Technical and Social Acceptance Evaluation of Microfiltration and Ultrafiltration Membrane Systems for Potable Water Supply to Rural Communities

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TT 374/08

Water Research Commission

TECHNICAL AND SOCIAL ACCEPTANCE EVALUATION OF MICROFILTRATION AND ULTRAFILTATION MEMBRANE SYSTEMS FOR POTABLE WATER SUPPLY TO RURAL COMMUNITIES

Report to the

Water Research Commission

by

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WRC Report No TT 374/08

March 2009

Obtainable from

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The publication of this report emanates from a project entitled: *Technical and social acceptance evaluation of novel micro filtration and ultra filtration membrane system for portable water supply to rural and remote communities*
(WRC Project No. K5/1227)

ISBN: 978-1-77005-781-4
Printed in the Republic of South Africa

EXECUTIVE SUMMARY

Background

In a project that was undertaken to investigate the upgrading needs of existing small water treatment plants in South Africa (Swartz, 1998), it was found that the major problems with sustainability of these small systems are the difficulty of controlling chemical treatment processes, especially when the raw water quality changes; inadequate disinfection of the final water as a result of lack of proper or reliable dosing systems and dosage control; poor back-up service by equipment suppliers; lack of training of plant operators. Another very important problem is the lack of community involvement, especially over the longer term. It has been shown that the acceptance of technologies by the community is of utmost importance to ensure a successful water supply project.

Microfiltration technology provides a promising alternative to chemical treatment in providing a good quality drinking water. Apart from providing a filtration system that can effectively remove impurities such as turbidity, algal cells and some colour causing compounds to produce a high-quality filtrate, it also acts as a barrier for removal of microbial contaminants such as bacteria and protozoan parasites (*Giardia* and *Cryptosporidium*). It therefore largely eliminates the use of coagulation chemicals and reduces the level of chemical disinfection required for virus inactivation or the maintenance of disinfectant residuals in the distribution systems. Microfiltration has decreased operational complexity compared to chemical treatment (systems are automatic and require minimal operator attention). An important advantage is that the treatment equipment does not require adjustment during varying feed water quality, such as occurrence of high turbidity, so that the facility can operate unattended. The finished water quality is largely independent of raw-water quality. The systems can satisfy more stringent water quality goals expected in future. As these technologies are further developed, its capital and operating cost are coming in line with conventional water treatment systems.

To date, the main draw-back with the application of membrane water treatment systems for treating variable quality surface waters has been fouling of the membranes, and research has focussed on providing appropriate pre-treatment systems and effective membrane cleaning procedures.

It was therefore proposed that microfiltration and ultrafiltration technologies be evaluated for treatment of surface waters, and that, in particular, the study includes the determination of social acceptance factors for transferring the new technologies to the community, so that the whole water supply project using these membrane systems can be completed successfully and that the systems be operated and maintained to a high standard by the community to ensure sustainability. This will in turn ensure that the community receives the full benefit of these new technologies that can improve the quality of life by consistently providing safe and high quality drinking water.

Aims of the Project

The overall objective of the project was the technology transfer of microfiltration and ultrafiltration membrane water treatment systems for drinking water supply to developing communities in South Africa.

The specific aims of the project were:

a. Evaluation of membrane microfiltration and ultrafiltration technologies for potable water supply to rural and remote communities.

b. Drawing up of guidelines for the application of these membrane treatment technologies for treatment of feed waters of varying quality.

c. Determination of application ranges for each of the two technologies for treating different raw water types, *i.e.* guidelines on which of the two technologies to use for a specific type and quality range of raw water.

d. Provision of social acceptance guidelines for long-term sustainability of these treatment systems in small and remote communities.

e. To understand the social acceptance factors for the use of membrane system water supply to rural and developing communities.

Methodology

During the project initiation stages, problems were encountered with the supply of the membrane systems originally intended for the technical and social acceptance evaluation in a community. Another supplier of membranes (microfiltration and ultrafiltration) had to be found who would also be able to construct a mobile pilot plant that could be used for the evaluation at a suitable community. During this period a number of options for engaging such a supplier were investigated, which led to some delay in the actual design and construction of the mobile pilot plant. While this process was taking place it was decided that initial tests to evaluate an ultrafiltration membrane will be done on bench-scale at the Cape Peninsula University of Technology (CPUT) (previously Peninsula Technikon).

The bench-scale studies using an ultrafiltration membrane supplied by the Institute of Polymer Science of the University of Stellenbosch, was undertaken by Mr J Setlolela of CPUT for his M.Tech studies. The evaluation of the UF membrane was done on four waters, namely groundwater (borehole water at CPUT), tertiary treated wastewater from the adjacent municipal wastewater treatment plant, eutrophic water from Voëlvlei Dam, and coloured water from Duivenhoks River in the South-West Cape.

While the bench-scale studies were in progress and arrangements being sought for construction of the mobile pilot plant, discussions and preliminary investigations were conducted with the Zinghutu community near Queenstown (in the jurisdiction area of Chris Hani District Municipality). The discussions and site visits were facilitated by Rural Support Services. A report was drawn up by RSS in which the issues raised by the community and authorities during these discussions and preparatory visits were captured. This led to proposals for further considerations of prevalent social acceptance factors within this community for supply of a water treatment system to supply the community with clean drinking water.

Quality Filtration Systems (QFS) undertook to construct a mobile pilot plant for use in the field work, and a 500 litres per hour plant was built consisting of one MF and one UF membrane (and also including an ozone doser and granular activated carbon columns). The plant was tested in Stellenbosch after which it was relocated to Caledon to do trials as part of the initial tests (the tests were performed on a coloured water). During these tests, it was proposed that the pilot-scale study at a small community will be done at the community of Genadendal, some 35 km to the north of Caledon. Initial discussions with the local authority (Theewaterskloof Municipality) and community members were very positive and it was decided to perform the tests in the Voorstekraal community of Genadendal.

The social acceptance study at Voorstekraal was done by the Health Sciences Department of CPUT. This consisted of holding initial and preparatory meetings with the community (***Phase 1: Pre-implementation phase***) before the pilot plant was installed. The pilot plant was installed at the clinic in Voorstekraal, which is a public facility that was very accessible to all members of the community. It also provided security faculties (security fencing and lockable gate) which could prevent possible vandalism to the plant during the periods of extended operation.

The pilot plant was operated by B.Tech students from CPUT after they were trained in operating and maintaining, and monitoring the operation of, the plant. Measurements of turbidity, colour, pH and temperature were done on-site. The students in turn trained two volunteers from the community to operate the plant and provide treated water to members of the community. A user-friendly and very concise operating manual was provided. The community operated the pilot plant entirely on their own for a period of two months. After installation of the plant, a further meeting and discussions with

community members were arranged by the project team, Health Sciences and the local authority (***Phase 2: Implementation phase***).

On completion of the pilot trials and running of the plant by community members themselves, Health Sciences held meetings and conducted interviews with community members (***Phase 3: Post-implementation phase***) as to their perceptions of the operation of the water treatment technology and the availability of improved quality drinking water to the community.

Following recommendations of the Steering Committee, similar trials were conducted at a second site that was identified for performing additional social acceptance evaluation of the membrane technologies (Upper Mnyameni in the Eastern Cape province). This was done mainly to determine to what extent the conclusions from the first social acceptance evaluation can or cannot be generalised, and in which important areas there may be differences.

Results of Bench-scale and Pilot Plant Studies

Bench-scale studies

As it was expected, the removal of suspended and colloidal solids on the UF membranes were excellent, *i.e.* 99% as turbidity, for the majority of the experiments. It was also observed that the suspended solids removal efficiency is constant, depending on the operating conditions. Certain differences observed in removal efficiencies of turbidity can be correlated with the change of the feed waters, i.e. each raw water used in the study had different percentage removal on turbidity due to different raw water turbidities and characteristics.

Organic compounds attached to suspended solids have also not been removed to a certain extent. Dissolved organic materials can easily pass through the UF membranes depending on the molecular mass. On the other hand, the UF membranes do not retain dissolved inorganic compounds and these compounds can further be retained by reverse osmosis systems.

Pilot plant studies

Voorstekraal:

The turbidity of the raw water was low during the trial period, but the microfiltration membrane reduced the turbidity to around 0.2-0.6 NTU, while the UF membrane reduced it further to 0.1-0.3 NTU.

Colour levels were reduced to less than 20 mg/L as Pt (the SABS 241 Class I limit), but could not be reduced to less than 10 mg/L as Pt, as expected. The exception was when ultrafiltration was operated without the preceding microfiltration step, in which case the colour levels were reduced to between 5 and 10 mg/L as Pt.

No specific conclusions were attempted here on the effect of varying cross-flow volumes on turbidity and colour removal, partially because this was not the main aim of the experimental work, but mainly because considerable research has already been done locally on the evaluation of microfiltration and ultrafiltration for the treatment of various raw water types.

Upper Mnyameni:

The performance of the membranes for turbidity and colour removal showed the same results as in the Voorstekraal trials, with turbidity of 0.14 NTU and colour of less than 10 mg/L as Pt in the final water. Excellent iron removal was also obtained: 95.2% removal with microfiltration and 99.5% with microfiltration followed by ultrafiltration.

Conclusions from the Social Acceptance Study

Conclusions from the Voorstekraal study
Acceptance does not necessarily mean usage. A large number of households indicated that they accepted the plant but not all of them used it. Usage rate was mainly influenced by the location of the plant, lack of community enthusiasm and drive, limited municipal involvement, misinformation and lack of awareness to use the plant.

Communities will always revert to the water they are used to. This is mainly because the alternative water (from purification plant) becomes a bother due to the fact that the water is not close at hand, and they are used to dealing with the problems of the original water.

A non-cohesive community intensifies a lack of interest.

Community meetings may not be a high quality way of informing households. People attend community meetings in their individual capacity and not necessarily representing their households. Whatever is discussed and decided at the meeting is not propagated to the rest of the households.

Participation must incorporate involvement. The Municipality participated fully in the planning stages but was not visible in the implementation phase. The limited involvement of the Municipality discouraged usage and created the perception that they disregard the community.

The safest location may not be the most appropriate, convenient or accessible place for the plant. Security should therefore not determine location.

General guidelines

- Microfiltration and ultrafiltration treatment systems are rapidly gaining ground as best available technology for small water treatment systems because of the following main reasons:
  - production of high quality treated water
  - do not require chemical pre-treatment
  - provide a barrier against bacteria, viruses and parasites
  - offer competitive costs when considering life-cycle costing
  - can be operated by semi-skilled community members (but requires excellent technical back-up).

- Design, choice of appropriate technology and operation and maintenance issues are identified as potential problems that need to be addressed in the technical evaluation processes.

- Social and technical factors form a critical part of sustainability of rural water supply both in the short and long term.

- ***Technical factors*** that determines sustainability include, *inter alia*:
  - construction costs
  - operation costs
  - performance
  - reliability of the service
  - provision for future upgrading
  - training of operators
  - community involvement.

- ***Social factors*** that have a major impact on sustainability include:
  - needs assessment prior the starting of the project
  - community involvement

- community participation
- financial aspect of the project including costs.

- The following factors need to be considered when planning the installation of a new water treatment unit for a rural community:
    - security of the plant/unit
    - location of the unit
    - cost
    - efficiency (ability to produce improved quality of drinking water)
    - awareness raising/community informed
    - community needs
    - job creation
    - replacement of existing water pipes

- Communication forms part of infrastructure development including technological information and transfer of knowledge between communities and engineers. Partnership is seen as most viable for a sustainable operation, especially in filling gap and counter-acting areas of weakness from various role-players.

- In the social process, inclusion of women in various ways for sustainability of a project is crucial. This includes decision-making, cultural issues, attitudes and awareness, roles and responsibilities, education and training.

- The NGO-approach to rural water supply, especially in South Africa confirmed that more emphasis is placed on customer-based (community), policy and procedure "enforcement", capacity building (both community and institutional) and post-project support.

- Though rural water supply is demand-driven, various methods are used to involve the community in the choice of technology to use.

- Using the Net Present Value-based approach (NPV) for costing of new treatment plants allows operating costs/cash flow projection of a project over a ten-year period to be made. This simple assessment captures both the capital and operating costs for alternative technologies and relates these as one financial sum in terms of current monetary value. This approach allows financial comparisons between technology options and clearly indicates which alternative is financially more viable, or the magnitude of any variation.

