF membrane (polyethersulphone 5) by using rejection of simple salts, rejection of neutral solutes and atomic force microscopy. Characterization using the simple salts enabled the researchers to find an effective pore radius (r_p) ratio of the effective thickness to porosity ($\Delta x/\Delta t$) and the effective charge density (X) of the membrane. The characterization by neutral solutes resulted in the determination of pp and $\Delta x/\Delta k$. Atomic force spectroscopy (AFS) was used to find the surface pore radius (r_p^s) and surface porosity (A_k^s). The use of AFM allowed the researchers to verify the presence of discrete surface pores in NF membranes. Bowen *et al.* found it easier to explain the transport of solutes through the membrane in terms of discrete pores on the basis of evidence from simple salts and neutral solute modelling by physical methods such as AFM and SEM.

Redondo and Lanari [23] characterized two NF membranes (NF 70 and NF 90) that are based on a cross-linked aromatic polyamide using $MgSO_4$ and NaCl solutions. The rejection coefficients (R) for the two membranes were as follows: $MgSO_4$ was 90-99%; NaCl was 70-90%. The membranes are negatively charged and the magnitude of R is determined by the anion. For example, R for $CaCl_2$ is approximately equal to that for NaCl. The degree of rejection for divalent and multivalent anions was very pronounced. The NF 70 and NF 90 membranes are thus suitable for partial desalination and softening of water. Nystrom *et al.* [24] characterized the NF membranes on the basis of their cut-off value molar mass of solutes which is 300 g/mol. That means that NF membranes are those membranes which reject solutes whose molar masses are 300g/mol and greater. They reject multivalent solutes and their R for multivalent ions were relatively higher than those for small organic solutes. Nystrom *et al.* further characterized an NF 40 membrane with some salts and obtained the following rejections: 45% for NaCl; 70% for $CaCl_2$; 97% for $MgS0_4$. They further observed that the rejection of monovalent anions decreases as their concentration increases as predicted by the donnan exclusion model.

2.8 MEMBRANE FOULING

Membrane fouling is the adsorption and deposition of material present in the feed water on the membrane resulting in a loss of efficiency of the separation process [4]. Substances in the feed or brine are deposited on the membrane surface or trapped in the membrane pores. Fouling originates from the three sources [15]: particles in feed water; accumulation of sparsely soluble minerals (for example, silica); by-products of growth of micro organisms. The sizes of the membranes pores are influenced by internal electrostatic repulsion between the pores and the solute particles [24]. Consequently, the flux (J) of a given membrane can be affected when some molecules are trapped in the membrane pores. The foulants can accumulate in the membrane pores or surface until they cause a loss in productivity (that is, decrease in flux J) and an increase in feed pressure requirements. The decrease in flux would in turn increase operation and maintenance costs of a membrane (NF or RO) plant. Further implications of fouling are frequent cleaning of membranes, reduced membrane life span and process down-time [15,25]. RO membranes are susceptible to fouling by scaling salts, inorganic oxides, colloidal or biological matter. The membrane flux can be improved through cleaning.

A silt density index (SDI) [26] is used to quantify the determinands that cause the clogging or fouling of nanomembranes during water treatment. It measures the degree or extent to which foulants or suspended particulates can clog a membrane and does not measure the concentration of particulates as their sizes are variable. An SDI value of less than 5 indicates that there will be a low rate of fouling whereas a greater value implies that further pre-treatment of the raw or feed water should be carried out. An SDI test should be performed regularly to monitor fluctuations in water quality. The method is based on the rate of clogging of a 0.45 μm membrane filter.

2.9 MEMBRANE CLEANING

A membrane has to be cleaned if there is a decrease of 15-20% in its normal operating flux, J [27]. The indicators that have to be monitored for membrane fouling are these: a decrease in product flow rate at a given inlet pressure, temperature and recovery; an inlet pressure increase of 1.5-2.0 bars or a 15% increase in transmembrane pressure at a given temperature flow rate and recovery. A fouled or clogged membrane is cleaned by a process called chemical in-process cleaning (CIP). The plant is isolated from the raw water supply and operated in closed circuit using a suitable cleaning solution that is prepared in the CIP tank. The cleaning solution is circulated through the system for a predetermined period. Table 2.2 gives three solutions that are widely used for defouling and the corresponding foulants.

Table 2.2: CIP chemicals for defouling various foulants

Defouling solution	**Concentration of defouling solution**	**Foulant**
Sodium hexametaphosphate (SHMP)	1% m/v $Na(PO_3)_6$	Biofoulants colloids
Ethylenediamine tetra-acetic acid (EDTA), sodium tripoly phosphate (STPP) and trisodium phosphate (TSP)	1% m/v Na_4EDTA, 1% STPP, 1%TSP adjusted to pH 11.5 with NaOH.	Organics Silicates Inorganic colloids.
Sodium dithionate	1%m/v $Na_2S_2O_6.2H_2O$	Metal oxides

where STPP is sodium tripolyphosphate and TSP trisodium phosphate.

The membrane is cleaned by permeating or flushing with the solution for about one and a half hours. Other workers have also investigated membrane fouling. Schoeman *et al.* [19] investigated the use of phosphoric acid and EDTA and SLS and/or STPP for cleaning tubular acetate membranes. They controlled fouling in tubular polyamide membranes by regular cleaning with HCl and Ultrasil 10.

CHAPTER 3 TREATMENT OF BRACKISH GROUNDWATER

3.1 INTRODUCTION

The water treatment of the brackish groundwater at Batlhaping Primary School in Madibogo village was performed using a cross-flow module reactor fitted a nanomembrane. Six nanomembranes were tested for their efficiency in treating the brackish groundwater at BPS in Madibogo village. Three nanomembranes were nanofiltration ones (Desal-DL, NF 90 and NF 270) and the remainder were reverse osmosis ones (S5, BW 30 and GM). One nanomembrane was used for the treatment of the brackish groundwater at a time. The cross-flow module reactor was used for the pilot-scale treatment of the brackish groundwater. The dead-end module reactor was only used for the characterization of the nanomembranes. The diagrams for the dead-end and cross-flow module reactors are illustrated in Figures 3.1 and 3.2.

3.2 EXPERIMENTAL SET-UP

The experimental set-up consisted of the laboratory scale dead-end module reactor and the NF/RO cross-flow module reactor pilot water treatment plant which was located at Batlhaping Primary School in the Madibogo village. The integral component of the pilot water treatment plant is the cross-flow module reactor.

3.2.1 Dead-end module reactor

All the feed water is forced through the membrane using the pressure of nitrogen gas. A porous support is used as template when cutting a membrane of the desired diameter (generally 9.0 cm). A magnetic stirrer is used for stirring the feed water. The concentration of retained solutes in the feed water progressively increases whilst the quality of the permeate decreases.

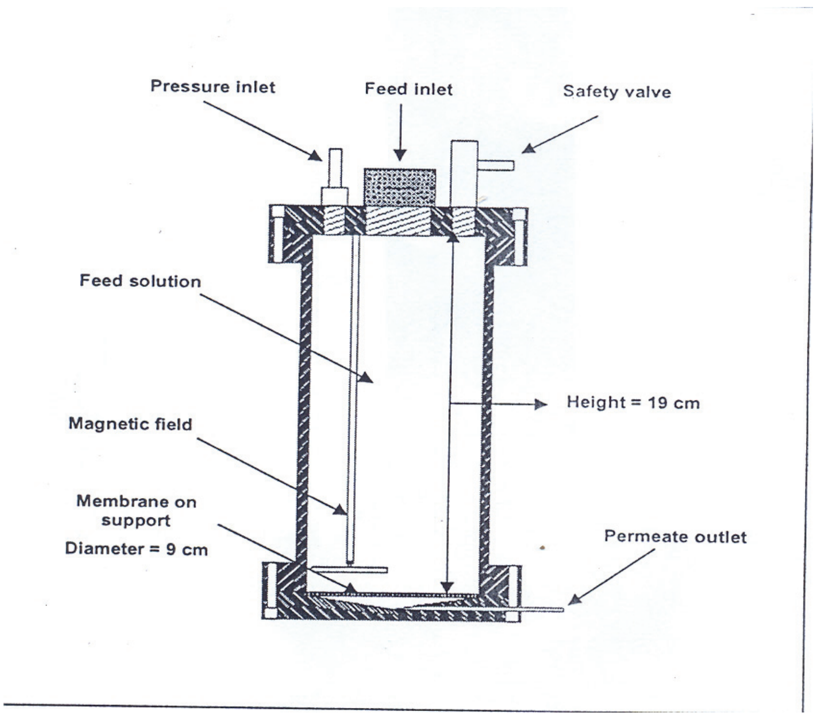


Figure 3.1 A diagram of the dead-end module reactor.

3.2.2 Cross-flow module reactor pilot water treatment plant

The cross-flow module reactor pilot water treatment plant consists of five major sections and these are illustrated in Figure 3.2. The feed section consists of a feed tank, feed pump and cartridge filters. The feed pump supplies the feed water to the membrane. The two cartridge filters remove any particulates in the feed water before the latter reach the membrane. The next section is the NF/RO membrane section which comprises the high pressure pump, feed flow adjustment, NF/RO membrane, back-pressure adjustment and the permeate. The high pressure pump forces the feed water through the membrane. The feed water flow rate can be adjusted. The membrane is contained in either a 2540 or 4040 inch pressure vessel. The resulting permeate is collected in a product tank and the brine is led to waste. The pilot plant is provided with a chemical in-process (CIP) cleaning aspect. A cleaning solution, contained in a CIP tank, is permeated through the membrane repeatedly for a predetermined period to clean a clogged or fouled membrane (see section 2.3).

The feed water is also subjected to chemical pre-treatment to prevent or minimize scaling. An anti-scalant solution is added to the feed water through a dosing pump before it reaches the membrane. Finally, the pilot plant is fitted with a control panel from which it can be operated in either manual/automatic or CIP mode. The cross-flow module reactor was supplied by Malutsa (PTY) LTD in Cape Town. The general abbreviations in Figure 3.2 are explained thus: PP = pressure pumps; FL = cartridge filter; PI = pressure gauge; S = switch; NV = back pressure control valve; HV = flow valve; FM = flow meter. The specific abbreviations in the diagram (Figure 3.2) are explained below:

PP1 = feed pump
FL 1/2 = cartridge filters
PI 101/102 = pressure gauges
PP2 = high pressure pump
PSL 101 = low pressure switch
HV 102 = feed flow valve
NV 101/102 = back-pressure control valves
PI 103 = design feed pressure (for normal operation)
PI 104 = pressure gauge on the outlet of the membrane
CIP = chemical in-process
TK 101 = CIP tank
LSH 102 = high level switch
LSL 101 = low level switch
PP3 = anti-scalant dosing pump
HV 105/107 = isolating valve on permeate and brine line
HV 104/103 = isolating valve on permeate and brine CIP line
FM 1 = brine flow rate
FM 2 = recycle flow rate
FM 3 = permeate flow rate
HV 104 = manual shut-off valve
HV 105 = permeate valve
HV 108 = drain valve
SV 101 = solenoide valve.

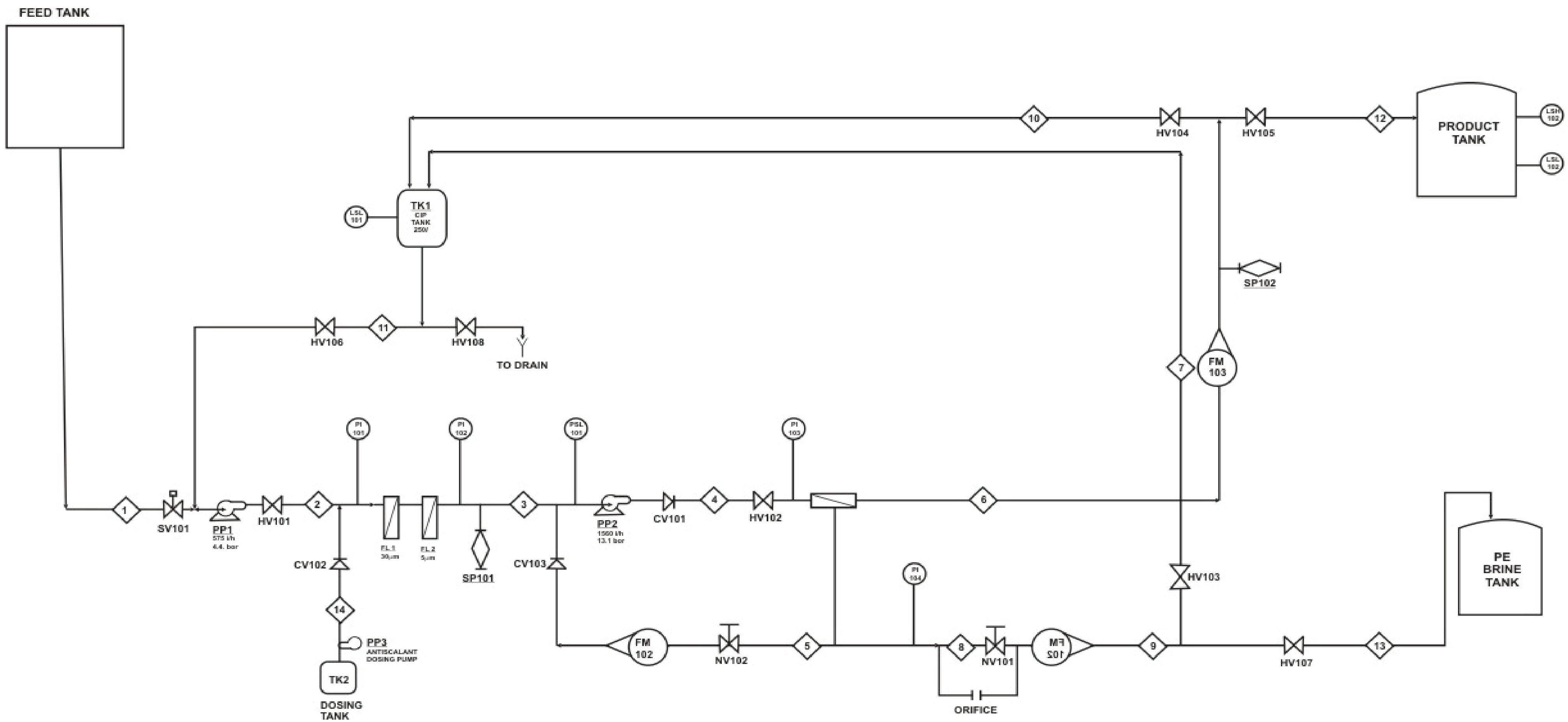


Figure 3.2 A diagram of a cross-flow module reactor pilot water treatment plant

3.3 MEMBRANES

3.3.1 Types

Six nanomembranes, of which three were NF (Desal-DL, NF 90 and NF270) and the remainder being RO (BW30, GM, and S5) nanomembranes were investigated for the treatment of brackish groundwater. The membranes were supplied in flat-sheet and spiral-wound configurations. Filmtec, a USA company, supplied the flat-sheet membranes and CHC Separations (Cape Town), a subsidiary of Filmtec, supplied the spiral-wound membranes. The flat-sheet membranes were used for characterization on the dead-end module reactor. The spiral-wound membranes were used for water treatment on the cross-flow module reactor pilot water treatment plant.

3.3.2 Specifications of nanomembranes

The specifications of the various NF and RO membranes used are given in Table 3.1.

Table 3.1 Specifications of some NF and RO nanomembranes

Parameter	Desal-DL	NF 90	NF 270	BW 30	S5	GM
MWCO (Dalton)	150-300	-	300	-	-	-
NaCl/ % rejection	-	-	-	99.5	98.5	-
$MgSO_4$/ % rejection	96	96	97	-	99.7	-
Design pressure/ bar	4.2-28	41	41	41	14-35	3-11
Maximum temperature/ ºC	50	17-35	40	45	50	50
pH range	2-11	3-9	3-10	2-11		2-11
Flow/ $m^3\ d^{-1}$	-	3.2	-	3.0	4.54	6.82

3.4 CHARACTERIZATION

The nanomembranes (NF and RO) were characterized in order to determine the most optimum membrane for the treatment of the brackish groundwater at the BPS in Madibogo village. The two methods that were used were clean water permeability (A_w) and retention coefficients (R).

3.4.1 Clean water permeability (A_w)

Approximately a litre of deionised water was added into a dead-end module reactor that was fitted with a nanomembrane. The deionised water was permeated through the nanomembrane at 20 bars of nitrogen gas pressure.

A stopwatch was used to record the time that was required to collect 5.00 cm^3 of the permeate or product water.

3.4.2 Retention measurements

The NF and RO nanomembranes were characterized using retention coefficients (R) to determine the separation efficiency of each nanomembrane for a given solute. A 1000 ppm stock solution of each solute was prepared from the following salts: KNO_3; NaCl; NaF; Na_2SO_4; $CaCl_2$; $MgSO_4$. A 20 ppm solution was prepared from the 1000 ppm stock solution for each solute in a one litre volumetric flask. The solutions for the first four salts (that is, KNO_3; NaCl; NaF; Na_2SO_4) were prepared in the anionic form. The solutions of the last two salts ($CaCl_2$; $MgSO_4$) were prepared in the cationic form.

3.4.2.1 Determination of the retention coefficient (R) of the nanomembrane

Approximately, a one litre 20.00 ppm solution was transferred into a dead-end module reactor that was fitted with a nanomembrane. The solution was permeated through the nanomembrane at 20.00 bars of nitrogen gas pressure. The time that was required to collect 50.00 cm^3 of permeate was recorded using a stopwatch.

3.4.2.2 Determination of chemical and physical determinands

The concentrations of the determinands (NO_3^-, Cl^-, F^-, SO_4^{2-}, Ca^{2+} and Mg^{2+}) were determined in the feed water, permeate brine. The samples were sent to the Department of Water Affairs and Forestry's Resource Quality Services (RQS) for analysis at Roodeplaat in Pretoria. The samples were also analyzed for physical determinands which included pH, electrochemical conductivity (EC) and total dissolved solids (TDS).

3.5 BRACKISH GROUNDWATER TREATMENT AT BPS

The brackish groundwater at Batlhaping Primary School (BPS) in Madibogo village was treated by means of the cross-flow module reactor, a picture of which is given in Figure 3.3.

Figure 3.3 A picture of the cross-flow module reactor pilot water treatment plant

3.5.1 The Cross-flow module reactor

The feed water tank (Figure 3.3) has an opening which is about 5 cm from its base. A black plastic pipe is connected from the feed water tank to the cross-flow module reactor membrane unit. The feed water is fed to the NF/RO membrane unit via the feed water pump PP1, cartridge filters FL1 and FL2, and high-pressure pump PP2. The permeate is collected in the product tank and brine is led to waste. Valves are used to control the flow rate and also to direct the water either to the NF/RO membrane unit or the CIP tank.

3.5.2 Cross-flow module reactor brackish groundwater treatment

The brackish groundwater was permeated through the nanomembrane at consecutive pressures of 16, 18, 20 and 22 bars sequentially. The brackish groundwater was permeated for 30 minutes at any given pressure to determine the optimum operating conditions (Table 3.2). A feed, permeate and blime samples were collected in 250 cm^3 polytheylene bottles after this interval. The sample was kept in a refrigerated cooler box at 4 ºC or less at the field or research site (that is, Batlhaping Primary School groundwater tap). The sample was subsequently taken to the laboratory at the university where it was also kept at 4ºC or less in a refrigerator until it was taken to the RQS in Pretoria for analysis.

Table 3.2: Operating parameters of the cross-flow reactor for the nanomembrane

1. Nanomembrane S5

Time/ Hours	Flow rate/l.h^{-1} Recycling	Flow rate/l.h^{-1} Brine	Flow rate/l.h^{-1} Permeate	Pressure/ bar	Sample number	Sample
0.50	1250	315	100	16	1	Feed
0.50	1250	315	100	16	2	Permeate
0.50	1250	315	100	16	3	Brine
1.00	1000	300	100	18	4	Feed
1.00	1000	300	100	18	5	Permeate
1.00	1000	300	100	18	6	Brine
1.50	750	240	100	20	7	Feed
1.50	750	240	100	20	8	Permeate
1.50	750	240	100	20	9	Brine
2.00	300	50	100	22	10	Feed
2.00	300	50	100	22	11	Permeate
2.00	300	50	100	22	12	Brine

2. Nanomembrane BW 30

Time/ hours	Flow rate/l.h^{-1} Recycling	Flow rate/l.h^{-1} Brine	Flow rate/l.h^{-1} Permeate	Pressure/ bar	Sample number	Sample
0.50	1350	275	90	16	13	Feed
0.50	1350	275	90	16	14	Permeate
0.50	1350	275	90	16	15	Brine
1.00	1100	175	100	18	16	Feed
1.00	1100	175	100	18	17	Permeate
1.00	1100	175	100	18	18	Brine
1.50	800	100	110	20	19	Feed
1.50	800	100	110	20	20	Permeate
1.50	800	100	110	20	21	Brine
2.00				22	22	Feed
2.00				22	23	Permeate
2.00				22	24	Brine

3. Nanomembrane NF 90

Time/ hours	Flow rate/l.h^{-1} Recycling	Flow rate/l.h^{-1} Brine	Flow rate/l.h^{-1} Permeate	Pressure/ bar	Sample number	Sample
0.50	1300	400	100	16	25	Feed
0.50	1300	400	100	16	26	Permeate
0.50	1300	400	100	16	27	Brine
1.00	1200	275	100	18	28	Feed
1.00	1200	275	100	18	29	Permeate
1.00	1200	275	100	18	30	Brine
1.50	900	160	100	20	31	Feed
1.50	900	160	100	20	32	Permeate
1.50	900	160	100	20	33	Brine
2.00	200	150	100	22	34	Feed
2.00	200	150	100	22	35	Permeate
2.00	200	150	100	22	36	Brine

4. Nanomembrane DL

Time/ Hours	Flow rate/l.h^{-1} Recycling	Flow rate/l.h^{-1} Brine	Flow rate/l.h^{-1} Permeate	Pressure/ bar	Sample number	Sample
0.50	1200	350	150	16	37	Feed
0.50	1200	350	150	16	38	Permeate
0.50	1200	350	150	16	39	Brine
1.00	950	225	175	18	40	Feed
1.00	950	225	175	18	41	Permeate
1.00	950	225	175	18	42	Brine
1.50	700	160	180	20	43	Feed
1.50	700	160	180	20	44	Permeate
1.50	700	160	180	20	45	Brine
2.00	200	160	125	22	46	Feed
2.00	200	160	125	22	47	Permeate
2.00	200	160	125	22	48	Brine

5. Nanomembrane NF 270

Time/ Hours	Flow rate/l.h^{-1} Recycling	Flow rate/l.h^{-1} Brine	Flow rate/l.h^{-1} Permeate	Pressure/ bar	Sample number	Sample
0.50	1250	370	100	16	49	Feed
0.50	1250	370	100	16	50	Permeate
0.50	1250	370	100	16	51	Brine
1.00	950	300	100	18	52	Feed
1.00	950	300	100	18	53	Permeate
1.00	950	300	100	18	54	Brine
1.50	800	260	100	20	55	Feed
1.50	800	260	100	20	56	Permeate
1.50	800	260	100	20	57	Brine
2.00				22	58	Feed
2.00				22	59	Permeate
2.00				22	60	Brine

3.5.3 Determination of chemical and physical determinands

Each water sample was analyzed for the chemical determinands (NO_3^-, Cl^-, F^-, SO_4^{2-}, Ca^{2+} and Mg^{2+}) and physical determinands which are pH, EC and TDS at the DWAF RQS in Pretoria (Roodeplaat).

3.5.4 Spiking of brackish groundwater with fluoride ion

A 10 000 litre green water storage tank (popularly called a **Jojo**), the feed water tank, was mounted on a stainless steel stand that was 10 meters above ground level. The groundwater tap at Batlhaping Primary School was connected to the feed water storage tank through a black plastic pipe. The feed water tank was then filled with brackish groundwater from the groundwater tap. Two litres of a 20 ppm F^- ion solution were added to the feed water tank giving a final F^- ion concentration of 4.0 ppm in this feed water.

3.6 TECHNOLOGY TRANSFER TO THE COMMUNITY

The research team comprised two chemists and a chemical engineer (staff members or researchers), three postgraduate students (M.Sc.) and engineering technicians. The staff members were responsible for teaching the postgraduate students the principles of membrane technology and for guiding them in the practical aspects of treating the brackish groundwater. This included training them in the operation and maintenance of the nanomembrane pilot water treatment plant. The engineering technicians used to service and operate the nanomembrane pilot water treatment plant whenever a need arose. Two members of the community, a school teacher and a security guard at the school (Batlhaping Primary School), were trained in the operation and maintenance of the nanomembrane pilot water treatment plant. This was to ensure the sustainability of the water treatment project after implementation[28]. The operation of the nanomembrane pilot water treatment plant was monitored through carrying out some tests on the nanomembrane pilot water treatment plant. These tests included monitoring cartridge filter inlet and outlet pressures, NF/RO inlet and outlet pressures, feed water pH, permeate pH, feed water conductivity and permeate conductivity. The results were entered into a log sheet (section C, Table 1). The community members participated in almost all the activities that the students performed.

CHAPTER 4 QUALITY OF THE PRODUCT WATER

4.1 INTRODUCTION

The first section, section 4.2, presents and discusses the results for the characterization of the nanomembranes. Section 4.2.1 gives the results for the clean water permeability (A_w) and section 4.2.2 the retention coefficients (R) of the nanomembranes. Section 4.3 discusses the selection of the optimal nanomembrane for the treatment of brackish groundwater. Finally, section 4.4 discusses the quality of the permeate or product water obtained through the treatment of the brackish groundwater with the various nanomembranes at BPS in Madibogo village.

4.2 CHARACTERIZATION OF NANOMEMBRANES

The nanomembranes were characterized through the use of the dead-end module.

4.2.1 Clean water permeability (Aw)

The clean water permeability (A_w) of the nanomembrane was determined according to the method that is given in section 3.4.1. The first column gives the nanomembrane and the second the clean water permeability in Table 4.1.

Table 4.1 The Aw of the nanomembrane

Nanomembrane	**A_w/ℓ.m^{-2}.h^{-1}.bar^{-1}**
DL	7.11
NF 90	6.38
NF 270	10.8
BW 30	1.74
GM	4.00
S5	1.86

4.2.2 Retention coefficients (R)

The retention coefficient (R) of the nanomembrane for a given solute was determined using the method that is outlined in section 3.4.2.1. The results are given in Table 4.2. Column 1 gives the nanomembrane and columns 2, 3, 4, 5, 6 and 7 give the retention coefficient of the nanomembrane.

Table 4.2 Retention coefficient of the nanomembrane

Nanomembrane	NO_3^-	Cl^-	F^-	$S0_4^{2-}$	Ca^{2+}	Mg^{2+}
Desal-DL	0.133	0.222	0.394	0.919	0.338	0.413
NF 90	0.869	0.949	0.884	0.953	0.957	0.975
NF 270	0.276	0.457	0.696	0.926	0.560	0.717
BW 30	0.874	0.971	0.888	0.907	0.978	0.991
GM	0.949	0.963	0.943	0.934	0.981	0.990
S5	0.893	0.949	0.889	0.976	0.975	0.973

4.3 SELECTION OF THE OPTIMAL NANOMEMBRANE FOR TREATMENT OF BRACKISH GROUNDWATER

4.3.1 Water permeability (Aw)

The results of the water permeabilities of the nanomembranes (Table 4.1) suggest, as expected, that these nanomembranes are of two types: nanofiltration; reverse osmosis. The water permeabilities (A_w) for the nanofiltration membranes range from 6.38 to 10.8 ℓ.m^{-2}.h^{-1}.bar^{-1} whereas that of RO nanomembranes range from 1.74 to 4.00 ℓ.m^{-2}.h^{-1}.bar^{-1}. These results confirm that NF nanomembranes have relatively more open network structures than RO nanomembranes. This is in agreement with Equation (3.4) which predicts that A_w is proportional to the product of porosity and the square of the pore radius. NF nanomembranes would be ideal for the production of larger volumes of treated water than RO nanomembranes. However, the choice for the optimal nanomembrane for water treatment also depends on the retention coefficient (R) of the nanomembrane for the determinand. Therefore, both the water permeability and retention coefficient has to be considered when choosing an appropriate nanomembrane for water treatment.

4.3.2 Retention coefficient (R)

Table 4.2 shows the retention coefficient (R) of the nanomembrane for the six determinands. Nanomembrane Desal-DL had the least R values for both monovalent and divalent determinands. Nanofiltration membrane NF 270 has R values which are higher than those of nanomembrane Desal-DL. The results suggest that Desal-DL and NF 270 nanomembranes have poor rejections (low R values) for NO_3^-, Cl^-, F^-, Ca^{2+} and Mg^{2+} ions. These poor rejections might be attributed to the small sizes of these determinand ions relative to the membrane pores. However, both nanomembranes show a high rejection for the divalent anion determinand, SO_4^{2-}. This can also be attributed to the bigger size of the determinand relative to the pores of the nanomembrane but also to the membrane charge. A negative nanomembrane charge would result in the repulsion of the SO_4^{2-} ions and thus to a higher value of R. The retention characteristics of nanomembrane NF 90 closely match those of the reverse osmosis nanomembranes (BW 30, S5 and GM). The retention coefficients of NF 90 for the six determinands range from 0.869 to 0.975. The retention coefficients for the three RO nanomembranes for the six determinands range from 0.874 to 0.991. The results suggest that the nanofiltration membrane NF 90 and the three RO nanomembranes could be appropriate for the removal of pollutant concentrations of these determinands from brackish groundwater.

4.3.3 Conclusion

The water permeability of NF 90 is intermediate between the water permeabilities of the nanofiltration and reverse osmosis nanomembranes. The retention coefficient of NF 90 is also intermediate between the retention coefficients of nanofiltration and reverse osmosis nanomembranes. It would therefore appear that NF 90 has the desirable properties of both NF and RO nanomembranes and would therefore be appropriate for the treatment of the brackish groundwater.

4.4 BRACKISH GROUNDWATER TREATMENT BY NANOMEMBRANES

Section 4.4 discusses the treatment of brackish groundwater by the cross-flow module. The composition of the brackish groundwater is given prior to nanomembrane treatment and composition of the product water or permeate is also given. The South African National Standard (SANS-241) for drinking water is given to determine if the feed water quality and product water quality comply with its specifications. The SANS – 241 Class 1 water quality was considered.

A previous study on the water quality at Batlhaping Primary School groundwater source revealed that the concentration of fluoride ion was very low (0.1 ppm). However, it is an established fact that F^- ion pollution is very wide spread in naturally occurring water sources in North West Province. It was therefore decided that the brackish groundwater be spiked with F^- ion in order to test the effectiveness of the nanomembrane for the removal of the F^- ion. The feed water concentration was made to have an F^- ion concentration of 4.0 ppm.

4.4.1 Groundwater maps

The groundwater maps that are given in Figures 2.1 to 2.10 give a general indication of the water quality at BPS in Madibogo village. The concentration values of nitrate, calcium and magnesium ions in the brackish groundwater at BPS are considerably higher than in the concentration ranges given for these ions in the maps. The concentration of sulphate anion in the brackish water at BPS matches the one that is given the map. However, the concentration of chloride anion that is given in the map is much lower than that at BPS. The electrical conductivity (EC) range given in the map for Madibogo (BPS) brackets the EC value at BPS. The TDS range given on the map, on the contrary, is well above the TDS value obtained at BPS. These discrepancies in some parameters might be due to the differences when the water samples were collected and analysed.

4.4.2 Nanomembrane treatment

4.4.2.1 Chemical water quality

Chemical water quality comprises the dissolved organic and inorganic substances that are found in water. These substances can determine aesthetic properties (for instance, appearance, smell and taste), toxicity and safety of the water to use. A wide range of anions and cations are measured for the assessment of chemical water quality.

The SANS-241 Class 1 water quality specification for drinking water is given in Table 4.3. Class I water is water that can be consumed for an indefinite period without causing any health risks to the consumer. The SANS-241 Class I was used to assess the quality of the brackish groundwater at Batlhaping Primary School. The composition of the Madibogo village brackish groundwater at BPS is given in Table 4.4.

Table 4.3: SANS-241 specification for determinands in the study

Determinand	SANS-241 specification/ppm
NO_3^-	<10
Cl^-	<200
F^-	<1.0
SO_4^{2-}	<400
Ca^{2+}	<150
Mg^{2+}	<70

Table 4.4: Composition of brackish groundwater at Madibogo village

Determinand	Concentration/ppm
NO_3^-	23.6
Cl^-	637
F^-	4
SO_4^{2-}	110
Ca^{2+}	176
Mg^{2+}	102

The brackish groundwater was treated with a nanomembrane according to the method that is described in section 2.5.2 and the results are given in Tables 4.5 to 4.10. Column 1 gives the pressure. Columns 2, 3, 4, 5, 6, 7 and 8 give respectively the sample, concentrations of $N0_3^-$, Cl^-, F^-, SO_4^{2-}, Ca^{2+} and Mg^{2+} ions in the feed, permeate and brine. The concentration of the determinand in the permeate was plotted versus the nanomembrane at the four permeation pressures to determine the optimum nanomembrane for the treatment of the brackish groundwater. The results are given in Figures 4.1 to 4.6. The selection of an appropriate nanomembrane for the brackish groundwater treatment was also investigated through the use of multivariate cluster analysis[29]. Multivariate analysis has the capacity to analyse several variables for a single sample. It was used for the identification of the optimal nanomembrane for the treatment of the brackish groundwater at a pressure of 16 bars for the six nanomembranes and the results are given in Figure 4.7.

Table 4.5: Treatment with nanomembrane S5

Pressure/ bar	**Sample**	**NO^{3-}/ ppm**	**Cl^-/ ppm**	**F^-/ ppm**	**SO_4^{2-}/ ppm**	**Ca^{2+}/ ppm**	**Mg^{2+}/ ppm**
16.0	Feed water	16.0	413	1.41	95.4	154	82.0
	Permeate	1.42	17.7	0.163	2.00	2.96	1.50
	Brine	21.6	580	1.71	126	180	112
18.0	Feed water	15.3	418	1.41	86.6	138	78.7
	Permeate	2.09	24.4	0.177	2.00	4.06	3.70
	Brine	17.8	482	1.70	104	163	89.7
20.0	Feed water	11.0	292	1.17	60.8	101	60.1
	Permeate	0.896	12.1	0.12	2.00	2.35	1.46
	Brine	20.9	479	1.83	162	163	115
22.0	Feed water	11.4	294	1.28	66.8	115	68.9
	Permeate	1.40	18.4	0.127	11.9	3.53	1.30
	Brine	29.9	858	2.48	191	296	175

Table 4.6: Nanomembrane treatment with BW 30

Pressure/ bar	**Sample**	**NO^{3-}/ ppm**	**Cl^-/ ppm**	**F^-/ ppm**	**SO_4^{2-}/ ppm**	**Ca^{2+}/ ppm**	**Mg^{2+}/ ppm**
16.0	Feed water	10.0	280	1.04	57.6	97.7	59.0
	Permeate	1.93	10.5	0.108	10.00	2.81	0.50
	Brine	21.36	532	1.92	135	180	121
18.0	Feed water	17.2	418	1.47	98.5	145	88.7
	Permeate	0.487	7.89	0.116	6.79	3.72	1.15
	Brine	15.3	404	2.21	88.5	146	88.9
20.0	Feed water	12.9	347	1.41	73.3	119	70.7
	Permeate	0.628	7.12	0.125	7.47	2.48	0.50
	Brine	27.2	756	3.24	166	275	154
22.0	Feed water	13.8	364	1.23	76.9	116	72.8
	Permeate	3.21	15.6	0.216	2.00	1.63	0.50
	Brine	25.4	746	2.91	157	287	168

Table 4.7: Nanomembrane treatment with NF 90

Pressure/ bar	**Sample**	**NO^{3-}/ ppm**	**Cl^-/ ppm**	**F^-/ ppm**	**SO_4^{2-}/ ppm**	**Ca^{2+}/ ppm**	**Mg^{2+}/ ppm**
16.0	Feed water	16.0	466	1.39	87.6	146	98.0
	Permeate	3.19	45.0	0.221	5.39	9.84	5.37
	Brine	18.4	475	1.44	90.4	149	104
18.0	Feed water	17.3	461	1.43	88.0	148	97.1
	Permeate	1.86	17.3	0.140	2.00	5.58	2.70
	Brine	20.0	551	1.65	111	171	130
20.0	Feed water	17.2	478	1.44	93.2	147	90.0
	Permeate	1.84	17.9	0.143	5.31	5.29	2.69
	Brine	21.0	650	1.84	126	198	117
22.0	Feed water	16.3	469	1.44	100	146	87.3
	Permeate	1.84	17.9	0.158	4.64	4.79	2.16
	Brine	22.0	629	1.84	132	206	123

Table 4.8: Nanomembrane treatment with DL

Pressure/ bar	**Sample**	**NO^{3-}/ ppm**	**Cl^-/ ppm**	**F^-/ ppm**	**SO_4^{2-}/ ppm**	**Ca^{2+}/ ppm**	**Mg^{2+}/ ppm**
16.0	Feed water	16.7	471	1.44	92.7	148	100
	Permeate	15.1	393	0.774	10.0	104	56.5
	Brine	18.0	523	1.82	147	185	111
18.0	Feed water	17.4	456	1.44	96.3	149	97.0
	Permeate	15.5	377	0.842	5.32	101	55.0
	Brine	19.3	552	1.96	178	197	120
20.0	Feed water	16.8	480	1.46	98.0	148	90.7
	Permeate	14.9	366	0.947	4.69	97.5	57.2
	Brine	20.2	573	2.01	205	205	131
22.0	Feed water	15.4	487	1.43	110	143	88.9
	Permeate	12.1	335	0.932	12.3	86.9	52.3
	Brine	18.6	582	1.95	190	207	138

Table 4.9: Nanomembrane treatment with NF 270

Pressure/ bar	**Sample**	**NO^{3-}/ ppm**	**Cl^-/ ppm**	**F^-/ ppm**	**SO_4^{2-}/ ppm**	**Ca^{2+}/ ppm**	**Mg^{2+}/ ppm**
16.0	Feed water	15.5	461	1.46	109	153	96.4
	Permeate	11.7	246	0.436	6.71	64.6	28.0
	Brine	16.7	517	1.62	111	166	110
18.0	Feed water	15.7	487	1.46	91.4	145	90.1
	Permeate	11.3	237	0.428	7.04	61.9	28.1
	Brine	16.9	522	1.67	124	167	111
20.0	Feed water	18.0	452	3.82	105	171	99.7
	Permeate	13.3	271	1.16	7.12	85.2	25.9
	Brine	19.2	572	4.91	138	242	130
22.0	Feed water	18.3	489	3.81	98.6	208	97.6
	Permeate	12.5	270	1.22	8.70	85.6	26.2
	Brine	16.2	578	4.76	134	251	125

Table 4.10: Treatment with nanomembrane GM

Pressure/ bar	**Sample**	**NO^{3-}/ ppm**	**Cl^-/ ppm**	**F^-/ ppm**	**SO_4^{2-}/ ppm**	**Ca^{2+}/ ppm**	**Mg^{2+}/ ppm**
16.0	Feed water	18.5	461	3.75	98.1	169	96.9
	Permeate	0.833	15.7	0.239	4.11	4.91	1.69
	Brine	21.1	530	4.57	125	223	117
18.0	Feed water	17.8	437	3.80	95.2	172	98.0
	Permeate	0.91	22.3	0.200	8.08	2.25	0.500
	Brine	23.7	659	4.85	77.0	252	135
20.0	Feed water	17.9	441	3.82	92.2	171	92.9
	Permeate	0.961	11.3	0.210	6.37	2.76	0.55
	Brine	25.6	714	5.23	144	271	144

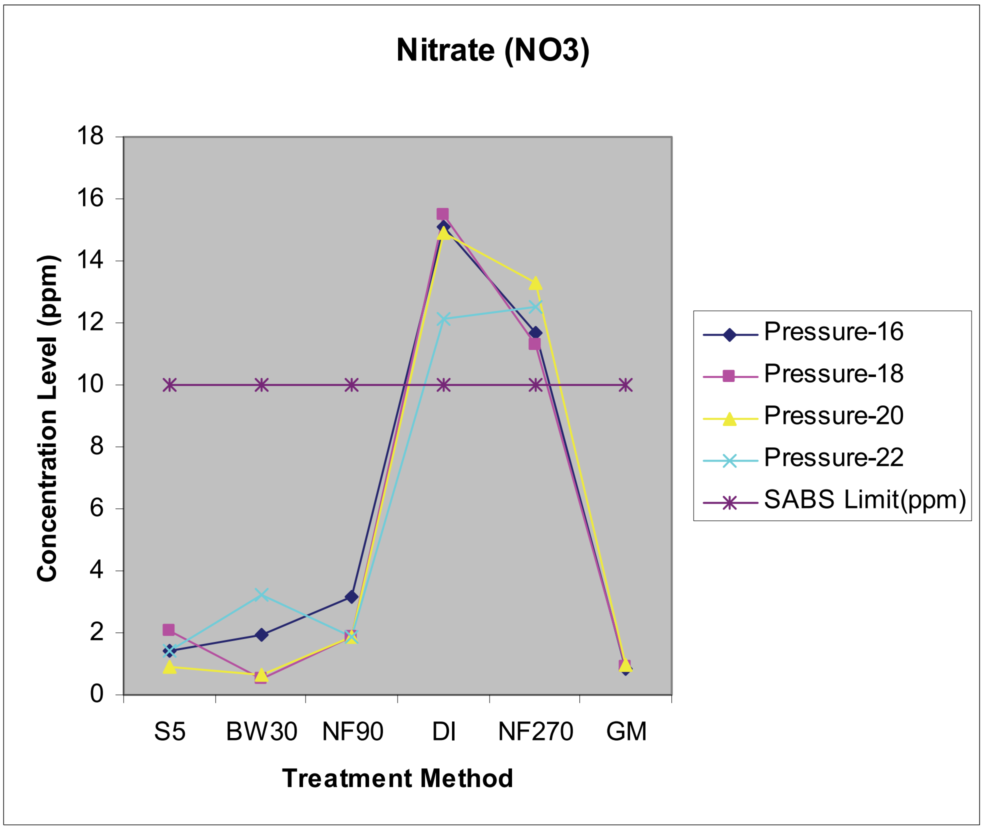


Figure 4.1 A plot of the concentration of NO3- versus nanomembrane treatment at various pressures

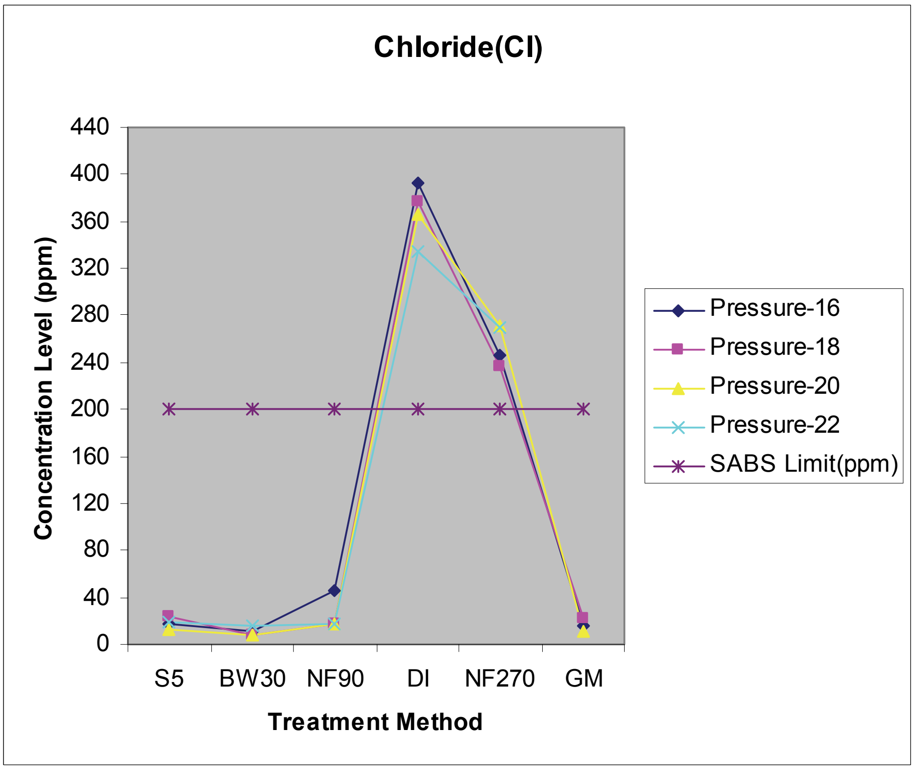


Figure 4.2 A plot of the concentration of Cl versus the nanomembrane treatment at various pressures

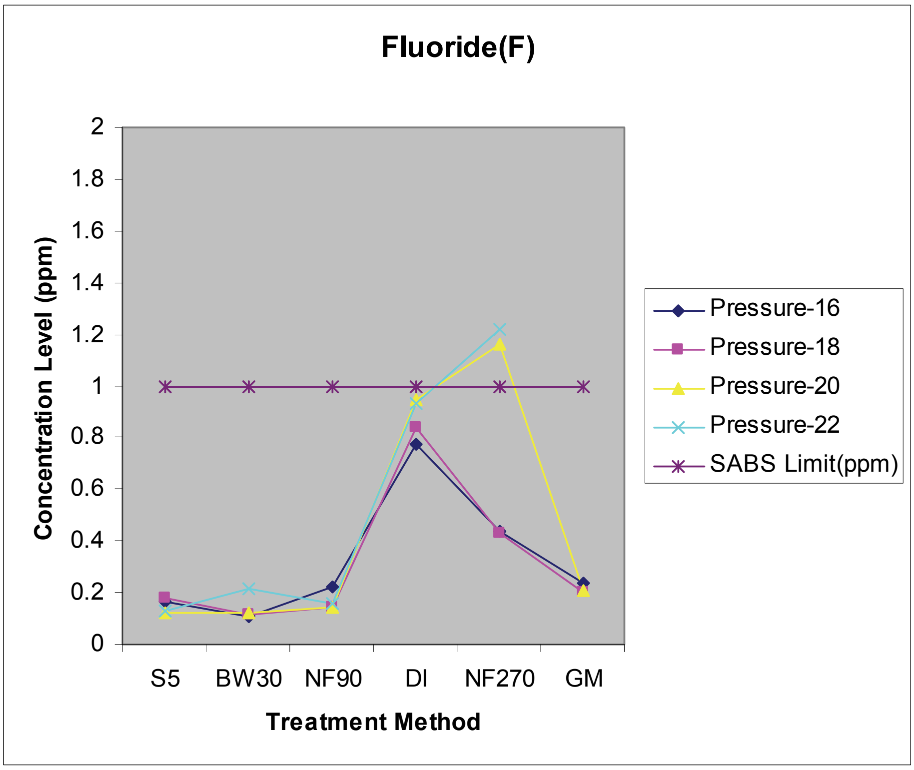


Figure 4.3 A plot of the concentration of F versus the nanomembrane treatment various pressures

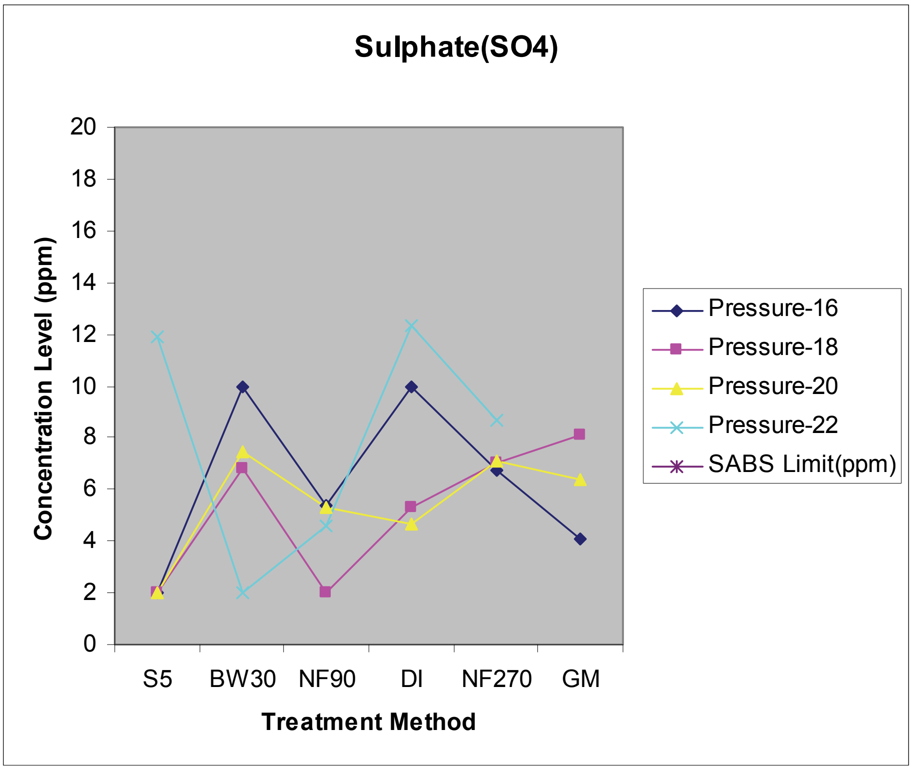


Figure 4.4 A plot of the concentration of SO42- versus the nanomembrane treatment at various pressures

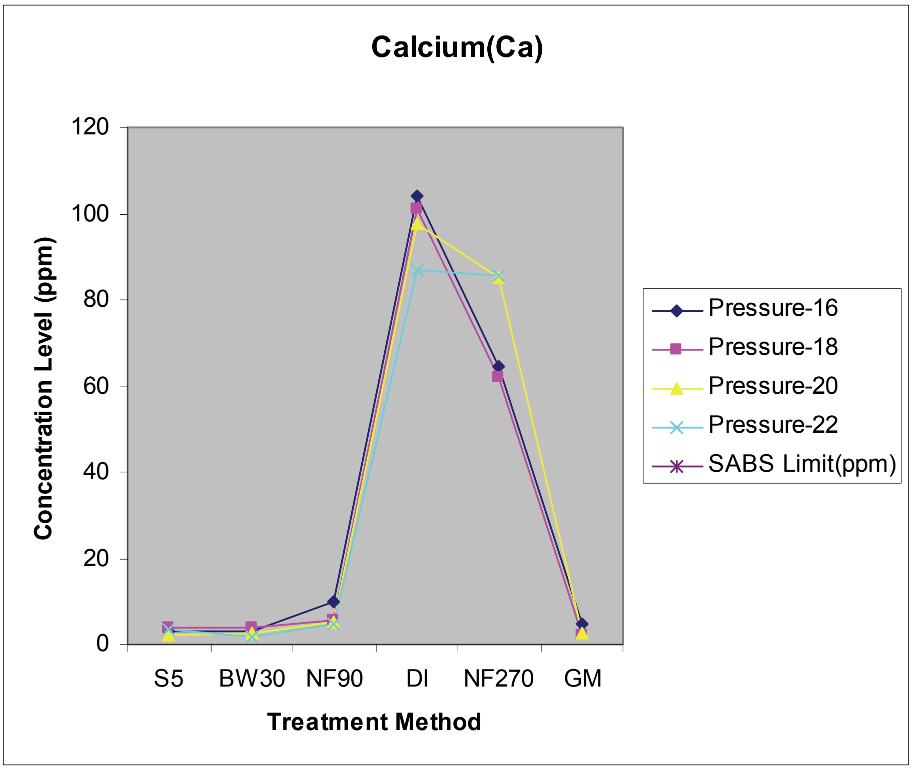


Figure 4.5 A plot of the concentration of Ca2+ versus the nanomembrane treatment at various pressures

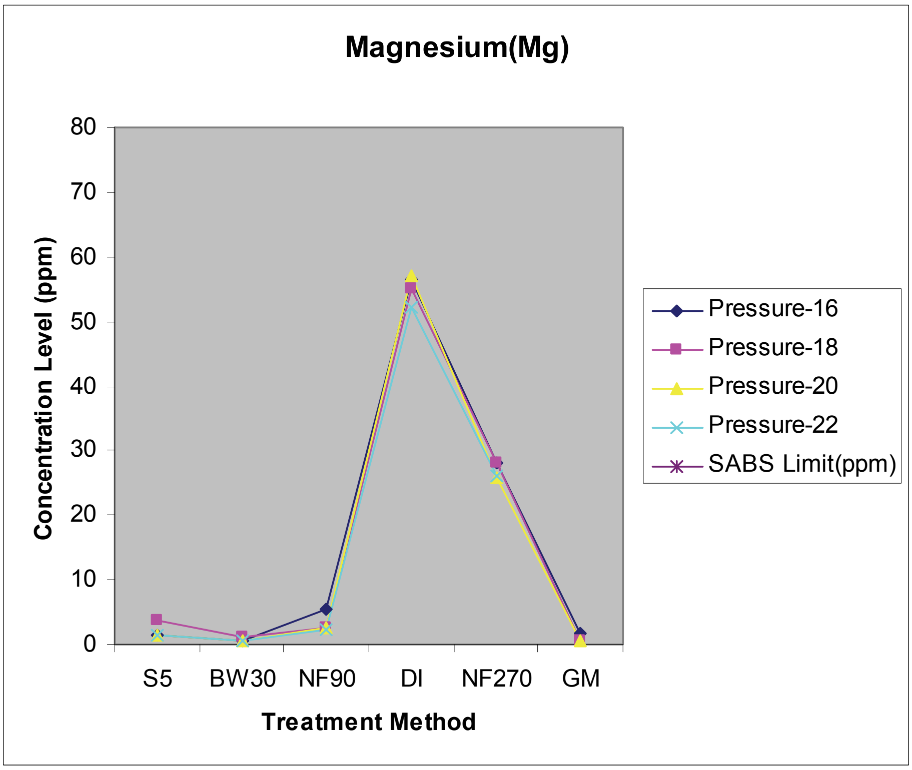


Figure 4.6 A plot of the concentration of Mg versus the nanomembrane treatment at various pressures

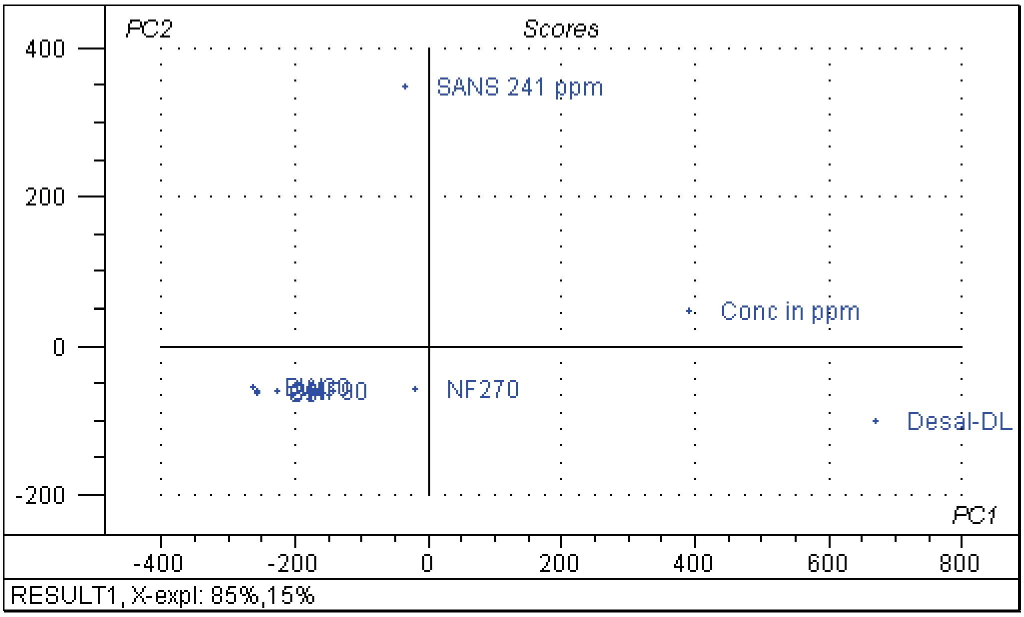


Figure 4.7 Multivariate cluster analysis for selection of appropriate nanomembrane

4.4.2.2 Physical water quality

Physical water quality can be expressed in terms of dissolved and colloidal substances that are present in given water. The most commonly used properties for assessing physical water quality include turbidity, pH, electrical conductivity (EC), total dissolved solids (TDS), colour, taste and odour. The South African National Standard (SANS-241) for drinking water (Class I) for the physical water quality determinands that were investigated in this study and the physical water quality at Madibogo village at BPS are given in Table 4.11.

Table 4.11: SANS-241 for physical determinands in the study

Determinand	**SANS-241**	**Madibogo village water quality**
pH	5.0-9.5	7.71
EC	< 150 µS/cm	220
TDS	< 1000 mg/l	86.1

The brackish groundwater was treated with a nanomembrane according to the method that is described in section 2.5.2 and the results are given in Tables 4.12 to 4.17. Columns 1, 2, 3, 4 and 5 give respectively the pressure, sample, pH, EC and TDS.

Table 4.12: S5 Nanomembrane permeate physical water quality

Pressure/bar	Sample	pH	EC/µS cm^{-1}	TDS/mg l^{-1}
16	Feed	7.43	223	89.4
	Permeate	6.46	10.3	4.33
	Brine	7.09	279	112
18	Feed	7.29	213	85.4
	Permeate	6.61	17.2	6.90
	Brine	7.02	243	97.4
20	Feed	7.28	128.4	51.3
	Permeate	6.65	7.49	3.15
	Brine	7.29	268	107
22	Feed	7.14	159	63.8
	Permeate	6.86	10.2	4.28
	Brine	7.18	377	151

Table 4.13: BW 30 Nanomembrane permeate physical water quality

Pressure/bar	Sample	pH	EC/µS cm^{-1}	TDS/mg l^{-1}
16	Feed	7.98	124.9	50.1
	Permeate	6.78	7.22	3.03
	Brine	7.45	279	112
18	Feed	7.49	221	88.6
	Permeate	7.01	2.81	1.18
	Brine	7.70	223	89.4
20	Feed	7.42	181	72.6
	Permeate	7.00	7.04	2.96
	Brine	8.73	361	145
22	Feed	6.89	193	77.4
	Permeate	7.91	9.63	4.05
	Brine	7.29	328	132

Table 4.14: NF90 Nanomembrane permeate physical water quality

Pressure/bar	Sample	pH	EC/µS cm^{-1}	TDS/mg l^{-1}
16	Feed	7.39	240	96.2
	Permeate	6.81	25.5	10.7
	Brine	7.40	244	97.8
18	Feed	7.31	239	95.8
	Permeate	6.88	12.6	5.29
	Brine	8.12	274	110
20	Feed	8.14	236	94.6
	Permeate	6.87	12.1	5.08
	Brine	8.17	300	120
22	Feed	7.98	240	96.2
	Permeate	6.87	13.2	5.54
	Brine	7.78	309	124

Table 4.15: Desal-DL Nanomembrane permeate physical water quality

Pressure/bar	Sample	pH	EC/ µS cm^{-1}	TDS/mg l^{-1}
16	Feed	8.05	241	96.6
	Permeate	8.18	181	72.6
	Brine	8.14	267	107
18	Feed	8.04	240	96.2
	Permeate	6.53	183	73.4
	Brine	7.78	289	116
20	Feed	7.86	241	96.6
	Permeate	6.73	181	72.6
	Brine	7.63	301	121
22	Feed	7.38	221	88.6
	Permeate	7.48	153	61.3
	Brine	7.54	283	113

Table 4.16: NF270 Nanomembrane permeate physical water quality

Pressure/bar	Sample	pH	EC/µS cm^{-1}	TDS/mg l^{-1}
16	Feed	7.70	223	89.4
	Permeate	7.27	113	45.3
	Brine	7.70	242	97.4
18	Feed	7.63	220	88.2
	Permeate	7.28	113	45.3
	Brine	7.66	244	97.8
20	Feed	8.04	262	105
	Permeate	7.18	112	44.9
	Brine	7.57	262	105
22	Feed	8.33	227	91.0
	Permeate	8.29	116	46.5
	Brine	8.22	267	107

Table 4.17: GM Nanomembrane permeate physical water quality

Pressure/bar	Sample	pH	EC/ µS cm^{-1}	TDS/mg l^{-1}
16	Feed	8.53	219	87.8
	Permeate	6.88	6.33	2.66
	Brine	7.43	272	109
18	Feed	8.09	224	89.8
	Permeate	6.86	6.03	2.53
	Brine	7.47	306	123
20	Feed	7.90	225	90.2
	Permeate	6.74	5.86	2.46
	Brine	7.93	326	131

4.5 DISCUSSION

4.5.1 Chemical water quality

Table 4.4 shows that the Batlhaping Primary School groundwater source is polluted with $N0_3^-$, Cl^-, Ca^{2+} and Mg^{2+} ions as their concentrations are higher than the corresponding values of the SANS-241 for drinking water (Table 4.3). The results of the nanomembrane treatment of the brackish groundwater at the school are given in Tables 4.5 to 4.10. The results obtained by plotting the concentration of the determinand in the nanomembrane permeates versus each one of the six nanomembranes at a given pressure are given in Figures 4.1 to 4.6.

The figures show the results of the treatment of the brackish groundwater with each one of six nanomembranes. The horizontal lines on the plots in the figures which are parallel to the nanomembrane axes in Figures 4.1 to 4.3 represent the SANS-241 specification for the determinand ion in drinking water. All the determinand concentrations in the permeate that are below this line are compliant with the SANS-241 specification for drinking water. Figure 4.1 shows that the lowest concentration of nitrate ion was produced by the treatment of the brackish groundwater with nanomembrane BW 30 at pressures of 18 bars and 20 bars which correspond, respectively, with nitrate ion concentrations of 0.487 ppm N and 0.628 ppm N. Figure 4.2 shows that the most efficient nanomembrane for the removal or retention of chloride ion is BW 30 at pressures of 18 bars and 20 bars which correspond to concentrations of 7.89 ppm Cl^- and 7.12 ppm Cl^-. The next figure, Figure 4.3, shows that the separation efficiency of nanomembranes S5, BW 30 and NF 90 are comparable for the retention of F^- ion in brackish groundwater at a pressure of 18 bars. The concentrations of F^- in the permeates of nanomembranes S5, BW 30 and NF 90 are respectively 0.177 ppm F^-, 0.116 ppm F^- and 0.140 ppm F^-. Nanomembrane S5 also shows a good separation efficiency for F^- ion at a pressure of 22 bars which corresponds to a concentration of 0.127 ppm F^-. Nanomembrane BW 30 also shows good retention for F^- ion at a pressure of 16 bars which corresponds to a concentration of 0.163 ppm F^-.

Figure 4.4 shows that the three nanomembranes that have the best retention efficiency for the sulphate ion are S5, BW 30 and NF 90. Nanomembrane S5 produced permeates with very low concentrations (2.00 ppm SO_4^{2-}) at pressures of 16 bars, 18 bars and 20 bars. Nanomembrane BW 30 produced a permeate whose SO_4^{2-} ion concentration was 2.00 ppm at a pressure of 22 bars. Nanomembrane NF 90 showed good removal efficiency of SO_4^{2-} ion by producing a permeate whose SO_4^{2-} ion concentration was 2.00 ppm SO_4^{2-}. Figure 4.5 shows that four nanomembranes (S5, BW 30, NF 90 and GM) produced permeates whose Ca^{2+} ion concentrations were less than 10 ppm Ca^{2+} at pressures of 16 bars, 18 bars, 20 bars and 22 bars. Nanomembranes Desal-DL and NF 270 produced permeates whose Ca^{2+} concentrations were greater than 60 ppm Ca^{2+}. Figure 4.6 shows that nanomembranes S5, BW 30, NF 90 and GM produced permeates whose concentrations of Mg^{2+} ion was less than 5 ppm Mg^{2+} at pressures of 16 bars, 18 bars, 20 bars and 22 bars. The concentrations of Mg^{2+} ion in Desal-DL and NF 270 permeates were greater than 50 ppm Mg^{2+}.

The above results can also be discussed in terms of the applied pressure across the nanomembrane. Nanomembranes S5, BW30, NF90 and GM (Figure 4.1) show very good rejections at all the pressures that were used. The permeates of the nanomembranes are well below the SANS-241 for drinking water of less than 10 ppm. The figure shows very poor rejection of NO_3^- by nanomembranes Desal-DL and NF270 whose permeates did not comply with SANS-241 for drinking water. The three RO and NF90 membranes showed relatively good selectivity at a pressure of 16 bars. The following figure, Figure 4.2, shows that the performances of the three RO membranes (S5, BW30 and GM) and NF90 membrane were comparable at the four pressures used except for that of NF90 at 16 bars pressure which showed a relatively poor rejection. All six nanomembranes (Figure 4.3) produced permeates which are compliant to SANS-241 for F^- ion in drinking water at the lower pressures used (16 and 18 bars). However, NF270 permeates which were produced at 20 and 22 bars were not compliant with SANS-241 F^- ion in drinking water. Figures 4.4, 4.5 and 4.6 show that the permeates produced by all six nanomembranes at all the four pressures used were compliant to SANS-241 for SO_4^{2-}, Ca^{2+} and Mg^{2+} ions in drinking water. Figure 4.4 shows that there is no apparent correlation between the applied pressure and nanomembrane performance. Figure 4.5 shows that the rejection of Ca^{2+} by the three RO membranes and one NF membrane (NF90) is comparable at pressures of 18, 20 and 22 bars. However, the rejection for Ca^{2+} by GM and NF90 is relatively lower at 16 bars. Finally, Figure 4.6 shows that the three RO and NF90 membranes have very high rejection for Mg^{2+} at 18, 20 and 22 bar pressures. The rejection of the nanomembranes at 16 bars was lower for Mg^{2+} for NF90 and GM.

The figures (Figures 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6) suggest that the various nanomembranes have different rejections or retentions for solutes at different pressures. However, the figures also show that the nanomembranes are more selective at the lowest pressure of 16 bars. That is, the rejection of solutes is relatively lower at the lowest pressure (16 bars). The selection of an appropriate nanomembrane for the brackish groundwater treatment was also investigated through the use of multivariate cluster analysis at the pressure of 16 bars for the six nanomembranes and the results are given in Figure 4.7.

4.5.2 Physical water quality

Tables 4.12 to 4.17 show the results for the physical determinands that were obtained when the brackish groundwater was treated by the six nanomembranes at four pressures. The results show that the pH of the feed water, the permeate and brine samples were all compliant to the SANS-241 for drinking water. The nanomembrane treatment of the brackish groundwater (feed water) produced a lower permeate pH and a higher brine pH. The pH of the feed water was above 7.00 which explains the scaling that was observed on the cross-flow module reactor pilot water treatment plant[30]. The pH of the permeate is ideal since it is approximately 7.00 and would cause neither corrosion nor scaling in a water distribution system. This trend was observed for all the six nanomembranes at all the pressures that were used.

The results show that the average electrical conductivity of the feedwater was 215 uS/cm which is not compliant with the SANS-241 for drinking water (< 150 uS/cm). An EC of this magnitude is indicative of pollution and it renders the water to be corrosive. The treatment of the brackish groundwater with each one of the three RO membranes and two of the NF membranes (NF90 and NF270) produced product water that was compliant to SANS-241 for drinking water at all the pressures that were used. However, the treatment of the brackish groundwater with NF membrane Desal-DL did not reduce the EC of the permeate or product water to the required level for drinking water at all the pressures that were used. These results suggest that any one of the four pressures that were used would be suitable for the nanomembrane treatment of the brackish groundwater for physical water quality.

The tables also show the results of the total dissolved solids (TDS) that were obtained after the feed water was treated with each one of the six nanomembranes at the four pressures that were used. Water that has a high value of TDS is undesirable because it attacks metallic components in a water distribution system[30]. The average value for the TDS was 86.1 mg/l which is in specification with SANS-241 for drinking water (<1000 mg/l) at all the pressures that were used. The RO membranes (S5, BW30 and GM) were very effective at reducing the TDS level of the feed water. The NF90 membrane reduced it to a level that was intermediate between that of the RO and NF membranes (Desal-DL and NF270). These results further show that any one of the four pressures that were investigated could have been suitable for the nanomembrane treatment of the brackish groundwater at BPS.

4.6 TECHNOLOGY TRANSFER TO THE COMMUNITY

The three postgraduate students who participated in this water treatment project were studying for their M.Sc. degrees whose dissertations they have yet to submit. These students have acquired expertise in the treatment of brackish groundwater by membrane technology which is a very critical area in water service delivery. The students will be an asset in the water treatment and provision sector, particularly for rural communities. The two community members, the school teacher and security guard, acquired the skills for the operation and maintenance of the nanomembrane pilot water treatment plant. The technology transfer to the rural community ensured the sustainable delivery of safe drinking water for the 1 000 pupils and their teachers at the school. This is in contrast to some water treatment technologies that were installed in some rural communities which collapsed immediately when the project was completed and the researchers had left[31].The community operators always called-out the researchers whenever there was a problem they could not solve. The implementation of the project was so successful that the pupils and their teachers now only drink the treated water.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

- Nanomembranes Desal-DL and NF 270 produced permeates whose NO_3^- and Cl^- ion concentrations did not comply with SANS-241 for drinking water at all the pressures that were investigated in the study (namely, 16 bars, 18 bars, 20 bars and 22 bars);
- All the nanomembranes produced permeates or product water that was compliant to the SANS-241 with respect to F^- ion at all the pressures that were used except NF 270 whose permeates at pressures of 20 bars and 22 bars were noncompliant to the SANS-241 for drinking water;
- The nanomembrane which had the highest retention efficiencies for all the determinands (except for SO_4^{2-}) at pressures of 18 bars and 20 bars was BW 30;
- Nanomembranes Desal-DL and NF 270 are not suitable for the treatment of the brackish groundwater at Batlhaping Primary School in Madibogo village;
- The reverse osmosis nanomembranes (S5, BW 30 and GM) virtually removed all the Ca^{2+} and Mg^{2+} cat ions, relative to their corresponding concentrations in the NF90 permeate, from the brackish groundwater. This is not desirable since these cat ions are nutrients that are required for the normal development of the human body;
- The optimal pressure for attaining the highest retention coefficients of the nanomembranes were 18 bars and 20 bars.

5.2 RECOMMENDATIONS

The nanofiltration nanomembrane NF 90 should be used for the treatment of the brackish groundwater at Batlhaping Primary School in Madibogo village since it combines the desirable characteristics of nanofiltration membranes (higher water permeability relative to reverse osmosis nanomembranes) and reverse osmosis nanomembranes (higher retention coefficients relative to the other NF nanomembranes that were used in this study). The product water produced by treatment with this nanomembrane had relatively higher concentrations of calcium and magnesium compared to RO nanomembranes.

The optimal operating pressure for the NF/RO cross-flow pilot water treatment plant should be 16 bars as this would result in reduction in energy consumption.

The two operators (the security guard and the teacher) who have been trained on the operation and maintenance of the NF/RO cross-flow pilot water treatment plant should receive a monthly allowance to ensure the sustainability of the water treatment project.

Currently, the brine or retentate is run to waste and permeates back into the soil and thus to the groundwater causing further pollution. A brine storage tank has to be installed for the NF/RO cross-flow pilot water treatment plant.

LITERATURE LIST

1. MULDER, M. 1997. Basic principles of membrane technology. 2nd ed. Dordrecht : Kluwer Academic Publishers.

2. PEETERS, J.M.M. 1997. Characterization of nanofiltration membranes. Enschede : University of Twente. (Thesis – Ph.D.)

3. MODISE, S.J. & KRIEG, H.M. 2004. Evaluation of nanofiltration for the treatment of rural groundwater for potable water use. Pretoria : Water Research Commission. WRC report no. 1230/1/04.

4. HILILIE, T., MUNASINGHE, M., HLOPHE, M. & DERANIYAGALA, Y. 2006. Nanotechnology: Water and development. [Web:] http://www.merid.org/nano/waterpaper [Date of access: 10 September 2008].

5. OFFRINGA, G. 2007. Personal communication with author. Water Research Commission.

6. SHOWERS, K.B. 2002. Water scarcity and urban Africa: An overview of urban-rural water linkages. *World development*, 30(4):621-648.

7. SHAW, P.A. 1997. Geomorphology of the world's arid zones: Africa and Europe. (In Thomas, D.S.G., *ed*. Arid zone Geomorphology: Perspectives and challenges. London : John Wiley & Sons.)

8. CBEN

9. ANON. 1999. The South African National Standard (SANS – 241) for drinking water. Pretoria : Water Research Commission.

10. CHRISTIAN, G.D. 1980. Analytical Chemistry. 4th ed. New York : John Wiley & Sons.

11. SCHUTTE, F. 2006. Handbook for the operation of water treatment works. Pretoria : Water Research Commission. WRC report no. TT 265/06.

12. REIDY, R., *ed*. 2005. Desalination: A snapshot. *Filtration Industry Analyst* 3:5-7.

13. NICOLAISEN, B. 2003. Developments in membrane technology for water treatment. *Desalination*, 153(3):355-360.

14. TSIOURTIS, N.X. 2001. Desalination and the environment. *Desalination*, 141(3):223-236.

15. COMSTOCK, D.L. 1989. Desal-5 membrane for water softening. *Desalination*, 76(1): 61-72.

16. SCHOEMAN, J.J., STEYN, A. & SLABBERT, J.L.. 2003. Treatment of landfill leachate from hazardous and municipal solid waste. Pretoria : Water Research Commission. WRC report no. 1167/1/03.

17. ERIKSSON, P. 1988. Nanofiltration extends the range of membrane filtration. *Environmental progress,* 7(1):58-62.

18. MIN. B.R., GILL, A.L. & GILL, W.N. 1984. A note on fluoride removal by reverse osmosis. *Desalination*, 49(1):89-93.

19. BOWEN, W.R., MOHAMMAD, A.W. & HILAL, N. 1997. Characterization of nanofiltration membranes for predictive purposes – use of salts, uncharged solutes and atomic force microscopy. *Journal of membrane science*, 126:91-105.

20. REDONDO, J.A. & LANARI, F. 1997. Membrane selection and design considerations for meeting European potable water requirements based on different feedwater conditions. *Desalination*, 113(3):309-323.

21. NYSTROM, M., KAIPIA, L. & LUQUE, S. 1995. Fouling and retention of nanofiltration membranes. *Journal of membrane science*, 98:249-262.

22. MAARTENS, A., JACOBS, E.P. & SWART, P. 2002. UF of pulp and paper effluent: membrane fouling-prevention and cleaning. *Journal of membrane science*, 209:81-92.

23. MALUTSA, A. 2005. Operating and Maintenance Manual for North-West University's BWRO plant. Mafikeng : North-West University.

SECTION B

AN INVESTIGATION OF RURAL CONSUMER KNOWLEDGE AND ATTITUDE TO WATER USAGE AND WATER PURIFICATION: A SOCIAL AND EDUCATIONAL DIMENSION

Report to the Water Research Commission

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CHAPTER 1 INTRODUCTION

1.1 MOTIVATION AND PROBLEM STATEMENT

1.1.1 Introduction and background

During 1994, the current ruling party in South Africa, the African National Congress (ANC), came into power. One of its major goals was to improve the well-being of the South African citizens and it included, amongst many other services, water services. The South African Constitution (Chapter 2) and the Bill of Rights (Section 27(1)(b)) clearly oblige the government to address and commit itself to delivering and fulfilling these goals (SA, Act No 108 of 1996). This obligation is in line with the Millennium Development Goals globally adopted by all governments as a blue print for building a better world in the 21st century (Khalfan, 2005).

However, when the current government came into power it was faced with several challenges. These included an inherited backlog of 14.1 million people who had no access to clean or safe drinking water (Duse *et al.,* 2003). The government took radical initiatives to improve the situation by developing policies and programs in line with the promotion and protection of human rights to facilitate development processes in communities, as well as the physical provision of water and sanitation. During 1996 7.2 million people had access to clean water and in 2004 10.4 million.

The White Paper on Water (1996/7) stipulated the policies and programs put in place by the government to improve water service provision. These are the Integrated Development Plan (IDP), Local Economic Development (LED), Reconstruction and Development Policies (RDP) and Free Basic Water Policy (FBWP). Their establishment is aimed at strengthening partnerships by including local communities in decision-making processes for poverty alleviation through service delivery. To accomplish this task, local municipalities joined hands with structures such as the Department of Water and Forestry, Community Based Organizations and water suppliers to address the issues surrounding the water sector and to sustain human well-being development (DWAF, 1994; Oranje *et al*., 2000).

The water service sector took a step forward to fulfil the needs of communities with reference to water service provision. Between 1995 and 2003 it managed to provide about 9 million people in communities with access to water. Therefore, only about 7 million of the 14 million people in rural areas still lack water and it is hoped that this could be cleared by 2008 (White Paper on Basic Household Sanitation, 2001). Although the water and sanitation policies are clear and the government structures and water agencies are in place, it has not been easy to achieve the desired goals regarding water provision because the population also increased simultaneously.

The most challenging issue in the water sector is water service provision. This includes the three most important water service provision determinants which are water *quality*, water *quantity* and *education programmes* which will be separately addressed when dealing with water service provision delivery. Water *quality* is about safe drinking water that meets the required drinking water quality standards. It has an acceptable physical appearance, and chemical and microbial components. Secondly, water *quantity* is about the availability of water, its accessibility or convenience and its affordability. This requires that special attention be paid to the socio-economic aspects of the communities. Thirdly, *water education programmes* that deal with hygiene practices, awareness *(human/consumer rights)*, technical programmes *(maintenance and operation of water systems)* and water management (*water supplies treatment and conservation).*

Furthermore, a concern about water service provision stems from the situation facing South Africa's rural areas where women, the elderly and children have to walk long distances to fetch water. This is more serious for elderly people since they have a concern as to how much they have to pay someone to fetch water as they can no longer walk long distances.

Another concern is the quality of the water which is influenced by contaminants from the environment such as salts (calcium, nitrates, manganese, and fluorides) and bacteriological contaminants, or inadequate sewage treatment which affect the household usability of the water. Therefore, this situation calls for a holistic approach that includes water quality, water quantity, hygiene and technical education. Van Leeuwen (2000) supports this statement by mentioning that water problems do not only affect the health of human beings but also the socio-economic and political welfare of communities.

The terms generally used to describe the users when discussing water provision to communities are water users or community members. This study will be done within the theoretical framework of community development and capacity building as well as the theoretical framework of consumer behaviour. The terms water users or water consumers will be used interchangeable.

Consumer behaviour is influence by internal and external factors. Internal factors include aspects such as perceptions, attitude, knowledge, skills and education. External factors include aspects such as cultural groups, reference groups, socio-economic factors and age. In order to understand consumers' behaviour towards water the factors that influence consumer behaviour in general and consumer socialization must be studied. Consumer socialization and general theory of consumer behaviour must be studied.

1.1.2 Problem statement

Duse, da Silva and Zietsman (2003) are of the opinion that, in South Africa, water is a scarce resource in terms of quality and supply. Bonello (2002) supports this statement by mentioning the importance of safety issues which should not be compromised with regard to chemical and microbiological components. Inadequate and inaccessible water supplies are determinants of a threat to water safety. According to Bonello (2002) an acceptable water supply is perceived as one that provides a continuous supply of good safe drinking water that has a pleasant taste and acceptable price if it has to be paid for.

Madibogo is in one of the many villages in North West Province's rural areas that depend on ground water and experiencing the problem of nitrogenous pollution. The Madibogo community was chosen as a study area among other communities because of its accessible location and very high concentration of nitrates in the water. Tests performed on groundwater from this community indicated a high concentration of nitrate *(commonly referred to as salt)* reaching levels of 22.66 mg/ℓ which results into hard water. As a reference point, the specification standard set by the South African Bureau of Standards (SABS) for nitrate in drinking water is not more than 10 mg/ℓ (Hlophe, 2004). It could be argued that this high level at Madibogo is unacceptable in terms of South African consumer rights and the Constitution that oblige municipalities and service providers to deliver services that are safe, healthy and friendly towards the environment which the human being is part of (Department of Local Government, 2006).

Consequently, membrane technology was investigated for the removal of excess concentrations of these determinants in brackish groundwater at Madibogo Batlhaping Primary School. Since membrane technology is relatively new in South Africa, it called for a thorough investigation of how the community would receive this type of water purifying membrane. Therefore, it was regarded important to investigate the consumers' perceptions and attitudes towards their water service provision. This process was designed to identify the gaps in the water service provision, to gauge the perceived ideal water source and its expected performance and to understand the concerns and views of consumers about the currently used water supply.

In this study the focus will be to investigate what the Madibogo groundwater consumers' perceptions, knowledge and attitudes towards rural water service provision are and to compare the purified water with borehole water from a consumer' or ordinary community member's perspective. Based on the first phase information and the communities' lack of knowledge and skills a Water Education and Training (WET) programme was designed, implemented and evaluated.

According to Managing National Forests for Non-Timber Forest Products the problem is that several studies have mainly focused on attitudes of consumers or stakeholders towards social issues, with little or no research on improving consumers' attitudes towards water. It lies within the interest of this study to survey the attitudes of rural water service provision consumers and stakeholders, to improve their attitudes and to promote sustainable development practices in rural water service provision.

1.2 AIM AND OBJECTIVES

The main aim of the *social dimension* of the project was to determine consumers' understanding of water in general, water usage in rural areas and water service provision - all by setting the following objectives:

- Exploring the perceptions and knowledge of consumers regarding current and general rural water supplies, general rural water household utilisation and the Free Basic Water Policy through:
  - the establishment and utilisation of community focus groups as data gathering instruments;
  - the exploration of consumers' perceptions of the water quality of a rural water service;
  - the exploration of consumers' perceptions of the water quantity of a rural water service;
  - the exploration of consumers' perceptions of the Free Basic Water Policy;
  - the exploration of consumers' perceptions of their daily household water utilization;
  - contributions towards the provision and maintenance of the Free Basic Water Policy and general rural water supply;

- Establishing whether there is a difference between the untreated borehole water and the purified water by means of:
  - focus groups;
  - sensory evaluation;
  - practical tests to evaluate water used for cooking, personal hygiene and laundry.
- Understanding the attitudes and knowledge of consumers towards current and general rural water supplies, general rural water household utilisation and the Free Basic Water Policy through:
  - the development of attitude and knowledge scales to be used as measuring instruments and the implementation of these scales;
  - the implementation of the attitude and knowledge before the WET-programme;
  - the repeated measuring of the community's attitudes towards and knowledge of different water issues after the WET-Programme.
- Developing, implementing and evaluating a basic water education programme, that includes information about water purification

The findings from the exploration of consumers' perception and knowledge regarding current and general rural water supply, general rural water household utilisation and the understanding of the Free Basic Water Policy; indicated that that the community's do not have much information or knowledge about general water usage and therefore the Wet-Programme was designed.