The report on the technical and social acceptance evaluation of microfiltration and ultrafiltration membrane systems for potable water supply to rural communities are presented in two separate documents, viz:

PART A Technical Evaluation

PART B Socio-Economic Factors influencing the Acceptance of Advanced Water Treatment Technologies

CD Swartz
April 2007

ACKNOWLEDGEMENTS

The research in this report emanated from a project funded by the Water Research Commission and entitled *Technical and Social Acceptance Evaluation of Microfiltration and Ultrafiltration Membrane Systems for Potable Water Supply to Rural Communities*.

The Steering Committee responsible for this project consisted of the following persons:

Dr G Offringa	Water Research Commission (Chairman)
Dr JJ Schoeman	University of Pretoria
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Mr D Nozaic	Umgeni Water
Mr MW Marler	Development Bank of Southern Africa
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Prof EP Jacobs	University of Stellenbosch
Mr M Fani	Rural Support Services
Mr J de Jager	Mvula Trust
Mr G Mackintosh	Emanti
Mr H Smit	Quality Filtration Systems

The financing of the project by the Water Research Commission and the contribution of the members of the Steering Committee is acknowledged gratefully.

The project was only possible with the cooperation of a number of individuals and institutions. The author therefore wishes to record his sincere thanks to the following:

- Mr Melvin Phillips of CPUT for facilitating project work by Civil Engineering Students, both post-graduate and under-graduate, and for his keen interest in the project
- Mr Jobo Setlolela, Master of Technology Student at CPUT Civil Engineering for performing bench-scale studies with ultrafiltration membranes
- Prof Ed Jacobs and personnel at Institute of Polymer Science for providing ultrafiltration membranes and providing guidance with bench-scale tests
- Mr Herman Smit and personnel of Quality Filtration Systems for manufacture of the mobile microfiltration/ultrafiltration pilot plant, and for technical support during pilot-plant trials
- The Health Sciences Team at CPUT (Messrs Jacob Seconna and Brian Delcarme and Mz Louella Daries and Liza Lodewyk) for socio-economic studies and for their keen interest in the project
- Messrs Jannie Venter and Denver Damons of Theewaterskloof Municipality for their inputs and assistance with pilot plant trials at Voorstekraal, Genadendal
- Ms Johanna Stuart-Malapa of Theewaterskloof Municipality for community liaison and facilitating meetings and communication at Voorstekraal
- Mr Petrus Malgas of CPUT Civil engineering for performing pilot plant trials at Voorstekraal
- Mz Bulelwa Dyobiso and Mihlali Simukonda of Rural Support Services for social studies at the Zingquthu community
- The communities of Voorstekraal and Zingquthu for their inputs and participation in the project.

TECHNICAL AND SOCIAL ACCEPTANCE EVALUATION OF MICROFILTRATION AND ULTRAFILTRATION MEMBRANE SYSTEMS FOR POTABLE WATER SUPPLY TO RURAL COMMUNITIES

PART A
Technical Evaluation

Report compiled by

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CHAPTER 1

INTRODUCTION

1.1 Need for Guidelines on Technology Transfer of Membrane Technologies to Rural Communities

In a project that was undertaken to investigate the upgrading needs of existing small water treatment plants in South Africa (Swartz, 1998), it was found that the major problems with sustainability of these small systems are the difficulty of controlling chemical treatment processes, especially when the raw water quality changes; inadequate disinfection of the final water as a result of lack of proper or reliable dosing systems and dosage control; poor back-up service by equipment suppliers; and lack of training of plant operators. Another very important problem is the lack of community involvement, especially over the longer term. It has been shown that the acceptance of technologies by the community is of utmost importance to ensure a successful water supply project.

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Following recommendations of the Steering Committee, similar trials were conducted at a second site that was identified for performing additional social acceptance evaluation of the membrane technologies (Upper Mnyameni in the Eastern Cape province). This was done mainly to determine to what extent the conclusions from the first social acceptance evaluation can or cannot be generalised, and in which important areas there may be differences.

1.4 Lay-out of the Document

In Chapter 1, the motivation for the project and the need of the guidelines for technology transfer to small communities are given. The aims of the project and methodology that was used are provided.

Chapter 2 provides a literature review of microfiltration and ultrafiltration treatment systems for potable water treatment, which then focusses on application in South Africa in particular. Information is also provided on socio-economic acceptance factors for the transfer of water treatment technologies, and specifically membrane technologies, to rural communities.

Chapter 3 provides results of bench-scale studies that were performed using the UF membranes to treat the four different raw water types. In Chapter 4, the methodology and results of pilot plant studies that were done with a mobile microfiltration/ultrafiltration plant are presented (at two different sites). In parallel with this evaluation, the scope, methodology and results of the social acceptance evaluations at the two sites are presented in Chapter 5.

Cost-comparison information for small-scale membrane technologies is given in Chapter 6, and Chapter 7 provides a summary of socio-economic guidelines for application of microfiltration and ultrafiltration technologies for potable water treatment for rural communities.

Chapter 8 presents a summary of conclusions from the social acceptance study

CHAPTER 2

LITERATURE REVIEW

2.1 Microfiltration and Ultrafiltration Membrane Systems for Potable Water Treatment

2.1.1 Ultrafiltration

Ultrafiltration is a membrane process with membranes in the wide range of pore sizes of 1 to 100 nm, operating under pressure range of 3-10 bar (Cheryan, 1986). The primary separation mechanism in ultrafiltration is selective sieving through the membrane pores. Dissolved salts, non-ionic materials and small particles (< 0,1 µm) pass through the semi-permeable membrane in the liquid phase while larger solids are rejected and concentrated (Tansel *et al.*, 1995). UF has the capability to retain colloidally dispersed particles, such as clays and paints, silts as well as macro molecules such as proteins and all bacteria whereas it allows dissolved substances and low molecular compounds to pass through. UF is particularly attractive for surface water treatment due to its removal efficiency of suspended solids, colloids and microorganisms because the finer separation capabilities of RO/NF will probably not be needed in some cases (AWWA *et al.*, 1996). In addition, they require much lower pumping pressure for operation and also yield higher flux and no brine disposal is associated with them. Ultrafiltration is used as a pretreatment for NF/RO, or direct treatment for surface water as combined with UF/powered activated carbon, UF/oxidation and UF/bioreactor (Aptel, 1994).

2.1.2 Microfiltration

Microfiltration is a pressure driven membrane process of retaining particles down within a micron size (0,1-10 µm), operating with low pressure (0,5 - 5 bar) (Roesink, 1989). Microfiltration allows removal of bacteria, colloidal and suspended matter larger than its pore size whereas smallest microorganisms such as viruses can pass through the MF membrane. The primary application for this membrane process is particle and microbial removal. Microfiltration membrane can be divided into two broad groups on their pore structure. These are membranes with capillary type pores, hereafter called screen membranes, and membranes with tortuous-type pores, hereafter called depth membranes. The table below shows the classification of membrane process used in drinking water treatment.

Table2.1: Classification of pressure driven membrane filtration (Roesink, 1989)

Items	Pore Size	Δ P (bar)	MWCO (*)	Application
MF	0.1-10 µm	0.5-5	> 100,000	separation of particles
UF	1-100 nm	3-10	1,000-200,000	separation of macromolecules
NF	<1 nm	10-30	200-1,000	separation of multivalent ions and low molecule mass solutes
RO	< 0.1 nm	30-100	200	separation of monovalent and low molecule mass

* MWCO = Molecular weight cut off at which 90% of compounds are retained

2.1.3 Classification of membranes

A membrane is the most important part of the separation module because every membrane separation process is characterized by the use of a membrane to accomplish a particular separation. The semi-permeable membrane acts as a selective barrier which permits the passage of one component more readily than others. The membranes used in various processes can be classified according to different criteria as mechanisms of separation, physical morphology, chemical nature and geometry (AWWA *et al.*, 1996).

a. Classification according to separation mechanism

There are essentially three mechanisms of separation, which depend on one specific property of the components to be selectively removed or retained by the membrane, *i.e.* sieving effect, solution-diffusion mechanism and electrochemical effect. The classification of membranes based on separation mechanisms leads to three main classes, *i.e.* **porous, non-porous** and **ion-exchange membranes**.

Porous membrane: Porous membranes are mainly used in UF/MF and their pore dimension mainly determines the separation characteristics. High selectivity can be obtained when the solute size is large relative to the pore size in the membrane (Mulder, 1990).

Non-porous membrane: Non-porous membranes, which are considered as dense media, are mainly used in reverse osmosis, gas separation and pervaporation processes. Its separation is based on the differences in solubility and diffusivity of materials in the membrane, *i.e.* the intrinsic properties of the polymer material determine the extent of selectivity and permeability (Mulder, 1990).

Ion-exchange membrane: Ion-exchange membranes are a specific type of non-porous membranes, consisting of highly swollen gels carrying fixed positive or negative charges. A membrane with fixed positive charges is called an anion exchange membrane whereas a cation exchange membrane has fixed negative charges (AWWA, 1996).

b. Classification according to morphology

Membranes can be classified into two categories according to morphology, *i.e.* symmetric or asymmetric.

Symmetric membrane: Symmetric membranes mean a constant pore size (or pore size distribution) over the whole cross section of the membrane (Weink, 1993). These membranes usually have a thickness a 10 to 200 μm (Mulder, 1990). The flux of permeate is inversely proportional to thickness of membrane, meaning that decrease in membrane thickness results in increased permeation rate. Therefore, asymmetric membranes were developed for this purpose.

Asymmetric membrane: Asymmetric membranes have a thin dense *skin-layer* (0,1-1μm) supported by a porous sublayer with a thickness of about 50-150μm. The small thickness of the skin layer results in a low resistance for transport through the membrane, easy to clean, and fairly high flux. The membranes usually used in UF are these types of membranes. *Composite* membranes are a special group of asymmetric membranes with a very thin dense top layer. In these membranes, the top layer and sub layers originate from different materials. Each layer can be optimized independently.

c. Classification according to chemical nature

The synthetic membranes which are mostly used in drinking water treatment can be subdivided into **organic** and **inorganic** membranes (Mulder, 1993)

Organic Membrane: Organic membranes are most common and offer the greatest degree of flexibility with respect to rejection characteristics and module design. In general, the advantages of organic membranes compared to inorganic membranes are mostly: easy processing, low cost, availability of wide structure variations, possibility to realize any configuration (Roesink, 1989). Disadvantages are their inferior stability at high temperature, the reduced chemical resistance and also time dependent relaxation phenomena.

The main types of polymer membranes are cellulose acetate membrane, polyamide membrane and polysulfone membrane. Polysulfone membranes are widely used in UF applications which are considered quite a breakthrough to a UF application due to wide temperature limits (up to 75°C), wide structure, pH tolerances (pH 1-13), fairly good chlorine resistance, easy to fabricate in a variety of configuration and wide range pore size available for UF applications when compared to other organic membranes. The main limitations of polysulfone membranes are the low pressure limits *i.e.* typically 1,5 bar with hollow fiber, 7 bar with flat sheet (Cheryan, 1986).

Inorganic membrane: Inorganic membranes, often described as mineral or ceramic membranes, can be made from silica-glass (SiO_2) or alumina materials. They generally have greater mechanical strength and greater tolerance to chlorination and extremes in pH and temperature compared with organic membranes (AWWA, 1992). Ceramic membranes are presently available in tubular form and microfiltration pore size, and their initial cost is greater than the cost of polymer membranes (Roesink, 1989). The table shows the properties of various types of membranes used in UF/MF.

Table 2.2: Properties of various membranes (AWWA, 1992)

Membrane Material	pH range	Tolerance to Chlorine(mg/l)	Max. temperature (°C)
Cellulose Membrane Acetate	2-10	~1	50
Polyamide	2-12	< 0.1	80
Polysulfone	1-13	~100	80
Aluminum Oxide (Ceramic)	0-14	> 100	> 100

d. Classification according to geometry

Membranes can be classified in two different configuration (*modules*), *i.e.* flat and tubular (Weink, 1993). *Flat* membranes involve plate-and-frame and spiral wound module whereas tubular, capillary and hollow fiber modules are based on tubular membrane configurations. The difference between the latter types of modules is the dimensions of the tubes employed (Weink, 1993):

- tubular membrane : internal diameter > 5 mm
- capillary membrane : internal diameter 1-5 mm
- hollow-fiber : internal diameter <1 mm

Hollow fibre and capillary: Hollow fibre and capillary modules have the advantage of a large surface area-to-volume ratio (packing density) and simplicity of construction, but they are more susceptible to fouling than any of the other modules due to narrow spacing. They can be cleaned by backflushing which tends to compensate for their propensity to fouling. In UF, backwashing is carried out by placing the permeate under a pressure greater than the feed pressure (AWWA *et al.*, 1996).