To conclude the research programme and to involve the community in the process an open day was organized to exhibit the nanofiltration apparatus and to provide the necessary information to community members to ensure community participation.

1.3 CONCEPTUAL FRAMEWORK

The conceptual framework presented in Figure 1.1 is a simplified illustration of the relationship between the concepts identified in this study. The inhabitants of Madibogo receive groundwater from boreholes that are stored in a reservoir and distributed throughout village by means of communal taps. The water has a high concentration of salts (nitrates) which influence the quality of water.

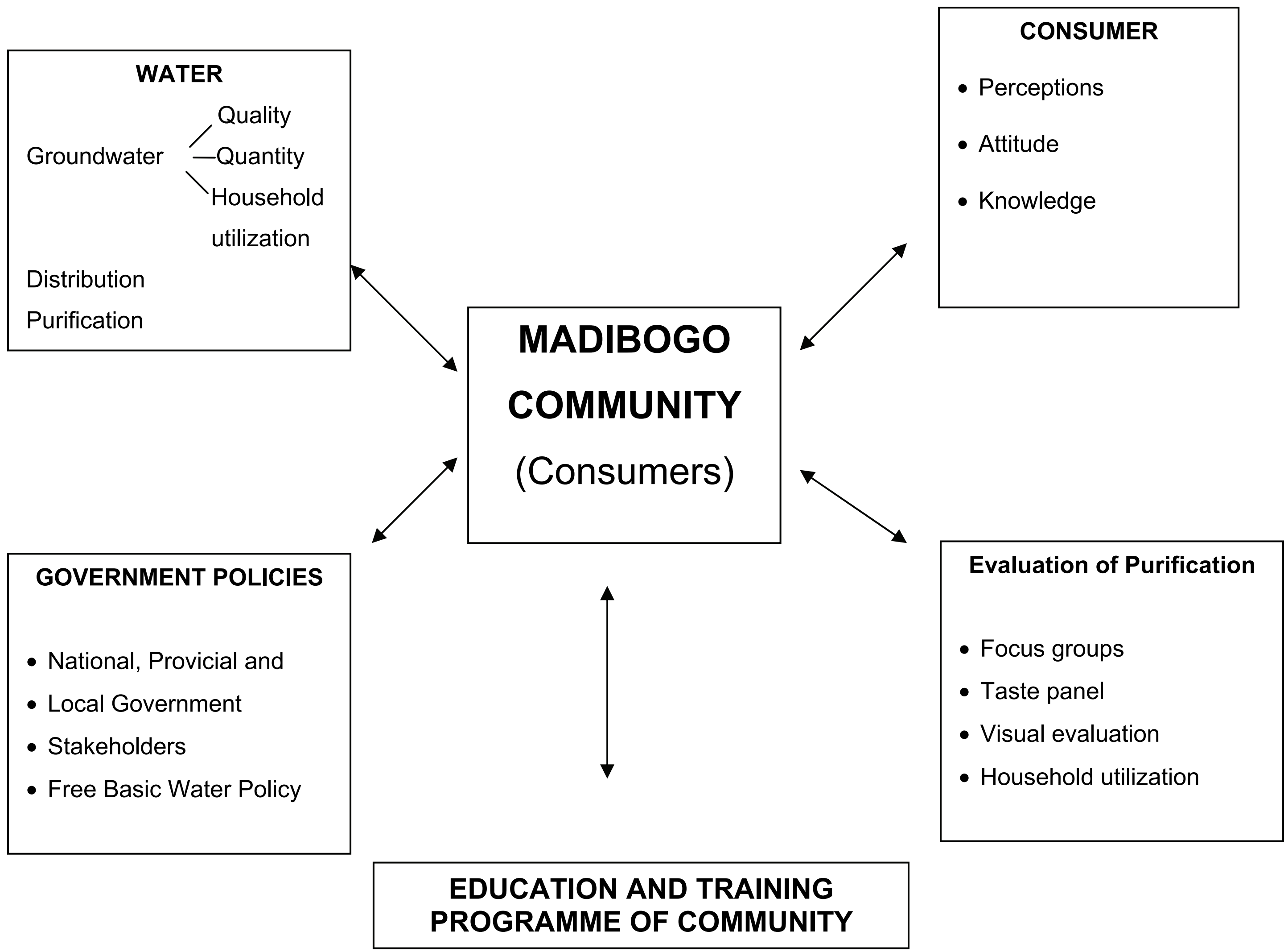

Figure 1.1 Conceptual framework regarding the social dimensions of water provision in Madibogo

1.4 OPERATIONAL DEFINITIONS

In order to clarify the terminology used in this study the following definitions are provided:

- **Attitudes** are an evaluation or judgment presented by a consumer (water user) towards rural water service provision based on his/her direct or indirect experiences.
- **Community members** refer to a social heterogeneous group that share resources including water supply in a common environment.
- **Consumer behaviour** is the behaviour that consumers display in searching for, purchasing, using, evaluating and disposing of products, services and ideas.
- **Consumer socialization** is the process by which an individual first learns the skills and attitudes relevant to consumer behaviour.
- **Consumers** are end users of products or services (water and water service provision).
- **Household water use** is the use of domestic water for many purposes in and around the house.
- **Learning** refers to the process of acquiring knowledge and experience to be applied for future decision making or behaviour.
- **Membrane treatment** is the removal of pollutants from water by passing (permeating) the raw water through a membrane under pressure.
- **Nanofiltration membrane technology** is the technology applied for the removal of dissolved salts from salty water, the removal of micro pollutants, water softening and wastewater treatment.
- **Nanotechnology** is the act, science and engineering for manipulating objects at nanoscale. One nanometre is one billionth of a metre.
- **Perception** is the process with which an individual interprets or views his or her world.
- **Rural water service provision** refers to the quantity and quality of water that is provided to the community living in the rural area as consumers who are end-users. It may incorporate regulations for use (management, maintenance, levy, livestock, and irrigation).
- **Sustainability** is related to assurance of water quality (treatment for microbial and chemical determinants), water quantity (capacity, distribution, maintenance) and the socio-economic issues (cost, unemployment rate, geographical factors) involved in the upkeep of the water supply for present and future.
- **Water purification** is the removal of pollutants from water by filtration, distillation or membrane treatment.
- **Water quality** is a description of the microbiological, physical and chemical properties of water that determine its fitness for use.
- **Water quantity** refers to the variables that include amongst other things affordability, reliability and convenience of the water supply.
- **Water supply** refers to the water supply from where the water is obtained, which in this instance is ground water, through boreholes pumped into reservoirs and distributed through communal taps in the community.

1.5 RESEARCH STRATEGY

In this study two research strategies will be followed, namely quantitative and qualitative. Both these methods will be used to provide a more complete picture of the perceptions, attitudes and knowledge towards rural water service. According to Grosvenor (2006) qualitative research can provide information about perception and attitude formation but not how it is distributed among the population. In this regard the two research methods will complement each other.

It should be noted that there are not many studies or water surveys regarding attitudes accompanied by focus discussions. However, studies done on travel behaviour have explored this method, which rests upon its ability to unfold the complexities of people's behaviour (Clifton & Handy, 2001). Therefore, it was decided to adopt the same research strategy of the travel behaviour studies in this case since it also deals with services and aims at unfolding complexities. Grosvenor (2006) is also of the opinion that, considering the type of target group, the use of familiar language is crucial in understanding their behaviour. He states that this is another way of giving participants an opportunity to have an input in the questionnaire. Thus the focus group discussions will from part of the survey to understand the logic behind the choice of response and to provide the participants with an opportunity to put sufficient thought into the exercise.

1.6 RESEARCH APPROACH OR DESIGN

A participatory development research approach will be used to achieve the objectives of the study. According to Jennings (2000) participatory research alerts people to the need for change. It includes community members as partners of the research and not just as subjects. It views them as expertise and most knowledgeable of the issues affecting them and intends partnering with the community to develop interventions that are acceptable to them.

In this study the community members' views gathered from the focus group discussions when exploring their perceptions will form the basis of the attitude statements to be used for survey. Furthermore, a survey will be conducted in which they will be able to contribute substantially with their opinions by ranking their attitude statements and their discussion. Their responses will determine the nature of the study.

1.7 ETHICAL ISSUES

The researcher used several opportunities to explain the research to the community. For example, during the introductory meeting with the chief, i.e. the 'Kgosi', and the community and before each focus group discussion, the researcher explained to the participating community members that their participation was voluntarily, confidential and anonymous and under no circumstances would they be held accountable for their contribution. They were ensured that there were no right or wrong answers and they were encouraged to speak freely. The participants were also given the opportunity to use nicknames rather than their own names to avoid identification within the focus groups. Data were also not linked to the comments of a particular participant. Findings would be reported to the Water Research Commission for further processing.

1.8 THE CONTIRBUTION OF THIS STUDY TO WATER RESEARCH

This study will give a consumers' perspective of rural water services which may result in a better understanding of the way in which the consumer perceives and utilizes rural water services. The study is intended to augment the body of knowledge already existing within water bodies and water research commissions. It could make a valuable contribution to the research field of consumer behaviour and the useful role that the consumer scientist plays in working with consumer needs. The study could also play an important role in consumer theory and water behavioural consumer research in a South African context.

1.9 DEMARCATION OF THE FIELD OF STUDY

This research project focussed on the water provision issues regarding social issues in Madibogo. Consumers' perceptions, knowledge and attitudes about their water provision were studied, and an educational project was launched and evaluated. Recommendations were made but no attempts were made to change the existing structures providing water to the community.

Simultaneously, the research for testing the Membrane Technology Unit for the removal of pollutants from groundwater was implemented at the local school. Consumers' knowledge and attitudes about water purification was studied and physical differences between the local and purified water were studied. Implementation of water purification on a bigger scale would still have to be investigated.

1.10 PROVISIONAL CHAPTER DIVISION

The research study consists of eight chapters and the contents of the chapters could be summarized as follows:

CHAPTER ONE: INTRODUCTION AND BACKGROUND TO THE STUDY
This chapter provides an introduction to the perceptions and challenges facing rural water service provision and how they influence consumer attitudes. It rural water service provision. Household utilization and opinions of the purified water will also be introduced.

CHAPTER TWO: LITERATURE REVIEW

The second chapter provides an overview of the literature of the most important aspects regarding this study. The situational context of Madibogo is discussed. This is followed by general water theory that includes the quality, quantity and household usage of the water. Free Basic water Policy is explained and the use of the consumer framework is motivated.

CHAPTER THREE: PERCEPTIONS OF CONSUMERS ABOUT WATER PROVISION

The methodology of establishing consumer's basic perceptions about the water provision and problems in Madibogo and the results are presented in this chapter.

CHAPTER FOUR: SENSORY AND PRACTICAL EVALUTION OF PURIFIED WATER

In chapter four the development of a taste panel and sensory evaluation of the purified water are discussed. Practical differences between some household uses of the unpurified and the purified water will be illustrated.

CHAPTER FIVE: DEVELOPMENT OF THE ATTITUDE SCALE

This chapter outlines the methodology of the development of the attitude scale and the measurement of the attitude of community members. The findings will be reported and discussed.

CHAPTER SIX: DEVELOPMENT AND IMPLEMENTATION OF THE EDUCATION PROGRAMME

In this chapter the development and implementation of the educational programme are discussed and possible differences in knowledge and attitude as measured before and after are reported.

CHAPTER SEVEN: CONCLUSIONS AND RECOMMENDATIONS

The summary, presentation of the results, recommendations for future studies and limitations are given in the last chapter.

Figure 1.2 Little girl at a tap in the Madibogo village

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

All the literature that is applicable for this project will be discussed in this chapter. Figure 1.1 gives the simplified version of the conceptual framework used for this study. According to this framework the first aspect to be discussed will be the **background to Madibogo,** then basic theory regarding **water,** such as sources of water, use of groundwater, quality, quantity, household utilization and water purification. Then the **legislative framework** of water provision will receive attention, especially the **Free Basic Water Policy** and relevant **stakeholders involved in water provision.** This study views the water users or community members as **consumers** and studies their behaviour within a **consumer framework.** Aspects such as **perceptions, attitudes and knowledge** of water usage will receive attention. The **design, implementation and evaluation** of an **outcomes based education programme** regarding basic aspects of water will be discussed.

2.2 SITUATIONAL CONTEXT OF MADIBOGO VILLAGE

The situational context of Madibogo village was explored through general congenial exploratory visits to the village and a study of the orientation of Madibogo in the North West Province. This section presents the situational context of the area of Madibogo in which the research was conducted and the research methodology and activities that took place during this study. The situational context of Madibogo is presented by the means of a map indicating its location in the North West Province.

Madibogo village is commonly known to its residents as Madibogopan. It is situated in the North West Province outside Mafikeng as illustrated in Figure 2.1. The North West Province is the sixth-most densely populated province in South Africa with approximately 3.4 million people. It is predominantly rural, with 66% of its population living in rural areas and 34% in urban areas. Madibogo is one of the ‘deep’ rural areas of the North West Province, being situated 90km southwest of Mafikeng in the Ditsobotla District in the former Bophuthatswana which forms the central part of the North West Province. It has a total population of approximately 23 616 people which is composed of 11 608 males and 12 008 females.

2.2.1 Orientation of Madibogo in the North West Province

Figure 2.1 North West Province (Mafikeng)

The village is divided into five sections namely: Seheri, Tlhaping, Morolong, Dikgantlong and Motsitlame. The village is characterized by a lack of access to basic services such as water, electricity, refuse removal and a proper sanitation infrastructure. It has several service buildings such as a post office, petrol station, several primary and secondary schools, a permanent health clinic and a railway station. The road from Setlagole to Dalareyville, which runs along the edge of the village, as well as the main road through the village, is tarred. All other access roads are gravel roads.

2.2.2 Water provision in Madibogo

Madibogo village's main source of water is ground water. There are five boreholes, of which four are in working condition. The borehole water goes to two reservoirs that are highly fenced and where chlorine is added as a disinfectant. From there the water is distributed through a series of pipes and the community then access the water from 86 standpipes distributed all over the village.

The following table is a summary of the composition of the groundwater in Madibogo. From this it is clear that the values of the most dissolved materials in the water are higher than recommended by the SANS-241 (Hlope, 2008).

Table 2.1 Composition of groundwater at Madibogo

Determinant	SANS-241 specification/ppm	Madibogo concentration/ppm
NO^{3-}	10	23.6(↑)
Cl^-	200	637(↑)
F^-	1.0	4(↑)
SO_4^{2-}	400	110(↓)
Ca^{2+}	150	176(↑)
Mg^{2+}	70	102(↑)

The following pictures illustrate some of the daily happenings in the Madibogo village as well as conditions of a water service of the Madibogo village.

Picture 1. A communal tap of Madibogo village

Picture 2. A non-functioning water service

Picture 3. Standpipe water shared by community members and animals

Picture 4. Wheel barrows used to carry water-filled containers to the households

Figure 2.2 A pictorial representation of water services in Madibogo

2.3 WATER

2.3.1 Introduction

Pietersen (2005) indicates that more than 400 rural communities in South Africa depend on ground water for household utilization. He furthermore reveals that this source is abstracted through boreholes stored in the reservoirs and distributed to the communal taps. The ground water is usually clean, but not necessarily fit for household utilization as some areas experience higher levels of nitrate in the water than expected. Based on these facts brought forward by these authors the main focus of this literature review will be on water quality, water quantity, the South African Free Basic Water Policy (FBWP) and household water utilization.

2.3.2 Water components

Water components have already been discussed in chapter one and in this section a broader view will be provided.

2.3.2.1 Defining water quality

Water quality is defined as the microbiological, physical and chemical properties of water that determine its fitness for use (Water Research Commission, 1999). The physical property is determined by the aesthetic quality factor that means the taste, smell and visual appearance.

The main idea related to the quality of water is the eradication of impurities and to produce water which is healthy and fit for consumption. However, in the natural environment there is not pure water available for general use. Even rainwater contains some impurities. These impurities are commonly in the form of dissolved solids or gases, suspended solids and micro organisms. Furthermore, Sami and Murray (1998) and Van Leeuwen (2000) divided these contaminants into two categories, namely natural and man-made contaminants listed in Table 2.2.

Table 2.2 Contaminants affecting the quality of drinking water

Natural contaminants	**Man-made contaminants**
Salt: sodium, potassium	Treatment or distribution of drinking water
Hardness: calcium, magnesium	Discharge from sewage treatment
Arsenic	Agricultural activities
Bacteriological contaminants	Uncontrolled discharges or leakages from landfill sites and chemical accidents
Manganese	Works and industrial plants

Van Leeuwen (2000) further maintains that water is a universal solvent that will never be pure, that will contain impurities prior to and after treatment. This is a concern that even after treatment water will contain some impurities. Generally, the assumption exists that a water source which has received treatment should adhere to the following standards which are basic requirements for both Van Duuren (1997) and the water treatment guide by WRC (2002).

These requirements are as follows:

- The water must not pose a health risk due to microbial contamination.
- It should not pose a risk due to chemical contamination.
- It should be aesthetically acceptable.
- It should not have economically detrimental effects on either the distribution systems nor on consumers' equipments in terms of corrosivity, scaling, and hardness or sediments.

To achieve the above, it is necessary that the water service providers consider the three main determinants of water quality which are microbiological, chemical and physical. It is further argued that water quality is a major concern that needs to be addressed. An illustration of this argument is presented by Vlok (2003) who quotes an article published in the Rand Daily Mail (1982) that states "A safe, reliable supply of water is thus an essential requisite for community health". To understand the issues related to this article and therefore to water quality it is necessary to examine the quality determinants. In the next section each of the water quality determinants will be discussed.

2.3.2.2 Water quality determinants

i) Defining microbiological water quality

The microbiological quality of drinking water refers to the presence of micro organisms that cannot be seen by the naked eye. It refers to the pathogens such as the ones listed in Table 2.3.

Table 2.3 The pathogens of concern in drinking water

Pathogen	**Example**
Bacteria	*Salmonella* and *Esherichia coli*
Viruses	*Hepatitis A*
Protozoan	*Cyclospora*

Theron (2001) warns that water service providers should be aware that the microbiological quality of water should not reach unacceptable levels. This is based on the fact that the consumer's health, which is dependent on such a water source, is endangered by ingesting directly or indirectly food prepared from a source with levels of micro organisms. In addition, using it for personal hygiene as well as for crop or vegetable garden irrigation may result in ill health.

The people most susceptible to microbial contaminants are the very young, the elderly, pregnant women and immuno-compromised individuals (i.e. people with a weak immune system, including AIDS patients, cancer patients undergoing chemotherapy and organ transplant patients). Several authors are of the opinion that the quality of water, especially the microbial quality, is a very important aspect of water quality that plays a role in the consumers' lives. They argue that, by addressing the microbial quality of water, the quality of lives of the consumers and those who were mentioned earlier, consumers with compromised immune systems can be improved. According to Ealse (2003) water is a simple and inexpensive way of extending the lives of the people who have compromised immune systems. This is based on the fact that proper nutrition and personal hygiene are dependent upon the state of the water the people are using. Meyer and Reed (2001) noted that disinfection of water is an essential process to destroy pathogenic micro organisms resulting in potable water that is safe for human consumption.

ii) Defining chemical water quality

Chemical water quality refers to the nature and concentration of dissolved substances such as salts, metals and organic chemicals. Many of these chemicals are essential for consumers' daily intake. However, if they are at high concentrations they can have a negative impact on human health. Listed below in Table 2.4 are a large number of chemical compounds in water both natural and man-made which affect humans.

Table 2.4 The chemical compounds in water that affect humans

Chemical compound	**Effects**
Nitrate	Methaemoglobinemia (Blue baby syndrome)
Mercury and lead	Interfere with the nervous system or upset the human metabolism
Carcinogens (cancer causing substances)	Increase the risk of tumour formation
High magnesium	May result in an upset stomach
Increased zinc, cadmium or copper concentrations	May have health or aesthetic problems
Sodium	Affects taste
Calcium	Kidney stones, calcification of eye membranes Can cause scaling and can reduce the lathering of soap
Fluoride	Brittle skeleton

Sami and Murray (1998), Modise and Krieg (2004) and Pietersen (2005) earlier observed that South African groundwater often contains high levels of nitrate. This observation is supported by the findings of the study conducted by Hlophe (2004) in one of the North West Province rural areas. Hlophe (2004) observed nitrate levels of 22.66 mg/ℓ from a groundwater source in

Madibogo. Pietersen (2005) raises a concern about the excess levels of nitrate found in drinking water as they can result in abortion or still birth, gastric and other cancers as well as hypertension.

According to the nitrate-nitrite classification system provided by WRC (1999), Table 2.5, if a water source falling between 20-40 mg/ℓ of nitrate levels is drunk; there might be chronic risk to some babies. However, no aesthetic effects from this source of water are found. If food is prepared from this source of water, possible chronic risk might be observed and if bathing is done slight chronic risk in some babies might be observed. It also suggests that there is no effect in household utilization such as laundering.

Table 2.5 The effect of a specific nitrite and nitrate range on the quality classification of water

Aspects that are influenced	**20-40 mg/ℓ as N (87-177 mg/ℓ as NO^{3-}**	**Quality classification**
Health	Possible chronic risk to some babies	Poor
Aesthetic	No aesthetic effects	Ideal
Food preparation	Possible: chronic risk to babies	Poor
Bathing	Slight risk to babies only	Marginal
Laundry	No effect	Ideal

The classification provided by the WRC guide (1999) indicates that babies are the most vulnerable to high concentrations of nitrate. It could be argued that this classification opposes the views of the consumers under study who are experiencing high nitrate concentration (22.6 mg/ℓ) in the water provided by the service.

iii) Defining physical water quality

As mentioned earlier in chapter one the physical quality is interdependent to the microbiological and chemical water qualities. This is based on the fact that physical quality is visible as it is evaluated through the sensory receptors such as taste, smell and visual appearance. The idea exists that when water looks clean, although the taste and smell are unpleasant it is perceived to be usable although it might not be healthy. Consumers' judgements about the physical appearance are very important if the appearance is not attractive they will not use the water for food preparation and drinking although it might be healthy. However, the physical quality of water is also affected by products added such as disinfectants applied to address the microbial quality of water (WRC, 2003). It therefore, raises the question as to what could be done to improve water quality affected by water quality components. The answer to this question may be found in water treatment and purification designs applied to a water service.

2.3.2.3 The role of water treatment and purification designs

According to Meyer and Reed (2001) there are various ways in which water can be treated or purified to reach the acceptable water quality standards. However, each of the systems has its own effects and concerns. The major concern regarding treatment or purifying systems seems to be that water should be safe and chemically stable to be consumed. To reach these levels of purification Sami and Murray (1998) and the WRC guide (2002) suggest that water should be treated to meet certain requirements to make it fit for domestic use. This means the standards of the drinking water should align with the South African Water Quality Guidelines provided by the WRC guide (1999).

To address the safety issue related to treatment and safety of water, the Department of Health and Water Affairs and Forestry developed a user-friendly guide to give a consumer and water service providers information on different ways in which water can be classified and the main effects each class of water may have. Table 2.6 contains relevant information.

Table 2.6 A classification system describing the effects of the different classes of water on the various household uses

Class/Description	Effects
Class 0 Ideal water quality	Drinking Health: No effects, suitable for many generations. Drinking Aesthetic: Water is pleasing. Food preparation: No effects. Bathing: No effects. Laundry: No effects.
Class 1 Good water quality	Drinking Health: Suitable for lifetime use. Rare instances of sub-clinical effects. Drinking Aesthetic: Some aesthetic effects may be apparent. Food preparation: Suitable for lifetime use. Bathing: Minor effects on bathing or on bath fixtures. Laundry: Minor effects on laundry or on fixtures.
Class 2 Marginal water quality	Drinking Health: May be used without health effects by the majority of individuals of all ages, but may cause effects in some individuals in sensitive groups. Some effects possible after lifetime use. Drinking Aesthetic: Poor taste and appearance are noticeable. Food preparation: Maybe used without health or aesthetic effects by the majority of individuals. Bathing: Slight effects on bathing or on bath fixtures. Laundry: Slight effects on laundry or on fixtures
Class 3 Poor water quality	Drinking Health: Poses a risk of chronic health effects, especially in babies, children and elderly. Drinking Aesthetic: Bad taste and appearance may lead to rejection of the water. Food preparation: Poses a risk of chronic health effects, especially in children and the elderly. Bathing: Significant effects on bathing or on bath fixtures. Laundry: Significant effects on laundry or on fixtures.
Class 4 Unacceptable water quality	Drinking Health: Severe acute health effects, even with short-term use. Drinking Aesthetic: Taste and appearance will lead to rejection of the water. Food preparation: Severe acute health effect, even with short-term use. Bathing: Serious effects on bathing or on bath fixtures. Laundry: Serious effects on laundry or on fixtures.

Table 2.6 illustrates how the water is categorized from an ideal water quality (class 0) to an unacceptable water quality (class 4) where the maximum limit of low risk of adverse health or aesthetic effects without treatment is reached. Even though this is a good example of how water quality should be assessed, it could be argued that this classification system is of little significance to the general rural consumer. The fact is that these consumers, in most cases, are illiterate and not concerned with the classification of water quality and it is proposed that the idea of how this classification system is supposed to be implemented might be of little use or importance.

Among other things, such as providing the water service, Van Duuren (1997) mentioned that the choice of a particular treatment method should depend on the socio-economic conditions, the technical requirements and capabilities of the particular area that requires the water service provision. Furthermore, Van Duuren (1997) elaborates on this matter by stating that the conventional water treatment processes used in urban areas would not be suitable for isolated rural communities of low socio-economic status. However, this does not dispute the fact that rural areas are in an urgent need of practical, simpler, inexpensive and sustainable technologies for the production of satisfactory drinking water.

Modise and Krieg (2004) and Pillay and Jacob (2004) observed that in South Africa researchers are engaged in finding and developing water purification systems that will be sustainable and provide drinkable water. They, furthermore, observed the international rapid growing favour towards membrane technologies for the production of high quality drinking water, without the direct addition of chemicals. Pillay and Jacob (2004) enumerated five pressure-driven membrane processes that the researchers are busy working on, namely micro filtration, ultra filtration, nanofiltration, reverse osmosis and particle filtration. These small-scale developing systems have different advantages and serve different purposes.

However, Pillay and Jacob (2004) mention the non-current use of these membrane techniques in drinking water production in South Africa. These are the possible reasons for the non-current use of some of the imported water treatments in South Africa. Some of the reasons blocking the current implementation are the high costs associated with purchasing treatment units, as well as the high cost of obtaining spares for such units, the perceived lack of local membrane expertise in terms of design, construction, operations and troubleshooting, a reticence to use new technology unless it can be sustainable in the long term. Water quantity will be discussed in the next section.

2.3.3 Water quantity

Water quantity refers to variables that include amongst other things affordability, reliability and convenience of the water supply. According to De Fontaine's (2000) water quantity related aspects such as reliability and inconvenience, may be equated with a concept of accessibility and availability, as they need to be included when referring to water quantity. This is based on the fact that Modise and Krieg (2004) noted that the consumer is highly dependent on the availability of clean water.

2.3.3.1 Different concepts regarding water quantity will be discussed in the next section.

- Availability – According to Kasrils (2002) the provision and availability of clean water and sanitation to all South Africans is indispensable to the success of the government's Reconstruction and Development Programme. According to the World Health Organization's guidelines and the South African's Water Quality guidelines water and water sources should be sufficient and reliable for household chores and activities such as food preparation, drinking, laundering and personal hygiene. The availability of water is further linked to accessibility of the water source to the consumers.
- Accessibility – In this study accessibility refers to water services and water facilities which should be reachable and attainable to everyone. This also refers to physical accessibility, economic accessibility, non-discrimination and information accessibility (Anon, 2002). During the nineties Jackson (1997) estimated that about 40-60% of the rural areas in South Africa do not have access to adequate water services. The RDP suggested that 25 ℓ per person per day should be available to each household in a rural community. These sources should be within 200 metres of the dwelling place and no consumer should be without a supply for more than seven full days in a year.
- Affordability – Under the concept affordability it is suggested that every South African has the right to basic services which includes the provision of water services, sanitation, refuse removal and electricity Netshiswinhze (2002) clearly states that it is the responsibility of the state to subsidize municipalities in an attempt to make water affordable to everyone.

2.3.4 Household water utilization

The primary idea of any source of water is that it should be used for drinking, personal hygiene, laundry and for preparing food. Water is important for household activities and it has a biological importance as it plays an important role in physiological functioning of the human body. The following paragraphs will illustrate this importance.

2.3.4.1 The general basic importance of water for the household use

Water is used for the following household activities:

- Regular washing of the skin and hair is necessary to remove dirt, grease, dead skin, sweat and pests such as lice, fleas and bedbugs, which may cause skin irritation or transmit diseases.
- Washing hands after using the toilet to prevent contamination of food and cooking utensils.
- Crockery and cutlery need to be washed with water and detergent to remove bacteria.

- Clothes need to be washed with water and detergent in order to remove dirt, bacteria, dead skin, sweat and lice, fleas and bedbugs.
- Water is also used for cleaning the house, for watering the garden, for cooking and for flushing the toilet (if there is a flush toilet).

The above mentioned household activities are important for the improvement of personal hygiene. If good hygiene is practiced the human quality of life, in this case the health aspect, will be improved. However, personal hygiene on its own will not improve quality of life. Water is essential in the functioning of the human body and is thus of biological importance.

2.3.4.2 The biological importance of water

The use of water should also be understood as an important biological aspect. This includes:

- Quenching thirst.
- The necessity for oxidation of carbohydrates, proteins and fats.
- Its usefulness for rinsing out the mouth after eating to prevent the formation of dental cavities and bad breath.
- Assisting in a metabolic, physiological or biochemical reactions in the body.
- It is important to make sure that digestion, absorption and elimination take place.

The importance of water cannot be underestimated. It is therefore necessary that water quality and water quantity of the water service are of acceptable levels to aid in the quality of life of the consumers. However, the intention of government's water policies, including FBWP, is to adhere to these requirements but the reality is that FBWP and its implementation to rural communities may sometimes not even reach the communities.

2.4 HARD AND SOFT WATER

Water that is provided to consumers is not supposed to contain any dissolved substances but this is hardly ever so in practice. When water is allowed to evaporate it should leave no residue but that only happens when distilled water is used for evaporation (Ling, 1972). Most tap or borehole water will leave a residue when allowed to evaporate which indicate that there are substances dissolved in it. In spite of this the water will be perfectly safe to drink, even beneficial because it contains minerals that is good for the body. In tap water harmful materials such as bacterial and organic matter (animal and plant material) are removed at the waterworks by special treatment, such as chlorination and filtration removes suspended material.

Where does the above mentioned residue, which is dissolved minerals, come from? According to (Ling, 1972) water from the sea evaporates in the air, the sea breeze blows and carries it inland. The moist air raises, cools down and will condense to form clouds. The water that condenses to form droplets is pure water. The droplets become bigger and bigger and eventually descend to the earth as rain. On the way down carbon dioxide of the air dissolves in the raindrops and reacts with water to form a weak carbonic acid. In the ground it reacts with the calcium carbonate to form a substance such as calcium bicarbonate.

Hard water is water that has a high mineral content and water with a low mineral content is called soft water. Hard water usually have calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, and possibly other dissolved compounds such as bicarbonates or sulphate. Calcium usually enters the water as calcium carbonate ($CaCO_3$) or calcium sulphate ($CaSO_4$) in the form of other mineral deposits. The predominant source of magnesium is dolomite.

The simplest way to determine the hardness of water is the lather or froth test: soap or toothpaste, when agitated, lathers easily in soft water but not in hard water (Ling, 1972 & Anon, 2008).

2.4.1 Temporary and permanently hard water

Water can be temporary hard or permanently hard. Temporary hardness is caused by a combination of calcium and magnesium ions. It can be removed by boiling the water or by the addition of lime (calcium hydroxide). Boiling promotes the formation of insoluble calcium or magnesium carbonate from the and precipitates calcium or magnesium carbonate out of the solution, leaving water and carbon dioxide, which makes the water cloudy. The water will be softer and will therefore use less soap is needed (Anon, 2008).

Permanently hardness is water with a mineral content that cannot be removed by boiling. It is usually caused by the presence of calcium and magnesium sulphates and/or chlorides in the water, which become more soluble as the temperature rises. Despite the name, permanent hardness can be softened by a water softener or ion exchange column. Permanently hard water contains calcium – and magnesium sulphate or chlorides which are not affected by boiling and boiled water will still use more soap or get scum when soap is used (Anon, 2008). According to Ling (1972) soap is a combination of sodium or potassium salt and fatty acids. When soap dissolves in water it splits up in two parts called a sodium ion and a fatty acid ion. The calcium bicarbonate also splits up in a calcium ion and bicarbonate ion. The calcium ion reacts with the fatty acid ion to form insoluble soap or scum.

2.4.2 Disadvantages of hard water

Hard water causes scaling, which is left over mineral deposits that are formed after the hard water had evaporated, this is also known as lime scale. The scale can clog pipes, ruin water heaters, cote the insides of tea and coffee pots, and decrease the life of toilet flushing units.

Hardness in water can cause water to form scales and a resistance to soap. Hard water is defined as water that doesn't produce lather with soap solutions,

but produces white precipitate or scum. More soap and detergent are used when doing laundry with hard water because of the scum forming.
The skin does not feel nice and soft after washing in hard water. It feels dry and scaly in contrast to after washing with soft water when the skin actually feels a little slippery. When soap is used with hard water soap is wasted and scum forms. Hard water may be treated to reduce the effects of scaling and make it more suitable for laundry and bathing.

Similarly, insoluble salt residues that remain in the hair after shampooing with hard water leaves hair rougher and harder to untangle.

2.4.3 Hard water and health issues

The World Health Organization says "There does not appear to be any convincing evidence that water hardness causes adverse health effects in humans". Hard water is usually not harmful. The calcium can give strong bones and teeth (Anon, 2008).

2.4.4 Ways to overcome hard water problems

For washing and cleaning purposes a little washing soda (sodium carbonate) can be added to the water before any soap or detergent is added. Many bath salts are actually sodium carbonate with perfumes. The water will become turbid because there is sodium and carbonate ions and these ions react with the calcium to form calcium carbonate (Ling, 1972). Washing soda is a relative cheap way to soften water for laundering and bathing.

Another more expensive option is to install an ion exchange water softener. Hard water is allowed to flow over an ion exchange resin which let the calcium and magnesium ions be replaced by sodium which doesn't affect the working of soap.

2.5 WATER POLICY

2.5.1 An overview of rural water supply in South Africa

Access to potable water for all has been one of the political priorities of the government of South Africa since the advent of full democracy in 1994. Ten years ago the number of people estimated to be without such access was estimated at 12 million. By June 2004 the Minister of the Department of Water Affairs and Forestry was able to state that the government had in the decade since 1994 supplied water to ten million people who had previously not had a proper water supply. She moreover stated that the backlog was now 4.4 million people; the original estimate of 12 million to supply was now outdated due to population growth, and in might have been an underestimate to start with.

2.5.2 The Water Services Act (No.108 of 1997)

The main objectives of the Water Services Act of 1997 were: to provide for the right of access to sufficient basic water supply and sanitation services; set to national standards; to provide a regulatory framework for water service institutions (including authorities and providers); and to establish the authority of the Minister of Water Affairs and Forestry in the water and sanitation sector.

The Act distinguishes between Water Service Authorities (WSA) and Water Services Providers (WSP) – two key functions at local level. A WSA is the local government body (district of local municipality) responsible for ensuring access to water supply services and sanitation services. This includes the following duties: preparation and adoption of a water services development plan; annual reporting on the development plan; ensuring that WSP are in place to operate and maintain water infrastructure (WSA) either create in-house WSP capacity, or they contract independent entities to provide this capacity); developing bylaws for the provision of water and sanitation services; and monitoring the performance of WSP within the WSA's area of jurisdiction. A WSP is defined by the Act as any person/entity who provides water and sanitation to customers. A WSP is to be contracted for a limited period and subject to conditions, and must provide any information requested by the WSA, provincial government, the Minister, or any consumer. An important stipulation for WSP is that "a water services authority may only enter into a contract with a private sector water service provider after it has considered all knows public sector water services providers which are willing and able to perform the relevant functions".

One of the effects of the implementation of the Water Services Act has been the decline in importance of the village water committee. In the 1990s rural schemes were, by and large, expected to be operated and maintained by village water committees, with limited external support. It was soon realised that continuous external support was required, and this needed to be provided within a local government framework that include all communities. This new dispensation was provided for in South Africa by the establishment in the year 2000 of a coherent and universal system of local government (previously lacking in South Africa due to the fragmentation of government services caused by the apartheid system). The current situation (in rural areas) is that municipalities do own and are expected to operate and maintain all communal water supply infrastructures. The official role of the village water committee is now primarily one of facilitation and liaison with the municipality, as the current legislation does not provide for a community based organisation to be legally contracted as a water services provider. For this reason the focus of the monitoring of water services has in the last few years changed from the village water committees to the water service provider who must ensure the quality, reliability and cost efficiency of the service itself.

2.5.3 The monitoring of water supply services

A Water Service Authority is required by the Water Services Act of 1997 to monitor the performance of all water service providers within its jurisdiction, ensuring that the WSP comply with national and local legislation and standards. In the case of a municipality which is itself both WSA and WSP (many have opted for this model); the two functions are required to be managed and accounted for separately, to allow for monitoring. The intention of the monitoring is to ensure that the people living in the WSA's area of jurisdiction do receive a reliable supply of water of an acceptable quality, and that the cost of this service is in accordance with national and local government policy. However, exactly how the WSA should go about this monitoring is left to the WSA to decide.

2.5.4 The Free Basic Water Policy (FBWP)

The 1996 South African Constitution listed access to water in the Bill of Rights and the 1997 Water Services Act provided the legal basis to implement this right. In 2001, the government introduced the Free Basic Water policy, which is the legislated right for every South Africa household to have access to a "basic" supply of water at no cost. This is funded by using the grants from the national treasury (termed "Equitable Share"), and by using cross-subsidisation.

An attempt by the South African government has been made by the initiative of FBWP to address the concepts of water quantity. According to The white paper this policy embodies the South African national values of reconciliation, reconstruction and development. This states that water is shared on equitable basis which in effect addresses the needs of those who do not have access to water and sees to it that the need for water in their daily lives are met. In turn this is also a basic human right.

By implementing the FBWP, Sussen and Vermeulen (2001) and Kasrils (2002) states that this policy will not only provide a human right but will also ensure the following:

- That no one is denied access to basic water due to the fact that he/she cannot afford to pay for the service.
- Poverty is alleviated.
- Community health is improved.
- The assurance that women labour is liberated from the chore of fetching water for the household.

To define a basic supply a guideline figure of 6 kℓ per household per month is used, which would equate to 25 litres per person per day for a typical rural household of eight persons, and 50 litres per person per day for a typical urban family of four persons. Some have criticised the 6 kℓ per household figure as being insufficient for basic needs (particularly in urban areas), and also for not allowing for cases where several families are served by one connection. However, in terms of the policy and guidelines Water Services Authorities are given considerable freedom to adapt the policy as they see fit, according to their means.

The Free Basic Water Policy was officially implemented from July 2001. This occurred on schedule in the larger urban areas without much difficulty, as an adjustment of tariffs to cross-subsidise those using less that the basic amount was all that was necessary. However, rural areas were much more difficult, due to the challenges of large distances, small volumes, high overheads and poor resources. Water Service Authorities is still at varying levels of implementation of the policy, with few having a fully operational policy that is reaching all their rural schemes. Some rural communities have still not been officially informed about FBWP and are still paying for all their water. Progress to date varies greatly between municipalities, from full strategy-based implementation to random default implementation. It is notable that in March 2005 the Department of Water Affairs and Forestry's website keeping track of the roll out of Free Basic Water put the number of people in South Africa without access to infrastructure (and therefore without Free Basic Water) at 10.9 million. This is 6.5 million more than the number of people reported as unserved in August 2004. Whatever the reasons for the discrepancy (e.g. what is meant by "infrastructure", and what is meant by "access"?) it does illustrate the level of uncertainty with much reported data in water supply in South Africa. Better monitoring systems would help to close the uncertainty gap.

Where FBW has been implemented in rural areas, consumption has proven to be generally within the free allowance, and therefore there is no longer any income generated from these schemes. Thus, municipalities with a primarily rural constituency, and no large cities, are greatly reliant on the Equitable Share allocations from National Treasury to cover the costs of water provision.

The intention of the FBWP is evident in addressing the quality of life of the South African water consumers. In order for the consumer to experience the improvement of water quantity, the South African government has proposed a model that is to improve the co-operation between the sectoral agencies that are part of the deliverance of water services. The model is illustrated in Figure 2.3.

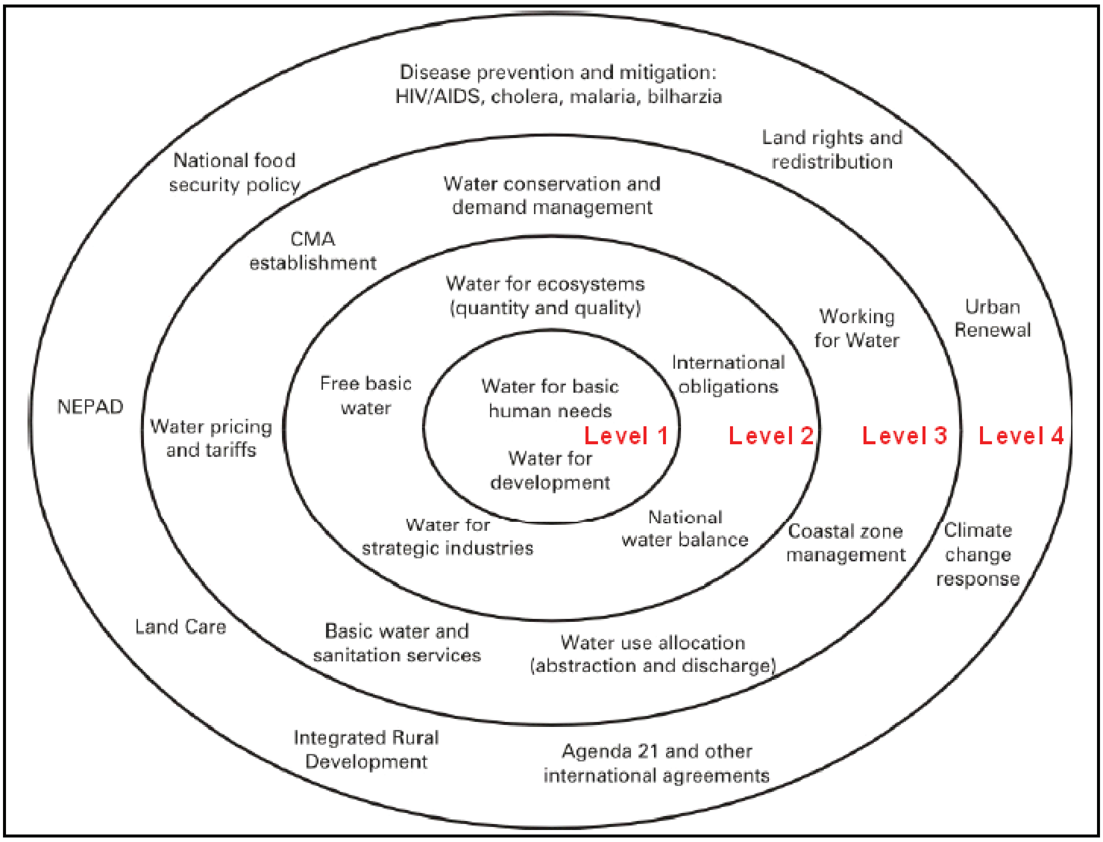

Figure 2.3 Proposed framework for water policy implementation across all sectors (Mackay *et al.,* 2004)

According to Figure 2.3 above level 1 illustrates that water is a need for human survival as well as for development. Level 2 supports level 1 as it focuses on programmes implemented and maintained by the lead agent DWAF. The 3rd level is a water-focused programme, which is implemented by other agencies at local levels. The 4th level is a broader societal program that affects or is affected by water policy implementation and they contribute to the long-term success of water policy implementation. However, according to MacKay and Ashton (2004) this framework is still at the early stages of which its success rate and implementation might be argued through its achievements. With implementation of FBWP comes the next theme which needs to be addressed and explored such as the utilization of the water service. An understanding of this theme may result in determining the success of the FBWP on the consumption stage.

2.6 STAKEHOLDERS INVOLVED IN WATER SERVICE DEVELOPMENT

Development is not something that should be taken for granted and accepted as a "hand out". It requires an internal process of change whereby people take responsibility for improving their living conditions. The legislative framework within the South African context requires local government to implement development programmes that allows local people, and all other relevant stakeholders, to actively participate in identifying their problems, planning and implementation of appropriate action. The marketing literature offers a model which indicates the role players, who initiate developmental programmes to inform, educate and thereby improve the quality of life of the consumers.

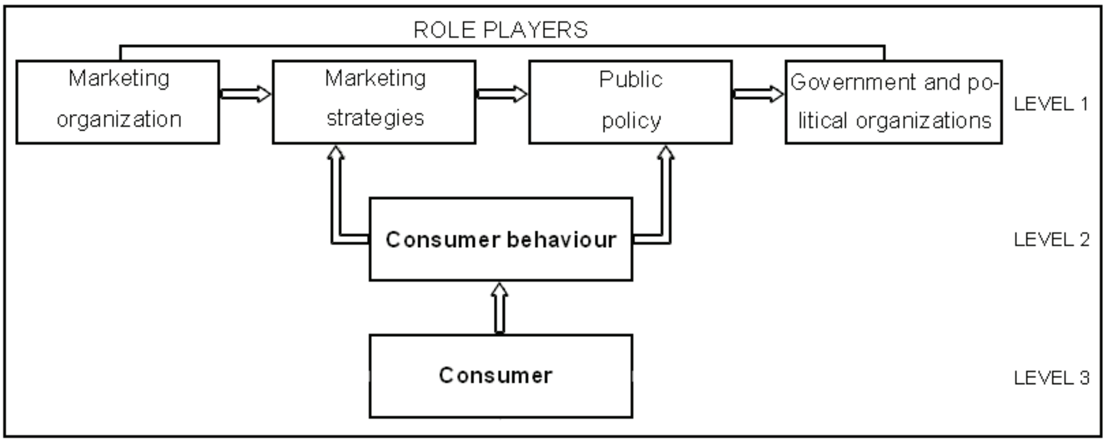

Figure 2.4 A model of the relationship within action-oriented groups interested in consumer behaviour

Figure 2.4 is of a model put forward by Peter and Olson (2005). It illustrates the relationship among the role players (Level 1 in Figure 2.4), consumer (Level 3 in Figure 2.4) and consumer behaviour (Level 2 in Figure 2.4) processes (perceptions, attitudes, cognition). It presents the consumer as the main focus. The consumer exhibits certain consumer activities (such as perception) that are of interest to the role players when formulating consumer development programmes. The model suggests that organizations (role players) have an influence on marketing strategy and public policy. The outcome of influences from the latter two aspects will influence further consumer activities. The outcome of this reaction will have an effect on strategy and policy and therefore on the result of a mutual relationship between levels one and two in Figure 2.4.

2.6.1 Consumers' role in water service provision

In light of the fact that the study argues from the position of the consumer it is important to identify and define the consumer. Sheth *et al*. (1999) provides an applicable framework of the consumer that is illustrated through the behaviours and role the consumer takes on, which is presented in Figure 2.5.

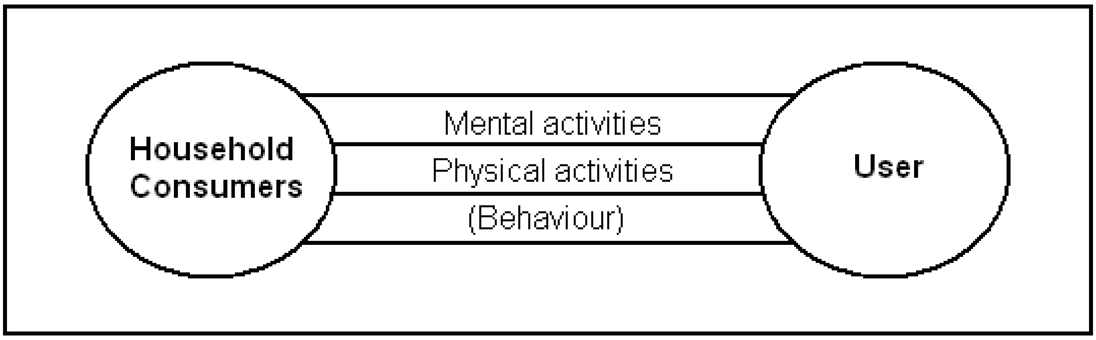

Figure 2.5 A redrawn model of a consumer role and behaviours

Figure 2.5 is of a model put forward by Peter and Olson (2005). It illustrates the relationship among the role players, consumers and consumer processes such as perceptions, attitudes, cognition. It presents the consumer as the main focus. The consumer exhibits certain consumer activities (such as perception) that are of interest to the role players when formulating consumer development programmes. The model suggests that organizations (role players) have an influence on marketing strategy and public policy. The outcome of influences from the latter two aspects will influence further consumer activities. The outcome of this reaction will have an effect on strategy and policy and therefore on the result of a mutual relationship between role-players. Furthermore, Pybus *et al*. (2001) is of the opinion that consumers are important role players in consuming and taking care of the product or service. In relation to this, it can be argued that if a community worker or facilitator intervenes and plays a role as educationalist, consumers of basic services will have a better chance of taking ownership of the service they receive. This is an important issue to consider if a basic service is to be sustainable.

These behaviours can also be associated with the academic principles of consumer behaviour. In this regard, consumer behaviour leads to the study of individuals and community groups and the processes they use to consume and dispose of water services as well as the impact that these processes have on the community as consumers. Consumer behaviour in general is defined through the marketing perspective by authors such as, Blackwell *et al*. (2001) and Solomon (2006). Their views however, form the bases on which consumer behaviour is viewed in this study.

The problem, however, is that little has been done on consumer perceptions and household water utilization in relation to water services in South Africa. In general studies have not paid much attention to the psychological processes such as perception of a water service through the consumer. Nor has the consumer been the focus of the research from a phenomenological perspective. Studies have only delivered results in an advisory capacity that should be considered in order to alleviate a particular community problem. These studies have not considered the consumers' understanding and opinions of the situation under study. It is therefore evident that a study looking at consumer perception and household water utilization will be an important contribution to the water research field and can be accomplished through studying the aspects this research has in view, especially as so little attention has been paid to the consumers themselves.

2.7 CONSUMERS' PERCEPTION PROCESSES

Perception can be studied through various models of the perception processes, such as presented by Sheth *et al.* (1999); Mowen and Minor (2001); Du Plessis and Rousseau (2003) and Schiffman and Kanuk. (2004). Mowen and Minor (2001) provide a suitable model to study the perceptual process of consumers that may be applied to this study (Figure 2.6).

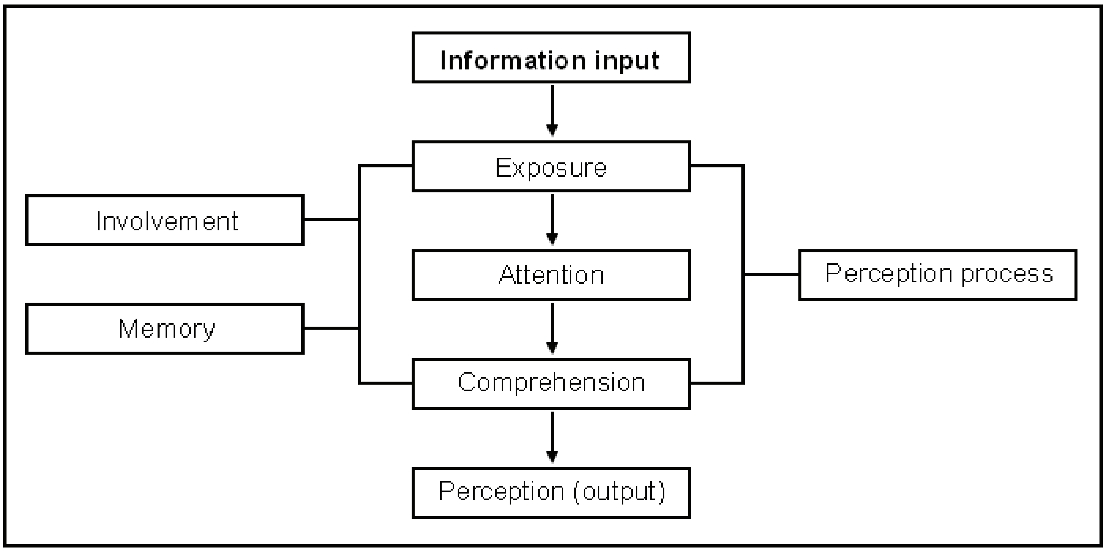

Figure 2.6 The perceptual process of a consumer

It illustrates that for this process to occur, the consumer needs to be exposed to stimuli which offer information to process and form perception. Mowen and Minor (2001) are of the opinion that before the stimuli penetrate the perceptual process two additional aspects, consumers' involvement and memory, become role players in the perceptual process which directly influences this process by guiding the way in which the stimuli will be perceived. Consumers' involvement is characterized by the type of service under consideration, the channels used to inform the consumer, the personality of the consumer and the consumers' situational context. The memory aspect for example refers to consumers' socialization.

The stimuli are then processed through the three stages of the perception process which are exposure, attention and comprehension (Figure 2.6). Exposure, occurs when the consumer's sensory receptors come into contact with the information or stimulus. Attention refers to the activation of one or more of the consumer's sensory receptors, as well as to the resulting sensation that is processed in the brain. The term comprehension is the way in which the processed sensation is interpreted in the consumer's brain or mind (Mowen & Minor, 2000).

2.8 ATTITUDE

2.8.1 Introduction

For decades attitudes have been the centre of research. This is based on the complex nature they possess. Thus, several researchers have been engaged in an intensive search trying to simplify, explain and interpret this complexity. Although that has been done, no consensus has yet been reached on this matter. However, several authors such as Eagly and Chaiken (1993); Shao (2002); Rogers (2003) and Assael (2004) have managed to reach a mutual agreement, on the fact that attitude has an evaluative element. The agreement was based on the opinion presented by the various attitude researchers that the evaluative element of attitude has an important role to play in directing people's lives. An attitude is a person's positive or negative feelings about a subject or specific behaviour and can be symbolised by opinion derived from specific behaviour (Anastasi, 1988).

The other important noted role that is played by attitude is within the various fields and disciplines that deal with human attitudes. Different fields possess various perspectives and approaches to deal with the nature of attitude. This is related to the conceptualisation and benefits that attitudes bring within those various fields/disciplines. For example, within the economics and the marketers field, attitudes are important in understanding the needs and the way of thinking of the target market. This is argued through the assumption that exists among the marketers field that the consumer's reaction towards the product or service indicates the consumer's behavioural intention that predicts the actual behaviour of the consumer. The concept of attitude in this field/discipline helps in planning, organizing finances and developing marketing strategies that will be beneficial and productive to the discipline.

In comparison to the marketers and economic field, the socio-psychology field, attitude forms the bases of understanding the way in which people relate, understand the world and the things that influence their reaction towards the environment and surroundings. The Consumer Science field does not diverse from the above discussed perspectives. However, with regard to the Consumer Science field, the attitude perspective is based on the field's mission statement. One of the core most major objectives carried by the mission statement is the improvement of quality of life. Quality of life commonly referred to as well-being consists of psychological, social and the personal factors that may influence the way in which a human being is comfortable within his/her environment. Furthermore, it can be argued that attitudes have a major role to play in this particular field as it deals with various issues such as usage, management, conservation of resources. Therefore, it can concluded that attitudes assist in: evaluation of plans, re-structuring strategies used in transferring skills and information, revision of infrastructures, policies and programmes intended to improve the quality or well-being of communities or consumers.

These factors make up some of the behavioural components such as perception, motivation, attitude and other factors of a consumer. It is therefore, through an understanding of the quality of life, created through these behaviours that the consumers' needs can be identified and addressed. Table 2.7 displays the various perspectives of different fields/disciplines and the main role they play in that particular field.

Table 2.7 The various fields' perspectives on attitudes

Concept	Field of study	Perspective	Main purpose/s
Attitude	Marketing and economics	To provide the service providers with the insight of what is expected by the target market	Helps in delivering services that will be productive and beneficial to the market and economy
Attitude	Social psychology	Attitude form the bases in which people socialise and interact with the environment	To understand the effects that are inflicted by the surrounding influencing factors to the way in which things are done
Attitude	Consumer science	They influence the way in which the consumer lives and conducts his/her life	Understand the consumer's needs and to improve their quality of life

For the current study, it is proposed that the Consumer Science field establishes its perspective of looking at consumer's attitudes especially when dealing with a service such as water service development.

2.8.2 The perspective of looking on attitudes

In part of developing the Consumer Sciences' perspective on attitudes in relation to water service provision, the concept of attitudes will be explored through the three-component-model provided by Hewstone, Stroebe and Stephenson, as discussed in Schiffman and Kanuk (2004). The theory behind this model carries assumptions stating that attitudes are composed of three attitude components. The components include three processes namely; cognitive, affective and behavioural processes.

The arising question might be why all the three components and not focus only on one of them. Arnould *et al.* (2004) responds to this question by stating that it is crucial to think of the three components when assessing attitude issues. Especially, when dealing with the most important object or subject e.g. water that is close to consumer's hearts as it is linked to beliefs or thoughts, experiences and feelings that may oppose each other. Furthermore, Kempen (2002) maintains this statement by stating that attitude can emerge from any of the three components. Therefore, when addressing a concept of water service provision and considering the consumer's perceptions it is proposed that it would be logic that all the attitude components be represented. To further justify the idea, an example is extracted from the findings; consumers evaluated water quality based on its physical appearance. The ideas, experiences and feelings shared about the water influenced the way in which the water service was perceived. Figure 2.7 presents the three-component-model.

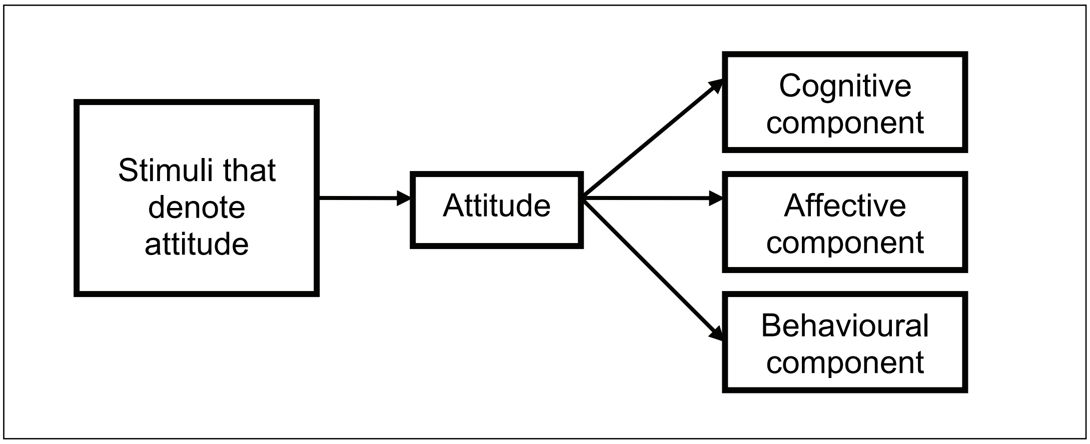

Figure 2.7 The three-component-model

The model in Figure 2.7, illustrates that the stimuli projected to an object triggers a certain effect towards an object. The stimuli can be presented in various ways such targeting all or one of the sensations such as visual, smell, taste, hearing and touch sensory receptors. The resulting consistent level of favourable or unfavourable response is then called attitude. Kempen (2002) views attitude as a term that represents the psychological process that occurs in ones mind that is expressed through the attitude object perception.

The attitude undergoes the process of interpretation which could be displayed through one or all of the attitude components depending on the situational context of the subject or object at hand. According to the three-component-model, each of the three components are treated separately although they can interrelate depending on the situation at hand. This is based on the way in which each component is formed or related. To further, elaborate on that the cognitive component is based from beliefs about the object, various learning processes such as direct and indirect experiences. The affective component refers to the emotional experiences that are associated with the attitude object. Lastly, the behavioural component is composed from past behaviours and direct experiences that direct the intention and action tendencies. It is clear that each of the attitude components have a role to play in attitude formation. Thus, it is argued that each component must not be omitted in the study of water service provision.

For example, the consumers perception of water quality towards the visual factor; the belief that good safe drinking water should have a clear colour and if not then the water is not of good quality. This example displays a situation in which the idea (cognitive) of good safe drinking water influences the feeling (affective) of the consumer about using the water. Consequently, dissatisfaction or rejection of the water will suffice (behavioural) resulting to some kind of coping mechanisms which can be harmful to the health of consumers.

Thus, it is proposed that all the three components from Figure 2.7 when addressing the water service provision be retained. Oppenheim (1992) and Chan and Cui (2004) support this notion by referring to the Fishbein and Ajzen's attitude model, as it illustrates people's attitudes as being formed and based on the cognitive component which includes beliefs, and through the experiences develop feelings that might result into a certain behaviour.

2.9 LEARNING AND KNOWLEDGE

Because not all learning theorists agree on how learning takes place it is difficult to come up with a generally accepted definition. Consumer learning is defined as the process by which individuals acquire the purchase and consumption knowledge and experience that they apply to future related behaviour. Consumer learning is a process by which the consumer obtains knowledge on how to function in the marketing environment. This process is called consumer socialization. Consumer socialization is the process by which children acquire the skills, knowledge, attitudes and experiences that are necessary to function as consumers. It will include consumers of household goods or water. The way in which a child or adult learn how to use water can therefore be referred to as **water socialization.**

It became very clear that there is a need to develop an education and training programme for water consumers in order to facilitate people to develop as efficient and informed water consumers. This would then be synonym to being a responsible citizen taking part in his/her own water development.

A water education and training programme, WET-programme was then developed. The training material consisting of a Water-booklet; lesson plans, training materials, evaluation material and certificates were developed and printed.

2.9.1 Outcome-based education, outcomes and assessment

Outcome-based education focus on the results of each learning process (called outcomes) and learners need to demonstrate that they have attained the outcomes. Secondly, the focus is on the instructive and learning process that guides the learners to these end results. Outcomes-based learning departs from a specific outcome which again impacts on how learning programmes are developed, taught and how learning and assessment will take place. Knowledge and skills become supportive in order to achieve the outcome.

Outcomes are skills, knowledge, attitudes and values that a learner can demonstrate after attending a learning programme.

Assessment is a way of finding out what someone knows, what they understand and what they can do. According to Van der Horst and McDonald (2001), assessment is a strategy for measuring knowledge, behaviour, values or attitudes. It is a data gathering strategy. The following is a schematic representation of outcomes based education and illustrates what needs to measured in order to measure integrated learning.

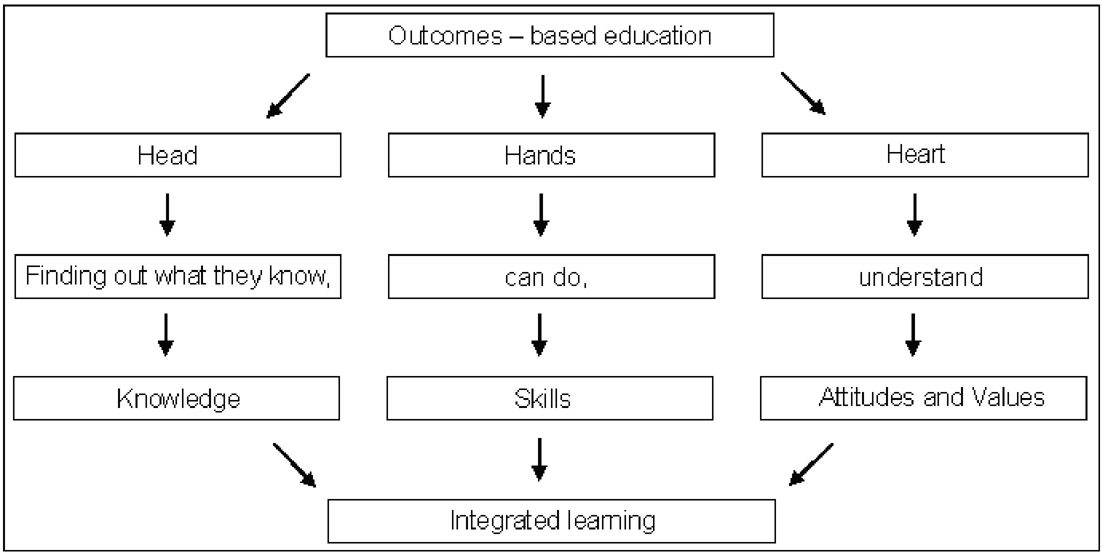

Figure 2.8 Outcomes-based education

Different authors that are experts in the field of developing education and training programmes state that education influence specific behaviours, these behaviours are a function of three sets of factors that will:

- Predispose knowledge, attitudes and beliefs.
- Enable increase in skills or access to service.
- Reinforce support, encouragement and reward.

According to the above it can be assumed that in order to decide whether the learners have achieved the desired outcomes of an educational programme the following attributes must change from before to after the assessment: knowledge, skills, attitudes and values.

Assessment after an education intervention involves finding out how much an individual or group has learned. According to Donley and Napper (1995) and Dreyer *et al*. (2001) learning is a change in skills, attitude and knowledge and assessment is about the worth of an individuals' learning – so a change in the above will indicate that learning has taken place. Van der Horst and Mc Donald (2001) refer to the desired learning outcomes to be achieved in terms of:

- knowledge to be discovered;
- attitudes to be formed and changed; and
- skills to be mastered.

Knowledge and attitude can be measured with a standardised knowledge and attitude scale; skills changes can be observed. A change in values is very difficult to measure and did not receive specific attention in this programme. Attitudes and values are however closely related and a change in attitude most likely would also involve a change of values. Schematically the previous discussion is illustrated in Figure 2.8.

2.9.2 Programme evaluation

Any educational and training programme consists of general aspects and learning outcomes. The general aspects include the following components:

- the training materials
- the trainers
- the participants
- the venue etcetera.

When an educational and training programme must be evaluated the general aspects as well as the educational and training aspects must receive attention. The general aspects are evaluated throughout the programme by means of interviews, questionnaires and focus groups. To establish whether the learning outcomes were reached the outcomes are assessed. Outcomes based education must be assessed by measuring:

- attitudes
- knowledge
- skills
- values

General aspects and learning outcomes must be evaluated to determine whether an education and training programme obtained its objectives.

In the assessment of outcomes based learning, assessment is a continuous activity where assessment is based on assessment of knowledge, skills and attitudes and adherence to specific processes as well as the achievement of outcomes. In this way, assessment becomes part of the learning process as well as a method of gauging success.

2.9.3 Observations

Observation and oral questioning are equally applicable as assessment tools and many important competencies can best be assessed in this way. Observation will happen when there is a strong skill component within a learning programme. To design the element of measurement for the skill or skills, it requires that the skill must be observed and demonstrated. According to De Vos, (1998) the best way a skill can be observed is to role-play it. This method therefore must play a strong part in the evaluation of a skills component.

Skills can also be evaluated by means of video tape recordings, which can be viewed afterwards, as many times as the researcher needs to observe the respondents efforts.

2.9.4 Outcomes based education vs. behaviour change

Levine *et al.* (1987) developed a model to plan, implement, assess and evaluate an outcomes based education programme. Education influences specific behaviours, these behaviours are a function of three sets of factors that will:

- predispose knowledge, attitudes and beliefs;
- enable increase in skills or access to service; and
- reinforce support, encouragement and rewards.

Figure 2.9 depicts the relationship between an educational intervention programme and behavioural changes.

Education and training programme (intervention)
↓leads to
changes in attitude and knowledge
↓and can predict
possible behaviour changes

Figure 2.9 Relationships between an educational intervention programme and behavioural changes

Spiegel and Leeds (1992) and Achterberg (1992) conclude that a positive change in knowledge, attitude and skills of the learners of an intervention programme can predict possible behaviour changes and can give an idea of the impact of a programme.

2.9.5 Success of an outcomes based educational intervention programme

It is very difficult to determine the success or failure of an educational intervention programme. The only indication of success is if behaviour changes in a sustainable manner. It was already mentioned in 1997 by experts that the aim of an educational intervention (whether it is housing, education, and consumer of health education) is to change the behaviour of the learners. The following model was used to evaluate the Water Education and Training Programme.

2.9.6 Final evaluation model of the Water Education and Training Programme (WET)

Figure 2.10 depict the evaluation model of the education and training programme as part of the intervention research by means of outcomes-based education

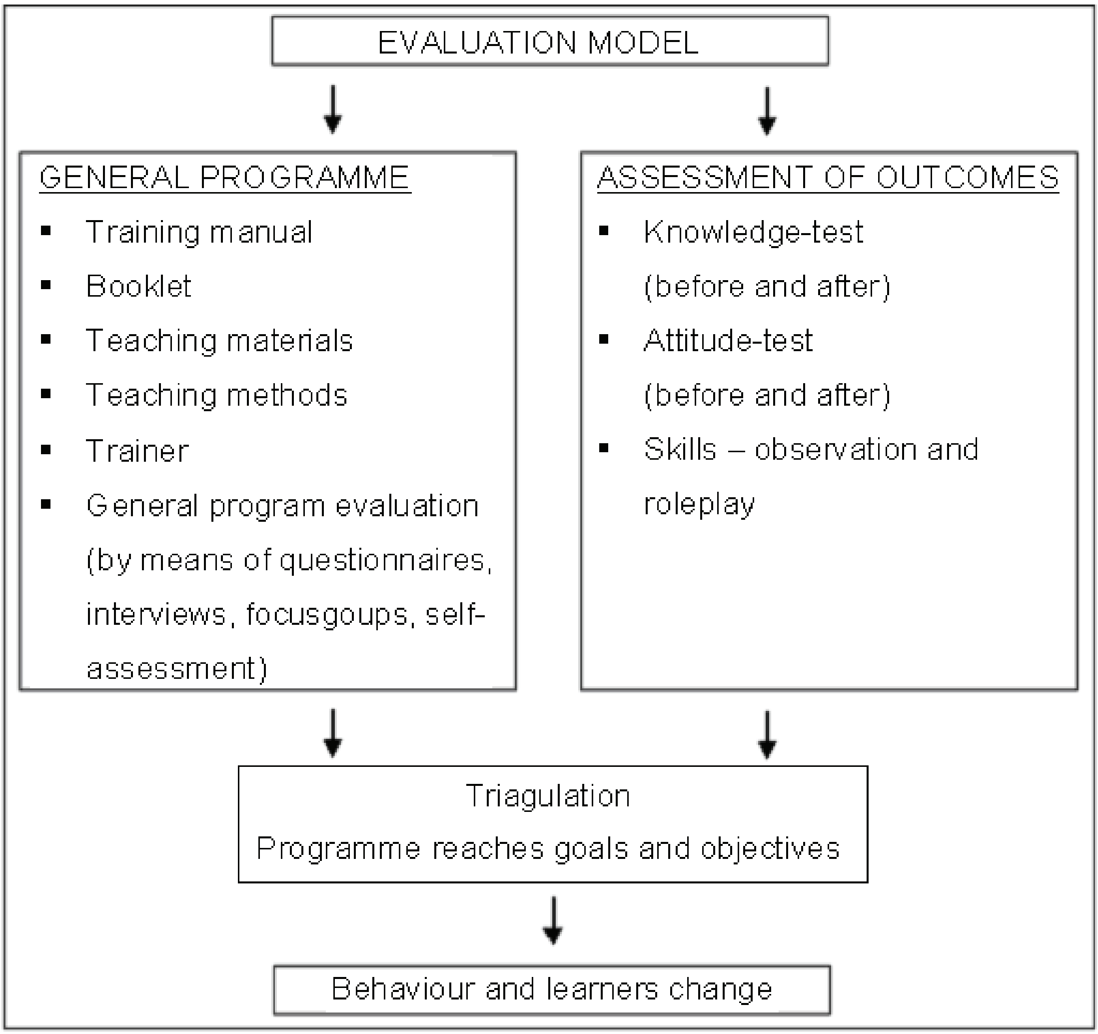

Figure 2.10 Evaluation model of the WET-programme

The general aspects will be evaluated by means of a general programme questionnaire (Annexure B-G).

Knowledge increase and attitude changes can be measured with standardised knowledge and attitude tests and changes in skills can be observed. It was decided that the most valid and reliable way to evaluate the WET-programme outcomes was to develop a standardised knowledge as well as a standardised attitude questionnaire while the mastering of skills would be observed.

Any educational intervention and measuring instruments should be based on the sound needs of the target population. For effective education and training programmes the community's needs must be assessed, an attitude and knowledge scale must be developed, base line measurement of knowledge and attitudes must be done. After the intervention, the same attitude and knowledge scales must be completed by participants and then the change in knowledge and attitudes can be calculated.

The motivation for the choice of the research methodology and procedures for the education programme was discussed in the previous section. The development of the attitude questionnaire will be discussed in Chapter 6.

2.10 CONCLUSION

This chapter presented an overview of the literature on which the following study is based. Consumers' perceptions, attitude, knowledge, sensory experience with unpurified and purified water from the Madibogo village were investigated and discussed. An education and training programme about Water (WET-programme) was developed, implemented and evaluated according to the most relevant theory and research. All the above was done to increase the information about different social aspects regarding water provision in a rural area.

CHAPTER 3 PERCEPTIONS OF CONSUMERS REGARDING MADIBOGO WATER PROVISION

3.1 INTRODUCTION

The first objective, namely the establishment of water consumers' perceptions about the use and provision of water in the village of Madibogo, will be addressed in this chapter. The objectives, methodology of research and results of the focus group discussions will be investigated and explained.

3.2 AIM AND OBJECTIVES

One of the aims of the social dimension of the project was to determine consumers' understanding of water in general, water usage in rural areas and water service provision by setting the following objectives:

Exploring the perceptions and knowledge of consumers (residents of Madibogo village in the North West Province) regarding current and general rural water supplies, general rural water household utilisation and the free basic water policy through:

- the establishment and utilisation of community focus groups as data gathering instrument;
- the exploration of consumers' perceptions of the water quantity of a rural water service;
- the exploration of consumers' perceptions of the Free Basic Water Policy;
- the exploration of consumers' perceptions of their daily household water utilization and;
- the investigation and introduction to an understanding of community leaders and stakeholders opinions and contributions towards the provision and maintenance of the Free Basic Water Policy and general rural water supply.

3.3 CONCEPTUAL FRAMEWORK

The following conceptual framework, presented in Figure 3.1, is an illustration of the relationship between the concepts identified in this section. It illustrates that rural water services are studied through two concepts, namely perceptions of water services and household utilization of such services. It is argued through evidence from literature that the perception of rural water services can be explored by means of water quality, water quantity and the FBWP.

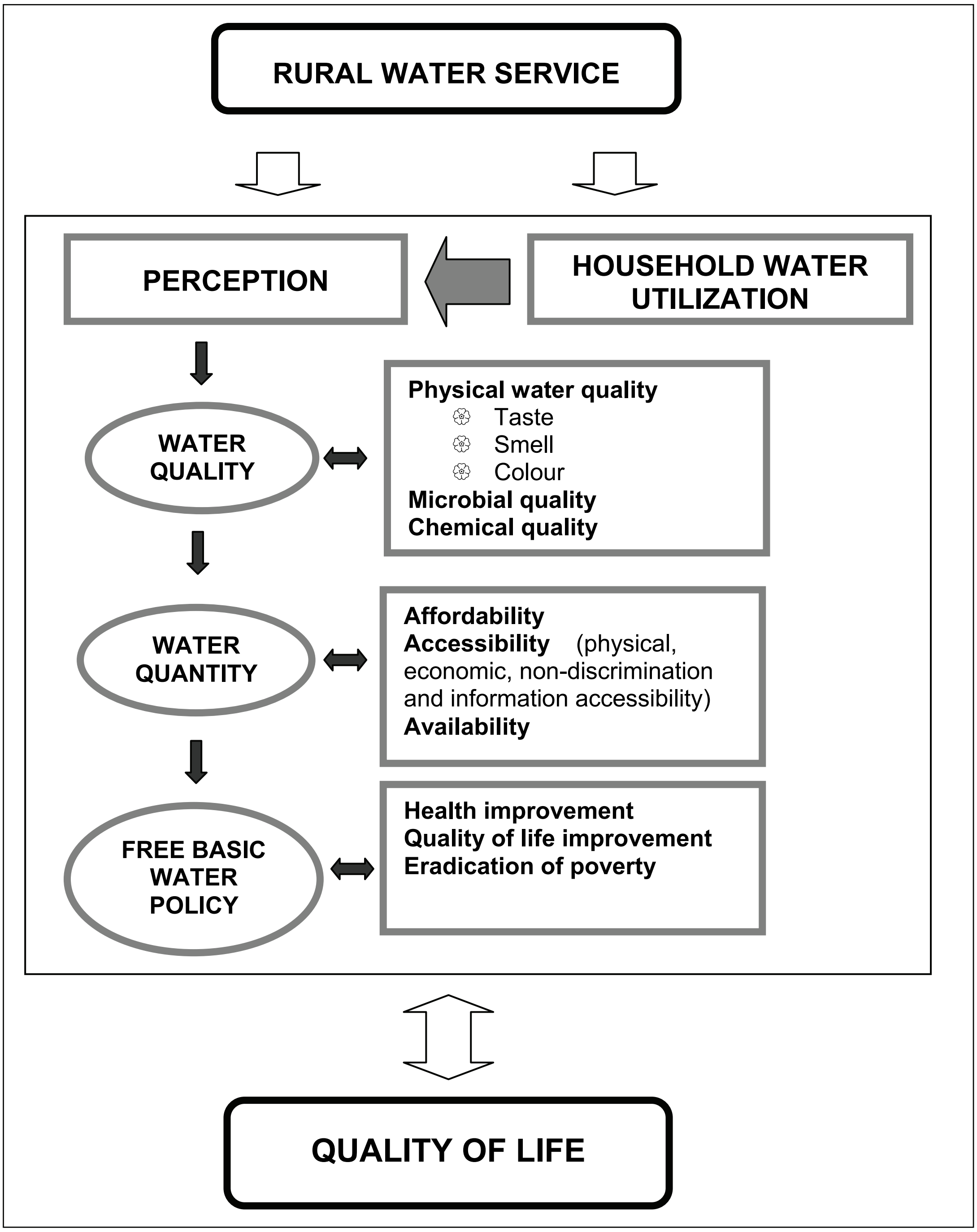

Figure 3.1 A conceptual framework representing the perception and household utilization of rural water services

3.3.1 The perception of water quality

According to the Water Research Commission (1999) water quality is viewed as defining the microbiological, physical and chemical properties of water that determine its fitness for use. The physical property is determined by the aesthetic quality factor that means the taste, smell and the visual appearance (Figure 3.1).

For the purposes of this study, water quality addresses the physical aspects of water although water quality is defined to have microbial and chemical properties as well. It is also known that and imbalance between these three aspects will have an effect on the physical quality of water (WRC, 1999). The physical quality of water can be visibly noticed. The idea exists that when water physically looks clean, although the taste and smell are unpleasant, it's perceived to be ideal. However, this physical component of water quality seems to have a very important role in the utilization of a water source as consumers' judgment is based on the appearance as well as the taste of water. Therefore they will not use the water for food preparation and drinking purposes although it may be safe to do so (WRC, 2000).

Concern is also expressed in the water guide published by the WRC (1999) which states that water of a bad quality occasionally contains disease-causing organisms that result in ill-health. Such water is sometimes accepted by the communities as a drinkable and usable source. In that instance the physical quality of the water misleads the consumers into making a wrong decision that may affect their quality of life. In this study it is argued that it is especially the physical quality of water that needs to be determined when water studies are performed in communities.

3.3.2 Perception of water quantity

According to De Fontaine (2000) and Modise and Krieg (2004), the following variables identify water quantity: affordability, accessibility and availability (Figure 3.1). A short definition of each one, as applied to this study, will now be given.

3.3.2.1 Affordability

Under the concept of affordability it is suggested that every South African has the right to basic services which includes the provision of water services, sanitation, refuse removal and electricity. Netshiswinzhe (2002) clearly states that it is the responsibility of the state to subsidize municipalities in an attempt to make water affordable to everyone.

3.3.2.2 Accessibility

In this study accessibility refers to water services and water facilities, which should be easily reachable and attainable to everyone. This also refers to physical accessibility, economic accessibility, non-discrimination and information accessibility (Anon, 2002).

3.3.2.3 Availability

Availability follows the World Health Organization guidelines and the South African Water Quality guideline, in terms of which water and water sources should be sufficient and reliable for household chores and activities such as food preparation, drinking, laundering and personal hygiene (Anon, 2002).

3.3.3 Perception of Free Basic Water Policy

The vehicle through which water quantity is addressed is the FBWP (Kasrils, 2002). The main aim of this policy is to eradicate poverty and, to improve the health and quality of life of South Africans (Netshiswinzhe, 2002). The government is subsidising 6 kℓ of free water per month to every poor household, which amounts to about 25-40 ℓ per person per day (Smits, 2004).

Furthermore, the illustration suggests that the perception of these three components is influenced by the utilization of the water service. Although household water utilization in Figure 3.1 refers to food preparation and drinking water it also plays a role in personal sustenance and also has a role to play in personal hygiene where it is used for bathing, laundering and other household uses. However, the study argues that the FBWP is attempting to address the utilization needs of the community, consequently influencing the perceptions of water quality, water quantity and FBW in general. Figure 3.1 presents a conceptual framework representing the perceptions and household utilization of rural water services.

3.4 METHODOLOGY

3.4.1 Introduction

The methodology employed in this study is based on a qualitative research strategy. This strategy argues from an inductive approach to research and more in line with an anti-positivism paradigm (Hayes, 2000). The reason for using an inductive approach is to summarise the raw data, to clear relevant links between study's objectives and findings, as well as developing a model that will illustrate the experiences and processes indicated in the raw data (Thomas, 2003).