Tubular: Tubular membrane modules are used in cases where the concentration of suspended solids are sufficiently high so as to block flow channels, *e.g.* wastewater. Tubular membranes are preferred in view of the ease of cleaning (with sponge-balls) but are more expensive and cost more to operate than spiral wound membranes (Roesink, 1990).

Spiral wound: Spiral wound modules, is essentially a flat sheet rolled, i.e. an envelope of two membranes enclosing a permeate spacer which is sealed along three edges and the fourth edge is connected and rolled up onto a perforated tube which carries the product water. They have shown the best compromise in compactness, sturdiness and limited susceptibility to fouling (AWWA, 1996). In drinking water treatment the hollow fibre and spiral wound modules are the most often applied. The table below shows the characteristics of membrane modules commonly used in water treatment.

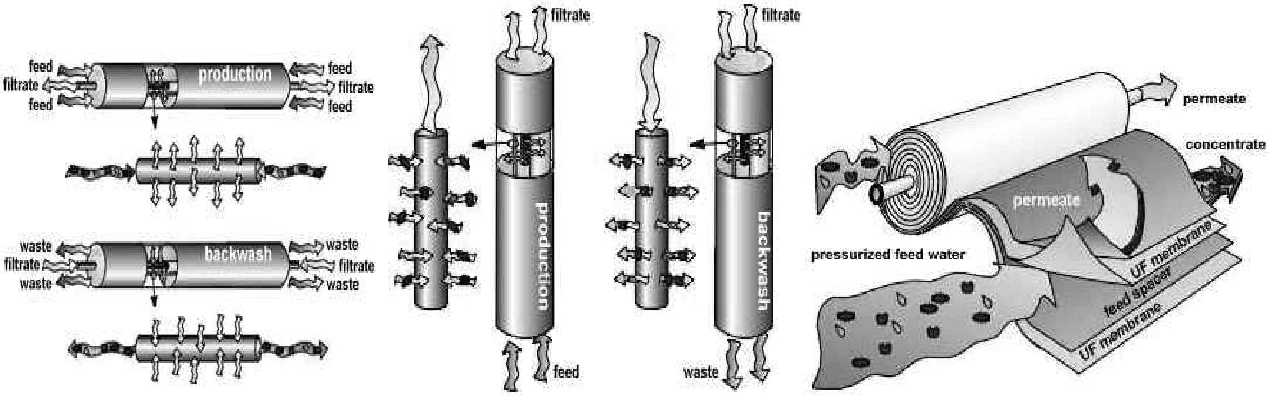


Figure 2.1: Hollow fiber UF membranes [inside out (left) and outside in (centre)], and spiral wound UF membrane (right)

Table 2.3: Qualitative comparison of various membrane configurations (Mulder, 1990)

Items	Tubular	Plate-and-frame	Spiral wound	Hollow fiber
Packing density	low			very high
Investment	high			low
Fouling tendency	low			very high
Cleaning	good			poor
Operating cost	high			low
Membrane replacement	yes/no	Yes	no	no

2.1.4 Process modes in membrane operation

In order to use membranes in the treatment process, the membranes are packed in units called modules. Membrane modules can then be operated in two process modes namely ***dead-end*** (normal) and ***cross-flow***, which are represented in the figure below.

Dead-end mode

In dead-end mode, the flow direction of feed is perpendicular to the membrane surface, leading to the continuous formation of a cake layer that causes a rapid flux decline. The main advantage of the dead-end filtration mode is simplicity. The feed suspension is not recycled or passed across the membrane and costly exit ports to accomplish this are unnecessary. In this mode, the cake grows with time and consequently the flux decreases with time. Intense concentration polarization and membrane fouling can occur under these conditions (Belfort, 1994). The permeate flux drag all solutes, suspended and dissolved materials towards the membrane resulting in solute intrusion and adsorption into and / or deposition onto the membrane. As a result, the dead-end filtration process must be stopped periodically in order to remove the particles or to replace the filter media or else, the cake must be continuously discharged (Davis, 1992).

Cross-flow mode

In cross-flow mode, the flow direction of feed is parallel to the membrane surface. Unlike dead-end filtration, a cake layer does not build indefinitely. Instead, the high shear exerted by the suspension flowing tangential to the membrane surface sweeps the particles toward the filter exit so that the cake layer remains relatively thin (Davis, 1992). This allows relatively high fluxes to be maintained over prolonged time periods. For industrial applications, cross flow operation is preferred because of the *lower fouling tendency* relative to dead-end mode (Belfort, 1984), but they require *higher energy* to maintain a high velocity over membrane for continuous operation.

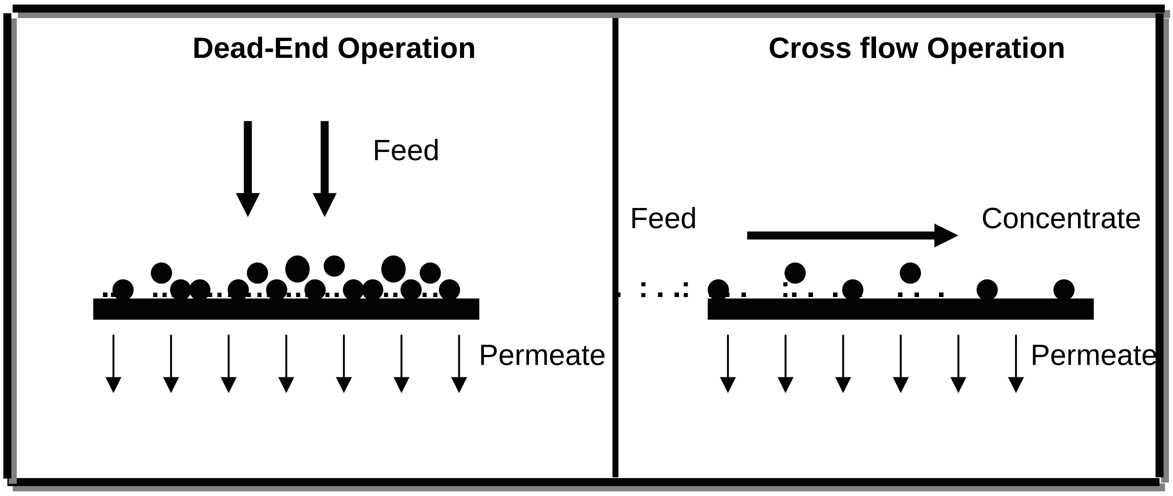


Figure 2.2: Schematic drawing of the two operational modes (Roesink, 1989)

The flux (rate of permeate production per unit membrane area) during UF/MF will decrease over time as the filtration process takes place. Flux decline is one of the most important reasons why membrane processes are not used on large scale (van den Berg *et al.*, 1990). It is caused by several phenomena inside, on and near the membrane which lead to a decrease in driving force and/or an increased resistance. Flux decline is relatively smaller in the cross flow mode and can be controlled and adjusted by proper module choice and cross-flow velocities. In dead-end UF, fouling is the major cause of flux decline. The cake deposits growth with time of filtration and can only be controlled by appropriate cleaning.

2.2 Application of Membranes in South Africa

South Africa is a relatively dry country, which receives an annual rainfall of less than 500 mm compared to a world average of 860 mm. In addition, large areas of the country may be classified as desert or semi-desert. Therefore, membrane development in South Africa naturally tends to focus more on the water-related applications, although some work on gas separation is also being done. Research and development (R&D) is being undertaken on most membrane processes, including reverse osmosis (RO), ultrafiltration (UF), microfiltration, (MF) and electrodialysis (ED). Research further focuses on membrane materials (polymeric and ceramic), electroconducting membranes, membrane bioreactors, membrane surface modification and defouling studies. Most of these technologies have been commercialized or are on the verge of being commercialized (Offringa, 2002).

The earliest fundamental membrane research in South Africa started in 1953 on ED systems and their membranes at the Council for Scientific and Industrial Research (CSIR). This research laid the foundation for a better understanding of the thermodynamic and physical processes involved in ED. Parchment paper membranes were developed and piloted for the low-cost desalination of brackish gold-mine underground waters. Initial research on polymeric membranes started in 1973 at the Institute for Polymer Research (IPS), University of Stellenbosch, leading to the establishment of the first local membrane manufacturing company in 1979. In conjunction with the IPS, this company developed low cost tubular RO and UF systems in the 1980s. The tubular UF systems were later successfully combined with anaerobic digestion and commercialized as the “ADUF” process. From humble beginnings the activities have grown to the current situation where R&D on membranes is actively pursued – not only at a number of tertiary educational institutions, but also at private companies and water and power utilities.

2.2.1 Application of ultrafiltration membranes

The types of capillary membranes produced in South Africa currently are polysulfone and polyerthersulfone at the Institute for Polymer Science. They can be produced as skinless, internally skinned, externally skinned or double skinned depending on how the bore fluid and the external spinning bath are introduced. These capillary membranes are applied in membrane bioreactor related research. It separates particles to size ranging from 0.001 to 0.1 microns. With the slight modification in the polymer the membranes also served as a low-pressure filter for the treatment of non-saline surface and subsurface water for potable use (Jacobs *et al.,* 1997).

Recently, polysulphone UF membranes were produced with a very thin internal skin layer and the dimension of the voids in the substructure is such that bacteria will not pass through the membrane should the skin layer be punctured during the filtration process. These membranes efficiently filters out very small particles, yet still has a suitably high pure-water flux. The membrane is intended, amongst other for the production of potable water for small communities (Offringa, 2002).

One important goal in membrane fabrication is to control membrane structure and thus its performance. To achieve this goal a lot of factors have to be considered and this includes; proper choice of polymer, proper choice of solvent and non-solvent, composition and temperature of coagulant and casting solution (Jacobs *et al.,* 1997). Fabrication protocol (e.g. dope morphological rate) plays an equally important role in controlling morphological properties and performance of the final membrane structure.

There has been joint research in the application of membrane technology to the small communities in South Africa. The University of Stellenbosch, ML Sultan Technikon (now Durban Institute of Technology) and the Water Research Commission of South Africa initiated a joint project. The project was initiated to develop a local UF system for potable water production in the rural and peri-urban areas of South Africa (Jacobs *et al.,* 2000). It aimed in developing a technology that would be sustainable in developing economy conditions. Throughout all the developments and field evaluations, a truly South African membrane water treatment system was developed.

Various separate pilot-scale investigations were initiated during the course of the project. The sites where the studies were conducted are Southern Cape, Western Cape, KwaZulu-Natal and Windhoek in Namibia. In Suurbraak a UF pilot plant was used to treat the water to the community over a period of six months in order to test the application in a rural environment. Another plant at Wiggins Water Works was monitored regularly to assess the particulate removal and disinfection capabilities of the UF membranes for potable water production (Jacobs *et al.,* 2000)

This system is ideally suited for drinking water production in South Africa. The system has demonstrated excellent quality of water in all field trials and is ideal for developing economies, thus ensuring the long-term sustainability and reliable long-term operation of the units (Jacobs *et al.,* 2000)

In 1994 the Ultrafiltration Rural Watercare Project was initiated by the IPS at the Mon Villa seminar center (Botes *et al.*, 1998). All the farms in the seminar center were supplied with irrigation water from the Theewaterskloof Irrigation Scheme, which are not fit for direct human consumption. The water has high concentration levels of turbidity (> 70 NTU) and colour (100-350 units PtCo) caused by natural organic matter, as well as the presence of iron, aluminum and microbiological contamination. The project was initiated with the installation of a 3 m^2 bench scale filtration unit. After initial experimental work the WRC funded a pilot plant for the project. The project was done to evaluate the low-cost modular membrane system produced from IPS for the upgrading of the substandard surface water from Helderberg Irrigation Scheme to potable standards. Subsequent performance and evaluation studies of these membranes indicated they exhibited a medium molecular-mass cut off of about 40 kDa. This evidence suggested that the membranes might be useful in potable water production from raw surface waters found in South Africa. These membranes produced excellent quality drinking water. The membranes were capable of reducing higher concentration levels of turbidity and iron by 97-99%. They were also capable of removing all the faecal and other bacteria present in the feed waters.