Furthermore, Hayes (2000) and Trochim (2002) identified the link between anti-positivism and a phenomological approach within which this study has been framed. Phenomology aims to understand people's views and experiences, though this can be better achieved through an anti-positivist approach such as the qualitative strategy used in this study. According to Flick (1995), a qualitative strategy is therefore, the best way of exploring such experiences and therefore the experiences consumers have of a rural water service.

3.4.1.1 Contact with the community

The context of Madibogo village was determined by the researcher through numerous visits to the village before commencement of the study. The reasons for the visits were to provide the researcher* with a better

* The researcher was U. Kolanisi who undertook this project for a M. Consumer Science degree at the North-West University, Potchefstroom.

understanding of the area and to build a relationship with the community in order to gain their participation and support for the research (Gillbert, 1998).

3.4 1.2 Exploratory visits to Madibogo village

It was necessary for the researcher to familiarize herself with the community structures and to identify the key community leaders and organizations who could act as gatekeepers. Gatekeepers are people who can assist the researcher in gaining entry to the community (Oka & Shaw, 2000). Through an introduction meeting with the Chief 'Kgosi' of the community, the researcher obtained permission to hold meetings with community members and to introduce the research. During these meetings, the researcher identified other structures through which the community operates: local municipality, political and church youth groups, various churches, soccer teams, educators, all of which were used to organize the focus group members and venues. The researcher kept a sound relationship with the gatekeepers to arrange meeting venues, times and dates and other organizational information.

According to various authors such as Gillbert (1998), Flick (1999) and Mathabatha and Naidoo (2004), preliminary fieldwork is an essential part of the qualitative research process, especially if unfamiliar circumstances are entered upon by the researcher.

3.4.2 Research methods

This study mainly used verbal methods to achieve an understanding of community members in relation to a communal water service. These methods included focus groups and individual interviews guided through semi-structured interviews (Flick, 1999). These methods or instruments were identified to be crucial to determine viewpoints of participants as these opinions were more likely to be expressed through this method than through standardized interviews or questionnaires (Flick, 1999). A brief discussion of each method follows.

3.4.3 Focus groups

Focus groups were selected as a research instrument because the group context within which in focus group sessions would be contextualized would create an environment within which the participants could reveal their experiences and ideas. These authors also identified additional factors that emphasized the necessity of the focus group method to be used in this study. For example, it would create a non-threatening environment, open for debate and producing believable results. It would also allow the researcher the opportunity to explore unanticipated issues brought forth in the discussion (Krueger, 1994; Shao, 2002). In the context of this study the focus group was especially relevant as it did not discriminate between the literate and the illiterate as both groups could participate and share their views verbally.

Seven focus groups, consisting of seven to fourteen members each, were used. These groups were composed of teachers, members of political youth organizations, church youth groups, a soccer team as well as a mixed community group: both male and female and mixed age groups.

Each discussion was guided by a questioning format of the main concepts of the study, i.e. water quality, water quantity and the FBWP. The first two concepts were discussed by the focus groups by means of a projective technique. The reason for using this technique was the encouragement of participants to express and expose their thoughts. Shao (2002) is of the opinion that this technique overcomes communication barriers and grants participants' freedom of expression. In this instance the participants were presented with three glasses filled with water containing different water qualities:

- Glass A contained water from the village taps;
- Glass B water from Madibogo communal taps; and
- Glass C water from Madibogo communal taps with sand added to it.

Participants were not told what was in the glasses and they only looked at the contents. They then discussed aspects such as quality of water, especially the issue that water that looks clear and clean are not always safe. After they had shared all their ideas regarding water quality and water quantity, a discussion on the FBWP was initiated.

A tape recording of each focus group's discussions was made to capture all the comments of the members. Notes were also made by the research assistant. This was an important reference method with which to complement the tape recording. This procedure follows Krueger's (1994) guidelines for the presentation of focus groups.

3.4.4 Interviews

Semi-structured interviews, commonly referred to as 'guided interviews', were used as a data collecting technique. Such interviews offer an opportunity to the participants to answer freely and to the researcher to have freedom in the way in which he/she asks questions (Hayes, 2000). These interviews were held with the community leaders such as the chief and the ward councillor after the completion of the focus groups. During the interviews attention was paid to issues brought forward and in need of clarification. Table 3.1 provides a schedule used during the semi-structured interviewing.

Table 3.1 The research aspects and questions posed to the community leaders

Key research aspect	Questions posed to the leaders
Water quality	How do you experience your drinking water? Is there such a thing as safe drinking water? Is there a perception that the Madibogo drinking water is clean?
Water quantity	Where do you get your drinking water? Are the water sources reliable, convenient and affordable? There is a belief that 'pensioners' are still paying R2.00 to the collectors for the maintenance of water services, your comment on that?
Free basic water	Are the people aware of the Free Basic Water Policy and what are your views about it? Do you have any suggestions as to what could be improved about rural water services?

The questions posed to the community leaders investigated the same research aspects presented to the focus groups, except for the opening question which was a projective technique and therefore not presented to the community leaders.

3.4.5 Sampling

A sample was drawn by means of a convenient or available sampling method. That refers to a sample which has been collected in the most convenient way, making use of volunteers and participants who were available and willing to participate at that point in time (Maisel & Persell, 1996; Coolican, 1999).

3.4.6 Data analysis method

Data analysis was conducted by means of content analysis, a method that refers to a textual investigation of the verbal data by means of inferences of data by identifying categories and themes that best represent the data (Shouhenessy & Zechmeister, 1997; Silverman, 2000).

In order to do content analysis the tape recordings of the focus groups as well as the semi-structured interviews were transcribed. According to Hayes (2000) such transcripts are a method with which to record the conversations for analytical purposes. Each transcript was read several times by the researcher after which concepts relating to each of the objectives were identified. These concepts were clustered to form the themes of the findings. The themes and concepts are discussed in the results section of this study. Besides the transcripts made from the verbal data, the notes of the researcher's assistant was also analysed. Oka and Shaw (2000) state that collected/recorded verbal data can be subjected to a form of analysis whereby the ideas brought forward by the focus groups can be further investigated subject to certain methods which will now be discussed.

3.4.7 Triangulation

This study aimed at achieving triangulation within the measuring instruments used in the study. Various authors, such as Bryman (1996), Denzin and Lincoln (1998) and Silverman (2000) consider this method as helpful to the researcher, to gain, through different measuring instruments, a true reflection of the situation under study. In this case the researcher used focus groups, semi-structured interviews and the projective technique with the three filled water glasses to achieve a consistent reflection of the situation perceived by the inhabitants of Madibogo. By using the above mentioned methods of data collection methodological triangulation was obtained.

3.4.8 Trustworthiness of the methods and analyses

One of the questions that could arise when implementing the qualitative strategy could be whether the methods of data collection applied in this study ensure a true reflection of the experiences of the participants. To ensure that the findings would indeed be truthful and reliable, the researcher made use of different measuring instruments. The researcher also followed a strict sequence of steps with which the focus groups were led and the semi-structured interviews conducted. Furthermore, the notes made by the researcher's assistant were also presented to the focus groups at the end of the session so that they could confirm that their opinions were correctly noted.

Before the actual study was undertaken, the researcher conducted several pilot focus group sessions to identify problems in question formulation, understanding of questions, thereby testing and adapting the measuring instrument and ensuring its suitability. According to Van Teijlingen and Hundely (2001) and Strydom (2003), such testing is a very important for the development of the research instruments and vital for the success of the research.

The researcher employed various techniques to ensure a truthful and consistent presentation of the experiencing of a rural water service by community members. The findings will be presented in the next section.

3.5 RESULTS

3.5.1 Introduction

With the application of the research methodology discussed in the previous chapter the main purpose of the study was to explore the perception of the consumers towards a rural water service in Madibogo village. The findings are discussed in relation to the perception of participants (community members) towards the rural water services which was measured through a visual evaluation as well as through the thoughts and opinions captured in the perception of the consumers. As mentioned in the previous chapter the community leaders' responses were incorporated with the participants' responses. The findings from the visual evaluation of water will be discussed in the section to follow.

3.5.2 Visual evaluation of water

This method was used to start the participants' discussion on water quality and water quantity. It can be seen as an ice-breaker (Krueger, 1994). Participants evaluated the three glasses of water presented to them by the researcher. During the evaluation the participants had to indicate their preference and give reasons for their choice. The findings revealed that the participants' perceptions varied although the majority of the participants chose glass A.

Table 3.2 gives an illustration of the concept that represents the fundamental factors with regard to each glass as perceived by the participants. For example glass A was perceived to be crystal clear, beautiful, healthy and purified. Glass B was perceived to be clean, unclear, fine and not good for human consumption. Glass C was considered to be dam water, contaminated dirty water, muddy and water from the valley.

Table 3.2 The participants' visual perceptions of the water in the glasses

Water in glasses	**Stimuli interpretation**
Glass A	Pure, purified, clean, best, beautiful crystal clear, soluble, healthy and distilled
Glass B	Clean, unclear, fine, not good for human consumption
Glass C	Dam water, contaminated, dirty water, muddy, water from the valley

The clear distinctions made by the participants through the perception of these three water filled glasses were an indication that they had identified differences in water quality.

3.5.3 Water quality

To further explore the water quality through the perceptions of the participants' situation in relation to the drinking water of Madibogo, three different themes were identified. These themes included the experience of drinking water, opinions on safe drinking water as well as water treatment and purification. Each theme will be discussed individually.

3.5.3.1 Theme 1: Experience of drinking water

As shown in (Table 3.3 below) the participants expressed their experiences towards the drinking water from the Madibogo community. From these responses it was evident that their experiences were based on both aesthetic and sensory evaluations. These evaluations were formed through experiences of vision, smell and taste. Gabbott and Hogg (1998) are of the opinion that individuals respond to their environment at every basic level by processing sensation received through the five senses, which in this case were the vision, taste and smell. These three categories were also found in the perceived experience of the water from Madibogo. In this instance, the colour of their drinking water was perceived to be of a milky colour, the smell was that of Jik or bleach and the taste was experienced as being salty, bitter and not pleasant. The community leaders also shared the same experience as the participants about the water, as they also experienced the salty taste and a milky colour.

Table 3.3 Experience of drinking water

Aesthetic and sensory evaluation factors	Experience
Vision	It has a milky colour
Smell	Smells like Jik or bleach
Taste	It is salty, bitter and not pleasant

The experience of the quality of water is further illustrated through a very descriptive quote used to express this experience found under the concept of taste.

Concept 1: Taste
In Table 3.4 below quote 1, the personal experience is depicted as that of water which tastes like freshen (laxative).

Table 3.4 Personal experience of drinking water through sensory receptors

Concept	Participants' statements
Taste	"The water tastes like freshen (laxative)"

To further explore the water quality factor, participants were asked whether they believed that there was such a thing as safe drinking water and what it meant to them as it was constantly brought forward during the evaluation of the three glasses of water. The theme below reflects the participants' opinions about the existence of safe drinking water.

3.5.3.2 Theme 2: Opinions on safe drinking water

Through this theme it was found that participants had different views about the existence of safe drinking water. The different views posed by participants made it possible for the researcher to categorize the opinions into two main categories, i.e. those who believed that there was such a thing as safe drinking water and those who held an opposite point of view.

Category 1:
Participants that held a belief that safe drinking water in general existed. Participants who held a belief that safe drinking water in general existed further elaborated on what forms of water were considered safe (See Table 3.5).

Findings point to the fact that rain water was considered to be the best form of safe drinking water as it has a pleasing taste and it satisfies their household needs (Refer to Table 3.5 below). Vlok (2003) supports the idea of these participants by the fact that falling rain-water is free of pathogenic microbes, it has no mineral salts and it is soft. Secondly the participants identified bottled water as another form of drinking water; their claim was that it was it was approved by the SABS. Most people choose bottled water because it is perceived to be safer and of better quality. The third form of drinking water was considered to be purified water when, according to the participant, it has been tested and the pipes of the service have been checked (See Table 3.5 below).

Table 3.5 Reasons for believing that there is safe drinking water

Concept	Participants' statements
Believers	"It is the water that has been cleaned and purified just like the water from the location" "It is water that you know what it consists, water that you do not have to worry when you are going to use it and it is approved by the SABS" "Purified water the pipes are checked and water is tested" "With rain water you can do anything and it also taste wonderful"

Category 2: Participants who had a belief that safe drinking water does not exist

In contrast to the believers' idea that safe drinking water existed in general, there were participants who were of the opinion that safe drinking water does not exist. According to this group the belief was that water could be contaminated at any time (See Table 3.6 below). The notion raised by the participants supports the statement made by Van Leeuwen (2000) that in the natural environment there is no pure water, including rainwater, as it contains some impurities.

The other contributing factors that influenced the participants' disbelief that safe drinking water existed were:

- They do not have trust in the people who are responsible for purifying water in general as they are scared that they could make a mistake and add more chemicals than required (Refer to Table 3.6 below). This statement supports the notion of Van Leeuwen (2000) when he mentioned that disinfectants and disinfectant by-products are known contaminants resulting from processes used by the industry responsible for the treatment or purification of water. Hence, this suggests that a toxicologist should provide risk assessments for chemical pollutants and derive guidelines for drinking water quality standards. The guidelines should ensure that drinking water is safe and can be consumed without any risk.
- The participants believed that boiled water or the addition of bleach makes water partially safe (Refer to Table 3.6 below). This is supported by the observation made by Solsona (1996) when he/she considers boiling and aeration as water treatment methods used on limited applications (small volumes) sometimes with unreliable results due to the relevant factors such as inaccurate dosing of disinfectant or lack of resources such as appropriate equipment for treating the water.

Table 3.6 Reasons for not believing that there is safe drinking water

Concept	Participants' statement
Non-believers	"Germs are all over therefore water can be purified but still have germs" "You will never know what if those people who pour chemicals in water pour more than it is required" "If water is boiled bleach or Jik is added then the water will be safe but not 100%"

Although the discussion was about the existence of safe drinking water in general, the participants found it relevant to discuss and categorize their drinking water service. Some of the participants believed that their drinking water service was safe in relation to their existence. The participants questioned whether the fact that the residents lived up to a certain age directly pointed to the fact that Madibogo village water was safe (See Table 3.7 below). According to the community leaders, Madibogo water was safe. To further elaborate on that statement one of the leaders related his existence to the safety of the Madibogo water (Refer to Table 3.7 below), in that he had been drinking it since childhood.

Table 3.7 Reason for believing that Madibogo water is safe drinking water

Concepts	Participants' statements
Part of existence	"Do you want to tell me that for the past twenty years you have been staying here drinking this water do you mean to tell me that this water is not safe?" "I cannot answer that because since childhood I have been using the water and I am still here"

3.5.3.3 Theme 3: water treatments and purification

According to the responses of the participants, a variety of methods were utilized in treating water. This theme was conceptualized through methods used for water quality improvement and cleaning process of the local water service.

Concept 1: Methods used for quality improvement

These methods included 'boiling water before use', 'adding Jik or Bleach' to the water or 'adding cement', which was claimed to improve the colour of the water (Refer to Table 3.8 below).

Table 3.8 Water treatments used by consumers

Concept	Participants' statements
Methods used for water quality improvement	"We add bleach or boil the water" "We add cement to our water to improve its colour"

Furthermore the participants were uncertain on whether Madibogo water was cleaned. According to the participants **'cleaned'** meant the addition of chemicals to clean the water (See Table 3.9 below) while purification meant water from the urban areas.

Concept 2: Consumers' concerns about the cleaning process
The participants were concerned about not knowing who was cleaning the water, which rendered the skills of those who were responsible for purifying the water questionable (Refer to Table 3.9 below). According to the way in which the water was treated and purified the participants moved on to give reasons for the desire for purified water. These reasons included the desire to have water purified as there was uncertainty about the cleaning process as they thought that water was being cleaned but still retained the milky colour (Refer to Table 3.9).

Concept 3: Consumers' desires for purified water
The participants wished that the water received, be exactly as that of the township (Refer to Table 3.9 below). The community leaders were also of the opinion that the water was cleaned even though no one wanted to commit him/herself to further explain the matter. However, one of the community leaders based his belief for the cleaning of water on his past experience, as that when he used to live in Johannesburg, the water had a milky colour. It was believed that milky water was an indication that the water had been treated recently (Refer to Table 3.9 below).

Table 3.9 The reasons for the desiring purified water

Concept	Participants' statement
Concerns	"The problem here at home is that they will say if there is no water for the day they just claim that they have been cleaning it" "We do know if the water is being cleaned and who cleans it. But the surprising thing is that we get the water with a milky colour: "I think our water needs to be purified"
Desire of purified water	"I wish the water could be like the one from the location because you do not have to worry with it" "I believe it is cleaned but I am not sure" "When I used to stay in Johannesburg we used to receive water with a milky colour when it just cleaned"

3.5.4 Water quantity

Water quantity was discussed by the participants through the idea of water sources. To this effect the participants were asked to identify different water sources in their community. They identified taps, reservoirs, streams, boreholes and rain water as particular to their community. Furthermore, water sources were explored through the aspects of reliability, convenience and affordability.

3.5.4.1 Theme 1: The reliability of the water sources

With regard to the reliability of water sources the participants referred to three main sources in relation to reliability of community taps, underground water and reservoirs. The communal taps were further debated in terms of availability of water provided by the communal taps. Concepts such as availability of water and vandalism, hygiene and safety were identified.

Concept 1: Availability of water and vandalism

According to the participants the availability of water was adversely affected by occurrences of vandalism in the community (Refer to Table 3.10 below). Even the community leaders shared the same view as the participants about the reliability of communal taps. They defined reliability through availability which was affected by factors such as vandalism; faulty pumps and leakages (Refer to Table 3.10 below). According to the participants the availability of water affected the community's needs and activities such as funerals.

Concept 2: Hygiene

The reliability of the water sources were further defined in relation to concepts referring to hygiene and safety. In this instance the participants commented that the water sources could not be trusted as they had to share the taps with animals. This would influence the hygiene of the water sources (Refer to Table 3.10 below and to picture 4 in chapter three).

Concept 3: Safety

Another aspect was revealed with regard to safety. In this instance participants mentioned the way in which a water source was constructed as being the cause of uncertainty about the safety of that source (Refer to Table 3.10 below).

Table 3.10 Factors affecting the availability of water from the taps

Concepts	Participants' statements
Availability and vandalism	"Sometimes the water is cut and we will be told that the water was being cleaned" "Sometimes water is not available during funerals" "People vandalize the taps, sometimes the water is unavailable because of faulty pumps and leakages" "People vandalize the taps by stealing the caps"
Hygiene	"We have to share the taps with the animals so that puts our health at risk"
Safety	"The reservoirs are not safe as they are open and anything can happen to them"

To further explore the water quantity the convenience factor was discussed.

3.5.4.2 Theme 2: The convenience of the water sources

Convenience was discussed in relation to water sources. Two concepts were identified, namely distance to the communal taps and economic implications which dominated the convenience of the water supply.

Concept 1: Distance to communal taps

In Madibogo the majority of participants claimed that the taps were far from the houses and as a result they, had to use wheel-barrows to carry water. Picture 5 in chapter three illustrates this practice. According to the RDP standard the distance of taps from the households is supposed to be 200m away (Mvula Trust, 2000). Hence the participants expressed their desire for this distance to be implemented. They also expressed the desire for individual taps, as they claimed that sometimes there are elderly people who are staying alone that cannot walk long distance, especially not while conveying water which is heavy to carry (Refer to Table 3.11 below).

Concept 2: Economic implications

According to Table 310 this has a major economic implication since the old citizens have to pay children to fetch water for them. The participants' idea about the distance of communal taps was also supported by the community leaders as they mentioned that the current distance from the dwelling place and communal taps measured ½ kilometres and sometimes ¾ kilometres. They furthermore explained that the local municipality's future plans are to implement the minimum RDP standard distance in their community. The implementation will take time as the current plan is to first provide water to villages that do not have water at all (Refer to Table 3.11 below).

Table 3.11 Economic implications of the distance to communal taps

Concepts	Participants statement
Distance and economic implications	“Sometimes there are old people who are staying alone therefore the taps are far from them, then they will have to pay children to fetch water for them" “Our people are suffering, the distance is a challenge as the taps are far from the households sometimes people have to walk long distances like 500m or even further ¾ kilometres” “We are planning to move them closer to the people but that will take time since now we are busy with other villages who do not have water at all”

The next section will deal with the affordability of water sources.

3.5.4.3 Theme 3: The affordability of the water sources

The main concept that dominated the affordability theme was the payment. It is clearly indicated through the findings that the participants were not paying because they are subsidized by the municipality (Refer to Table 3.12 below). However, a minority of participants claimed that there were people who were still paying for the water. They claimed that the pensioners were still paying two rand every pension day.

According to the spokesman of Mvula Trust (2000) and MacKay and Ashton (2004), the South African government has committed itself in ensuring that all South African citizens receive at least a basic level of municipal services such as water, sanitation, refuse removal and electricity, regardless of the ability to pay. Hence there are guidelines to help the municipalities to implement the policy that has been developed by the department of Water Affairs and Forestry. The national government subsidizes the municipalities so that the South African citizens can receive free water (Mvula Trust, 2000). The participants are aware of this (Refer to Table 3.12). They know that the municipality is subsidizing them hence; they do not have to pay for water. The community leaders were not aware that there were people who were still paying for their water supply especially pensioners as they claimed that people were receiving free water (Refer to Table 3.12).

Table 3.12 No cost for the consumers for the provision of water

Concept	Participants’ statements
Payment	" We are not paying, the water is free" "The municipality is paying for the maintenance" “People are receiving free water”

3.5.4.4 Theme 4: The responsibility to look after the water services

This question was conceptualized through the concept of ownership. In this instance two parties were identified by the participants as being responsible for the water service.

Concept 1: Community

The participants identified themselves as the community and as the consumers who receive the water service. This implied that they had to be the ones who would take care and be responsible for the water service. They also suggested that the community should have structures that would look after the water services (Refer to Table 3.13 below). Netshiswinhze (2002) and Mathabatha and Naidoo (2004) support this idea by arguing that community involvement encourages ownership, accountability and independency to help themselves.

Concept 2: Government

The participants made a clear point of suggesting that the government should be responsible for the improvement of water quality (Refer to Table 3.13). Netshiswinhze (2002) also found it important for the people to understand the role of the government and other external agencies as facilitators of development.

Table 3.13 Responsibility of each partner in development

Concepts	**Participants' statements**
Ownership	"Community and the community structures should look after their taps" "If the government can improve the quality of water we are drinking then we would be happy"

The section below will give a clear insight about whether the participants were aware of FBWP, or not, and what their perceptions were.

3.5.5 The National Free Basic Water Policy

The FBWP was interpreted by the participants in terms of four themes namely awareness, non-beneficiaries, recommendations and expectations. In the next section each theme will be discussed in detail highlighting the concepts related to each theme.

3.5.5.1 Theme 1: Awareness

The theme of awareness was identified through the concepts of knowledge, source of information and transfer of information.

Concept 1: Knowledge

The findings indicated that the majority of the participants' awareness about the FBWP was that water was given for free (Refer to Table 3.14 below).

However, the amount of water that was given for free was not really known to the participants (Refer to Table 3.14).

Table 3.14 The importance of information through the right channels

Concept	Participants statement
Knowledge	"We are not paying, water is free" "The government is giving free water" "I have heard about it but it is my first time to hear how much was actually given" "The water that we are given free by the government is 1000L per household"
Source of information	"I have heard about it from the radio, television and news papers" "When the councillors were canvassing for the elections they told us about free water" "I have seen it in my municipality invoices and on television"
Transmission of information	"Our leaders never called a formal meeting to inform us about this policy" "We told our people about the FBWP when we were canvassing"

Concept 2: Sources of information
The participants were informed about the FBWP through various sources which were (in no particular order): ward councillors, television, radios, newspapers and invoices from municipality statements for mainly those who are from the urban areas (Refer to Table 3.15).

Concept 3: Transfer of information
The only time they were informed of the FBWP from the councillors was when they were canvassing during the national elections (Refer to Table 3.13). The community leaders were aware of the FBWP and they stated that the community was also informed of FBWP as the information was transferred to them when they were canvassing for the national elections (Refer to Table 3.1) Pybus *et al*. (2001) are of the opinion that the situation and the context in which the information is transferred have an influence on the way in which the information will be interpreted.

3.5.5.2 Theme 2: Non-Beneficiaries

The theme of non-beneficiaries was conceptualized in terms of the distinction of site and the rural people's opinion about the FBWP.

Concept 1: Distinction of site
The participants thought that the FBWP mostly benefited people from the township, as they (people from rural areas) used communal taps which constantly supplied water and was not monitored in any way (Refer to Table 3.14).

Concept 2: Rural people's opinion about the FBWP

The participants felt that the people from the locations were rather benefiting from the FBWP as they were able to monitor their water consumption through the meters in their homes. It is based on this idea that the participants were inclined to think that the FBWP was a waste of government money and not benefiting them in any way (Refer to Table 3.15). The community leaders opposed the participants' view about the FBWP as they believed that FBWP was aimed at improving the well-being of the poor. According to the findings, the community leaders believe that FBWP is benefiting the poor communities, such as Madibogo community as there is a high rate of unemployment. To further expand on that view one of the community leaders viewed it as a government hand-out that should not be refused (Refer to Table 3.15). Pybus *et al*. (2001) state that community leaders, also known as opinion leaders, are people who pass information to the community through interpersonal skills communication. They have more access to information compared to the community members, thus they have a power over the community.

Table 3.15 Reasons for not believing that the FBWP is for the poor people including rural people

Concepts	Participants' statements
Distinction of location	"It does not make a difference in rural areas because we get our water from communal taps and they are far from our homes and people from the location they can see how much water they are saving"
People's opinions	"I think it is a waste of government's money as it is not benefiting the target group, which are the rural people who are the poor people" "The poor people like us are going to benefit because here people are not working" "it is government's handout, we have no choice, we have to accept it, it will help our people"

3.5.5.3 Theme 3: Recommendations

This theme was identified through the concept of water service improvement. Water quality and objects such as the water taps were included (Refer to Table 3.16 below). In support of the findings Netshiswinhze (2002) foresees that if yard tap connections are put in place, as suggested by the participants, the same consumers who are not paying for the water would consume more water. This would have a negative impact on their economic situation. In effect this situation would not alleviate the problem of providing water for all.

It is based in this discussion that the participants made suggestions that they thought would help change the focus of the FBWP to target the rural communities. In addition to what had been suggested by the participants the community leaders suggested that the water should be available at all times to limit inconveniences (Refer to Table 3.16).

Table 3.16 Participants' suggestions for the improvement of the FBWP

Concepts	**Participants' statements**
Improvement of water services	"If the government can improve the quality of water we are drinking then we would be happy" "I think the government can help the disadvantaged areas like Madibogo by supplying them with taps and pipes in their yards and make sure that the water is purified" "We should have individual taps" "Yard taps would be a better solution as now we are sharing our taps with animals" "At least if you have your tap you have a control over it, you take care of it and you are guaranteed to get safe water" "The government must help us with the water because sometimes when the water is cut and people do not have water for funerals they say the Chief 'Kgosi' has cut the water"

3.5.5.4 Theme 4: Expectations

The participants shared their views about the free basic water policy in light of their expectations. These expectations were conceptualized through the idea of misconception.

Concept 1: Misconception
In this instance the participants were under the impression that if water was free due to the fact that FBWP provided the source, there should be no charge on any source of water for example water from boreholes in the community, people who are selling water at water points and other points (Refer to Table 3.17 below).

Table 3.17 Expectation leading to consumers' misconception

Concepts	Participants' statements
Misconceptions	"We won't be buying water from the people who are selling water from their own boreholes"

The next section will reflect the consumers' perception towards household utilization.

3.5.6 The household water utilization

The participants listed their daily household uses of water in no particular order as being bathing, cooking, drinking, animal drinking, car washing, garden watering, washing of clothes and household chores. These water uses listed by the participants were also mentioned in the WRC guide (1999). Furthermore, household water utilization was explored through the following themes: water use and the problems of consumers with regard to the water usage.

3.5.6.1 Theme 1: The problems when using water for household activities

The theme of challenges of water usage was defined by the concepts of personal image, social image, concerns with laundering, food preparations and biological needs.

Concept 1: Personal image
The participants perceived the water they used for personal hygiene as unpleasing as they had to add powdered soap to make it soft and to get lather (Refer to Table 3.18 below). Furthermore, the participants stated that the water consumed was responsible for the patches, changes in complexion in their faces and it discoloured their hair (Refer to Table 3.17). This is the participant's opinion not necessarily justified, claiming that the patches in their faces and discolouration of hair were caused by the Madibogo water. Because of this perception the participants stated that the state of Madibogo water was killing their self-esteem and they could not live their lives freely (Refer to Table 3.18). Blackwell *et al*. (2001) are of the opinion that one of the social needs explains that personal social image depends at least in part on

the products that the person buys and consumes which in this case is the Madibogo water.

Concept 2: Social image
The participants reflected that they were not comfortable with giving water to visitors as they were concerned about the visitors' health. Furthermore, they were not comfortable offering the water (especially tea with powdered milk) to visitors, because of uncertainty over the effect it might have on their health (Refer to Table 3.18) and the tea's appearance (refer to Table 3.18).

Concept 3: Laundering
The participants were unhappy about the water quality performance when doing the laundry, as the water discoloured their clothes. They also claimed that their clothes lost quality as they became discoloured when washed with the water (Refer to Table 3.18). Van Duran (1997) mentioned that water should not pose any economical detrimental effects on either the distribution systems or on consumers' equipment or belongings.

Concept 4: Food preparations
This was dominated by the unpleasant taste experienced when preparing food (Refer to Table 3.18). As mentioned, there was a concern on the coagulation of powdered milk as a result of the water, when preparing tea. They had to wait for the tea to cool down, consequently not being able to serve a hot beverage (Refer to Table 3.18).

Concept 5: Biological needs
Biological needs were also of concern to the participants, as they were of the opinion that the Madibogo water did not quench thirst (Refer to Table 3.18), although Anon (2004) in chapter two listed one of the water functions as the best liquid to quench thirst. Even if the participants tried other means like putting the water in the refrigerator to make it cold, the taste and the appearance of water would not improve (Refer to Table 3.18). Solomon (2006) is of the opinion that people are born with a need for certain elements necessary to maintain life, such as food, water, air and shelter. Even the community leaders were of the opinion that the water was not good for food preparation as its unpleasant taste affected tea making and coagulated powdered milk when making tea (Refer to Table 3.18 and picture 2 in chapter three).

Table 3.18 Consumers' dissatisfaction with the performance and taste of drinking water

Concept	Participant's statements
Personal image	"When taking a bath, if we want to get lather and the water to soften we have to add powdered soap or else we will have a dry skin as if you have not bathed yet" "It changes our complexion" "Our faces have patches because of this water" "I have to shave my hair because if I do not, I will have ginger hair" "This water is kill our self-esteem" "We cannot live our live freely with this water"
Social image	"If you are a visitor and drink this water you will have a running tummy" "It is not easy to make tea with this water as if you use powdered milk the milk will coagulate
Laundering	"It discolours our clothes, therefore they lose quality"
Food preparation	"To show you how salty this water is, when you cook 'pap' you do not have to add salt" "If you add powdered milk, when making tea it coagulates, you have to wait for it to cool down before you drink it" "When making custard it coagulates and the taste is affected"
Biological needs	"It does not quench thirst" "Even if you put it in the refrigerator it does not help, the only thing you will notice is a white substance on top of the ice cubes"

3.5.6.2 Theme 2: Economic implications

The theme of economic implications is defined through the concepts of addition of water substances, appliances/time as well as fuel or electricity.

Concept 1: Addition of water substances

The findings indicated that the participants were adding foam bath or powdered soap, an expensive addition, to the bath water or extra powdered soap to do laundry (Refer to Table 3.19 below).

Concept 2: Appliances/time

The electric appliances such as kettles and irons had to be replaced on regular basis as the water affected the elements (Refer to Table 3.19). It also affected the fuel or electricity consumption as the water took a longer time to boil. This is their personal observation and not necessarily justified in any way. They also had to boil the water before they gave it to babies (Refer to Table 3.19). If they were going to have visitors they had to buy water from the people who own boreholes. The visitors and people who are taking medication were required to bring or buy water, as the people were concerned about the after effects of drinking the water from Madibogo water supply (Refer to Table 3.19).

The views of these participants supported the concerns raised by the WRC (2002) when recommended the importance for treatment of domestic water. This implies that the failure to treat the water may result in costs that could have been prevented, for example higher electricity costs for heating the water and earlier or regular replacement of elements.

Table 3.19 The cost effect as a challenge in water consumption

Concepts	**Participants' statements**
Addition of water substances	"Foam bath is expensive some of us do not afford to buy it" "You have to add more powdered soap to the water when doing washing"
Appliances/ time	"It takes time for the water to boil because of the white sediment in the kettles" "Electrical appliances are affected by this water"
Fuel or electricity/ time	"If you boil water it takes long to boil because of the white sediment" "If you have a baby you have to boil the water before giving it to the baby" "People who visit Madibogo cannot drink this water some of them they bring their own water" "If there is someone who takes treatment you have to buy water from the people who have their own boreholes"

The section below will elaborate more on participants' concerns about the water supply.

3.5.6.3 Theme 3: Concerns

The theme of concern was related through the concept of health relation.

Concept 1: Health relation

The findings reflected that the participants were concerned about the health problems that would be caused by the water especially of those who have to take treatment (Refer to Table 3.19 below) for chronic diseases. Easle (2003) also shares the participants' concerns as he/she is of the opinion that, personal hygiene and proper nutrition are instrumental in extending the lives of people who have compromised systems such as HIV positive people. Thus, the proposed model for the implementation of the water policy presented by MacKay and Ashton (2004) level 4 in chapter one (Refer to Figure 2.7) also incorporated and targeted the diseases like HIV/AIDS as they affect development.

Participants also had fears about using water, as they were scared of skin cancer. They claimed that the water caused itchiness and dryness of the skin (Refer to Table 3.20, quote 3). Pietersen (2005) also shares the participants' concern as he/she is of the opinion that the excess levels of nitrate in drinking water can result in cancers as well as hypertension. The health concern was also shared by the community leaders as they were worried about the effects that the salty tasting water could have on its consumers (Refer to Table 3.20, quote 4).

Table 3.20 Reasons for the concerns of participants

Concepts	Participants' statements
Health relations	"I think the water is not healthy for people with ulcers, because it is salty" "If the water is not good for the kettles and pots how much more for the stomach and especially for people who are taking medication, because you cannot take tablets with alcohol what about this water?" "I think this water can cause skin cancer because after bathing you will feel that your skin becomes itchy and dry' "Coming to saltiness of water I cannot really say the water is safe as I do not know if it is affecting their health or not"

The next section will present the conclusion of this chapter.

3.6 CONCLUSION

In this chapter the consumers' perceptions and household utilization of a rural water service were revealed. The consumers' perceptions were identified through the study objectives listed in the beginning of the chapter (3.2). Focus groups were held and the results analysed. Concepts and themes were identified and discussed to bring meaning to the participants' responses. The findings revealed that the participants perceived water quality through the aesthetic factors and that the physical appearance was dominant in their evaluations. They indicated that the water had a salty taste, with a milky colour and that it smelt of Jink / bleach. These perceptions lead to the belief by participants that the water they consumed is not safe. This was caused by the fact that they had uncertainties about its safety and hygiene as they lacked trust in the people who were responsible for cleaning the water system as it still maintained the milky colour, even after the cleaning process.

The most important issues that were identified when discussing water quantity were water availability and the distance of communal taps from their homes. According to the findings, availability of water was mainly affected by vandalism, tap leakages and faulty pumps. These affected the reliability of the communal taps as at times the water was not available. This caused disturbance in the community as at times this water was needed for funeral and health purposes. The distance of communal taps mostly affected the elderly as they had to pay people to fetch the water for them as the communal taps are about ½ kilometres to ¾ kilometres away from the households.

According to the participants the FBWP did not benefit the rural people as it was still favouring the location citizens. This perception was a result of the fact that the rural people had a continuous central water supplying system and they could not see how much water they were consuming or how much they were saving or given for free as opposed to the township people who have meters and individual taps. Therefore the participants suggested some changes such as improvement of water quality, installation of yard taps and others provisions to be made by the FBWP to benefit the rural areas. The participants did not have enough information about the FBWP.

In relation to household utilization of the rural water service, the participants related the quality (the aesthetic factors) to poor performance of the water. The findings indicated that the salty taste affected food preparation as it had an unpleasant taste. The participants blamed water quality, which is due to poor water services for affecting their personal and social image. The findings also reflected that the water quality affected the participant's economic situation to name a few examples; where they had to add powdered soap to bathing water as they could not afford foam bath to soften the water and for lather formation. Furthermore the water service raised participants' health concerns as they feared what health implication the water would have to its consumers.

This chapter described the perceptions of the inhabitants of Mafioso (the area in Madibogo where the study was conducted) and it is clear from these results that there are problems with the community's water provision and that there are many misconceptions regarding the day to day use of water. It was decided that an education and training programme was necessary to improve the community's attitude and knowledge about water and that nanotechnology will be installed to improve the quality of the water. As a pilot study the technology was installed just at the primary school. The following chapter will describe the results of the evaluation of the community's acceptation of the purified water and new technology.

CHAPTER 4 SENSORY AND PRACTICAL EVALUATION

4.1 INTRODUCTION

The membrane filtration plant was installed at the Bathlaping Primary School and therefore the school children and surrounding community have access to the purified water. Apparently everybody is satisfied and happy with the situation but the quality of the water and the impact thereof on the community must be establish in an objective manner.

Figure 4.1 Water tank with purified water

The methodology and the results will be discussed simultaneously and where possible illustrated with photos. The perceptions of the household water usage were not investigated with laboratory experiments but rather evaluated according to the observation of what the community members do in the homes.

4.2 AIM AND OBJECTIVES

In order to evaluate the water purifying intervention the following was done to establish whether there is a difference in the community's perceptions of the borehole water and the purified water by means of:

- focus group discussions that were held;
- the purified water that were sensory evaluated; and
- practical tests to evaluate how water is used in households for cooking, personal hygiene and laundry that were done.

4.3 METHODOLOGY AND RESULTS

4.3.1 Focus groups

Three focus groups were held to establish whether there is a difference between the unpurified borehole water and purified water at the school. The focus group's participants were chosen randomly from the available people near the borehole. The first one was with community members that live near the school (8 women), the second was with some teachers (3 women and two men) and the third one was with seven children (three girls and four boys). The same methodology followed for implementation and analysing the results was followed as for the focus groups in Chapter 3 (see 3.4.3) to ensure that the results are trustworthy. After three focus groups the results were saturated. The following is a summary of the focus group discussions' main findings:

- General
  - Most people know about the water purifying process and -
    "the children are drinking the water from this machine"
  - Most people are positive about the new technology-
    "we are happy about the machine"
  - They are eager to have clean water-
    "we want water that is safe for drinking"
- Taste
  - The community members indicated that their usual water ("Madibogo water") tastes salty, it do not quench their thirst and sometimes smell like bleach –
    "we want tasty water"
  - They agreed that the purified water "tastes nice" –
    "there is a difference between the water we used to drink and this water"
- Appearance
  - Water is clear –
    "I do not like a milky colour in my water"
- Safety of children
  - They are glad that the children stay inside the school-yard –
    "the children do not go outside to drink at the pump anymore"
    "it is safer for our children"

- Cost
  - They indicated that they are willing to pay for a sustainable supply of clean water –
    "the water should be safe for drinking then I can pay"
  - Nobody knew what purified water would cost –
    "we do not know how much it would cost nobody told us"
    "we should know what we are paying for"
- Maintenance
  - They are worried about the maintenance of the purification plant
    "I am worried about the people who will be looking at the machine"
    "at times the machine gives problems so what is going to happen?"
    "we cannot always wait for someone from Mafikeng to help"
- Security
  - They are worried about vandalism
    "what if strangers break the machine?"

To summarise, it is clear that the general opinion about the membrane filtration process of purifying water, is positive.

4.3.2 Methodology of sensory evaluation

Sensory evaluation is a scientific discipline used to evoke, measure, analyze and interpret those reactions to characteristics of food and materials as they are perceived through the senses of sight, smell, taste, touch and hearing" (De Kock *et al.*, 2008). The process of sensory evaluation was followed to evaluate whether there is practical and statistical difference between the taste of the unpurified and purified water.

The basic steps as suggested by De Kock, Kinnear and Minnaar (2008) were followed closely to ensure reliability and validity. All the standardized guidelines for the experimental design of sensory evaluation were followed:

- Analyse the sensory question
  The question is whether the purified water from the borehole at the Bathlaping School in Madibogo tastes better then the unpurified water from the borehole, by means of a sensory evaluation of different consumer groups.
- Define the test objective
  The objective was to establish whether there is a valid difference between two water samples. A standardized methodology was used of the results. The process of analytical discrimination (only difference) vs. affective (which one is the most acceptable).
- Select the test conditions
  Because most of the consumers in Madibogo are illiterate or semi-literate and it is a basic test between one attribute (taste) of two samples. the methodology of directional paired comparison was chosen. Each person will receive a set of two samples and he/she must choose the sample he/she prefers. A substantial amount of consumers will be necessary to obtain valid statistics.
- Design sensory evaluation form (Annnexure B-H)

- Run the test
  - The taste panels were informal and conducted in the open and nor in a structured taste panel room.
  - Cream crackers were served between the two samples to refresh the mouth.
  - For paired preference comparison two coded samples were used to establish whether there is a difference between a certain characteristic, in this case taste.
  - They were presented to the consumers in a different sequence and in a random way. Almost half the time FFG first and the other times FLG. The possibility that the panel would choose any sample is 50%.
- Analyze the test results.
  - In the following section the results of the sensory evaluation and taste panels will be discussed.