The need for the reliable supply of potable water to growing remotely located coastal settlements where the only sources of water supply are ground water and seawater have received renewed attention. Jacobs e*t al.* (1993) did a study on the development of a locally manufactured UF membrane system for seawater pretreatment prior to reverse osmosis. The main aim of the study was to identify the requirements of a UF system for use in pretreatment by RO, and to develop and evaluate the UF pretreatment through long-term continuous operation.

The cost effectiveness of using these UF membranes for the pretreatment to RO, were found to depend on a combination of membrane configuration, type and frequency of the cleaning regime as well as average productivity. The development of the experimental module has resulted in the commercial manufacture and use of a practical membrane separation system for the treatment of seawater prior to desalination (Jacobs e*t al.,* 1993)

In a study by Mackintosh *et al*, the financial and technological sustainability of a membrane-based treatment plant versus a conventional type treatment plant was compared at two small rural communities in the Southern Cape (Mackintosh *et al.*, 2002). The importance of socio-political sustainability was also observed during the study. The membrane-based process was shown to consistently produce good quality water, whilst the conventional treatment process only intermittently produced good quality water. The membrane-based plant was successfully operated for an extended period by a community member with no prior skills in water treatment, and showed superior technological sustainability. Using a Net Present Value based approach, financial comparison showed that contrary to conventional wisdom in South Africa, the membrane-based plant had superior financial sustainability. The principal advantage of the membrane-based treatment process is that it provides consistently high quality drinking water and it is not possible for the system to pass on partially treated water that fails bacteriological standards. This will ensure the socio-political sustainability of the membrane based process. In comparison the regular failure of the conventional system is likely to lead to eventual rejection of the technology by the community.

Two spiral wound ultrafiltration membrane plants have been installed at the Gillis Game Farms in the Eastern Cape. These plants, with capacities of 6 m^3/h and 3 m^3/h respectively, treat poor quality raw water from the Fish River to potable standard, and are reported to be operating effectively for the last number of years (Swartz, 2005).

2.2.2 Application of microfiltration membranes

Woven fibre microfiltration (WFMF) technology underwent significant development at the Pollution Research Group, University of Natal, in the 1980s, and is currently being further refined by the Durban Institute of Technology (DIT). The system consists of two layers of a woven polymer material, stitched together to form rows of parallel filter tubes, called a “curtain”. Feed is from the inside. Clear liquid permeates the tube wall, and runs down the outside of the tubes as permeate. The system is used in cross-flow or dead-end mode in clarification applications. A current project concerns a proposal for a new immersed membrane microfiltration (IMM) technology that utilises this flexible woven fibre material – a woven fibre reverse-flow microfilter (RFMF). Here, a porous support is inserted into either woven fibre tubes, or between flat sheets. Thus the inexpensive WFMF curtain may be used as an IMM. A distinguishing feature of these units is that they are very robust. For example, complete drying out of the membrane does not damage the membrane, but is used as a cleaning technique.

A 20 m^3/h microfiltration plant has been installed at the Dwarsrivier Correctional Services facility near Wolseley in the Western Cape for the treatment of turbid dam water for supply of drinking water to the facility and houses. A spiral wound microfiltration system (0,2 micron) is also in operation as pretreatment for nanofiltration in a drinking water treatment plant on the banks of the Berg River near Piketberg in the Western Cape (Swartz, 2005).

2.3 Socio-Economic Acceptance Factors for Membrane Technology Transfer to Rural Communities

2.3.1 Introduction

The provision of potable water supply to rural and remote areas has become a critical option for the water development services in South Africa, more especially in the rural areas (Pillay *et al.*, 1996). The rural water supply schemes face difficulties with declining water table levels, deteriorating water quality, inadequate repairs and maintenance, thereby limiting access to potential water services as a traditional water right to water consumers. The reasons for this disservice vary accordingly, taking into consideration the social and technical variations of the process.

This result in difficulties towards a sustainable water supply system and include technical aspects related to choice of technology that is locally specific, chemical treatment processes, and social aspects ranging from lack of community involvement to financial contribution especially for sustainable maintenance and operation of the water supply infrastructure. As a result threatening situations emerge which destabilizes the sustainability of the existing small water treatment plants in rural and remote communities.

However, research studies have been conducted to investigate use of membrane filtration as an alternative to chemical treatment for good quality drinking water in rural villages. Therefore, social and technical factors are seen as indicators to evaluate sustainability of the membrane systems in small rural communities.

This will possibly ensure benefit to rural community members and later generally applied to other rural water users in South Africa as a whole.

2.3.2 Social evaluation of the systems

This aspect often lacks when engineers design plants in rural communities. It is a barrier that often leads to the project failure yet it forms part of the sustainability of the water treatment systems in these rural communities.

Factors to consider when evaluating the social aspects of sustainable water treatment works:

<u>Needs assessment:</u>
The approach used to communicate with the communities even before the project start is secondary to identifying the needs of the community based on the provision of the system in the area. Every need is locally based and specific. An assessment and data collection study as a form of evidence for general feelings of the community are needed.

<u>Community involvement:</u>
Community involvement over a longer term is crucial in sustaining the treatment systems. Ownership of the system is crucial in that responsibility is not pushed to the government or consultants. Institutional support on the other hand may either successfully drive or destroy the project. This aspect forms part of both social and technical evaluation of the systems as

the community is needed on both levels.

Community participation:

Social indicators such as poverty bring about feelings of helplessness, isolation and lack of confidence. More often beneficiaries are women and children who need to participate in project design and taking control of their own lives. Community support is needed where land and water will be used as resources in the project and community approval is crucial as well. The community itself needs to define their problem and make decisions to remedy such situations. Use of existing community development structures not in isolation with community members is also a distinct factor in project success.

Financial aspect:

Grant finance for upgrading and O&M services is needed in rural water development. Contribution by community members is also an option to consider as dependency on outsiders or government is not sustainable over a longer period of time. During that process bookkeeping and proper financial systems need to be in place for accountability and transparency purposes.

2.3.3 Strategies and options to sustainability

It is known a fact that sustainability has three components though Strachan and Anderson identified five of them:

- Social
- Economic
- Environmental
- Operation and Maintenance
- Technology

These components are yardsticks to achieve sustainable growth and technical innovations from research thus providing strong foundation for growth.

2.3.4 Technical elements in sustainable water treatment systems

Swartz (2000) identified elements crucial for sustainable water treatment systems. These elements need to be adhered to during planning, designing, managing and upgrading the water systems:

Low construction costs:
Resources and preferences of the users are determining factors in cost reduction during construction of the water systems. It is important not to import the material as this increases construction costs.

Low operation costs:
The more complex the processes of the system, the higher the costs. Operation costs have implications in human resources, funding resulting in high tariffs thus affecting the end beneficiaries. The ongoing operational and maintenance funds are scarce in South Africa so only low operating technologies need to be used.

Simple operation:
The cost implication in the small treatment works go hand in hand with the operation of the systems. So constant operation results in high maintenance costs, which is not beneficial to the community and the small systems especially if the system is community-owned. It is suggested in the documents that operators should use guideline documents to help with

problems and not rely on consultants or rather limit operation and repair costs as much as possible through retained skill.

Reliability of service:
Quality of raw water and breakdown of treatment system are expected in every technology system. In order to prevent such a mishap of poor quality water leaving the plant, an automatic valve needs to be provided.

Performance:
Regular audits are needed from service providers to monitor the performance of the system.

Provision for future upgrading:
In this instance more finances will be needed.

Well-trained operators:
The operators should have a thorough understanding of all functions of a treatment system for optimum water quality and cost control. They need continued training on operation of the plant and water quality control. Refresher courses are important.

Community involvement:
Local technical staff or the users should be used during post/implementation stages of the project. Available skills should be assessed in the community. The choice of technology should be considered from the community side.

2.3.5 Operation and maintenance challenges for sustainability

Numerous reports reflect on the record of poor operation and maintenance and the following list highlights the main constraints (McPherson, 1990; Ittissa, 1991; Wyatt, 1988; Roark, 1993):

- The low profile and hence low priority given to O&M by policy makers.

- There is a need for clear policies, appropriate legal frameworks and a well defined division of responsibilities to support O&M in the sector. Centralized government departments are often unable to respond efficiently to the maintenance of scattered rural supplies. Governments, therefore, need to adopt workable policies which devolve responsibility to autonomous agencies and communities.

- Political interference makes sustainability that much more difficult to achieve. The political decision to provide free water means users do not contribute funds for the upkeep of supplies. Political influences can determine technologies (e.g. tied to aid) or result in sub-standard systems. Such influences can be reduced by devolving management responsibilities away from government.

- A focus on capital construction and expansion by governments and external support agencies neglects the maintenance of existing supplies.

- Overlapping responsibilities of staff and departments can divert skills, funds and equipment away from O&M. This often happens when operational staff are redeployed to construction work as a new project is started. New projects benefit while existing projects are neglected.

- Inappropriate design and technology choice creates unnecessary operation and maintenance difficulties and increases costs. Initial design must consider long term O&M. Poor design is often compounded by inadequate supervision of construction.

- A lack of community involvement in project development can lead to inappropriate designs. Poor user understanding of how to correctly operate systems can result in the misuse and damage of facilities.

- Some communities are disadvantaged by their remoteness or difficult access. This adds to the cost and problems of maintenance and requires special attention.

- There is often inadequate data for planning O&M. Data is required, for example, on the cause of breakdowns and the maintenance and repair costs involved. O&M can then be planned based on field experience.

- The state of national and regional economies can have a crippling effect on O&M as high inflation and fluctuating exchange rates can significantly increase O&M costs. For example, the operation of powered pumps and maintenance crew transport is especially affected by fuel prices increases.

- Water supply facilities are often poorly managed. Some of the management constraints, such as unskilled staff, may be a result of underfunding but are often also due to poor management. O&M responsibilities are rarely delegated to individuals and this can result in a lack of sense of responsibility for the proper use and upkeep of facilities. Management supervision of operation and maintenance may be virtually absent in many cases.

- A lack of training and understanding of maintenance procedures leads to the poor performance of O&M staff (operators, mechanics, caretakers, etc.).

- Insufficient and inefficient use of funds for O&M restricts the availability of spare parts, tools and the recruitment and training of competent staff. A lack of accountability in many maintenance departments leads to inefficient use of maintenance funds.

2.3.6 Social aspects of sustainability

Gender mainstreaming

Various social factors are commonly found when addressing sustainability of water supply systems. One that has been scrutinised even in water policies is empowerment of women in water supply project. The implications of their non-involvement are detrimental to the sustainability of the project. In as much as there are different reasons given for women unwillingness to participate and their unobtrusive participatory role in decision-making, the end result is the unwillingness to take ownership of the project, not to mention the refusal to take responsibility for the service. Willingness may lead to the acceptance of the project by the community, which is necessary for the sustainability of a project.

In order to address this issue, some steps need to be taken to involve women in various ways including broadly (Ducker, L. WRC Report No. 817/1/99):

- Decision-making
- Cultural issues
- Roles & responsibilities
- Education & Training
- Attitudes and awareness

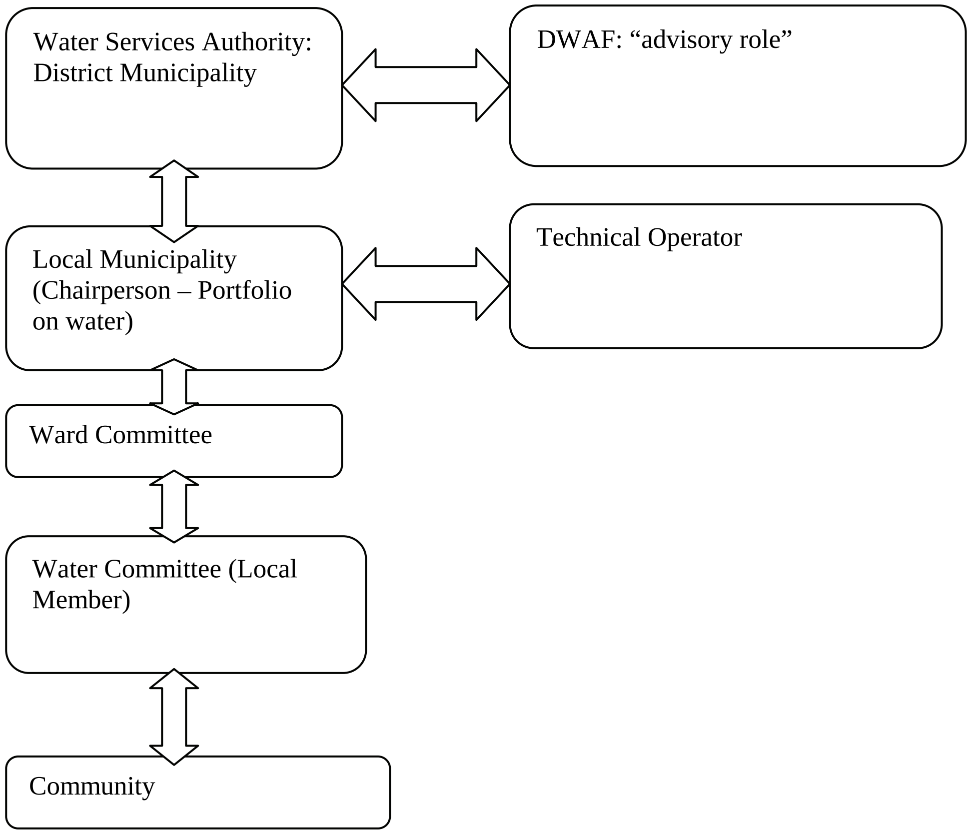
Communication

Pybus *et al.* (2001) and Matji (2003) advocate the use of communication as one of critical components in infrastructure development especially for technological information and transfer of knowledge between communities and engineers. Their view is that communication breakdown occurs as a result of language barriers, settings in which communication occurs and the relationship of the participants. Also there is a mention of different purposes for communication where they are either unidirectional or transactional. Communities need to be active, critical and positive participants in the process of communication. Another problem outlined from the engineers' side is that they see the purpose of the project in technical terms with technical end-product thereby limiting the social, institutional and developmental aspect of the project. As long as the technical objectives have been met, engineers view the project successful regardless of the fact that the level of service did not meet the wishes of the community.

Therefore the study suggests that:

- A proper needs analysis of the community should be undertaken prior to the adoption of any project. This includes who has been consulted and endorsed the decision to continue with the process.
- The focus of communication is a critical issue as most of the time the project steering committee is used in place of communities.
- Lack of identifying capacity for affordability and willingness to pay for services. An external view of affordability and level of service may differ to that of the community from an internal and firsthand experience.
- Communication is important in outlining the capacity building issues from functions of governance, provision of service as well as increased access to resources and improved general awareness of local population in regard to their services.
- Information sharing, consultation and communication need to be transactional and not in a single direction. The dialogue approach will ultimately address questions of what the system would cost in terms of money and time and effect on the lifestyle of the community members.
- Commitment of local recipients to the project as an end result rather than performance indicators of the system. Indicators of the commitment would address sustainability.
- There needs to be clear communication lines between communities and engineers as implementing agents cause constraints to direct consultation from the engineering side.

Matji (2003) designed a communication model that can be used to ensure success of water supply projects.



This model has to be implemented in such a way that the down-top approach is not undermined. The approach strengthens the ties with other structures therefore contributing towards acceptance and sustainability of the project. It also affords the advantage of “community ownership” through involvement and active participation by community members. The community may be at the bottom level of the model but they form the core and strong foundation for the entire project post/implementation process.

2.3.7 Willingness to pay

O&M costs can only be recovered from users if they are both able and willing to pay for a water supply. It has been said that people should not have to pay more than 3 to 5% of their income for water and sanitation services. Actual payments vary greatly (Evans, 1992). A higher percentage of income expended on water will mean other important needs may not be fully met. Therefore, great care is required when setting user contributions.

Even if users can afford to pay O&M costs they may still be unwilling to pay. People will want to weight the cost of an improved supply against a range of factors before committing themselves to paying.

Some important factors which influence the willingness of users to pay are listed below.

Income
If users cannot afford to pay they will clearly be unwilling to pay.

Service level
Users may be able and willing to pay for a handpump but not for a more expensive yard tap. On the other hand, users may only be willing to pay for a higher service level.

Standard of service
People are unlikely to pay for a poor service.

Perceived benefits
Agencies and donors may see the most important outcome of a safe water supply in terms of health benefits. However, users may place a higher priority on the more immediate social and economic benefits. Perceived benefits may vary within a community. For example, men may be attracted by the commercial opportunities of greater quantities of water whereas women may be more interested in the greater convenience of a supply. Some people may stand to gain more than others and this can result in a variable willingness to pay within the same community.

Opportunity cost of time
In the majority of situations it will be women's time that will be saved by an improved supply. Men and women may value the time saved in collecting water differently and women may be more willing to pay than men.

Acceptability of the existing source
If users perceive their existing source to be acceptable they may be unwilling to pay for a new supply.

Confidence in the service agency
Part disappointments have often undermined people's confidence in existing agencies and new initiatives. Users must have confidence that whatever they pay will be used by the management body to provide an acceptable service. An open and clear financial management system will help to instill trust and encourage payment.

Community cohesion
Individuals in a divided community (due to ethnic, clan, class, political, or leadership divisions, for example) may be unwilling to pay into a common fund.

Policy environment
Previous policies have encouraged the belief that access to safe waters should be free. People may be unwilling to pay for something which they feel should remain free.

Perception of ownership and responsibility
People may be unwilling to pay for the upkeep of a facility which they feel belongs to the government. Such a feeling may persist even when a system has been formally handed over to a community

2.3.8 Partnerships as an alternative approach to sustainable rural water supply

Wood's (1997) assumption of the provision of systems to address lack of access to safe and reliable water supply has become one of the indicators in the water technologies in recent years. The terms of partnership between beneficiaries and providers of improved water supplies have proved to be volatile as communities are not static but are continuing to change due to political, developmental, economic and social challenges.

Partnerships are seen as the most viable way when looking for a sustainable operation, especially rural water supply schemes. This has been noted in successful situations and the benefits have been noted:

- Water systems have been more sustainable.
- Both sides, beneficiaries and providers, understand each other's roles and responsibilities better.
- Each side assists the other in achieving project objectives
- One sides' areas of strength are often the other sides' areas of weakness so an effective partnership leads to a strengthening of each of the partners.

In order for a partnership to work, certain criteria need to be established:

- Willingness to enter into partnership from both parties
- Trust and willingness to work together in co-operation
- Understanding of advantages and disadvantages of a partnership
- A written, legally binding partnership agreement signed by both sides
- Neither side should dominate the other in implementing the agreement.

Sustainability in water supply to these areas will include (Ravenscroft & Cain, 1997):

- Community involvement and participation.
- Operation and maintenance realities. This will also include reference to the White Paper on Water and Sanitation Policy, role of district and local municipal structures, community structures and Department of Water Affairs. Locals that will be used must be people who have been trained technically with high ability. Project drawings and contact information need to be furnished. Government policy on water supply requirements needs scrutiny for collaboration and legality purposes.
- Shortage of human, financial, limited or inadequate infrastructure and a no "culture' of payment for services (especially in the areas of former Transkei as water supply schemes were government-owned and locals were never involved in the projects).
- The training component which comprises:
  Technical training, which requires skilled supervision.
  Committee training focusing on committee skills (roles and responsibilities) and financial management; physical and management structure of project. The language needs specifically to be indigenous. Training methods should include manuals, group work exercises, report-backs, role playing, video exercises (where activities are video-taped then played to participants for review and response). Participatory methods are recommended in this kind of training.
- Participation of women in decision-making processes. This concerns management of water point operation and maintenance, a clear indication to accessibility of water.

2.3.9 Challenges to sustainable water supply

There are challenges facing sustainable water management ranging from the revolution of technology, economy and vital importance of achieving sustainability. These challenges can be grouped as follows (Strachan & Anderson, 2003):

- Technology
- Service Management including human resources
- Economic
- Social
- Environmental, including climate

Sinclair (2003) lists these as hindrances to achieve sustainability to water systems:-

- Financial difficulties due to demographic situation (health, age, income levels, high unit costs)
- Personnel limitations – low level of technical skills in community
- Remoteness – difficulty with microbiology sampling, isolation from knowledge (scientific, technical, indigenous, etc.).

- Politics – parochialism that leads to political influence rather than rational decisions.
- Constant interruptions of water supply due to water shortage or infrastructure failure
- Failure to monitor results or no monitoring performed
- Social or climate conditions sometimes inappropriate for climate/water quality.
- Water quantity may be inadequate
- Lack of responsibility/ownership, vandalism

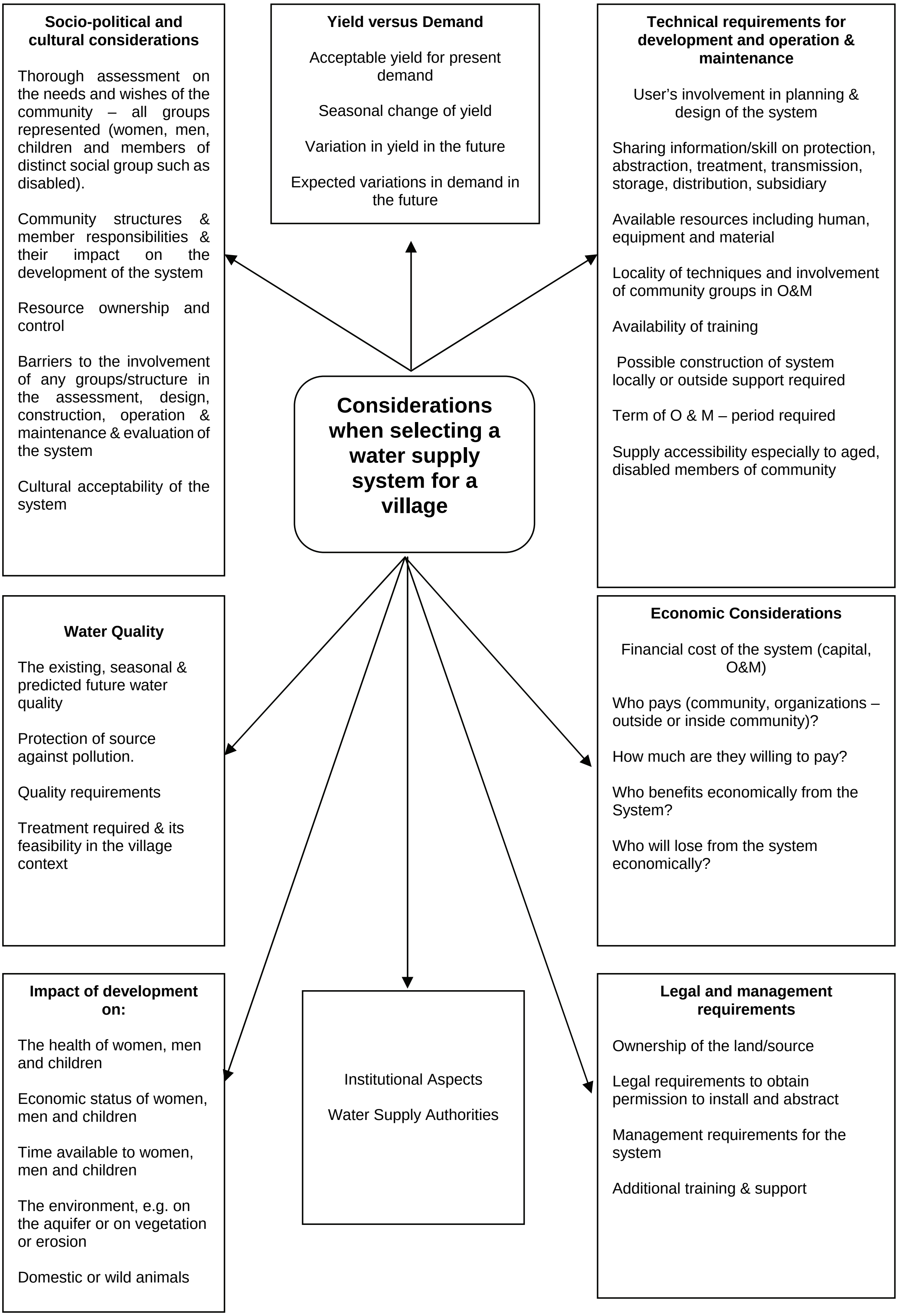
2.3.10 NGO approach to sustainable rural water supply

Mvula Trust, one of the water and sanitation organisations working with rural communities in South Africa, outlines some of the important factors that influence the sustainability of such rural water systems (Rall, 1998):

- The cost of the service and the ability and the willingness of consumers to pay
- The level of complexity of management and technical skills required to run the system
- The management and technical skills that have been developed in the community to do so
- The legitimacy and sustainability of the committee that undertakes to manage the system
- The accessibility and effectiveness of technical service back-up
- Institutional support for the committee
- Policies and procedure to ensure that these factors are adequately adhered to in order to ensure sustainability as discussed
- The consumers as empowered clients rather than passive beneficiaries. The initiative is to develop a "demand responsive approach where clients have rights and equal responsibilities. The acceptance of the project is an indicator for success, willingness through cash contributions, key decisions including project design and technology options, managing project funds and the technical and social support agents, and then paying for water on operation.
- In order for communities to take on the responsibilities, intensive capacity building and training is required. This process or activity brings forth the committees effectively in the decision making process from the mere start of the project through proper work shopping. The emphasis is on capacity-building rather than formal skills training.
- The review of community contribution towards project costs to an "emergency fund" after project completion in the case of unexpected damages to the capital infrastructure has been noted as critical. The community then controls the fund whereupon the members are asked to contribute cash and the level of response in payments over a specified time measures its success.
- Post-project support for operations and maintenance is needed. This is a mentoring process where external support to the community is used. Communities are dynamic and many external political and other factors also play a role. There is a need to strike a realistic balance between the respective capacities of water committees and local government. The role of local government must be promoted, involving monitoring, advice and assistance in accessing support, rather than setting up complicated and unsustainable bureaucracies.