4.3.3 Results of the sensory evaluation

The participants were 60 primary school children from the Madibogo village, 18 stakeholders from community organisations, 11 community members and 29 staff members from the North-West University. The first section indicated who the participants were, the second what alternative they chose and the third part whether there was a difference between the choice depending on which sample was presented first.

4.3.3.1 To indicate the different stakeholders that took part in the sensory evaluation

Table 4.1 Frequencies and categories of participants that took part in the sensory panel

Category	Count	Cumulative count	Percent
Community	16	16	9.41
Children	50	66	29.41
Stakeholders	38	104	22.35
NWU-consumers	66	170	38.82
Missing	0	170	0.00

Almost 40% of the participants were from the community of Madibogo, 30% were children. Approximately one fifth was stakeholders from the surrounding government structures and 40% NWU staff members.

4.3.3.2 To establish the difference between the treated and untreated water

Table 4.2 Frequency of water sample preference of participants that took part in the sensory panel

Category	Count	Cumulative count	Percent
Untreated water	52	52	30.59
Purified water	118	170	69.41
Missing	0	170	0.00

It is clear that more than two-thirds of the participants preferred the purified water.

4.3.3.3 To establish whether there is any difference in the preference depending on which sample were presented first

Table 4.3 Frequency of the preference of the participants according to the different sequences of samples provided

Category	Count	Cumulative count	Percent
Sequence 1 FLG-FFG	83	83	48.82
Sequence 2 FFG-FLG	87	170	51.18

Table 4.4 Two-way table of the observed frequencies of the preference of the participants according to the different sequence samples provided

Order	Prefer 1	Row %	Prefer 2	Row %	Row totals
Sequence 1 FLG-FFG	29	34.94%	54	65.06%	83
Sequence 2 FFG-FLG	23	26.44%	64	73.56%	87
Totals	52		118		170

Two-way tables for Preference and Order, as well as Chi-square tests were done (p=0.229, phi=0.092) and the results indicated that there was no difference of the participants preference according to the different sequences of samples provided to the consumers.

Table 4.5 Two-way table of observed frequencies of the preference of the community members according to the different sequence samples provided

Order	Prefer 1	Row %	Prefer 2	Row %	Row totals
Sequence 1 FLG-FFG	2	25.00%	6	75.00%	8
Sequence 2 FFG-FLG	3	37.50%	5	62.50%	8
Totals	5		11		16

Table 4.6 Two-way table of observed frequencies of the preference of the children according to the different sequence samples provided

Order	Prefer 1	Row %	Prefer 2	Row %	Row totals
Sequence 1 FLG-FFG	9	37.50%	15	62.50%	24
Sequence 2 FFG-FLG	6	23.08%	20	76.92%	26
Totals	15		35		50

Table 4.7 Two-way table of observed frequencies of the preference of the stakeholders according to the different sequence samples provided

Order	Prefer 1	Row %	Prefer 2	Row %	Row totals
Sequence 1 FLG-FFG	3	25.00%	9	75.00%	12
Sequence 2 FFG-FLG	5	19.23%	21	80.77%	26
Totals	8		30		38

Table 4.8 Two-way table of observed frequencies of the preference of the NWU consumers according to the different sequence samples provided

Order	Prefer 1	Row %	Prefer 2	Row %	Row totals
Sequence 1 FLG-FFG	15	38.46%	24	61.54%	39
Sequence 2 FFG-FLG	9	33.33%	18	66.67%	27
Totals	24		42		66

Two-way tables for Preference and Order as well as Chi-square tests were also done for every consumer group and no significant difference was found ($p>0.05$ and $phi<0.15$).

Table 4.9 Two-way tables of observed frequencies of the preference of the total group of participants of different samples

Order	Prefer 1	Row %	Prefer 2	Row %	Row totals
Community	5	31.25%	11	68.75%	16
Children	15	30.00%	35	70.00%	50
Stakeholder	8	21.05%	30	78.95%	38
NWU consumers	24	36.36%	42	63.64%	66
Totals	52		118		170

Two-way tables for Preference and Order as well as Chi-square tests were done for the preferences of all the different participant groups (p=0.444 and phi=0.125). The above value indicates a statistical significant value (p<0.5).

The effect size (d-value) of participants' choice between unpurified and purified water was calculated by using the following formula:

$$d = \frac{\overline{x}_{diff}}{s_{diff}}$$

d=0.78

A d-value that is >0.7 indicates a practical significant difference of participants that chose the purified water rather than unpurified water. It was clear that almost two-thirds of the participants choose the purified water as the most preferred sample, irrespective of which sample was presented first. The results were statistically and practically significant.

4.3.4 Practical examples

4.3.4.1 Methodology

For this section a few practical tests were done to illustrate whether the community's objections against the Madibogo water are valid. The tests were not done in a laboratory, but more in the manner that consumers will use the water in their households, although the amounts of water and additives were measured for the sake of comparison. The objective was to indicate what happens when different household processes take place as observed by the consumers from Madibogo and not doing scientific experiments. The general methodology followed was to use:

- Ordinary Madibogo borehole water collected from the Bathlaping Primary school;
- Purified water collected from the plant at the Bathlaping Primary School;
- Potchefstroom water provided to households from the tap; and
- Potchefstroom water after being purified by the process of reverse osmosis in a household purifying machine.

Four samples of 200 mℓ water each were used; different additives were added, and dissolved. The mixtures were observed and photographed.

After the literature study about hard and soft water was done (par 2.3.5) it was decided to do the following observations about the interaction of the different types of water with different substances. The following household cleaning materials were used:

- Toilet soap
- Soap used for laundry
- Soap powder used for laundry
- Detergent used for washing dishes
- Detergent used as bath foam
- Washing soda
- Household bleach
- Fabric softener

4.3.4.2 Results

i) Visual appearance

The results of Chapter 3 indicate that the community of Madibogo says that the colour of their water is milky and it smells like Jik (chlorine). In the photo below there are pictures of ordinary borehole water, purified water, Potchefstroom tap water and Potchefstroom purified water.

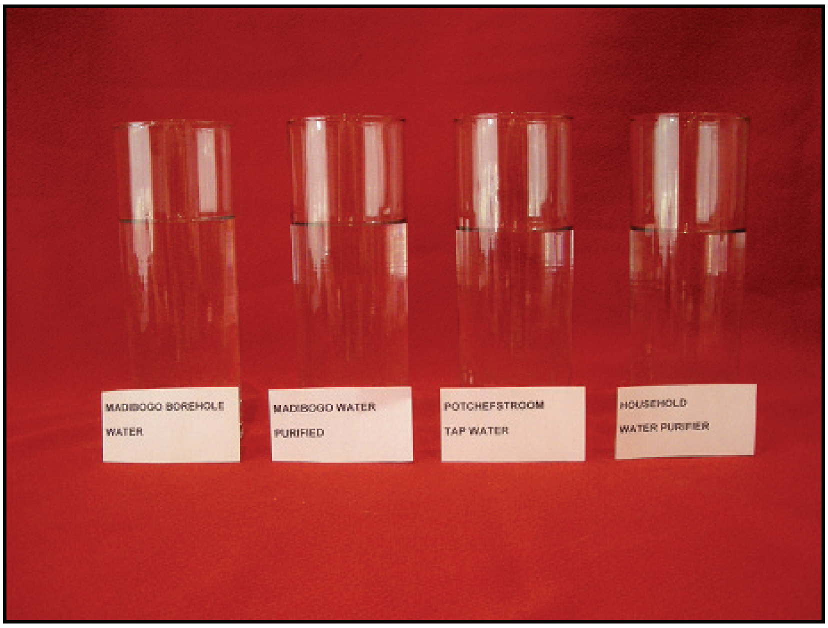

Figure 4.2 Water samples without anything added

It is clear that there is visually no difference between the four samples.

ii) Toilet soap

The toilet soap was grated and dissolved in 200 mℓ of the different types of water. A 10 mℓ spoon was used and the grated soap was not compressed in the spoon.

Figure 4.3 Toilet soap added to the water samples

The substances dissolved in the water and reacted with the soap to make a scum. The reaction is more with the Madibogo unpurified water and the Potchefstroom tap water. The purified Madibogo and Potchefstroom water is less turbulent and there is less scum. However the reaction is the greatest with the Madibogo borehole water. More soap is also needed to form lather. It is therefore not pleasant to wash in hard water unless the water is softened (which can be costly) and the scum is visible every time soap is used. According to experts the hard water is not dangerous and the skin must just be moistened additionally in order for individuals to feel comfortable. This additional moisturising can also be costly.

iii) Soap used for laundry

The reaction was almost the same as the above

iv) Soap powder used for laundry

5 mℓ soap powder was added and dissolved in the 4 water samples for two types of soap powder.

Type A

Figure 4.4 Washing powder used for laundry dissolved in the four different water samples

The soap powder dissolved in all four samples and formed scum. The most scum was formed in the unpurified Madibogo water which again indicates that more soap powder or other means of water softening must be used for the soap powder to perform effectively.

Type B, soap powder with fabric softener added (the soap powder is bought with the fabric softener already added).

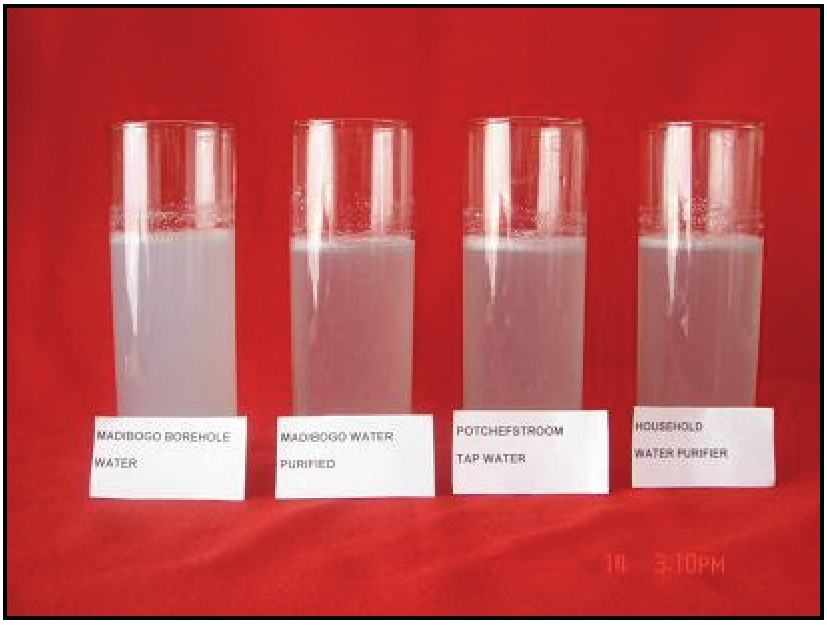

Figure 4.5 Washing powder used for laundry with added fabric softener dissolved in the four different samples

It is clear the unpurified Madibogo water has the greatest reaction with the soap powder in which fabric softener was added because the most scum formed and the water is the most turbulent.

v) Detergent for dishwashing

2.5 mℓ detergent was added to the four samples (200 mℓ water each) respectively and it was stirred thoroughly.

Figure 4.6 Dishwashing detergent dissolved in the four different samples

Again the unpurified Madibogo water is the most turbulent which indicate that there are the most substances dissolved in the water that can react with the detergent. More detergent is therefore needed to perform effectively.

vi) Detergent used as bath foam

2.5 mℓ bath foam was added to the four samples (200 mℓ water each) respectively and it was stirred thoroughly.

Figure 4.7 Bath foam added to the four different water samples

Again the unpurified Madibogo water is the most turbulent which indicate that there are the most substances dissolved in that water that can react with the bath foam. More bath foam is therefore needed to perform effectively.

vii) Washing soda

5 mℓ washing soda was added to the four water samples (200 mℓ each). It was stirred until the washing soda dissolved.

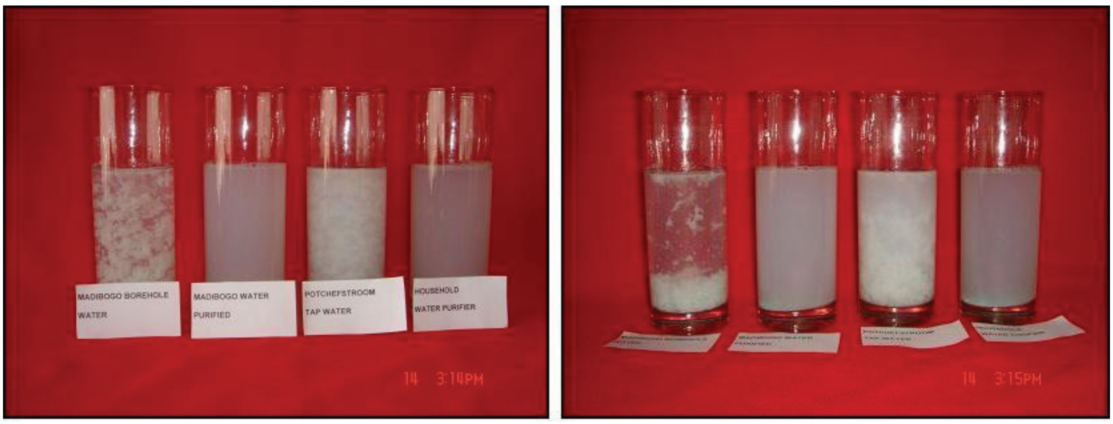

Figure 4.8 Washing soda added to the four different water samples

Washing soda reacted with the calcium and magnesium in the water therefore the water are cloudy in all four the samples and it forms a precipitation in the unpurified Madibogo water and the unpurified Potchefstroom water. The reaction is just more extreme with the Madibogo water. Test B illustrate that the precipitation of insoluble calcium and magnesium carbonate in the bottom of the glass. Because of this precipitation the water is softened.

Washing soda is a way to soften hard water but the community must realise that this can be costly and it is why the water looks milky, but that it is not dangerous.

viii) Household bleach

5ml household bleach usually used for laundry was added to the different water samples respectively.

Figure 4.9 Household bleach added to the four different water samples

Household bleach showed no different reaction between the different water samples.

ix) Fabric softener

5ml Fabric softener usually used for laundry was added to the different water samples respectively.

Figure 4.10 Household fabric softener added to the four different samples

It is clear from the above that only the unpurified borehole water from Madibogo reacted with the softener. The water is turbid as the water reacted with the softener.

4.3.4.3 Household cooking

Making tea was used as an example because it was one thing that the consumers in Madibogo complained about. The tea was made with 200 mℓ water, one teabag and 10 mℓ whitener or 10 mℓ powder milk. The teabag was kept in the different boiled water samples for 1 minute.

i) Tea made with powdered milk

Figure 4.11 Tea made with powdered milk using the four different water samples

Powdered milk was used because fresh milk made no curdles, but it is shown that there are also no problems with the powdered milk.

ii) Tea made with whitener

Figure 4.12 Tea made with whitener

The tea made with the Madibogo borehole water shows that the whiter coagulated and formed curdles. When the colour is observed it is clear that the two purified samples' colours are a little darker although the same methodology was followed.
The community members said that when they make tea the borehole water reacts with the powered milk or whitener and form curdles. A photo of tea made with borehole water, purified water and powdered milk are shown below. The main complaint was that the milk coagulates and that their tea is unattractive.

Figure 4.13 Tea with whitener

The sediment in the tea made with Madibogo water is a clear indication of the formed curdles.

4.4 CONCLUSIONS

The results from the focus groups indicated that the people are generally satisfied with the purified water and that they are willing to pay for good quality water. Their main concern is the maintenance of the purifying plant.

The taste of the Madibogo water really improved with the membrane treatment. Sensory tests clearly indicated, with statistically and practically reliable values, that participants, which are inhabitants from Madibogo as well as people from another environment, found that the purified water taste better than the unpurified water.

It is clear that visually there is no difference between the four water samples without anything added to it. It is also indicated that more reaction take place when the borehole water from Madibigo or Potchefstroom tap water are used versus the purified Madibogo or Potchefstroom purified water when different soaps and laundry powders are added to them. This happens because there are more calcium and other minerals in the unpurified water. When toilet/hand wash soap was added to the water curdles and scum were formed. The reaction was more visible with the Madibogo borehole water, with almost no reaction when the purified water was used. The other soaps and detergents followed the same pattern and when washing soda was used the water turned totally turbulent. According to the literature washing soda can be used as a water softener.

The teas made with the different types of water do not show a difference but when powdered milk or whitener (coffee or tea whitener) is used coagulation takes place and curdles form in the Madibogo water which is very unattractive and not pleasant to drink.

In conclusion it can be said that the community must remember that hard water is not dangerous, maybe just inconvenient. They must also know that water purification is a costly exercise for which they will have to pay. They must make informed decisions if they want to improve their water services.

This chapter investigated the sensory evaluation of the community members from Madibogo (consumers) regarding their experiences when practically using the unpurified Madibogo borehole water versus the purified water. In the following chapter the development of an attitude scale of consumers regarding Madibogo water will be described.

CHAPTER 5 DEVELOPMENT OF ATTITUDE SCALE

5.1 INTRODUCTION

Change in knowledge, attitude and skills of participants give an idea of the impact of an education and training programme. To measure this change a specific instrument must be developed that is appropriate for this specific target group programme (Spiegel & Leeds, 1992). The development of an attitude scale for semi-literate people regarding possible water and water-provision will be discussed in the following section (Oppenheim, 1992).

Qualitative research has been done and data was gathered with the use of focus groups to establish what the community members of Madibogo think about the water service that is provided to them. Their knowledge and perceptions about water were classified as being about water quality, water quantity, household usage and the FBWP. In order to be able to change people's attitudes about water, a standardised attitude scale about water should be developed.

5.2 AIM AND OBJECTIVES

In order to understand the attitudes of consumers towards water usage and provision the objectives of this part of the study were to develop a standardised attitude scale to be used as measuring instruments for understanding community's attitude against current and general rural water supplies, general rural water household utilisation and the understanding of the free basic water policy.

5.3 METHODOLOGY TO DEVELOP A WATER SERVICE PROVISION ATTITUDE SCALE

Various methods for construction of attitude scales are described in the literature. Pioneers who can be mentioned in this respect are researchers such as Thurstone, Lickert and Guttman. Currently a method that gives satisfactory results (Nel, 1978; Reitsma, 1996 and Kruger *et al.*, 1996) is to combine the Thurstone, Lickert and Guttman-method. This method was used in a slightly modified way to construct an attitude scale suitable for this programme's evaluation.

The process of developing an attitude scale to measure consumer attitude towards rural water service provision is divided into three parts: the gathering of statements, the implementation phase and selection of appropriate statements for the final attitude scale.

5.3.1 Gathering statements for a preliminary water service provision attitude scale

5.3.1.1 Development phase

The first step was to design subscales. With reference to Kruger *et al*. (1996) the subscales were chosen to investigate from the findings of the focus group discussions previously conducted (see 3.1) by (Kolanisi, 2005) on consumer perceptions towards water quality, water quantity rural water service provision and household utilization. The intention of using these findings was to use concepts and language familiar to the participants. Grosvenor (2006) encourages the use of familiar and understandable language to ensure the best results. Approximately 75 initial attitude statements were gathered.

Assessing consumer attitudes towards rural water service provision required a specific, consistent and reproducible ranking scale to be developed (Oppenheim, 1992). For quantifiable measurement, a ten continuous point Likert-type scale consisting of a series of declarative statements with favourable or unfavourable choice was used (Albaum, 1997; Sclove 2001). The idea was to use the Schutte-scale, which was specifically designed as a measuring instrument for semi-literate and illiterate people.

5.3.1.2 Preliminary testing of initial attitude statements

For face validity the initial 75 attitude statements were taken to experts in the field to assess appropriateness and relevancy to rural water service provision. The initial statements were reduced to 70 as some of the statements were identified as repetition. Since the statements were in English they were translated to Setswana, the local language.

The preliminary attitude scale (70 statements) (Annexure B-A) was translated in Tswana and completed by five Tswana speaking women from the same demographic group as where the final testing of the instrument was done. This was implemented to ensure that each statement was clear and understandable. The secondary researcher was also Tswana speaking and that increased the reliability because she was knowledgeable enough to understand all finer nuances of the language and double checked that the questions really conveyed what the study/questionnaire meant. Each statement was read through and discussed in a focus group situation. The statements were then changed where necessary to ensure the face validity of the measuring instrument

70 attitude statements were piloted to a group of 20 people similar to the targeted population group. This was done to test if the statements were simple, concise and understandable. Subsequently, some language revision and statement rephrasing were made to obtain the questionnaire that was to be used for standardization (Annexure B-A).

5.3.2 Implementation phase

5.3.2.1 Sampling

Of the eleven Madibogo village sections, six sections were systematically selected; they were numbered and all the odd numbers were drawn. The survey interviews were held in these six village sections. A convenience sample was used based on the accessibility and availability of the participants. The survey and approximately 18 focus group discussions; composed of 20-25 people each were held, comprising a total of 351 community members who were all consumers of the rural water service provision scheme. Ten of the18 groups were mixed groups composed of the community members and the other eight were four groups of educators, two adult education basic education and training (ABET) learners and two women groups.

5.3.2.2 Completion of attitude questionnaires

Fieldworkers came from five of the eleven sections of the village and they spoke the local language. One session was used to train the fieldworkers. Their main task was to explain and read loud the instructions to the participants, assist those who cannot write to complete the questionnaire. Multiple surveys and focus groups were conducted simultaneously. The combination use of survey and focus group discussions was anticipated to provide clarity if discrepancies arise (Oandasan *et al.*, 2000; Grosvenor, 2006).

Before commencing with the survey, the researcher allowed the fieldworkers to introduce themselves to the participants and to carry out their task. After reading, evaluating and rating each statement with the help of the fieldworker the questionnaires were completed after which focus group discussions was held with each group.

i) Focus group discussion

In this study, the in-depth discussion function is performed by the focus group discussion. This is justified by the procedures and principles followed during the discussion process. These discussions provided for in-depth deliberation as the various participants responses led to a debate as they revealed their experiences and ideas. The debate provided great insight as it reflected and provided a broader understanding to a researcher of what the statement ranking (numbers) meant to the participants (Grosvenor, 2006). Krueger (1994) is of the opinion that focus groups create a non-threatening, debatable environment producing believable results and grants the researcher the opportunity to explore unanticipated issues brought forth during the discussion. Furthermore, detailed notes were recorded, and written, read to the group for verification before the end of each session (Annexure B-B).

5.3.3 Selecting the most appropriate statement

Both quantitative and qualitative data analysis were performed to select the most appropriate statements.

5.3.3.1 Statistical analysis

To compile the final attitude scale the following statistical analysis procedures were applied:

- Elimination of items using the scale discrimination technique.
- Exploratory factor analysis was applied to determine the correlation between different factors in order to ensure construct validity.
- The different sections of the questionnaire were done according to the initial focus groups, namely water quality, quantity, utilization of free basic water.
- For each factor, the Cronbach's coefficient alpha was calculated to determine the reliability of each factor. Cronbach's coefficient alpha is a measure of internal consistency (reliability) and a value of 0.5 or higher is considered reliable. The calculated Cronbach's coefficient alpha values for this measurement were not found to be statistically reliable.
- Findings from the pre-test indicated that the concepts about water were abstract to such an extent that the consumers (participants in the study) were possibly unable to understand the general idea of the statement they were to rate. The reason for the Cronbach's coefficient alpha not being reliable is possibly due to the abstract nature of the statements and this lead to the inclusion of focus groups results and not only the application of the attitude measuring questionnaire. The focus groups allowed for the participants to verbally discuss their views of the statement (Annexure B-B).

5.3.3.2 Qualitative data analysis

All the data that were collected through focus group discussions were recorded, transcribed, coded and categorised into themes and concepts through content analysis. According to Hayes (2000) such transcripts are a method with which to record the conversations for analytical purposes. Each transcript was read several times by the researcher after which concepts related to each of the objectives were identified. These concepts were clustered to form themes of the findings through an interpretation of the data.

5.3.3.3 Elimination of items for final attitude scale

In the final attitude scale the number of statements was reduced from 70 to 35. As precautionary measure the statements were revisited to detect ambiguous ones. A statement was identified as ambiguous and was split into two questions, which increased them to 36. Thorough checking continued and four statements were rephrased bringing the final total number to 40 (Annexure B-C).

The final draft of survey instrument was translated into Setswana. For validity and reliability of translation the Setswana statements were proof read and translated back to English, which was then compared with original English text. The text was read by five people who spoke both Setswana and English and they were changed where necessary to ensure face validity. The final attitude scale was further tested to a group of 20 people.

5.4 RESULTS AND DISCUSION

The results of this study are presented based on quantitative and qualitative research methods used in the study.

5.4.1 Quantitative analysis results

A survey of 351 people was conducted to develop an attitude scale. Approximately 25 attitude statements were completed by the first group from the community who acted as pilot group.

The continuous -10-point Likert scales were used with a Schutte-scale. However, the first group seemed confused in following instructions and using the Schutte-scale. The Schutte-scale is supposed to be a simple and reliable visual tool used to measure attitudes that is suitable for both literate and illiterate respondents (Schutte, 1992). Even though the instructions were repeated to them, confusion was still observed from facial expressions and murmuring of participants. The participants murmured because they could not apply the scale.

Attempting to encourage participation the researcher intervened and treated the first group as a pilot group. Consequently, the continuous 10-point scale was reduced into three point scale with 'one' representing a positive response which was 'agree'; two being a 'neutral point' and three 'disagree'. According to Kruger *et al.* (1996) when dealing with illiterate participants a simple three point scale always works better.

A three point scale and new instructions were formulated and communicated to the next groups. Some of the groups became too big because people did not arrived according to schedule and instead of turning them away they were accommodated. Therefore the estimated total of correctly completed questionnaires was 276 instead of 351. An estimation of 55 questionnaires was either incomplete or incorrectly completed. Part of incorrect completed questionnaires could be blamed on changing from the continuous 10-point scales to a three point Likert scales and the illiteracy of the people.

5.4.1.1 Internal consistency and reliability of questionnaire

To examine the internal consistency, reliability analysis and a factor analysis was performed using SAS procedure. A factor analysis was used to screen and eliminate the statements that had a low correlation. The reliability of scale was determined by determining the Cronbach's coefficient alpha of each variable. Cronbach's coefficient alpha measures how well a set of items or variables measures a single unidimensional latent construct. The higher the score the more reliable the generated scale will be.

There were 70 statements subjected to an exploratory factor analysis and computation of Cronbach's coefficient alpha. No interpretable factor structure could be established. The aggregated attitude score were also not reliable. Thus the statements were individually discussed. Some of the interesting results are indicated in table 5.1.

Table 5.1 Results of participant's attitude about different aspects regarding water usage and provision

Statement	Category	Count	Percent
Crystal soluble water is always good for human consumption	Agree Neutral Disagree	272 3 1	98.55 1.08 0.36
The milky colour of water indicates that the water has just been cleaned	Agree Neutral Disagree	139 68 69	50.36 24.36 25.00
I hate the smell of disinfectant in my drinking water	Agree Neutral Disagree	231 13 32	83.69 4.71 11.59
I do not trust the people who clean water Missing value	Agree Neutral Disagree	145 34 93 4	52.53 12.31 33.69 1.44
The government has to provide development services to the communities all the time	Agree Neutral Disagree	269 5 2	97.46 1.81 0.72
Knowing my human rights about receival and utilization of water means nothing to me Missing value	Agree Neutral Disagree	160 4 155 1	38.40 1.44 59.79 0.36
I would turn down any water supply that require me to pay anything for water service provision	Agree Neutral Disagree	108 8 160	39.13 2.89 57.94

Statements one, two and three revealed a misperception of consumers towards water quality. The results reflected by these statements support the findings of several researches who have found that consumers use physical appearance of water to judge water quality. This is justified by the fact that consumers are not empowered and able to judge other water quality determinants. This attitude requires attention, consumers need to be empowered to be able to ask relevant questions and understand that sensory evaluation is not a single determinant to judge quality of water. Statement four shows that the majority of participants do not trust the people who are responsible for their drinking water. This is a concern as water is a basic need used every day. Therefore it is important to understand and address the underlying factor that lead to such attitude. The qualitative analysis provides a deeper insight on why the consumers presented such attitude.

The growing dependency syndrome needs urgent attention. Statement five reflects that participants are totally depended on government. The government has introduced new policies mandating municipalities to include communities in decision-making. However the question is if there is such an attitude of what significance are these policies to communities? Furthermore, statement six revealed conflicting responses from the participants as the majority claimed to know their human rights towards water. The qualitative analysis provides another perspective of understanding the participant's response to this statement. In statement seven participants showed their attitude towards paying for water services. There is still uncertainty about payments of water services.

5.4.1.2 Reliability of questionnaire

It could be argued that the reliability of the scale was affected by several things. Some of those effects include dealing with a topic such as water. Water is something that is abstract, that most people do not really think about. Individual interests and motives of participating in the survey might have had the influence. In all the sessions participants revealed their main concern and interest as improved water for household utilization.

Time intervals between the sessions and group sizes might also have an impact. In dealing with a rural community some of the groups were too big as people just arrived and were not keen to wait. It was difficult to turn them away and ask them to come later as they would not avail themselves. However, when dealing with rural communities it is not always easy to follow rigid rules stated by the literature.

Furthermore factor analysis is a statistical analysis designed to work with continuous point of scale and not a three point scale. But for illiterate people a three point scale is more appropriate. However, it was realised that researchers are indecisive about the three point scale especially the exclusion or inclusion of the neutral point (Albaum, 1997). Researchers such as Eyensck (1998) are of the opinion that the inclusion of neutral point encourages indecisiveness. The exclusion of the neutral point can affect the reliability of the scale. Exclusion of neutral point also limits participant's choices, and forces them to make a choice that might not comply with the participant's ideas jeopardising the true reflection of participant's point of view.

5.4.1.3 Construct validity of questionnaire

This was assessed by comparing the quantitative ranked responses with the reasons provided by the participants. The reasons were anticipated to provide the participants an opportunity to think about their responses before they make their final choice. In contrast to the quantitative results the participants revealed their true understanding of the statements. Important reasons provided by the participants are directly reported as quotes.

5.4.2 Qualitative results

A summary of the group discussion is provided below in the following subsections: water quality, water quantity, and social responsibility and human/consumer rights.

5.4.2.1 Water quality

Water quality was discussed to identify water quality aspects. The participants viewed the physical appearance of the water as the most important factor that determines its safety. They preferred water with crystal clear with sparkling colour. For them the milky appearance of the water was perceived as a chemical addition such as chlorine or limestone which makes it unnatural and unhealthy: *"The white colour indicates that the water has chemicals such as limestone"; "Naturally the water has to be colourless"; "Water with chlorine can infect people".*

Furthermore, the smell of the disinfectant was unacceptable to the participants. This attitude is related to their previous experience when the people who are looking after the reservoir used some chemicals to treat the water. The consumers had bad experience with the water; hence they requested the reservoir caretakers to stop adding the chemical to the water as it was related to the diarrhoea outbreak that occurred in the community.

The researcher verified the information provided by the participants by questioning one of the care takers of the reservoir, who confirmed that they used to pour some chemical in the water to treat it. The chemical is assumed to be *'chlorine',* but caretakers were not sure of its name as it was referred to a *'white substance'*. However the community members requested them to stop. What was disturbing was that the interviewed caretaker could not even remember the name of the chemical that they were adding to drinking water: *"We add something ….eh. .. a white thing. Its name starts with a 'C'…".*

With regards to taste, rain water was considered to be tasteful and natural. Hence, when talking about rain water the consumers mentioned terms like 'natural', 'pure' and 'crystal clear', 'soluble' and 'safe' or 'healthy'. Rain water was the most appreciated water, as the consumers believed that it was natural and also minimized the household economic implications as it used less soap than ground water. Furthermore, other than drinking purposes, rain water was regarded as good for laundering and gardening. Consumers evaluate water based on colour, smell and taste (WRC, 1999). If one of the physical qualities does not comply with the consumer perceptions then there will be suspicions about the water supply, leading to its rejection.

5.4.2.2 Water quantity

Availability of water was a main issue. This was based on the lack of community responsibility; misuse and vandalism of communal water taps. Even though participants are not paying for water they blame the chief if there is no water available. The blame is based on previous experiences; when the community was obliged to pay a water service maintenance fee. A household that failed to pay the fee would be restricted to use of the communal taps. Even now when water is unavailable for any reason, participants think the water has been cut because they are not paying. This suggests that the consumers are not really secure about the non-payment of the water: *"The chief is in charge of everything, so they cut our water"; "The water is cut because we are not longer paying"; "No one told us not to pay for water".*

The majority of the participants posed a question as to why they had to pay for water as it was a natural resource. This concern came up almost in all the groups. However in some groups there were people who saw a value in paying for water even though the majority was against it. Those who were in favour of the payment of water raised the following reasons for their argument: '*to ensure availability of water, for the improvement of water quality, to ensure that the water supply is maintained'.* They made it clear that the willingness to pay was only on the basis that they would receive good water quality. Furthermore, the participants emphasized the point that there is high rate of unemployment in their community, which would be an obstacle to payment by all. The government has introduced Free Basic Water Policy to benefit the poor. However, water supply technologies such as purifying membranes, their maintenances and management in rural areas have not received the attention it deserves.

5.4.2.3 Social responsibility

There is evidence of dependency syndrome among the participants as they expect the government to deliver whatever service whenever time allows: *"We are poor so the government gives us everything"; " we have to wait for the government to provide us with services at whatever time they can"; " I do not mind to wait for the government to deliver services to me my problem is that takes longer to deliver them"; "This is our government they should provide us with services", "They know what we want as needy people".*

The mentality presented by consumers seeing themselves as 'needy'**,** makes them vulnerable and accepting whatever they are given. This attitude needs to be changed so that consumers could see themselves as partners with government. It is anticipated that a change would facilitate rapid development and ensure sustainability. It has been proved that providing communities with resources if they were not part of in the decision-making usually results in less utilization and non-sustainability (Bhandari & Grant, 2007). This kind of attitude requires urgent attention; if ignored; it could have negative implications for the country as it would delay the development progress, subsequently affecting the economy.

5.4.2.4 Human/consumer rights

The consumers stated that they were aware of their human rights and claimed that they had been trained. It became clear through the discussions that the participants were not really clear about their rights. The knowledge of human rights which they referred to was based on the training that was offered by the government election official in preparation of the elections: *"we were trained* *about our human rights when we were about to vote".* It also became evident that participants were still caught up in the past, believing that the water will be cut if they do not pay for it. According to the South African constitution this is not allowed as no one should be refused basic water because she/he cannot afford to pay (DWAF, 1997).

The participants made it clear that FBWP meant nothing to them as they are struggling with the water quality: *"The government is killing us, we are not happy to receive our kind of free water" "It would be better if the government can give us better water";" The politicians promised us free water".* This attitude is related to the way in which the FBWP was introduced. It was introduced as *'free water'* by the politicians. The behaviour of expecting handouts needs attention. Introducing free services without explaining the responsibilities needs to change as consumers become attracted to the *'free service'* and bear the consequences later (Netshiswinzhe, 2000).

5.5 LIMITATIONS OF THE STUDY

It is not possible to generalize the findings to other rural communities but findings can be evaluated as useful source of information regarding consumer attitudes towards rural water service provision. Secondly, the scale was not standardised as it required more time. With regards to this study standardisation was viewed as waste of time, as the scale had to be tailor-made to suit different needs of target population, subsequently when repeating the study elsewhere the scale could not be used as it is. Thirdly, a precaution has to be taken as some participants did not complete the questionnaire. It is advised to do a thorough check-up when collecting the questionnaires. Fourthly when dealing with heterogeneous groups, there should be a certain criteria followed. For example the level of education and age difference should be considered as they can result to bias affect the reliability of the scale. The groups should be divided according to the level of education as it becomes challenging to deal with a group with both literate and illiterate people. Lastly, in rural areas power and cultural issues need to be considered. In some village sections the participants' decisions were influenced by those who were regarded as knowledgeable. For example, if there was a person who was regarded as more knowledgeable than others, those participants would wait for the knowledgeable person to raise his or her view, and then agree or base their response on the suggested opinion. In some instances, in mixed groups the women tended to be overpowered by men or the women would wait for men to make a decision first and then respond.

The results of this chapter and developed attitude scale will be used to investigate the attitude of other consumers from Madibogo about the water available to them. It will also be used to measure impact of an education and training programme regarding water to consumers if implemented before and after the education and training programme.

CHAPTER 6 THE DEVELOPMENT, IMPLEMENTATION AND EVALUATION OF THE WATER EDUCATION AND TRAINING PROGRAMME

6.1 INTRODUCTION

After the attitude and knowledge scales were developed the programme material for the education and training programme was designed. The concepts identified from the focus groups, namely the quality and quantity of water supplies, general rural water household utilisation and the understanding of the free basic water policy were used as guideline for the programme material. A group of community members was trained using the above material, the standardised attitude and knowledge scale and evaluation material. The methodology and results will be discussed in this chapter.

6.2 AIM AND OBJECTIVES

The objectives of this part of the study were:

- The development, implementation and evaluation of a basic water education programme.
- Assessment of the education and training programme, WET-programme's impact was done by comparing the scores of the attitude and knowledge tests from before the course to after the course as well as by observing the change in practical use of water during the course

6.3 METHODOLOGY

6.3.1 Development of a basic Water Education and Training Programme (WET-programme) and appropriate evaluation material

6.3.1.1 Compiling information for the education programme

After the development of the attitude and knowledge instrument the basic water education programme (WET-programme) was developed. The concepts that needed to be addressed upon which the WET-programme (information and outcomes) was based were extracted from the results achieved in Objective 1 of the research project (Kolanisi, 2005). The information in the programme was also obtained through water related

6.3.1.2 Development of learning outcomes

Applicable learning outcomes were formulated for the education programme. (See Annexure B-E).

6.3.1.3 Compiling a booklet with information

The booklet was compiled with the necessary information which was used as a guide to the basic information on water. The WET-programme is available from the researchers in the form of a hard copy or CD.

The information was transmitted through a facilitator who used appropriate teaching aids.

6.3.1.4 Develop lesson plans and teaching aids

Appropriate lesson plans and teaching aids were developed by the course presenter in order to communicate the information from the education programme as well as to help with the skills demonstrations by the educator (available from researchers).

6.3.1.5 Development of knowledge scale

The Knowledge scale was developed by using the information of Chapter 3 and the information booklet. It was composed of 20 true or false questions. (See Annexure B-D). The same methodology to ensure reliability and validity of the questionnaire as for the Attitude scale (Annexure B-C) was followed.

6.3.1.6 Assessment

Assessment of the educational value of the programme was done by measuring the change in knowledge and attitude (Annexures B-C and B-D) from before the course to after presentation of the course.

A schedule to measure the mastering of skills was also designed. Skills were observed by the presenter who evaluated role play and demonstrations completed by the education and training programme participants.

6.3.1.7 Development of evaluation material

A questionnaire to measure the participants' evaluation of the educational experience and practical aspects of the course, the programme questionnaire, was developed. (See Annexure B-G).

6.3.2 Implementation of education programme

The initial arrangements of the education and training programme consisted out of the following:

- Arranging with gate keepers in the community for an appropriate date on which to visit the community.
- Determining the number of attendees.
- Making the necessary travel arrangements.
- A purposeful sample.

A purposeful sample was to be used, as only people from a particular section were expected to undergo the education program. The targeted people were to originate from the section which had a pilot water purifying plant and volunteer themselves to partake in the education program. The assumption was that the presence of the piloting plant in that section could have triggered curiosity and thirst for knowledge. Secondly, a certain criterion was set for the volunteers it had to be youth between the ages 18-35. Justification for setting this criterion was to include youth as it was believed there are the most active members of the community who do most of the household chores, they are more exposed and informed in water issues, the literacy level and medium was also of concern thus participant were expected to speak both local and English language.

Unfortunately, after several reminders the volunteers failed to attend the program. Only two volunteers arrived. Due to time factor the program could not be rescheduled therefore the researcher went out to look for consumers of rural water service. This type of sampling is called accidental sampling. It is a non-probability sample where a researcher selects and uses available participants to suit his /her desired criteria and research purpose. Approximately twenty participants from the village section with the water purifying plant were used.

After all necessary arrangements were finalised the programme could commence. The three day course (See Annexure B-F for programme) was characterised by the following activities:

- Application of the attitude questionnaire: As stated before the implementation of the education programme a pre-attitude questionnaire (40 questions) was applied together with the use of focus groups before every section.
- Application of the knowledge questionnaire: The questionnaire tested basic knowledge about current and general rural water supplies, general rural water household utilisation and the free basic water policy (20 questions).
- Presentation of the course material: The course was presented by a qualified secondary school teacher from the North West Province and an enrolled master's student in Consumer Sciences at the North-West University, Potchefstroom campus.
- Activities during different sessions: Role-play, storytelling and other creative activities were done throughout the course to establish whether participants have mastered certain skills and knowledge.

6.3.3 Post-course activities

After completion of the education programme the following activities took place:

- Completion of evaluation material: Participants completed the post knowledge test, the post attitude questionnaire and general programme evaluation questionnaire.
- Presentation of certificates: Certificates were also handed to the participants stating their attendance of the WET- programme.

- Data analysis: Data from the pre and post tests from all measuring instruments and questionnaires were analysed. The following comments on the findings from these analyses are proposed.
- Further development of education programme: The programme was revised and recommendations made by participants were implemented.

6.4 DATA ANALYSIS AND RESULTS

Both quantitative and qualitative findings will be presented and discussed. As mentioned earlier an integrated research method was used. Therefore, the results have both numerical and verbal data complementing each other to provide synergetic effective results.

6.4.1 Results of participants who completed the course

Initially 20 participants were to attend and complete the four days work session. Participants were informed on the first meeting about the importance of attending the whole course. However, participants who felt they could not manage to attend all the sessions were excused. Therefore, of the 20 participants who formed the initial sample only 18 completed the course and two dropped out. For the knowledge scale there were three spoilt papers as two persons did not complete the course and one attitude questionnaire was incorrectly completed.

6.4.2 Quantitative findings

This type of findings provided a numerical value of participant's demographics as well as scores for knowledge and attitude scales.

6.4.2.1 Demographics of participants

Table 6.1 Gender of participants

Gender	Frequency	Percentage	Cumulative frequency	Cumulative percentage
Female	9	52.94	9	52.94
Male	8	47.06	17	100.00

There was a well balanced grouping representing both genders. Females were just a fraction more than males. This was found to be interesting as most studies indicate that water is usually a concern of men and women are usually not seen as the primary stakeholders who need to be chiefly involved in water issues.

Table 6.2 Age of participants

Age	Frequency	Percentage	Cumulative frequency	Cumulative percentage
18	2	11.76	2	11.26
20	2	11.76	4	23.53
21	1	5.88	5	29.41
22	2	11.76	7	41.18
25	2	11.76	9	52.94
29	2	11.76	11	64.71
31	1	5.88	12	70.59
33	2	11.76	14	82.24
35	1	5.88	15	88.24
43	1	5.88	16	94.12
49	1	5.88	17	100.00

The majority of the participants (80.2%) who participated in the education program were between the ages of 18-33. Two participants (11.8%) were above the specified age group but they were allowed to participate because one of them was one of the volunteers who had been keen in attending the course. It should also be mentioned that the eldest participant was illiterate which also went against the set criteria. Both of these participants were motivated to attend the course. Even though the inclusion of the two participants bridged the criterion specifications, it is argued that their interest showed an unfulfilled need that motivated them to be part of the work session (Hoyer & MacInnis, 2007).

6.4.3 Quantitative analysis

The quantitative data of both scales was statistically analysed using South African Statistic Analysis Programme (SAS). Because the total scores of the questionnaires did not produce statistical meaningful results at this stage the individual questions' results were analysed and the d-values calculated. The individual questions will be discussed to indicate practical significant changes in knowledge and attitude.

6.5 ASSESSMENT OF THE PROGRAMME OUTCOMES

In order to establish whether there were a change in the attitude and knowledge of the participants, the SAS®-programme version 8, was used to analyze the results. The scores and measurements of attitude and knowledge for each individual before and after attending the programme were analyzed to indicate an increase in knowledge or attitude, which will indicate the effect of the programme.

The p-value is a criteria of the effect of the programme on the participants attitude about and knowledge of water, a small p-value (e.g. smaller than 0.05) is considered as sufficient evidence that the results are statistically significant and are usually used for larger samples. It does not however indicate that the results are practical significant, especially in smaller samples. The term practical significance can be understood to be a large enough difference to have an effect in practice. When working with smaller samples it is necessary to calculate the effect size (d-value). The effect size (d-value) is independent of sample size and is a measure of practical significance (Steyn, 2000).

The d-value is calculated by using the following formula:

$$d = \frac{\overline{x}_{diff}}{s_{diff}}$$

Where x $_{\text{difference}}$ is the mean increase in attitude/ knowledge, and s $_{\text{difference}}$ is the standard deviation of the increase in attitude/ knowledge.

Cohen (1988) gives the following guidelines for interpretation of the effect size (d):

d ≈ 0.2 small effect and not practical significant,
d ≈ 0.5 medium effect that might be of practical significance,
d ≈ 0.8 large effect that is significant in practice.

The attitude scale was designed so that a high score indicates a positive attitude. There are negative questions in the questionnaire but those questions' answers are reversed before statistical analysis. If the attitude score of a person increases it indicates that their attitude becomes more positive, while an increase in the knowledge score indicate an increase in knowledge of the individual. However when the Cronbach's coefficient alpha were calculated for the Attitude- as well as the Knowledge-scale it was not statistically reliable in both cases. Therefore the totals of the questionnaires cannot be used. The d-value that indicate the effect size of the change from before the educational programme to after the questions, especially where there were large and medium effect sizes will be discussed.

6.5.1 Attitude measurements

In the following section the results of the attitude measurements before and after the course are presented. Only questions that have a medium and high effect size (meaning a statistical and practical reliable increase) will be discussed.

Table 6.3 Measurement of the participant’s attitude

Variable	N	Mean Attitude before	Standard deviation	Mean Attitude after	Standard deviation	p-value	d-value
1. I want my water to be clear and not milky	17	1.0000000	0	1.1176471	0.4850713	0-3322	0.24254*
2. Water needs to be purified	17	1.0000000	0	1.0000000	0	-	-
3. I hate the smell of disinfectant in drinking water	17	1.5882353	0.7952062	1.3750000	0.7187953	0.5805	0.14123
4. The slight salty taste of water is acceptable	17	2.8823529	0.4850713	2.6470588	0.7859052	0.3322	0.24254*
5. Physical appearance (colour, smell and taste) of water is the only single indicator that determines which water is good for human consumption	17	1.4117647	0.7952062	2.6000000	0.8280787	0.0034	0.90962***
6. No water should be accepted without knowing its content	17	2.2941176	0.9851844	2.5000000	0.8944272	0.4320	0.20189*
7. Ground water is as good as rain water	17	1.5294118	0.8744746	1.4000000	0.8280787	0.7921	0.069361
8. The rain water collected from the roof is an example of water of a good quality	17	2.8823529	0.4850713	3.0000000	0	0.3332	0.25*
9. I enjoy using rain water for household purposes	17	1.2352941	0.6642112	1.0000000	0	0.332	0.25*
10. I am definitely not interested in playing a role in reducing the outbreak of diseases	17	2.8823529	0.4850713	2.8571429	0.5345225	1.0000	0
11. I have some knowledge about water purification	17	1.2352941	0.6642112	1.0000000	0	0-1643	0.37893*
12. I do not trust people who clean water	17	2.4117647	0.8702603	2.6875000	0.7041543	0.1881	0.34473*
13. Water storage containers may affect the purity of water	17	1.1176471	0.4850713	1.0000000	0	0.3343	0.25820*
14. I am happy to share communal taps with animals	17	3.0000000	0	3.0000000	0	-	-
15. Water good for consumption does not have to satisfy the household chores	17	1.9411765	1.0289915	1.9333333	1.0327956	0.7192	0.094733
16. Receival of good drinking water would definitely improve the health status of our community	17	1.2352941	0.6642112	1.0000000	0	0.3343	0.25820*
17. I am satisfied with receiving any kind of water	16	2.6250000	0.8062258	2.8666667	0.5163978	0.3356	0.26726*
18. There is definitely no need to worry about the water quality standard	16	1.6875000	0.9464847	2.5625000	0.8139410	0.0054	0.84865***
19. I do not share water with other people	17	1.2352941	0.6642112	1.2500000	0.6831301	-	-
20. There is no need for me to be concerned	17	2.8235294	0.5285941	2.8125000	0.5439056	1.0000	0

about communal taps							
21. I am not happy that water taps are far from my home	17	1.3529412	0.7859052	1.3125000	0.7041543	0-7915	0.067298
22. If I could have in-yard taps I would not really care about how much water I use	17	2.7058824	0.6859943	2.1250000	1.0246951	0.0235	0.63054**
23. The far distance of communal taps encourages minimal usage of water	17	1.2352941	0.6642112	1.2500000	0.6831301	1.0000	0
24. I know that we should not pay for water	17	1.7058824	0.9851844	2.5625000	0.8139410	0.0487	0.53623**
25. If there is a need for me to pay for water service I am eager to do so	17	1.1764706	0.5285941	1.3125000	0.7041543	0.4320	0.20189*
26. I am willing to pay for the yard tap connection water service	17	1.2352941	0.6642112	1.5333333	0.9154754	0.1643	0.37893*
27. Installing in-house water connection means more cost	16	1.8125000	0.9810708	1.6666667	0.8997354	0.8692	0.044880
28. I would hesitate to be part of water community	17	2.8823529	0.4850713	2.8666667	0.5163978	1.0000	0
29. I am comfortable with waiting for the government to provide me with anything including water if they can	17	2.6470588	0.7859052	2.6250000	0.8062258	1.0000	0
30. I would be reluctant to take an initiative to improve my standard in relation to water even if I have enough information	16	2.8750000	0.5000000	2.8750000	0.5000000	1.0000	0
31. I expect the government to provide my with services such as water	17	1.7058824	0.9851844	1.4000000	0.8280787	0.3343	0.25820*
32. I am aware of my human rights towards utilization of water service	16	1.1250000	0.50000000	1.0000000	0	0.3343	0.25820*
33. Knowing my human rights about receival of water service secures my fears	16	1.0000000	0	1.1250000	0.5000000	0.3343	0.25820*
34. Knowing my human rights about receival and utilization of water service mean nothing to me	17	2.8823520	0.4850713	2.7333333	0.7037316	0.3343	0.25820*
35. I know where to go when I am experiencing problems with water	17	1.2352941	0.6642112	1.0000000	0	0.1639	0.36596*
36 FBWP means no paying for water service	14	1.1428571	0.5345225	2.0000000	0.9660918	0.0254	0.70757***
37. I am content about receiving free water	16	1.8750000	0.9574271	2.7500000	0.5773503	0.0025	0.94668***
38. FBWP is only applicable to people who have individual taps	17	3.0000000	0	2.6250000	0.8062258	0.0825	0.46513**
39. The politicians were sincere when they promise us free receival of water	16	1.3750000	0.7187953	1.3750000	0.8062258	0.5457	0.15991
40. I would turn down any water supplier that requires me to pay anything for water service provision	17	2.0000000	1.0000000	2.000000	1.0377490	0.8606	0.047883

* Low effect ** Medium effect *** Large effect

Statements 5 *(large effect size)* and 18 *(large effect size)* deal with water quality as a physical determinant and consider that very important. It is repeatedly mentioned in many studies that consumers rely on physical appearance as the determinant of safe drinking water. Most of the times consumers do not really concern themselves about the water content as they usually trust and rely on water suppliers for receiving safe drinking water. Their view about the importance of water quality increased in a practical significant way from before to after the course.

The other interesting statements are 24 *(medium effect size)*, 36 *(large effect size)*, 37*(large effect size)* and 38 *(medium effect size)*, these statements deal with free receival of water and Free Basic Water Policy. In South Africa water is a human right, however there is tendency among government and consumers who are the beneficiaries of water to treating this mandate as a hand out. Consumers usually overlook their responsibilities and focus more on *'free'* service. Their attitudes indicate that they would take free water for granted and that they will be willing to pay for water services. On the other hand after the course their answers indicate that they will be careful of how much water they will use if they have in-yard taps (statement 24, *medium effect size*). Their attitudes were definitely influenced by the Water Education and Training Programme (WET-Programme).

6.5.2 Knowledge measurements

In the following section the results of the knowledge measurements before and after the course are presented. Only questions that have a medium and high effect size (meaning a statistical and practical reliable increase) will be discussed.

Table 6.4 Measurement of the participant's knowledge

Variable	N	Mean Know-ledge before %	Std Dev	Mean Know-ledge after %	Std Dev	p-value	d-value
1. Water that looks clean and clear is suitable for drinking	18	11	0.3233808	33	0.4850713	0.416	0.51946 **
2. Water from rivers is suitable for drinking water	18	100	0	100	0	-	-
3. We must receive all our water free of charge	18	50	0.5144958	83	0.3834825	0.0096	0.68718**
4. The government must make sure that everybody receives clean and fresh water daily	18	100	0	94	0.2425356	0.3322	0.24254*
5. Water can be stored in any container and no lid is necessary	18	94	0.2357023	88	0.3233808	0.3313	0.23570*
6. Water containers need to be washed as often as possible	17	100	0	100	0	-	-
7. Taps that leak will be fixed by the government	18	38	0.5016313	61	0.5016313	0-1037	0.40528*
8. The RDP provides water	18	33	0.4850713	75	0.4472136	0.0038	0.85391***
9. South Africa is a dry country and we must save water	18	83	0.38348258	94	0.2357023	0.3313	0.23570*
10. All water that is purified tastes bad	18	83	0.3834825	72	0.4608886	0.3313	0.23570
11. Toilets must be built near your borehole	18	61	0.5016313	94	0.2357023	0.0096	0.68718**
12. If your water are not suitable to drink the only thing you can do is complain	18	10	0	88	0.3233808	0.1631	0.34359*
13. You are not allowed to form part of a Water Users Association	18	83	0.3834825	83	0.3834825	1.0000	0.23570*
14. Water can be purified by throwing cement into it	18	50	0.5144958	0.5	0.2357023	0-0018	0.86923***
15. Washing your hair in your village's water will turn your hair / discolour your hair (ginger)	18	50	0.5144958	33	0.4850713	0-2687	0.26954*
16. The community does not like strangers to purify their water	18	61	0.5016313	88	0.3233808	0-0560	0.48350*
17. The machine that is used to purify the water is not our responsibility	18	55	0.5113100	66	0.4850713	0.4299	0.19059
18. We can survive without water	18	100	0	100	0	-	-
19. Government does not care if we have /do not have enough clear, safe drinking water	18	77	0.4277926	72	0.4608886	0-7168	0.86923***
20. The water purifying machine can be costly	18	88	0.3233808	94	0.2357023	0-5786	0.13349

* Low effect ** Medium effect *** Large effect

Table 6.4 presents the findings of the knowledge evaluation. With several trials of statistical analysis, the results were still not significant but managed to be practical significant thus only the statements where there are a statistically and practical reliable increase in knowledge will be discussed. The answer to Question 1 indicates (*medium effect size*) that the participants knowledge about factors affecting the quality of water increased. Their knowledge about the provision of free basic water increased in a statistically and practically (question 8, *large effect size*) significant manner.

Questions 4 (*small effect size*) and 19 (*large effect size*) revealed an interesting finding. Both of these questions dealt with government responsibilities. However, according to the results in Table 6.4, the participants had different idea after undergoing the education and training programme about the role of government. There are two reasons for these responses. One reason is that the participants are still not clear of roles and responsibilities. Secondly, the depreciation could be an indication of transformation, indicating that consumers are trying to take some kind of responsibility towards their own services. This therefore signifies a need for more reinforcement in consumer education, creating and proving information on roles and responsibilities of various stakeholders need to be given attention.

Question 11 about the distance between the borehole and toilet was probably not understood because after the course more participants answered the question wrong. If after undergoing the education and training programme participants were still attached to their beliefs of building toilets next to the borehole it is a real problem. Casterlfranchi (undated) explains this behaviour by saying beliefs are not easy to change. The more attached they are to previous knowledge the more it becomes challenging to introduce new knowledge as it usually conflicts with the existing beliefs. He further states that if a new knowledge conflicts with existing belief, new belief will be rejected and not even be stored as information.

Question 14 (*large effect size*) indicates that the percentage that belief that cement can be used to soften water significantly decreased.

6.5.3 Skills measurement

Attitude is difficult to change but experts suggest that a free and open discussion can promote the desired response. Hence focus group discussions were used as a platform for reflection and information synthesis. To reinforce and repeat the information to stimulate desired response various techniques were used to guide focus group discussions. These techniques included projective techniques, role plays and group discussions.

6.5.3.1 Projective technique

After each session participants were given a chance to synthesize the information and review whether they have understood the message. When participants were presented with three jars of water from various water sources after having a session on water quality these were the results presented in Table 6.5.

Table 6.5 Comparison of water jars from different water sources

Jar	N=participants chose a jar	Reasons for choosing a particular jar	N
Jar 1 Mineral water	9	Sparkling, clean, good, pure, no smell, safe, no chemicals, fresh bubbly, drinkable, beautiful colour	18
Jar 2 Swimming pool water	3	No bubbles, no smell, clean, good drinking water	18
Jar 3 Madibogo water	6	Sparkling, clean, fresh, no impurities	18

Regardless of the new information received about not relying on physical appearance when judging water quality. The participants still believed that physical appearance of water was the main determining factor of good drinking water. The results of the pre- and post- Knowledge questionnaire presented in table 6.3 *(statement1)* confirm this statement. When beliefs are attached to attitudes for a long time it complicates the individual's change process. Thus the change intervention process has to be a very effective and influential message. The impact of the message mainly depends on its credibility, source reliability, importance and plausibility. The message importance and plausibility determine the acceptability or rejection of the belief. The more important is the belief and attitude to an individual the more reason for resistance to change.

6.5.3.2 Role play

A role play was used as a technique to create a conducive environment for participants to express themselves and to show their understanding. De Vos (1998) and Venter (2006) suggest that role plays also assist in observing skills development. In this study participants showed that they had understood the lesson about roles and responsibilities of each stakeholder. They managed to ask critical questions that they thought were of importance before accepting the water service that was offered to them. These are some of the interesting questions presented as quotes*: "How will we know if the water is clean; Bring us proof that will tell us about the contents of water?; We can see that water is clean but we are not sure if it's up to standard?"*.

6.5.3.3 Group discussions

Participants were asked to divide themselves into four groups of five to discuss their water household utilization. Table 6.6 presents participants perspective of their water and their coping strategies.

Table 6.6 Consumer coping strategies

Consumer perspectives	Coping Strategies
Water tastes salty and bitter	Buy water from those with tanks Visitors bring own water
Milky colour (participants believed that the milky colour came from limestone inside the reservoir)	Use chlorine
Has a smell (car oil)	Buy water from those with tanks Visitors bring own water
Coagulates with powdered milk and whitener	Must let the tea cool before they add the whitener
Skin feels dry after bathing	Add powdered soap to bathing water to soften the water
Water does not form any lather	Add foam bath or powdered soap
Water does not remove grease from laundering	Addition of paraffin to laundering water and bathing Boil the water for laundering Addition of cement in laundering water Use more soap powder

Participants made it clear that it would be difficult for them not to use their coping strategies: *"no matter how much you can teach us, we shall remain using these substances because they work for us"; "we do not have money, this works for us"; "the taps are far from our households, so it is better for us to add cement in our laundering water to save water and time"; we can only let go if we can receive good quality water".*

The reasons provided for this action resulted from the inability to afford foam water softeners. They also mentioned that at times they even run out of powdered soap hence, one of the substances that are added in the bathing water is paraffin. It is believed that paraffin is good especially for the darker skins. Addition of cement was done to save water. The participants stated that when the laundering water gets dirty they add cement, which settles down and the dirt floats. They remove the floating dirt or scum and the water becomes clean again. They add more laundry and continue with their washing.

These practices and coping strategies are the result of trying to cope with usage of hard water. Hard water is the result of high concentration of Calcium and Magnesium. There is no health effects associated with the high concentration of these minerals in drinking water (National Research Council of Science). However the water is of low quality because of the negative effects it poses to the household water utilization. Hard water results to more fuel cost, frequent repairs and purchasing of electrical appliances, regular maintenance of pipes.

Furthermore, hard water on itself might not pose any harm but the practices might endanger one's life. The practices might bring temporal relief but they can cause more damage in the long run. Although there is no valid proof of the negative health impacts caused by the use of powdered soap in bathing water but it is general knowledge that powered soap is meant for washing clothes. Most of the powdered soap brands have cautioned consumers to moisturize their hands immediately after wash. How much more when it is used to wash one's hair or face?

When it comes to paraffin, it is a fuel commonly used for stoves and lamps. Skin exposure to paraffin may result in dermatitis through the extraction of endogenous skin lipids. This can be associated with the complaint launched by the participants that the water caused them dark patches on their faces. Even though there is no evident correlation between paraffin and cancer but chronic skin exposure might result in tumour genesis (Chillcot, 2006).

In relation to these findings it can be argued that the integration of the two methods provided a good insight of participants' change in knowledge and attitude. In further reflected the strengths of each research method. Nevertheless the findings of this study show that even though the participants had undergone the education program but they still retained some of their beliefs. This therefore suggests that there is still more to be done than information provision.

Several studies have also shown that information in attitude change is usually not enough. Hence several education programs fail to change attitudes.

6.6 PROGRAMME EVALUATION

The programme evaluation questionnaire (Annexure B-G) was presented to the participants and the following section will discuss their responses. The first question was whether the information presented during the course was relevant to the topic. All the respondents answered "yes" to this question and the following were mentioned as reasons:

"we were talking about water"

"it was basically on water and the importance of water"'

They said that their needs were met and that "*we learned how to deal with water issues*" When they were asked whether the topic was treated to their satisfaction they responded positively and said that they "*learned many things about water*" and even that "*we did not have the information but now we have the light*".

The next question was whether the time was enough, again all the respondents answered "yes" to this question and they mentioned that "*everything was covered*" and that "*we had enough time for discussion*"

When they were asked whether the outcomes of the course were reached they again answered positively and also said that "*everything was organized*" and "*everything was done in the right way*". They indicated that the teaching materials were relevant, suitable and matched the topic. It helped them to "*understand the topics*" and because "*real life examples were used*" they understood everything. The manual was easy to read and "*contained all the important things".* The level of instruction was suitable according to the participants. The teaching methods were interesting and allowed everybody to participate." *We were making different roles about what we have learnt*". According to the participants the WET-programme was successful

6.7. CONCLUSION

Assessment of whether the outcomes of an education intervention programme have been reached is done by measuring the change in attitude, knowledge and skills (previously discussed). By measuring change in attitude, knowledge and skills, possible behavioural changes can be predicted (Achterberg, 1992). Standardized attitude and knowledge scales were developed and filled in before and after the intervention, while the change in skills was be observed. According to the results the participants' attitudes and knowledge were changed in a positive manner, their skills that involve the solving of their water issues and problems improved. The programme evaluation was positive so the WET-programme is suitable to be implemented in other communities and address the problem of community's ignorance about general water usage.

CHAPTER 8 CONCLUSIONS AND RECOMMENDATIONS

In this chapter the results of the different chapters will be highlighted and briefly discussed. Final conclusions and recommendations will be made according to the initial aims and objectives that were set. The main aim of the *social dimension* of the project was to determine consumers' understanding of water in general, water usage in rural areas and the Free Basic Water Policy as well as water purification, particularly nanotechnology. The **conclusions** can be summarised as follow:

8.1 THE CONSUMERS' PERCEPTIONS AND KNOWLEDGE REGARDING CURRENT AND GENERAL RURAL WATER SUPPLY, GENERAL RURAL WATER HOUSEHOLD UTILISATION AND THE FREE BASIC WATER POLICY

After the series of focus groups that were held to determine the consumers' perception and knowledge about water usage the first item identified was their opinion about water quality.

8.1.1 Quality

The participants expressed their experiences towards the drinking water from Madibogo based on experiences of vision, smell and taste. According to them their water have a milky colour, smells like bleach and tastes salty, bitter and not pleasant.

Participants believe that safe water exists and name examples like river water, boreholes and purified water. Participants also think that boiling the water or adding bleach make the water partially safe. In general they perceive Madibogo drinking water as safe, although they do not trust the people that treat their drinking water and add chemicals to the water. People from Madibogo "clean" their water by boiling it or add bleach to their water or add cement to improve the colour of the water.

8.1.2 Quantity

Participants identified taps, reservoirs, streams, boreholes and rainwater as sources in their community. They identify aspects such as reliability, convenience and affordability as important issues regarding water quantity. Availability is influenced by occurrences of vandalism in the community. Sometimes the pumps are faulty and there are a lot of leakages in their distribution system which can influence the water availability of water.

Participants also said that the water sources are not safe because sometimes the animals use the same taps and containers as the humans. Another concern is that the reservoirs are open and they do not know what can happen to the water.

Many of the participants claimed that the taps are far from the houses and they must use wheelbarrows to transfer the water. They also expressed the desire for individual taps, especially for elderly people who cannot carry water around anymore. These elderly people must pay children to fetch water for them.

The participants also indicated that the RDP-guidelines, as promised in 1994 are not yet implemented. The Municipality is to provide safe water to villages that have no access to water at all. Currently they do not pay anything for water and the municipalities are paying for the maintenance of the water systems. The participants identified the community as being responsible to take care of the water services and that the government is responsible to improve the water quality.

8.1.3 Free Basic Water Policy

The participants knew that government provide them with free water but they do not know anything about the amount of water they are to receive. They received water information from ward councillors (when canvassing for elections), television, radio, newspapers and water statements. They think that people from the city benefit more from the FBWP. They suggested that the Madibogo-people should have individual taps and that government can help to install them.

8.1.4 Household water utilization

They identified a number of problems such as bad personal image, bad social image and problems with laundry and food preparation. Participants perceived the water that they use for hygiene as unpleasing because the water are hard they had to add powdered soap to all their water to make it soft and that is costly. Furthermore they say that the water is responsible for changes in their complexion and discoloured their hair. These opinions are not justified because very few people’s face and hair was discoloured. More pressing is that they say that their self esteem is influenced by the Madibogo water because they are also embarrassed are if they present their guests with bad tasting water or coagulated tea which is unattractive. Even worse are if the guests bring their own water with the.

The participants are unhappy with the water’s performance when doing laundry because it doesn’t produce lather and discolour their clothes. According to the participants they most also use more soap and soap powder.

According to the participants Madibogo water doesn’t quench their thirst; even when cooled or frozen the water’s quality doesn’t improve. Economically they feel that the water is also not beneficial because it is costly to add additional substances to the water and the lifespan of their appliances are shorter because of the hard water. It is also costly because they must buy additional water when they receive visitors.

Their main concerns however are about health issues such as that they want good quality water for the children, aged and sick.

8.2 THE DIFFERENCE BETWEEN THE UNTREATED BOREHOLE WATER AND THE PURIFIED WATER

The results of focus group discussions held with community members about the use of the purified water at the Bathlaping School can be summarised as follows:

- Most people are positive about the new technology, they are eager to have clean water. Their usual water tastes salty and it do not quench their thirst but the purified water tastes "*nice*" and they "*like it*". They indicated that they are willing to pay for safe, clean and tasty water but at this stage no one has told them what the treated water would cost.
- They are worried about the maintenance of the plant and are especially concerned that people from Mafikeng must always come and help when there is a problem with technology. They also think that strangers might vandalise the plant.
- Most parents are glad because their children are safer now because they do not go outside to go and drink from the water pump but stay inside the school yard and drink the purified water.

The second part, namely the sensory evaluation indicated that the purified water definitely taste better than the borehole water. 170 consumers took part in the sensory test and 118 (70%) preferred the purified water as opposed to 30% that indicated that they prefer the other sample. Two-way tables for preference and order, as well as Chi-square tests were done for the preference of all the participants and a p=0.444 and phi=0.125 were calculated. When the effect size of the participants' choice between the unpurified and purified water were calculated a d=0.78 was determined. This indicates a practical difference of participant's choice of choosing the purified water.

The purified water also performed better for laundry and cleaning purposes. Because the water is "softer" the soap and detergents will form less scum and coagulants but more lather. There are also less scum when making tea and even ice.

8.3 THE CONSUMER'S ATTITUDE AND KNOWLEDGE REGARDING CURRENT AND GENERAL RURAL WATER SUPPLY, GENERAL RURAL WATER HOUSEHOLD UTILISATION AND THE FREE BASIC WATER POLICY

The purpose of this study has been to develop an attitude scale to measure consumer attitude towards rural water service provision. An attitude scale was developed and tailor-made to suit the target population. Even though the measurement was not standardised, it could be used as a model that could be adopted to suit any other target population.

- The pilot study indicated that the instrument (questionnaire) needed to be translated into Tswana. The methodology used was to translate the questionnaire into Tswana by an expert and then translated questionnaire back to English by someone else to ensure the best possible translation of concepts for the rural community to understand.
- The measuring instrument was tested again by 20 people who had not previously seen the questionnaire and who were part of any follow up research process. Each statement was read through and discussed in a focus group situation. It was then changed where necessary to ensure face validity.
- The findings from this test suggest that the instrument could be re-applied in the community and used in the educational study as measuring instrument, with the support of focus groups (Annexure B-C).

The attitude measuring instrument is used as a test with which to determine consumers' attitude towards current and general rural water supplies, general rural water household utilisation and understanding of the free basic water policy before information is given to consumers (unprompted awareness).This is also referred to as the pre-test and after information has been passed on to consumers through such methods as an education programme (prompted awareness) which is referred to as the post-test. The difference between the scores of the attitude instrument is an indication of how attitudes have changed or not.

The integration method that was followed in this study (combining qualitative and quantitative methodology) provided complementary results by using the strength of each method. It helped in gaining parallel value from both qualitative and quantitative data. The quantitative measurement was limiting but the qualitative data provided a better understanding and uncovered the overlooked issues. The results of this study showed interesting misperceptions, inadequate information, and lack of trust and ignorance of rural water service provision by consumers. The attitude scale has a potential to assist in designing and delivering water services. Measurement of consumer's attitudes prior to service delivery provides insight to consumers' opinion about government, water service bodies and agencies provision of water services.

The questionnaire was re-evaluated; certain questions eliminated or the wording changed to produce a more reliable measuring instrument with 40 attitude statements which was tested again in follow-up meetings and information sessions. Thus after the final formulation the attitude instrument was completed the questionnaire was applied to community members from Madibogo before the general water education programme was implemented.

8.4 DEVELOP, IMPLEMENT AND EVALUATE A WATER EDUCATION AND TRAINING PROGRAMME (WET-PROGRAMME), WHICH INCLUDES INFORMATION ABOUT WATER PURIFICATION AND NANOTECHNOLOGY

Developing, implementing and evaluating a basic water education programme with information about water purification and nanotechnology. The findings from the exploration of consumers' perception and knowledge regarding current and general rural water supply, general rural water household utilisation and the understanding of the Free Basic Water Policy; indicated that that the community's do not have much information or knowledge about general water usage and therefore the Wet-Programme was designed. Following the guide provided by the literature reviewed certain measures such as considering the level of education of the target group, use of visual tools, language factor and other factors were taken in consideration in designing the programme.

8.4.1 Knowledge and attitude

Statistical analysis indicated that a change in the knowledge and attitude of participants was practically significant. The knowledge increased and attitudes became more positive. The totals of the questionnaires could not be used but individual questions showed definite statistically practical significant changes.

8.4.2 Skills

Practical application of skills developed in the programme indicated that the participants were able to perform tasks assigned to them.

8.4.3 Programme evaluation

The comments from participants indicated that the course was thoroughly enjoyed by all and that they learned a lot. They found the course interesting and practical and they found their participation extremely valuable. They were also of the opinion that the information was relevant, the objectives were clear, the course were well organised. Examples were relevant; the teaching aids were relevant and made the understanding of the course easy,

8.5 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions regarding the social dimension of this programme can be noted:

- The perceptions and knowledge of consumers regarding current and general rural water supplies, general rural water household utilisation and the Free Basic Water Policy are not always correct or sufficient. There are quite a few wrong perceptions and practices regarding water quality, provision and daily household usage.
- There are many wrong perceptions amongst consumers regarding government's provision of free basic water services, especially in rural areas.
- There is a definite need for a water education and training programme to enhance community members' knowledge about water, water usage and water provision.
- There is a difference between the untreated borehole water and the purified water. Community members are satisfied with the purification plant and purification processes. There is a practically significant difference in taste of the water: the purified water tastes better.
- The purified water will be better for laundry, personal grooming and food preparation than the unspecified borehole water.
- The developed of an attitude scale did not produce statistically reliable results when implemented before and after the education and training programme. This is because the community members that had to complete the questionnaire are semi-literate and attitude is an abstract concept. In traditional communities water is taken for granted, it is always there and not something they ever thought about before. It is therefore difficult for them to answer questionnaires about that.
- The task of developing, implementing and evaluating a basic water education and training programme, with information about water purification were completed successfully. Community members found the course useful and their attitude about water supply improved and their knowledge increased.

The following **recommendations** to improve water provision in rural areas can be made:

- Because there are a lack of knowledge and many misconceptions regarding water usage and water provision in rural communities one of the main issues that must receive attention is the educational component. If people's knowledge regarding water can improve they will be able to improve their lifestyle and save valuable resources for their own pocket as well as the environment.
- Government has a lot of good policies to improve water provision to consumers but they cannot implement it alone. The ordinary water-user or consumer must play an active part in their own water provision in order to make the process sustainable. This will only happen if the consumer is empowered by enough knowledge to understand the whole process and play an active role in their community.

- Nanotechnology is an option where the water has a high mineral content that may make it unsuitable for household use. All the role-players in the community must be empowered to understand the process, especially if there is financial implications’
- In the area of Madibogo the people’s most pressing need is to have individual yard taps so that they do not have to carry water so far or use communal taps. This should be taken into consideration when planning the water provision in that area.

During the time that fieldwork was done in the community, the researchers organised an open day as well as several information sessions in the community involving all stakeholders. A representative committee was elected to represent the community’s problems to the local municipality and relevant authorities.

The White Paper on National Water Policy outlines the issues, processes, roles and responsibilities of stakeholders on how to approach water service delivery. However the problem is that the frameworks and policies acknowledge the importance and participation of consumers as beneficiaries in water service delivery. Nevertheless, there are no clear indications on the frameworks and models of how and when consumers’ consultation should take place. Furthermore there are no substantial suggestions of how consumers should be empowered and or when that should occur. Further research on these issues should therefore be done.

LITERATURE LIST

ACHTERBERG, C. 1992. Conferences, symposia and reports – effective communication for behavioural change. *Nutrition Today* 27:29-30.

ALBAUM, G. 1997. The Likert scale revisited: an alternative version (product preference testing). *Journal of market research society*, 39(2):331, April.

ANASTASI, A. 1988. Psychological testing. 6th ed. New York: McGraw-Hill.

ANON. 2008. Wikipedia: Hard water. [Web:] http://en.wikipedia.org/wiki/Hard_water [Date of access: 13 August 2008].

ANON. 2004. Lifestyle: Health and Fitness. Clean water Challenge - Rand Water. [Web:] http://www.randwater.co.za/ [Date of access: 17 August 2004].

ANON. 2002. The Right to Water: General comment No.15. [Web:] http://www.unhchr.ch/html/menu2/6/gc15.doc [Date of access: 09 February 2004].

ARNOULD, E.J., PRICE, L.L. & ZINKHAN, G.M. 2004. Consumers. 2nd ed. Boston: McGraw-Hill.

ASSAEL, H. 2004. Consumer behavior: A strategic approach. 1st ed. Boston: Houghton Mifflin Company.

BANDARI, B. & GRANT, M. 2007. User satisfaction and sustainability of drinking water schemes in rural communities of Nepal. *Sustainability: Science, practice & policy*, 3(1):12-20, Spring.

BLACKWELL, R.D., MINIARD, P.W. & ENGEL, J.F. 2001. Consumer behaviour. 9th ed. Forth worth: Hartcourt College Publishers.

BONELLO, B.B. 2002. Money spent on drinking water - Is it good value for money? Malta: Consumers' Association.

BRYMAN, A. 1996. Quantity and Quality in Social Research. London: Routledge.

CHAN, T. & CUI, G. 2004. Consumer attitudes toward marketing in a transitional economy: a replication and extension. *Journal of consumer marketing*, 21(1):10-26.

CLIFTON, K.J. & HANDY, S.L. 2001. Qualitative methods in travel behaviour research. Institute of Transportation Studies. University of California: Davis. (Research Report).

COHEN, J. 1988. Statistical power analysis. 2nd ed. New York: Lawrence Elbaum.

COOLICAN, H. 1999. Research methods and statistics in psychology. 3rd ed. London: Hodder & Stoughton.

DE FONTAINE, J. 2000. Trouble shooting guide for the domestic consumer. Pretoria: Water Research Commission. WRC report no. 963/1/00.

DE KOCK, R., KINNEAR, M. & MINNAAR, A. 2008. Six steps to sensory evaluation. Sensory research division. Pretoria: Department of Food Science.

DENZIN, N.K. & LINCOLN, Y.S. 1998. Strategies of Qualitative Inquiry. Thousand Oaks: Sage Publications Inc.

DEPARTMENT OF LOCAL GOVERNMENT. 2006. South African Local Government Association – Agricities summit report. Pretoria: Government printer.

DEPARTMENT OF WATER AFFAIRS AND FORRESTRY (DWAF). 1994. A history of the first decade of water service delivery in South Africa 1994 to 2004: meeting the millennium goals. Pretoria: Government printers.

DEPARTMENT OF WATER AFFAIRS AND FORRESTRY (DAWF). 1997. The white paper on water policy: For us water is a basic human right. [Web:] http://www.thewaterpage.com/wp3.htm - 233k [Date of access: 30 April 2004].

DEPARTMENT OF WATER AFFAIRS AND FORRESTRY (DAWF). 2001. White Paper on Basic Household Sanitation. [Web:] www.dwaf.gov.za/dir_ws/content/lids/PDF/summary.pdf. [Date of access: 20 November 2006].

DE VOS, A.S. 2000. Researchers at grassroots. Pretoria: Van Schaik.

DE VOS, A.S. 1998. Intervention research. In DE VOS, A.S (*ed.*). 1998. Research at grass roots. Pretoria: Van Schaik.

DONLEY, J & NAPPER, R. 1995. Assessment matters in adult learning. Oxford: Oxfordshire Country Council.

DREYER, J, KEEVY, J, VAN DER HORST, H & MCDONALD, R. 2001. Uitkomste-gebasseerde onderrig en kurrikulum 2005: Opleidingshandleiding. Pretoria: UNISA.

DU PLESSIS, P.J. & ROUSSEAU, G.G. 2003. Buyer Behaviour: A multi-cultural approach. 3rd ed. Cape Town: Oxford University Press Southern Africa.

DUSE, A.G., DA SILVA, M.P. & ZIETSMAN, I. 2003. Coping with hygiene in South Africa, a water scarce country. *International journal of environment and health Research,* 13(1):95-105.

EAGLY, A. & CHAIKEN, S. 1993. The psychology of attitudes. New York: Harcourt Brace & Company.

EALSE, K. 2003. Interviews with People successful in the Water Field. *Water Wheel*, 2 (2): 10, March /April.

FLICK, U. 1999. An Introduction to Qualitative Research. London: Sage Publications.

GABBOTT, M. & HOGG, G. 1998. Consumer and Services. Chichester: John Wiley & Sons Ltd.

GILLBERT, N. 1998. Researching social Life. London: Sage Publications.

GROSVENOR, T. 2006. Workshop on qualitative and quantitative methods: qualitative research in the transport sector. [Web:] www.trb/org/onlinepubs/circulars/EC008/wprkshop_kpdf [Date of access: 10 May 2004].

HAYES, N. 2000. Doing Psychological Research. Buckingham: Open University Press.

HLOPHE, M. 2004. The testing of a membrane technology unit for the removal of pollutants from ground water. North-West University – Mafikeng campus. (Unpublished report for the Water Research Commission).

Hoyer, W.D. & MacInnis, D.J. 2007. Consumer behaviour. 4th ed. Boston: Houghton Mifflin Co.

JACKSON, B. 1997. The water page. [Web:] http://www.africanwater.org/ppp_debate.htm [Date of access: 03 May 2004].

JENNING, R. 2000. Participatory development as a new paradigm. [Web:] www.usaid.gov/our_work/crossputting_programs/transition_initiatives/pubs/ptdv100 [Date of access: 10 April 2007].

KASRILS, R. 2002. Parliamentary media briefing. [Web:] http://www.info.gov.za/speeches [Date of access: 8 February 2005].

KEMPEN, E.L. 2002. Die ontwikkeling van onderrigmetodes, hulpmiddels en asseseringsmetodes vir 'n behuisingsopvoedingsprogram (HELP) vir volwasse leerders. Potchefstroom: PU vir CHO. (Honours script).

KHALFAN, A. 2005. The human right to water: recent progress and continuing challenges. [Web:] http://www.hri.ca/tribune/onlineisue/V11-32005/Right_to_Water.html [Date of access: 20 September 2006].

KOLANISI, U. 2005. A South African study of consumer's perceptions and household utilization a rural water service provision. Potchefstroom Campus: North-West University. (Dissertation – M.Sc.)

KRUEGER, R.A. 1994. Focus groups. 2nd ed. Thousand Oaks: Sage Publications.

KRUGER, H.S., VAN AARDT, A.M. & STEYN, H.S. 1996. The development of an attitude scale for assessment of body image of obese black women. *The SA Journal of Food Science and Nutrition* 8(9):106-112.

LEVINE, D.M., GREEN, L.W. & MORISKY, D. 1987. Effect of a structural health education program on reducing morbidity and mortality from high blood pressure. *Biblithca cardiology* 42: 8-16.

LING, E.M. 1972. Modern Household Science. London: Bell and Hyman Ltd.