2.3.11 Integrated approach to water supply system from a community perspective

The diagram presented below illustrates the connection or link between various fields in water supply and some issues to consider. They are all critical and important and relevant when addressing the sustainable water rural supply. Also it is important to note that some factors are contextual, e.g. land, environment issues. They need not be applied in every situation and community, especially the cultural issues that define the social aspect of the services to be rendered. It is imperative to use the lens of the community when evaluating the sustainability of the systems, as they are the main beneficiaries in the whole process. It is, in a nutshell, a community-driven approach and a "buy-in" is needed to create sense of ownership of the system to be implemented.



CHAPTER 3

BENCH-SCALE STUDIES WITH ULTRAFILTRATION MEMBRANES

Trial runs with ultrafiltration membranes were performed on bench-scale at the Cape Peninsula University of Technology on four waters, namely groundwater (borehole water at Peninsula Technikon), tertiary treated wastewater from the adjacent municipal wastewater treatment plant, eutrophic water from Voëlvlei Dam, and coloured water from Duivenhoks River in the South-West Cape. This was done to establish test protocols for further evaluation of the ultrafiltration and microfiltration systems on different raw waters to be tested.

3.1 Experimental Protocol

The membranes were obtained from the University of Stellenbosch Institute of Polymer Science. The IPS also provided guidance on setting up the membrane module and equipment for performing the bench-scale study and for drawing up the experimental protocol. During the performance of the trial runs the IPS was also visited to discuss progress and receive advice on the experimental work and interpretation of results.

3.1.1 Bench-scale unit

The laboratory bench scale ultrafiltration unit that was used in this study consisted of the following components:

- UF membranes
- Membrane test cell
- Feed water storage tank
- Permeate storage tank
- Volumetric flask
- Feed pump
- Associated piping
- Pressure gauge
- Back pressure valve

The design layout of the experimental bench scale unit allowed for cross flow filtration only and the unit was operated under constant pressure of 1 bar. The experiments were run using one set each of clean membranes for different experimental waters at different percentage recoveries for both sets.

The low-pressure capillary ultrafiltration membranes used during the study were manufactured at the Institute of Polymer Science, University of Stellenbosch by Dr. Ed Jacobs. The capillary membranes have an internal and external diameter of ~ 1.2 mm and ~ 1.9 mm, respectively. Performance testing indicates that a medium molecular mass cut off (MMCO) of approximately 50 000 Dalton can be achieved and the membranes can withstand an instantaneous burst pressure of 1.6 MPa.

A known number of membranes were housed in a test cell and a quickset epoxy was used to avoid any leakage during the experiment. The O-ring groves with rubbers inside were molded on the outside of the test cell to ensure a leak free fit when the membrane capillaries were inserted into the test cell. Each test cell contained 8 membranes with an effective filtration path-length of 372 mm and membrane area of 0,0112 m^2 .

3.2 Methodology

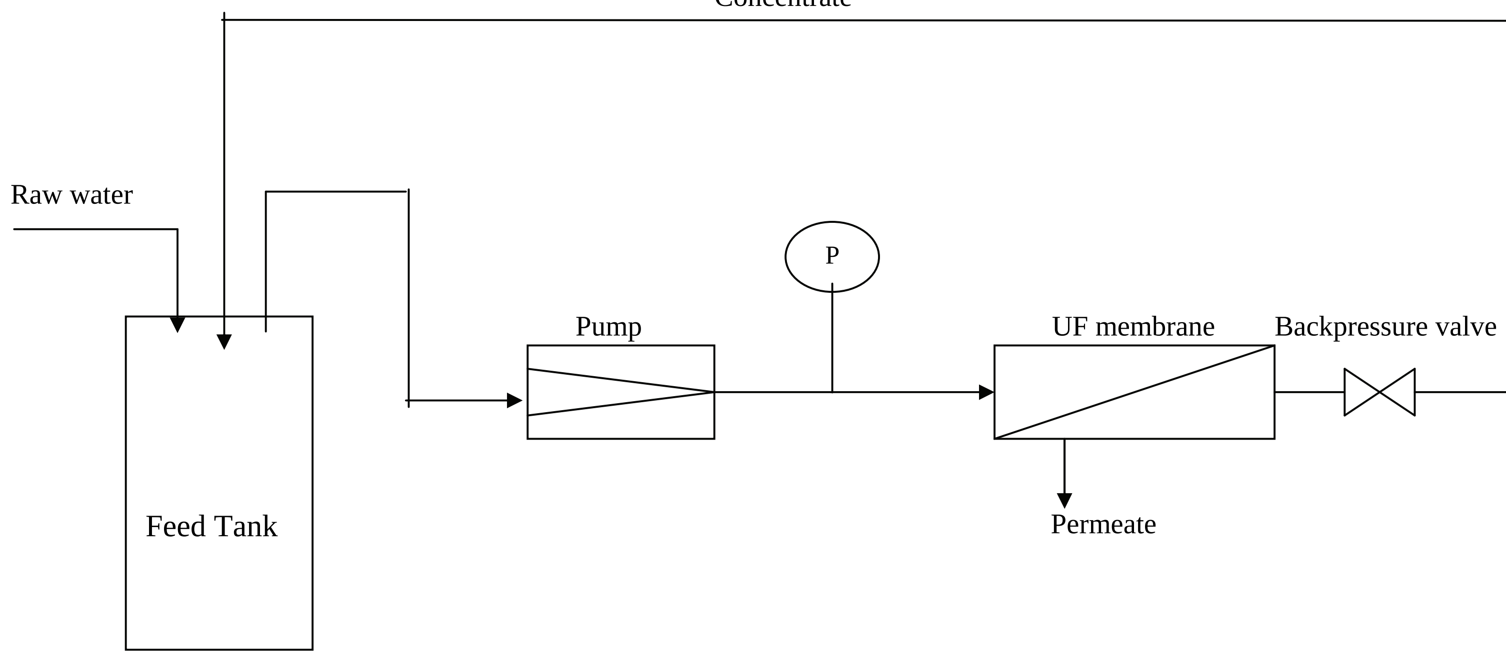
The flow diagram for the bench-scale study using different experimental waters is presented in the figure on the next page. For all the experiments, the ultrafiltration process was operated in a cross-flow mode, with one permeate outlet opening.

Figure 3.1 shows the flow diagram of the laboratory bench scale ultrafiltration unit, which was operated at Peninsula Technikon Laboratory. Feed waters were sampled from the four different raw water sources and brought to the laboratory.

The feed water was pumped from the feed tank using a peristaltic pump. The pumping rate was set to allow the flow rate of one liter in two minutes and this was done manually. The pressure gauge was used to measure the pressure during the filtration process and the pressure was constantly set at 1 bar using the backpressure valve. During the filtration process, permeate was recorded and the retentate was allowed to recycle back into the feed tank.

At the start of each evaluation, 10 liters of raw water was used in the feed tank and the experiment was allowed to run for 10 minutes before the first reading was recorded. After 10 minutes the first reading was recorded and thereafter at 30 min intervals until the last reading was recorded. For every reading recorded, the turbidity (and/or colour) of the permeate, retentate and feed tank contents were also recorded. The permeate volume recorded was measured manually. It was measured at a constant volume of 100 ml against the time taken, hence, the permeate fluxes could be calculated.

Figure 3.1: Schematic diagram of the experimental set up



3.3 Waters tested

The following raw waters were tested in the bench-scale study:

a. Ground water

The ground water was obtained from Peninsula Technikon Lake. The water is pumped directly from the borehole to the lake. Iron was present in fairly high concentrations in the raw water (~ 1.67 mg/L). The quality of the groundwater is shown in Table 3.1.

Table3.1: Typical quality of groundwater at Peninsula Technikon Lake

Determinant	Raw groundwater
pH	6.78
Conductivity (*mS/m*)	152
Alkalinity (*mg/l* $CaCO_3$)	214
Chloride (*mg/l Cl*)	nd
Colour (*mg/l as Pt/Co*)	120
Calcium (*mg/l Ca*)	73.5
Magnesium (*mg/l Mg*)	37.0
Aluminum (*mg/l Al*)	0.182
Iron (*mg/l Fe*)	1.667
Manganese (*mg/l Mn*)	0.014
Sodium (*mg/l Na*)	177
Potassium (*mg/l K*)	4.48
Sulphate (*mg/l* SO_4)	123.2
UV 4cm at 300nm	nd
Total Dissolved Solids	1000
Nitrate/Nitrite (*mg/l* NO_3/NO_2)	nd
Turbidity (*NTU*)	11.9

nd: not determined

b. Coloured water

The coloured water sampled from Duivenhoks River, which normally has water with high levels of colour and high turbidity during rainy seasons. The river runs through Heidelberg in the Western Cape. This river is being used by Overberg Water treatment plant to supply potable water to Heidelberg and surrounding areas. The water is usually reasonably clear, but has a typical brown colour ranging from 130-160 mg/l as Pt, and fairly high iron concentrations of up to 1,3 mg/l.

The quality of the coloured water is shown in table 3.2.

Table 3.2: Quality of coloured water from Duivenhoks River used in UF tests

Determinant	Raw Duivenhoks River water
pH	6.82
Conductivity (*mS/m*)	25.0
Alkalinity (*mg/l* $CaCo_3$)	9.5
Chloride (*mg/l Cl*)	61.0
Colour (*mg/l as Pt/Co*)	160
Calcium (*mg/l Ca*)	5.49
Magnesium (*mg/l Mg*)	5.70
Aluminum (*mg/l Al*)	nd
Iron (*mg/l Fe*)	1.286
Manganese (*mg/l Mn*)	nd
Sodium (*mg/l Na*)	36.8
Potassium (*mg/l K*)	5.77
Sulphate (*mg/l* SO_4)	10.0
UV 4cm at 300nm	2.418
Total Dissolved Solids	162.50
Nitrate/Nitrite (*mg/l* NO_3/NO_2)	0.359
Turbidity (*NTU*)	12.3

nd: not determined

c. Tertiary treated wastewater effluent

Tertiary wastewater effluent used for the study was obtained from Bellville South Wastewater Treatment Plant (BWWTP). A number of analyses were conducted on the level of microbiological contamination in the feed. High concentration of *feacal coliform* and *Escherichia coli* were present in the raw water before chlorine dosage and the results were as follows: *Feacal coliform* (per 100 ml) = 12×10^4 and *Escherichia coli* (per 100 ml) = 10×10^4.

The quality of the tertiary treated wastewater effluent is shown in Table 3.3.

Table 3.3: Quality of tertiary treated wastewater effluent used in UF tests

Determinant	Tertiary treated wastewater effluent
Total Suspended Solids (*mg/l)*	1
COD (*mg/l)*	31
TKN (*mgN/l*)	12.4
NH_3 (*mgN/l)*	11.9
Organic Nitrogen (*mgN/l*)	0.5
NO_3/NO_2 (*mgN/l*)	6.6
Ortho-phosphate (*mgP/l*)	4.7
pH	7.0
Conductivity (*mS/m*)	66
Cl^- (*mg/l*)	79
Alkalinity (*mgCaCo$_3$/l*)	118

d. Eutrophic water

Eutrophic water was collected from the Voëlvlei dam. The Voëlvlei dam is used to supply the adjacent areas after treatment in the Voëlvlei water treatment works (CMC). The dam is situated approximately 87 km from Cape Town. The raw water contained substantial concentrations of algae species and are as follows; *carteria* at 98 cells/*ml, centric diatoms* at 49 cells/*ml*, *Melosira* at 685 filaments/*ml* and trachledomonas at 49 cells/*ml*. No blue green algae were found in the raw water.

The quality of the eutrophic Voëlvlei Dam samples that were used is shown in table 3.4.

Table 3.4: Quality of eutrophic water from Voëlvlei Dam used for UF evaluation

Determinant	Raw dam water
pH	7.16
Conductivity (*mS/m*)	7.4
Alkalinity (*mg/l* $CaCO_3$)	12.0
Chloride (*mg/l Cl*)	19.9
Colour (*mg/l as Pt/Co*)	10
Calcium (*mg/l Ca*)	4.14
Magnesium (*mg/l Mg*)	nd
Aluminum (*mg/l Al*)	nd
Iron (*mg/l Fe*)	nd
Manganese (*mg/l Mn*)	nd
Sodium (*mg/l Na*)	nd
Potassium (*mg/l K*)	nd
Sulphate (*mg/l* SO_4)	3.20
UV 4cm at 300nm	0.19
Total Dissolved Solids	48.1
Nitrate/Nitrite (*mg/l* NO_3/NO_2)	0.007
Turbidity (*NTU*)	13.5

nd: not determined

3.4 Results and Discussion

The results of the bench-scale studies are summarised and discussed below. Detailed results appear in Appendix A of the report.

Groundwater

For the entire experimental study, turbidity was mainly used to monitor the membrane removal efficiency. Figures 3.2 and 3.3 shows the reduction in turbidity effected by membrane filtration process.

Figure 3.2: First set showing permeate turbidities at different percentage recoveries over the operating period (only to 60% recovery, would be more economical above 90%)

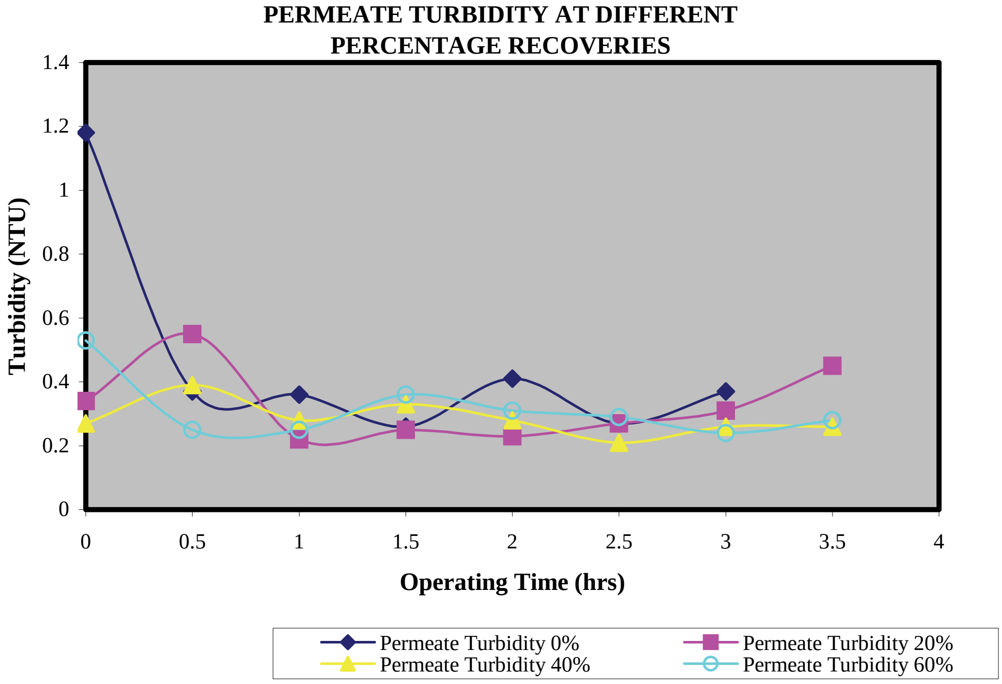


Figure 3.3: Second set showing permeate turbidities at different percentage recoveries over the operating period

Turbidity of the raw water, feed tank, retentate and permeate were recorded at 30 min intervals. The raw water turbidity ranges between 5 - 9 NTU and individual product turbities of $< 0{,}5$ NTU were recorded. Figure 3.2 and 3.3 show the permeate turbidities at different percentage recoveries for both the first and the second set of results. Average turbidities of less than 0,4 NTU were recorded in both the first and second set. The results show that there is no difference in turbidity reduction in both sets, although some spikes were observed in both sets. In figure 3.2 permeate turbidity level at 20% recovery at 3-3.5 hours of operating time was more than 0.8 NTU, and in figure 3.3 the permeate turbdity of more than 1 NTU was recorded at 0% recovery (permeate returned to feed tank) and this could be due to the contamination in the sampling bottles and due to the foulants from the previous set which affects the turbidity of the permeate stream at the beginning of the each set. It can further be concluded that the reduction in turbidity was $> 96\%$.

Figures 3.4 and 3.5 show the flux variation with time at different percentage recoveries. Initial average permeate fluxes of 70,2 l/m^2h and 47,0 l/m^2h were achieved on the first and second set of results, respectively. Initial and final permeate flux of 99,4 and 89,1 l/m^2h were achieved respectively after 5,36 hrs of operation at 0% recovery in the first set. The average flux decline for the different percentage recoveries is 13,14% on the first set and 18,4% on the second set.

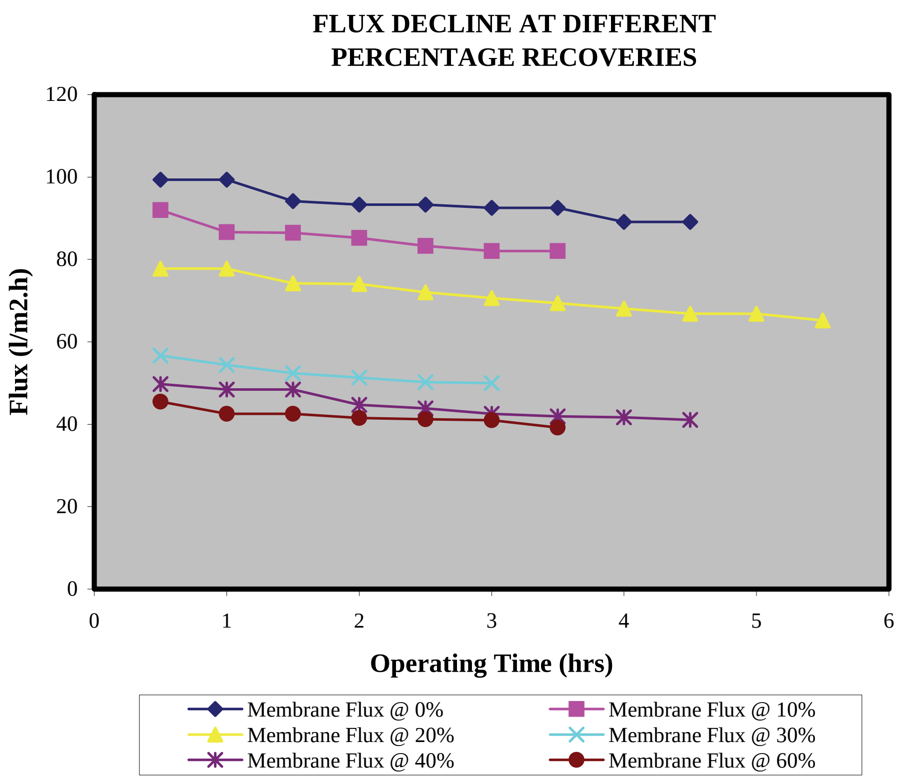


Figure 3.4: First set showing flux decline over time at different percentage recoveries

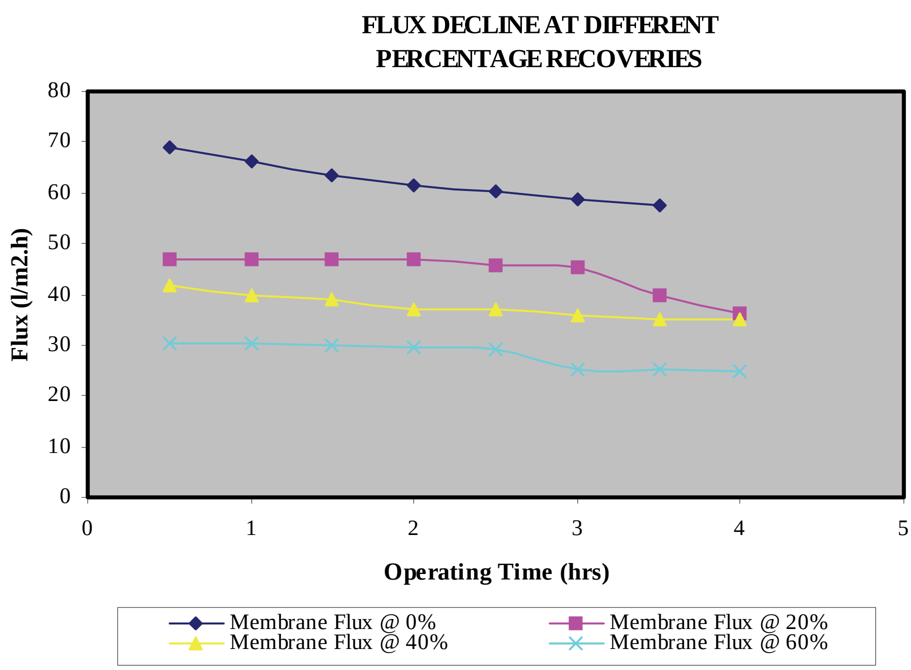


Figure 3.5: Second set showing flux decline over time at different percentage recoveries

Coloured Water

The raw water for this study is characterised by high colour levels content and moderate concentrations of iron (>1.3 mg/l as Fe). Figures 3.6-3.7 show the true colour levels of the permeate in relation to the feed stream over the operating period at different percentage recoveries. Although high colour concentrations between 330-360 mg/L as Pt were recorded in the feed , the UF membranes shows consistency in producing product water with very low colour content between 7-24 mg/L as Pt. This shows a colour reduction between 81 and 97% for the entire filtration process.

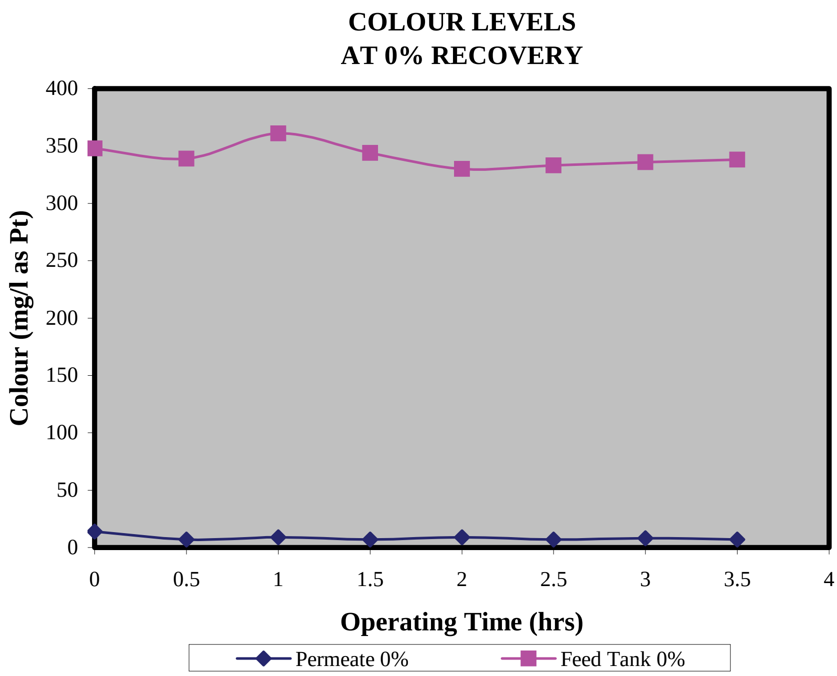


Figure 3.6: First set showing colour retention capabilities of the UF membranes over the operating time at 0 percentage recovery

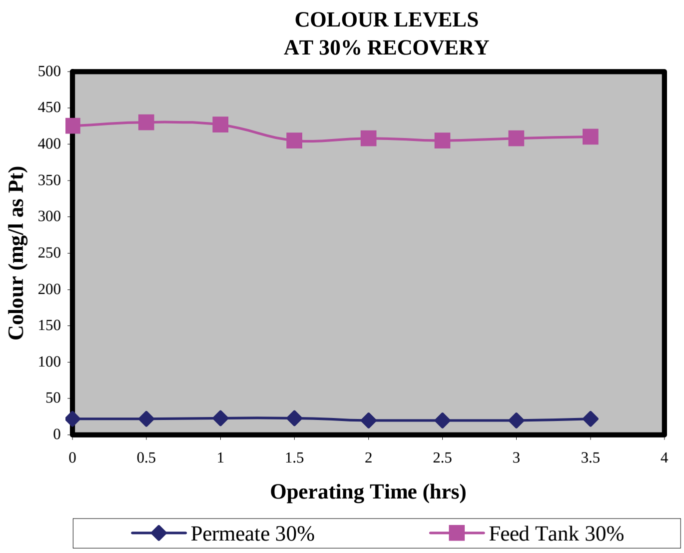


Figure 3.7: First set showing colour retention capabilities of the UF membranes over the operating time at 30 percentage recovery.