MACKAY, H.M. & ASHTON, P.J. 2004. Towards co-operative governance in the development and implementation of cross-sectoral policy: Water policy as an example. *Water SA* 30(1) 1-8, January.

MAISEL, R. & PERSELL, C.H. 1996. How sampling works. Thousand Oaks: Sage Publications.

MATHABATHA, S. & NAIDOO, D. 2004. A review of public participation in the rural water and sanitation setting. Pretoria: Water Research Commission. WRC Report No. 1381/1/04.

MEYER, V. & REED, R.H. 2001. SOLAIR disinfection of coliform bacteria in hand-drawn drinking water. *Water SA*, 27 (1), 49-52 January.

MODISE, S.J. & KRIEG, H.M. 2004. Evaluation of nanofiltration for the treatment of rural ground water for potable water use. Pretoria: Water Research Commission. WRC report no. 1230/1/04.

MOWEN, J.C. & MINOR, M.S. 2001. Consumer behaviour: a framework. Upper River: Prentice Hall.

MVULA TRUST. 2000. Free basic water tapping its developmental potential in rural areas. [Web:] http://www.mvula.co.za/resources [Date of access; 20 August 2004].

NEL, SJ. 1978. Die ontwikkeling van 'n skaal vir die bepaling van die houding van eerste jaar studente aan Afrikaans medium universiteite teenoor die natuurwetenskap en natuurwetenskaplikes. Potchefstroom: PU vir CHO. (PhD thesis).

NETSHISWINZHE, B. 2002. Free Basic water-Tapping its Developmental Potential in rural Areas. [Web:] http://www.mvula.co.za [Date of access: 1 August 2004].

OANDASAN, I.F.; GHOSH, I; BYRNE, P.N. & SHAFIR, M.S. 2000. Measuring community-oriented attitudes towards medical practice. *Family practice,* 17(3):243-247, January.

OKA, T. & SHAW, I. 2000. Qualitative research in Social work. [Web:] http://www.incds.pweb.sophia.ac.jp/~t-oka/papers/2000/qrsw/qrsw.html [Date of access: 11 November 2004].

OPPENHEIM, AN. 1992. Questionnaire design, interviewing and attitude measurement. London. Pinter.

ORANJE, M., HARRISON, P, VAN HUYSSETEEN, E & MEYER, E. 2000. A policy on integrated development planning. Department of provincial and local government. [Web:] http://www.thedplg.gov.za/subwebsites/idp/documents/National%20IDP%. [Date of access: 13 February 2007].

PETER, J.P. & OLSON, J.C. 2005. Consumer Behaviour and marketing strategy. 9th ed. Boston: McGraw-Hill.

PIETERSEN, K. 2005. Groundwater crucial to rural development. WRC, *Water Wheel*, 4(2) 26-27p March/April.

PILLAY, V.L. & JACOB, E.P. 2004. The development of small-scale ultrafiltration systems for potable water production. Pretoria: Water Research Commission. WRC report no.1070/1/04.

PYBUS, P.; SCHOEMAN, G. & HART, T. 2001. The level of communication between communities and engineers in the provision of engineering service. Pretoria: Water Research Commission. WRC report no. TT 133/00.

REITSMA, GM. 1996. Die invloed van 'n voedingsopvoedingsprgram op die kennis van en houding oor gesonde eetgewoontes van swart vroue. Potchefstroom: PU vir CHO. (M.Sc thesis).

ROGERS, A. 2003. What is the difference? A new critique of adult learning and teaching. Niace: Leister.

SAMI, K. & MURRAY, E.C. 1998. Guidelines for the evaluation of water resource for rural development with an emphasis on groundwater. Pretoria: Water Research Commission. WRC report no. 677/1/98.

SCHIFFMAN, L. G. & KANUK, L.L. 2004. Consumer Behaviour. 8th ed. New York: Pearson/ Prentice Hall.

SCHUTTE, DW. 1992. Prioritisering van gemeenskapsbehoeftes. Cape Town. Human Science Research Council.

SCLOVE, S.L. 2001. Notes on Likert scales. www.uic.edu/classes/idsc/ids270sls/likert.ht. [Date of access: 03 November 2006].

SHAO, T.A. 2002. Marketing Research: an aid to decision-making. Australia: South Western/Thomson Learning.

SHETH, J.N., MITTAL, B. & NEWMAN, B.I. 1999. Consumer Behaviour and Beyond. Fort Worth: Dryden Press.

SHOUHENESSY, J.J. & ZECHMEISTER, E.B. 1997. Research Methods in Psychology. New York: McGraw-Hill.

SILVERMAN, D. 2000. Doing qualitative research. London: Sage publications.

SMITS, S. 2004. Free Basic water and "steeping up the ladder" in South Africa. [Web:] http://www.pt.irc.nl/page/9684 [Date of access: 9 February 2005].

SOLOMON, M.R. 2006. Consumer Behaviour: buying, having and being. 7th ed. Upper Saddle River, N.J.: Pearson/Prentice Hall.

SOLSONA, F. 1996. Non conventional disinfection technologies for small systems. Pretoria: Water Research Commission. WRC report no. 449/1/95.

SPIEGEL, MR & LEEDS, C (*eds.*). 1992. The answers for program evaluation a workbook. Ohio: Ohio State University.

STEYN, H.S. 2000. Practical significance of the difference in means. Journal of industrial psychology 2b (3):1-3.

STRYDOM, C.B. 2003. Research at Grass Roots. 2nd ed. Pretoria: Van Schaik Publishers.

SUSSEN, H. & VERMEULEN, A. 2001. Providing free basic water in South Africa. People and systems for water, sanitation and health. [Web:] www.iboro.ac.uk.departments/cv/wedc/papers/27/.../17 [Date of access: 08 February 2005].

THERON, J. 2001. The challenge of identifying waterborne pathogens leads to new technology. *South African Water Bulletin*, 27(3):10-11, May/June.

THOMAS, D.R. 2003. A general inductive approach for data analysis. [Web:] http://www.health.auckland.ac.nz/hrmas/resources/Inductive2003.pdf [Date of access: 4 February 2005].

TROCHIM, W.M.K. 2002. Qualitative approaches. [Web:] www.socialresearchmethods.net/kb/qualapp.htm [Date of access: 11 April 2005].

VAN DER HORST, H. & MCDONALD, R. 2001. Outcomes-based education: Theory and practice. 2nd ed. Centurion. TeeVee Printers.

VAN DUUREN, F.A. 1997. Water Purification Works Design. Pretoria: Water Research Commission. WRC Report No. TT 92/97.

VAN LEEUWEN, F.X. 2000. Safe drinking water, the toxicologist's approach. WHO European Centre for Environment and Health. 38 Supplement (1):51-58. Netherlands: Bilthoven Division. [Web:] http://www.ncbi.nlm.nih.gov/entrez/query.fcgi? [Date of access: 04 March 2004].

VAN TEIJLINGEN, E.R. & HUNDLEY, V. 2001. The importance of pilot studies. [Web:] http://www.soc.surrey.ac.uk/sru/SRU35.html [Date of access: 2 March 2005].

VENTER. M.D. 2006. The development, implementation and evaluation of a housing education literacy programme for semi-literate recipients of government subsidised housing. Stellenbosch: Universiteit van Stellenbosch. (PhD thesis).

VLOK M. E. 2003. Manual of community nursing. Pretoria: Juta and Co. Ltd.

Water Research Commission (WRC). 2003. Quality of Domestic water Supplies. Analysis guide. Volume 3. Pretoria: Water Research Commission. WRC TT

Water Research Commission (WRC). 2002. Quality of Domestic Water Supplies. Treatment guide. Volume 4. 1st ed. Pretoria: Water Research Commission. WRC report no. TT 181/02.

Water Research Commission (WRC). 2000. Quality of Domestic water Supplies. Analysis Guide. Volume 3. 2nd ed. Pretoria: Water Research Commission. WRC report no. TT 129/00.

Water Research Commission (WRC). 1999. Quality of domestic water supplies. Assessment, analysis and sampling guide. Volume 1. 2nd ed. Pretoria: Water Research Commission. (WRC report no. TT 101/98.).

SECTION C: TECHNICAL GUIDELINES FOR NF/RO PLANTS

The technical guidelines for the nanomembrane processes (NF and RO) are the same since both processes are based on the same principles. The major differences between them being the type of the network structure of the membrane and the operating pressure. There are several technical guidelines[25] that should be observed for the proper operation of nanomembrane cross-flow module reactor pilot water treatment plant at Batlhaping Primary School (BPS) in Madibogo village which include the following:

1.1 PRETREATMENT

NF/RO water treatment plants should have a pre-treatment stage which will protect the primary treatment technology from problems such as fouling. The pre-treatment in membrane processes is accomplished through filtration by cartridge filters. These filters remove particles and by-products of growth of micro-organisms from the feed water. Another form of pre-treatment is one in which one membrane process precedes another with the ultimate objective of producing water of higher quality. The ultrafiltration (UF) membrane process is generally used as pre-treatment in the production of potable water. It prolongs the life of the membrane.

1.2 THE SILT DENSITY INDEX (SDI)

The silt density index (SDI) is used for monitoring membrane fouling in NF and RO water treatment plants. The fouling is caused by the deposition, precipitation, accumulation of biological growth, physical and/or chemical reaction of feed water components. For the efficient operation of a membrane plant, the SDI should be less than three.

1.3 CHLORINE

There should be no free chlorine in the feed water as it reacts with the membrane components. All chlorine should be removed from the feed water before it can be permeated through the membrane.

1.4 ROUTINE MONITORING OF MEMBRANE PLANT DURING OPERATION

The proper operation of a membrane plant is assessed by monitoring two parameters:

- the pressure drop across the cartridge filters using pressure gauges on the common inlet and outlet;
- completing a log sheet to maintain a plant operating record as shown in Table 1 below.

Table 1. Log sheet for the operation of a membrane water treatment plant

	Unit	Design	1	2	3	4	5	6	7
Date									
Time									
Feed pump PP1 Hours									
Cartridge filter inlet pressure	kPa	590							
Cartridge filter outlet pressure	kPa	460							
Cartridge filter diff. press.	kPa	Max 100							
RO inlet pressure	kPa	1500							
RO concentrate pressure	kPa	1400							
RO pressure drop	kPa	Max 200							
RO permeate flow rate	l/h	460							
RO concentrate flow rate	l/h	115							
RO recycle flow rate	l/h	985							
RO feed flow rate	l/h	1560							
RO recovery x100	%	80							
Feed pH	pH	7							
Feed conductivity	uS/cm	2400							
Permaeate pH	pH	6.7							
Permeate conductivity	uS/cm	2000							
Brine pH	pH	7							
Brine conductivity	uS/cm	9000							
Feed water temperature		20							

Table 1 was adapted from the Operating and Maintenance Manual of North-West University BWRO plant which was supplied by Malutsa (PTY) Ltd.

Comments

1.5 PRESERVATION OF MEMBRANES

NF and RO polymeric membranes have to be preserved in a 0.1% sodium metabisulphite solution if they are not going to be used for more than seven days.

1.6 MEMBRANE CLEANING

NF and RO membranes have to be cleaned when the flux drops to below 15%. The decrease in flux is calculated from the operating data that is recorded twice daily on a log sheet (see Table 1). The various solutions that are required for cleaning membranes depend on the foulants on the membrane surface. Table 2.3 (section A) gives the membrane cleaning solution concentrations that are required to remove the various foulants.

Annexure B-A Development of standardized water attitude scale – 2006

Attitude statement	Agree	Neutral	Disagree
	1	2	3
Water quality		***Score***	

Physical appearance

1. Crystal clear soluble water is good for human consumption
2. I know that microbiological and biological contaminants are responsible for bringing illness
3. The milky colour of water indicates that the water has just been cleaned
4. I hate the smell of disinfectant in drinking water
5. I do not appreciate water that has a salty, bitter, sour and unpleasant taste
6. I would probably accept water with a clear crystal colour without asking questions
7. Physical appearance (colour, smell and taste) of water is the only single indicator that determines which water is good for human consumption
8. It is important to know what water consists of
9. I am interested in finding out about water content
10. No water should be accepted without knowing its content
11. The rain water collected from the roof is an example of water of a good quality
12. I enjoy using rain water for household activities
13. I would boil rain water collected from the roof before using it
14. Water quality is related to some health or disease infections
15. I am agitated by the outbreak of diseases related to water quality
16. Stored water in unwashed containers can be infectious
17. I dislike washing water containers
18. Washing water containers is a routine
19. It is probably important to know about water quality

Attitude statement	1	2	3
20. I am definitely not interested in playing a role in reducing the outbreak of diseases			
Safe drinking water			
21. I know that purified water is safe drinking water			
22. Purified water would satisfy my household activities			
23. I would definitely appreciate receiving purified water			
24. I understand what water purification is			
25. I do not trust people who purify water			
26. Understanding the process of water purification would secure my doubts about the safety of the process			
27. Taking care of the container used to store water is not important			
28. I take pleasure in washing and keeping the containers that collect water			
29. Learning about taking care of the containers for water containers is not important			
30. I am aware that water can also be contaminated from collection of unclean vessels or storage containers in the home			
Water quantity			
Availability			
31. Water has to be available all the time			
32. I become disappointed when the water is unavailable for use			
33. I would reject a water service that is not reliable			
34. Having my own yard or in-house tap would give you control over water utilization			
35. I hate sharing water with other people			
36. There is no need for me to be concerned about communal taps			

Hygiene and safety

37. Animals should not share drinking from the communal taps
38. I am happy to share communal taps with animals
39. I would certainly consider providing animals with a separate drinking water source from human

Attitude statement	1	2	3

Distance of water sources

40. Most of the communal taps in this village do not comply with RDP standards *(200m away from the households)*
41. I become angry when I have to buy or pay someone to provide water for me
42. If I could know how I can solve this problem I would be part of the problem solvers

Affordability

43. I know that we should not pay for water
44. Receiving water for free excites me
45. If there is a need for me to pay for water service I am eager to do so

Sharing responsibilities

Community

46. I believe that communities have a role to play towards taking care of the water service
47. I am dedicated on being involved in protecting and taking care of our communal water service
48. I would hesitate to be part of the water committee

Government

49. Government role is to facilitate the development of our communities
50. The government has to provide development services to the communities all the time
51. I am comfortable with waiting for the government to provide me with anything when they can
52. I would be reluctant to take an initiative to improve my situation even if I have enough information

Free Basic Water Policy

Human/consumer rights

53. I am aware of my human rights towards receival and utilization of water service
54. Knowing my human rights about receival and utilization of water service secures my fears
55. Knowing my human rights about receival and utilization of water service mean nothing to me

Attitude statement	1	2	3

56. I know that human rights are consumer rights
57. I know where go when I am experiencing problems with water

Awareness

58. FBWP means no paying for water service
59. I am content about receiving free water
60. There is no need for rural area people to conserve water

Transfer of information

61. The politicians were sincere when they promised us free recieval of water
62. I am at ease that I will never pay for any water service
63. I would turn down any water supply that requires me to pay anything for water service provision

Attitude statement	1	2	3

Household utilization

64. Water good for human consumption does not have to satisfy the household chores
65. I feel confident when using water that satisfies my household activities
66. Knowing about the water quality standards is my priority
67. Receival of good drinking water would definitely improve the health status of our community
68. I am satisfied with receiving any kind of water
69. There is definitely no need to worry about the water quality standard
70. Bad water quality has a bad effect on household activities

Annexure B-B Results of focus groups held when the attitude statements was standardized

Attitude statement **1 = Agree 2= Neutral 3 = Disagree**

Water quality

Physical appearance	***Reasons for the chosen answer***
1. The milky colour of water indicates that the water has just been cleaned	Agree The white colour indicates that the water has chemicals such as limestone. Disagree Naturally the water has to be colourless
2. I hate the smell of disinfectant in drinking water	Agree It can infect people Indicates that the water is not good for drinking purposes It affects the taste It can cause diseases (Probe more on their own experience with the water that had/has disinfectant) Disagree) It shows that the water has been purified/cleaned
3. The slight salty taste of water is acceptable	
4. Physical appearance (colour, smell and taste) of water is the only single indicator that determines which water is good for human consumption	Agree It indicates whether the water is purified or not The colour, taste and smell are the most important determining factors The colour is the most important determining factor indicating whether or not the water is good for drinking purposes on not Disagree The water can look clean but not be good for drinking purposes
5. No water should be accepted without knowing its content	Agree You will not know whether the water has been purified or not If you lack the information about the contents you might drink water that will be harmful or infectious The water might be poisonous without knowing The water might be contaminated with germs

	Disagree Why should you bother the?
6. Ground water is as good as rain water	
7. The rain water collected from the roof is an example of water of a good quality	Agree Rain water is natural and pure It does not have any chemicals It is clean Disagree The water might not be safe coming from the roofs (Probe on why is that?)
8. I enjoy using rain water for household purposes	Agree It is good for laundry and gardening purposes It economizes or minimizes the use of soap It is has a wonderful taste It is natural
9. I am definitely not interested in playing a role in reducing the outbreak of diseases	Agree Disagree I have to help myself and my community to reduce the number of outbreaks. By so doing I will be minimizing the disease infection in my community. As a community member I have a responsibility to make sure that the community is safe. If I do not play a role we can all be infected (Probe on what activities are they engaged in to protect the community)
Safe drinking water	
10. I have some knowledge about water purification	Agree Water that will not cause diseases The water becomes germ free It is good for health Disagree
11. I do not trust people who clean water	Agree They do not have the skills to do what they are doing They might kill us Doubtful skills Disagree They are helping us to make sure that the water is clean
12. Water storage containers may affect the purity of water	Agree Disagree If they are unwashed they can cause diseases

	To keep water clean If the containers are not clean they can cause germs
13. I am happy to share communal taps with animals	Disagree They have their own diseases they can infect us They can transfer germs to our water They should have their own place to drink
Household utilization	
14. Water good for human consumption does not have to satisfy the household chores	Agree Disagree If it is good for drinking then it can be used everywhere Purified water is good for drinking and household chores
15. Receival of good drinking water would definitely improve the health status of our community	Agree Some water do not have a good taste
16. I am satisfied with receiving any kind of water	Disagree Some of it might not be safe Some might be contaminated Some water is not purified Sometimes it is sewage water Agree It is good for all of us
17. There is definitely no need to worry about the water quality standard	Disagree We have to drink clean water It is not good to drink water without knowing its value Our lives depend on it We should drink water that we know it is safe
Water quantity ***Availability***	
18. I do not like sharing water with other people	Agree Some people are irresponsible which makes it uncomfortable it share communal taps with other people Other people misuse and vandalize taps Disagree We have to share because the water is a scarce resource.
19. There is no need for me to be concerned about communal taps	Agree Disagree

	I have to take responsibilities as I am a user If it is damaged I will be the who will suffer
Distance of water sources	
20. I am not happy that water the taps are far from my home	
21. If I could have in yard-taps I would not really care about how much water I use	
22. The far distance of communal taps encourages minimal usage of water	
Affordability	
23. I know that we should not pay for water	Agree The government/politicians promised us free water I am not working I have no income
24. If there is a need for me to pay for water service I am eager to do so	Agree If I do not pay they will refuse to give me water If I do not pay they will cut the water I will only pay if the water has a good taste and the price is affordable I cannot live without water Disagree
25. I am willing to pay for the yard connection water services	
26. Installing in-house water connection means more cost	
Community	
Sharing responsibilities	
27. I would hesitate to be part of the water committee	Disagree I want to be responsible
Government	
28. I am comfortable with waiting for the government to provide me with anything including water if they can	Agree I do not mind waiting It should not take longer I am needy Disagree Government always takes long to deliver
29. I would be reluctant to take an initiative to improve my standard of in relation to water even if I have enough information	Disagree I have to act responsible Keeping the knowledge and doing nothing about it will be killing the nation I will be the one suffering Agree

30. I expect the government to provide me with services such as water	
Human/consumer rights	
Free Basic Water Policy	
31. I am aware of my human rights towards utilization of water service	Agree I have been trained To look after it
32. Knowing my human rights about receival of water service secures my fears	I know my rights
33. Knowing my human rights about receival and utilization of water service mean nothing to me	Disagree It has a great meaning I will be irresponsible
34. I know where to go when I am experiencing problems with water	Agree I will go to the relevant people
Awarenes*s*	
35. FBWP means no paying for water services	It is self explanatory I do not pay for water
36. I am content about receiving free water Can we discard this one and replace it with the following one?	Disagree I should be responsible Government promised us I have been promised free water Agree I should use water responsibly even if it is free
37. FBWP is only applicable to the people who have individual taps	
Transfer of information	
38. The politicians were sincere when they promised us free recieval of water	Agree We are not paying We are receiving free water
39. I would turn down any water supplier that requires me to pay anything for water service provision	Agree Some criminals can advantage of us and take our last cent We want an office for relevant people

Annexure B-C Water attitude questionnaire

WATER QUESTIONNAIRE

Instruction

Read the following statements and in an appropriate box write 1 if you agree, 2 neutral and 3 if you disagree. Please give reasons for your chosen answer.

DEMOGRAPHIC INFORMATION

Name

Sex

Age

Level of education

Village section

Statement	Agree = 1	Neutral g = 2	Disagree = 3	Reasons for the chosen answer
Physical appearance				
1. I want my water to be clear and not milky				
2. Water needs to be purified				
3. I hate the smell of disinfectant in drinking water				
4. the slight salty taste of water is acceptable				

5. Physical appearance (colour , smell and taste) of water is the only single indicator that determines which water is good for human consumption
6. No water should be accepted without knowing its content
7. Ground water is as good as rain water
8. The rain water collected from the roof is an example of water of a good quality
9. I enjoy using rain water for household purposes
10. I am definitely not interested in playing a role in reducing the outbreak of diseases

Safe drinking water

11. I have some knowledge about water purification
12. I do not trust people who clean water
13. Water storage containers my affect the purity of water
14. I am happy to share communal taps with animals

HOUSEHOLD UTILIZATION

15. Water good for consumption does not have to satisfy the household chores
16. Receival of good drinking ate would definitely improve the health status of our community
17. I am satisfied with receiving any kind of water
18. There is definitely no need to worry about the water quality standard

WATER QUANTITY

Availability

19. I do not sharing water with other people
20. There is no need for me to be concerned about communal taps

Distance of water sources

21. I am not happy that water taps are far from my home
22. If I could have in-yard taps I would not really care about how much water I use
23. The far distance of communal taps encourages minimal usages of water

Affordability

24. I know that we should not pay for water
25. If there is a need for me to pay for water service I am eager to do so
26. I am willing to pay for the yard tap connection water service
27. Installing in-house water connection means more cost

SHARING RESPONSIBILITIES

Community

28. I would hesitate to be part of water community

Government

29. I am comfortable with waiting for the government to provide me with anything including water if they can
30. I would be reluctant to take an initiative to improve my standard in relation to water even if I have enough information
31. I expect the government to provide me with services such as water

FREE BASIC WATER POLICY (FBWP)

Human/consumer rights

32. I am aware of my human rights towards utilization of water service.
33. Knowing my human rights about receival of water service secures my fears

34. Knowing my human rights about receival and utilization of water service mean nothing to me
35. I know where to go when I m experiencing problems with water

Awareness

36. FBWP means no paying for water service
37. I am content about receiving free water
38. FBWP is only applicable to people who have individual taps

Transfer of information

39. The politicians were sincere when they promise us free receival of water
40. I would turn down any water supplier that requires me to pay anything for water service provision

Agree =1 Neutral = 2 Disagree = 3

Thank you for taking your time to complete this questionnaire, your inputs are valuable.

DIPOTSO KA GA METSI

Ditaelo

Bala dipolelo tse di latelang mme o kwale mole bokosong 1 fa o dumela, 2 fa o le magareng , 3 fa o sa dumelane. Neela mabaka goya ka tlhopo ya gago.

DEMOGRAPHIC INFORMATION

Leina

Bong

Bogolo

Borutegi

Lefelo

Dipolelo	**Ke a dumela = 1**	**Ke magareng = 2**	**Ga ke dumelane = 3**	
	Boleng Jwa Metsi			
Tebego ya metsi				***Mabaka***
1. Metsi a ke dirisang a tshwanetse go galalela eseng go nna masweu				
2. Metsi a tshwanetse go phepafadiwa				
3. Ga ke rate monko wa sebololaya ditwatsi mo metsing a a nowang				
4. Metsi a a utlwang letswai ga nyenyane a a amogelesega				

5. Tebego (mmala, monko le tatso) ya metsi ke seshupo se le sengwe fela sa gore ke metsi a feng a a siametseng go ka nowa ke batho
6. Metsi a tswang kwa tlase ga lefatshe a si ame fela jaaka a pula
7. Ga gona metsi ape a a tshwanetseng go amogelesega ntle le kitso ya gore a na le eng
8. Metsi a a tswang mo dithulelong ke sekai sa metsi a a siamemeng
9. Ke itumela go dirisa metsi a pula mo bakeng a a faraloganeng mo lapeng
10. Ga kena kgatlego gotlhelele mo go nneng le seabe mo go fokotseng go nna teng ga malwetse

Mesti a a bolokesileng go ka nowa

11. Ke na le kitso ka phepafatso ya metsi
12. Ga ke tshepe batho ba ba phepafatsang metsi
13. Dikgamelo tsa metsi dikgona go kgotlela metsi
14. Ke itumelela go tlhakanela ditepe tsa botlhe le diphologolo

TIRISO YA METSI MO LA PENG

15. Metsi a a siametseng go nowa ke batho ga a tshwanela go ka dirisetswa ditiro tsa ma lapeng

16. Kamogela yametsi a a siameng go ka tsholetsa itekanelo ya sechaba
17. Ke kgotsofalela go amogela metsi mangwe le mangwe
18. Ga go tlhokege gore o tshwenyege ka seemo sa metsi a a siameng

SELEKANYETSO SA METSI

Gonna teng

19. Ga ke rate go dirisa metsi le batho ba bangwe
20. Ga ke tlhoke go tshwenyega ka ditepe tsa botlhe

Sekgala sa metsi

21. Ga ke itumelele bokgakala jwa metsi gotswa mo legaeng lame
22. Fa ke ka nna le metsi mo segotlong ke kase tlhokomele gore ke dirisa metsi a a kae
23. Go nna kgakala ga ditepe (metsi) tsa botlhe go rotloetsa tiriso e e ko tlase ya metsi

Bokgoni

24. Ke itse gore ga re a tshwanela go duelela metsi
25. Fa go na le tlhokego ya go duelela tiriso ya metsi ke ka dira jalo
26. Kena le phisego ya go duelela tiriso ya go tsenngwa gametsi mo segotlong sa me

27. Go tsenya metsi mo segotlong go raya dituelo tse dintsi

GO AROGANYA MAIKABELO

Sechaba

28. Ke ka goga dinao go kanna karolo ya komiti ya metsi

Puso

29. Ke dula ke repile ke letetse puso go nneela dilo tsotlhe go sita le one metsi fa e le gore go ka kgonega
30. Ke ka goga dinao go tsaya maikarabelo go tsholetsa seemo sa metsi le fa ke ntse ke nale kitso e e lekaneng
31. Kena le tsholofelo gore puso etshwanetse go nneela ditirelo ditshwana le metsi

FREE BASIC WATER POLICY (FBWP)

Ditshwanelo tsa batho/Ditshwanelo tsa badirisi

32. Ke itse ditshwanelo tsame tsa botho mabapi le tiriso ya metsi.
33. Ke itse ditshwanelo tsa botho ka kamamogelo ya metsi go tlosa letshogo la me
34. Goitse ka ditshwanelo tsame tsa batho le tiriso ya metse ga go reye sepe mogonna
35. Ke itse kwa ke tshwanetseng go ya teng fa ken a le mathata ka metsi

Kitso

36. FBWP e bolela gore diterelo tsa metsi ga di duelwe
37. Ke itumelela go amogela metsi a mahala
38. FBWP ke ya ba banang le ditepe tsa bona fela

Go fetisetsa kitso

39. Bo radipolitiki bane ba bolela nnete fa bare solofetsa metsi a mahala
40. Ke ka seamogele sepe sesetlang ka ba baneelang metsi mme sebatla tuelo ya sengwe se se mabapi le go neelana ka metsi

Ke a dumela =1 ke Magareng = 2 A ke dumelane = 3

Re le bogela nako ya gago e o tshotseng go araba de potso. Di tshwaelo tsa gago re di tsaya di le bo tlhokwa.

Annexure B-D Knowledge questionnaire

WATER QUESTIONNAIRE

DEMOGRAPHIC INFORMATION

Name: ________________________________
Sex: ________________________________
Age: ________________________________
Level of education: ______________________
Village section: ______________________

Instructions

Read the statement carefully; please tick in the box true if you agree and false if you do not agree with the statement

	WATER QUESTIONNAIRE 2006	**TRUE**	**FALSE**
1	Water that looks clean and clear is suitable for drinking.		
2	Water from rivers is suitable for drinking water.		
3	We must receive all our water free of charge.		
4	The government must make sure that everybody receives clean and fresh water daily.		
5	Water can be stored in any container and no lid is necessary.		
6	Water containers need to be washed as often as possible.		
7	Taps that leak will be fixed by the government.		
8	The RDP provides water.		
9	South Africa is a dry country and we must save water.		
10	All water that is purified tastes bad.		
11	Toilets must be built near your borehole.		
12	If your water is not suitable to drink the only thing you can do is complain.		
13	You are not allowed to form part of a Water Users Association		
14	Water can be purified by throwing cement into it.		
15	Washing your hair in your village's water will turn your hair discolour your hair (ginger)		
16	The community does not like strangers to purify their water		
17	The machine that is used to purify the water is not our responsibility		
18	We can survive without water		

19	Government does not care if we have do not have enough clear, safe drinking water.		
20	The water purifying machine can be costly		

DIPOTSO KA GA METSI

DEMOGRAPHIC INFORMATION

Leina:_______________________________________
Bong:_______________________________________
Bogolo:_______________________________________
Borutegi:_____________________________________
Lefelo: _______________________________________

Detaelo

Bala di polelo tse di latelang mme o tshwaye ka mo le bokosong ee fa o dumelana kgotsa nyaa fa o ganetsa.

Dipolelo	Ee	Nyaa
1. Metsi a a lebegang a le phepha e bile a galalela a siametse go ka nowa		
2. Metsi a a mo melapong a siametse go ka nowa		
3. Re tshwanetse go bona metsi otlhe mahala		
4. Go matshwanedi gore puso e dire gore mongwele mongwe a bone metsi a a phepa tsatsi lengwe le lengwe		
5. Metsi a ka nna mo kgamelong nngwe le ngwe ebile ga a tlhoke go ka khurumelwa		
6. Dikgamelo tsa metsi ditlhoka go phepafadiwa nako lenako		
7. Ditepe fa di dutla di tla ba akangwa ke puso		
8. Metsi a neelwa ke RDP		
9. South Africa ke naga e e senang metsi ka ga jalo re tswanetse ra somarela metsi		
10. Metsi otlhe a a phepafaditsweng ga a na tatso e emanate		
11. Matlo boithusetso a tshwanetse go agiwa gaufi le mo go nang le metsi a a tswang kwa tlase ga lefatshe		
12. Fa metsi a gago a sa siamela go ka nowa selo sese sengwe se o ka se dirang ke go ngongorega		
13. Ga o a letlelelwa go kanna karolo ya Mokgatlo wa tiriso ya metsi		
14. O ka tshela samente go phepafatsa metsi		
15. Fa o ka tlhapa moriri wa gago ka metsi a ko magaeng a ka fetola mmala go nna mohibidu (ginger)		
16. Badudi ba motsega ba rate gophepafatswa metsi ke batho ba bas a ba itseng		

17. Mochini o o diriswang go phepafatsa metsi gase maikarabelo a rona		
18. Botshelo bo ka tswelela ntle le metsi		
19. Puso ga e na sepe le fa re sena metsi a a lekaneng a a phepa ebile a bolokesegile		
20. Mochini o o diriswang go phepafatsa metsi o dirisa madi a mantsi		

Re le bogela nako ya gago e o tshotseng go araba de potso. Di tshwaelo tsa gago re di tsaya di le bo tlhokwa.

Annexure B-E Learning outcomes and education and training methodologies

Outcomes	Content	Method	Media	Assessment
To determine prior knowledge on quality of water	A. WATER QUALITY			
	1. Ice breaker	Game		Observation
	2. -Where do you get water? (Water sources) - Is the water that you get from there sources safe for drinking? Give reasons for your answer. -Do you think there can be measures taken to ensure that you get safe water? Explain	Question and answer Discussion	Flip chart	Base-line Prior knowledge of learners is determined through question and answer as well as discussion
To determine knowledge on water sources	3. Water cycle	Verbal information Role play Music	Poster Water education and training programme (WET-programme) p.13-14	Observation by means of group participation
Able to understand the difference between underground and rain water	4. -Rain water and underground water -The quality of rain water and underground water	Experiment Lecture	Groundwater Model Poster (water cycle)	Observation Listening to presentation of results
Ability to assess water based on three water determinants	5. -Properties of water -Physical: smell and taste -Microbiological: microbes invisible – need a microscope to see them e.g. germs, fungi. Results in diseases like cholera, typhoid, fever diarrhoea	Discussion Lecture Demonstration	Flip chart Three glasses containing different types of water. Glass 1: Salty/hard wooer Glass ²: Swimming pool water Glass 3: Distilled or mineral water Worksheet	Comparison on a worksheet
-To determine knowledge on water contaminants -To determine knowledge on prevention of water contamination	6. Water contamination -Responsible behaviour to avoid water contamination -Water purification	Discussion Question and answer Demonstration	Poster (water contaminants) Poster (how to safe water) White cloth, Jink, 25ℓ	Listen to group presentation Observation

through responsible behaviour -To develop skills in home water purification	-Cost in water provision Purification Maintenance Installation	Lecture Discussion	water, 1ℓ water	
-To determine knowledge on the costs of water provision	-3 glasses of water (making choices)	Focus groups discussion Choices towards safe water	Tape recorder Laptop	Listening to responses
-To determine the knowledge on consumer rights	B. WATER QUANTITY 7. Do you know your rights as far as water is concerned?	Question and answer Discussion	Poster Flip-chart	Prior knowledge
-To determine the knowledge on free basic water policy (FBWP)	-RDP-developed principles on provision of safe water to people	Lecture	Poster Flip-chart	Observation of role play
-To determine the knowledge of the structures of the municipality as service providers	-DWAF-adopted the principle and developed (FBWP)	Role play		
	-Local government-mandated to provide the services to people and to incorporate the FBWP	Question and answer		
	-Three types of municipalities			
-To determine the awareness of existing organizations in the community and how they can use them to their advantage -Develop the skills and knowledge on the need for active participation on problems experienced e.g. water	C. STAKE HOLDERS AND SHARING OF RESPONSIBILITIES 8. Which social organizations exist in your community: -Which issues of the community do they address? -Are they influential? Give reasons -Is there a need for new organization?	Question and answer Discussion		Prior knowledge
-To determine knowledge on channels to follow to resolve problems	-Different governing structures e.g. National, Provincial, Local government, community (stake holders)	Lecture Discussion Debate	Flip-chart WET-programme	Listen to the debate
	-Procedure to follow to complain			
	-Different roles			

	played by governing structures			
	-Debate: who is not doing his job			
-To determine the water related problems in the community -To determine the knowledge on the negative effect of chemical/ingredients in the products they add to water	D. HOUSE HOLD WATER UTILIZATION 9. What do you use water for? - How is Madibogo water? -Which coping mechanisms do you use? -Are they helping/reducing the problem or are they increasing the problem?	Question and answer	Water sample Powdered soap Paraffin Cement	Prior knowledge Observe Listen to presentation
	-Display different products used as a solution to hard water	Compare, analyze		
	-Participants to explore ingredients, precautions and instruction on how to use the products	Demonstration		
	-Lecture on effects of the detergents on their health and skin			

Annexure B-F Water service provision education and training programme

WATER SERVICE PROVISION EDUCATION PROGRAM
12-15 DECEMBER 2006
Presented by Mrs Mavis Molefe and Ms Unathi Kolanisi from North-West University Potchefstroom Campus
DAY ONE
INTRODUCTION SESSION

Theme: Prior knowledge and attitude measurement

Time	Activity
09:30am-10:00 am	Tea/ coffee
10: 00 am-10:15 am	• Opening Prayer • What brings us together
10:15 am-10:30 am	Getting to know each other
10:30 am-11:00am	Completion of knowledge questions
11:00 am-12:30 am	Attitude questionnaire completion and discussion
12:30 am-1:00 pm	Refreshments
1:00 am	Disperse

DAY TWO

Theme: Water quality and water quantity

Time	Activity
09:30am-10:00 am	Tea/ coffee
10: 00 am-10:05 am	Opening prayer
10:05 am-10:20 noon	• Introduction of the topic – activity • Participants expectations • What do they know?
10:20 am-11:00am	Topic introduction and presentation
11:00 am-11:30 am	Focus group discussion
11:30 am-12:00 noon	Reflections and lessons learnt
12:00 noon-1:00pm	Refreshments
1:00pm-1:20 pm	• Introduction of the topic – activity • Participants expectations What do they know?
1:20 pm-2:00 pm	Presentation of the topic
2:00 pm-2:30 pm	Focus group discussion
2:30 pm-3:00pm	Reflections and lessons learnt
3:00 pm	Disperse

WATER SERVICE PROVISION EDUCATION PROGRAM
12-15 DECEMBER 2006
Presented by Mrs Mavis Molefe and Ms Unathi Kolanisi from North-West University Potchefstroom Campus

DAY THREE

Theme: Sharing responsibilities and Free Basic Water Policy

Time	Activity
09:30am-10:00 am	Tea/ coffee
10: 00 am-10:05 am	Opening prayer
10:05 am-10:20 noon	• Introduction of the topic • Participants expectations • What do they know?
10:20 am-11:00am	Topic presentation
11:00 am-11:30 am	Focus group discussion
11:30 am-12:00 noon	Reflections and lessons learnt
12:00 noon-1:00pm	Refreshments
1:00pm-1:20 pm	• Introduction of the topic • Participants expectations What do they know?
1:20 pm-2:00 pm	Presentation of the topic
2:00 pm-2:30 pm	Focus group discussion
2:30 pm-3:00pm	Reflections and lessons learnt
3:00 pm	Disperse

DAY FOUR

Theme: Household utilization and Post knowledge and attitude measurement

Time	Activity
09:30am-10:00 am	Tea/ coffee
10: 00 am-10:05 am	Opening prayer
10:05 am-10:20 noon	• Introduction of the topic • Participants expectations • What do they know?
10:20 am-11:00am	Topic presentation
11:00 am-11:30 am	Focus group discussion
11:30 am-12:00 noon	Reflections and lessons learnt
12:00 noon-1:00pm	Refreshments
1:00pm-1:30 pm	Completion of knowledge questions
1:30 pm-2:30 pm	Attitude questionnaire completion and discussion
2:30:00 pm	Disperse

Annexure B-G Programme evaluation questionnaire

EVALUATION FORMS

WATER SERVICE PROVISION EDUCATION PROGRAM

1. Content

Was the information presented in the session relevant to the topic?
Yes 1
No 2
Comments:

Was the time enough for the session?
Yes 1
No 2
Comments:

Was the topic treated to your satisfaction?
Yes 1
No 2
Comments:

Was the content well organised?
Yes 1
No 2
Comments:

Were the objectives clear and relevant to the topic?
Yes 1
No 2
Comments:

2. Outcomes

Were the outcomes of the topic discussed reached?

Yes	1
No	2

Comments:

3. Teaching materials

Were they relevant to the topic discussed?

Yes	1
No	2

Comments:

Were they helpful in understanding the topic?

Yes	1
No	2

Comments:

Were they interesting?

Yes	1
No	2

Comments:

Were they easy to read?

Yes	1
No	2

Comments:

Were they easy to read?

Yes	1
No	2

Comments:

Was the level of instruction suitable for you?
Yes 1
No 2
Comments:

Were teaching methods interesting?
Yes 1
No 2
Comments:

Did the method allow you to participate?
Yes 1
No 2
Comments:

4. Trainer

Did the trainer have knowledge of the subject matter?
Yes 1
No 2
Comments:

Was the trainer able to arouse your interest?
Yes 1
No 2
Comments:

Was the trainer encouraging you to participate?
Yes 1
No 2
Comments:

Did the trainer voice your ideas?
Yes 1
No 2
Comments:

Was the trainer able to relate the topic to the objectives?

Yes	1
No	2

Comments:

Was the trainer able to mange time efficiently?

Yes	1
No	2

Comments:

Did the trainer reach the outcomes of the topic?

Yes	1
No	2

Comments:

Annexure B-H Sensory evaluation form

Sensory evaluation of water **Madibogo** **July 2007**

You have received two coded water samples.
Please taste the samples in the order presented.
Taste the samples and tick the box of the sample with the most acceptable taste.
Remember to eat a cracker between tasting the two samples.

☐ ☐

FFG FLG
Please not any further comments regarding the following:
Appearance:
Smell:

Thank you for your time.

Sensory evaluation of water **Madibogo** **July 2007**

You have received two coded water samples.
Please taste the samples in the order presented.
Taste the samples and tick the box of the sample with the most acceptable taste.
Remember to eat a cracker between tasting the two samples.

☐ ☐

FLG FFG
Please not any further comments regarding the following:
Appearance:
Smell:

Thank you for your time.