The iron in the water was reduced by 97 to 99% at which permeate iron concentrations levels below 0.03 mg/l were recorded.

Figures 3.8 and 3.9 present UF product turbidities at different percentage recoveries. Similar to the previous results an excellent permeate turbidity is obtained from the start of the filtration cycle in both sets. Permeate turbidity ranged from 0,13-0,44 NTU, and was generally around 0,3 NTU. Average permeate turbidity of 0,3 NTU were recorded in both sets of results, but few points arise from the graphs. In figure 3.8 permeate turbidity value of more than 0.4 NTU at 0% recovery was recorded at the start of the analyses and in figure 3.9 permeate turbidity value of more than 0.35 NTU at 2,5 hours of operating time at 30% recovery was recorded. However, this increase my be due to the same problem found in ground water, being that the product water is contaminated in the sampling bottles, which affect their turbidity. The two sets do not show much difference in their permeate turbidity in comparison.

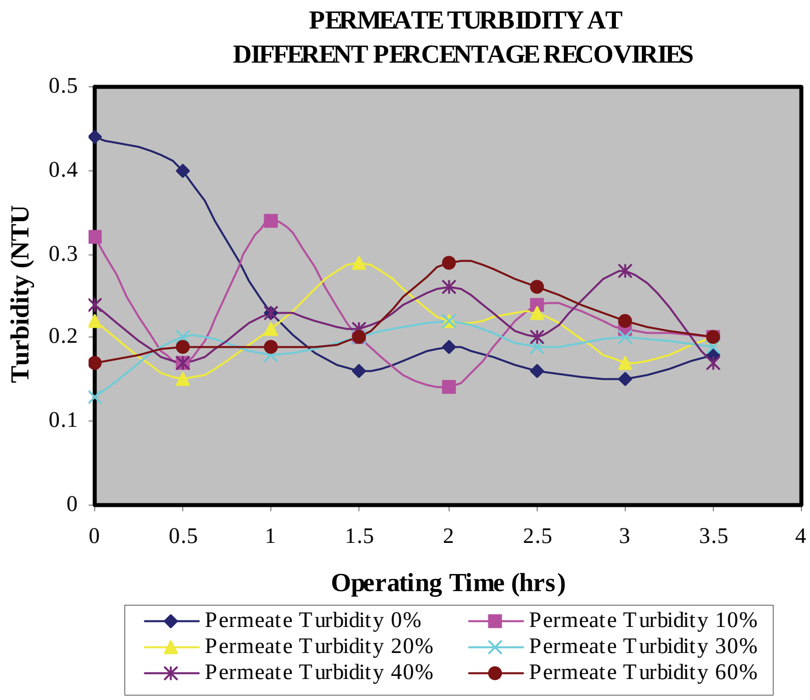


Figure 3.8: First set showing permeate turbidities at different percentage recoveries over the operating period

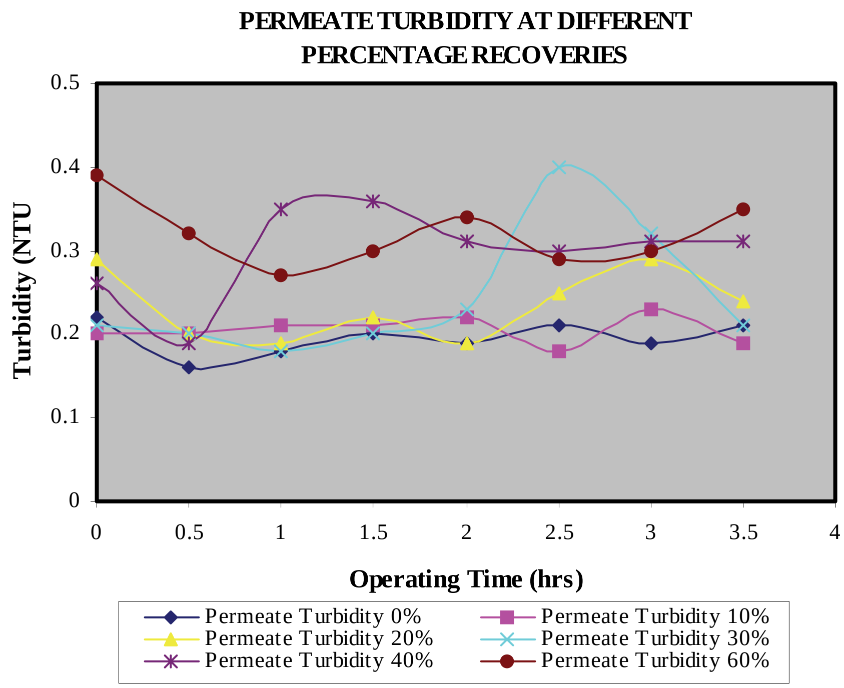


Figure 3.9: Second set showing permeate turbidities at different percentage recoveries over the operating period

Figures A.15 and A.18 in Appendix A present turbidity levels of permeate in relation to the feed and retentate streams over the operating period at 0% and 60% for both sets of results. The results shows fairly good constant permeate tubidities ranging between 0,13-0,40 NTU. Turbidity for both the feed and retentate ranged between 4 NTU and 9 NTUs, respectively, for the entire filtration process. The turbidity of the retentate is higher than that of the feed. This indicates good retention of suspended solids.

The average flux per cycle and the system productivity can be used as a tool to asses the removal effeciency of the UF systems. The filtration period for different percentage recoveries was normally between 4,5 and 6 hrs. Figure A.19 and A.20 shows flux variations with time which result in flux decline. In the first set, initial and final average permeate flux of 67,51 l/m^{2}hr and 56,49 l/m^{2}hr were achieved, respectively. And in the second set initial and final average permeate flux of 38,00 and 33,16 l/m^{2}hr were achieved respectively. The average flux decline in the first set is 16,45% and 13,13% in the second set. Initial permeate flux of 101,44 l/m^{2}hr and final permeate flux of 81,99 l/m^{2}hr were achieved in the first set after 4,81 hours of operation at 0% recovery and the flux decline for the entire operation period is 19,17% .

Tertiary Treated Wastewater

The influent into the Bellville South Wastewater Treatment Plant, consisted of surface water run-off, domestic and industrial waste water. Three main treatment processes are used at the plant and these are:Primary, secondary and tertiary treatment processes. Chlorine is dosed into the clear water sump as a disinfectant before the effluent is discharged into the environment.

A number of analyses were conducted to determine the level of microbiological contamination in the feed and also to evaluate the removal effeciency of the membranes. Because of the cost associated with an analyses of this nature and the limited number of samples to the Scientific Services, the analyses were done on *Escherichia Coli* (*E.Coli*) and Feacal Coliform (FC) only. The overall turbidities of the raw water were fairly low, ranging from 1-1.6 NTU. Turbidity levels of feed, retentate and permeate are depicted in Figures 3.10-3.13.

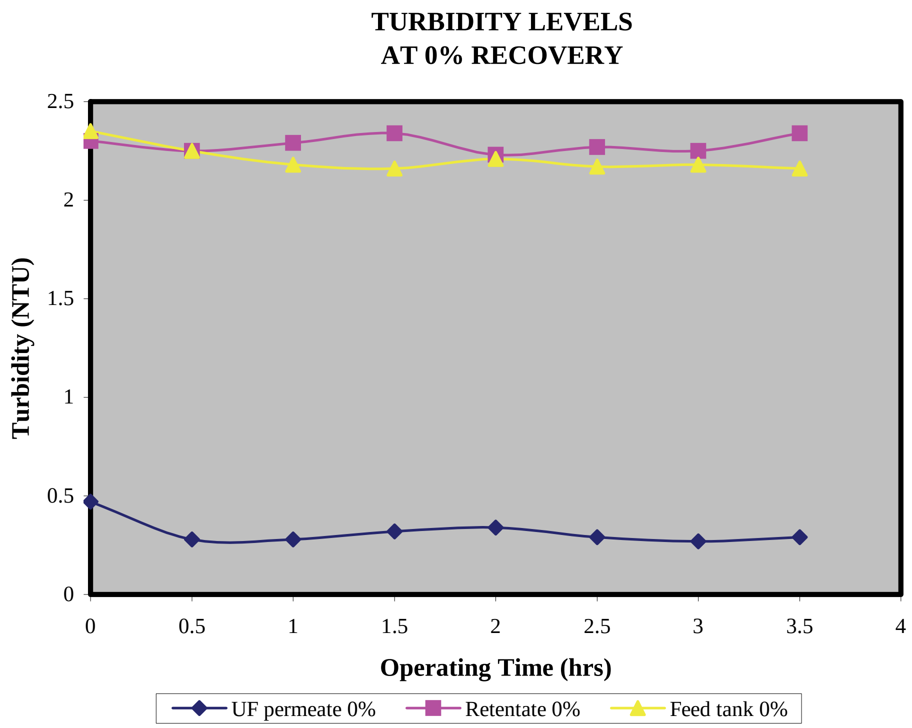


Figure 3.10: First set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 0 percentage recovery

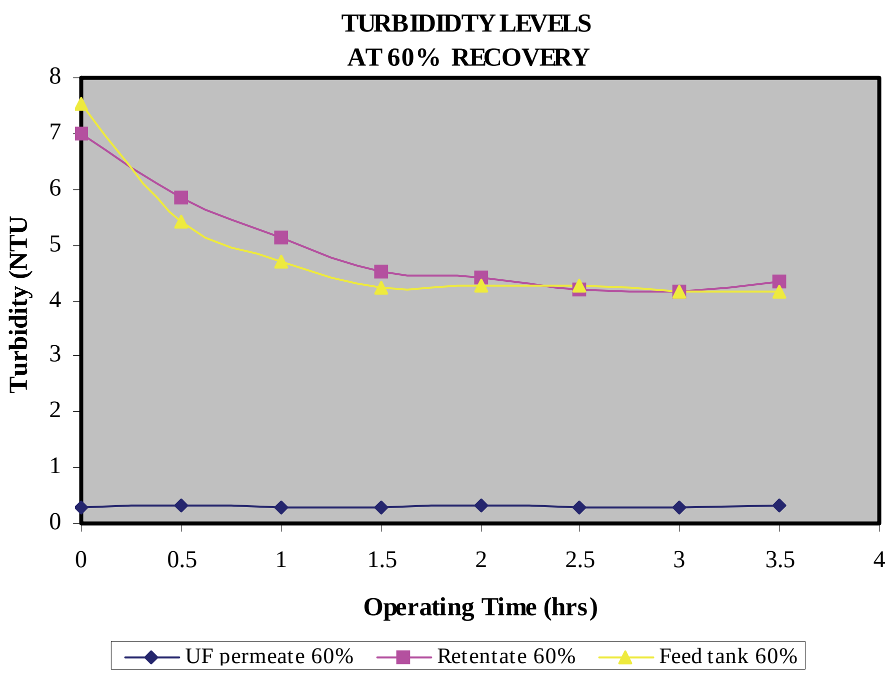


Figure 3.11: First set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 60 percentage recovery

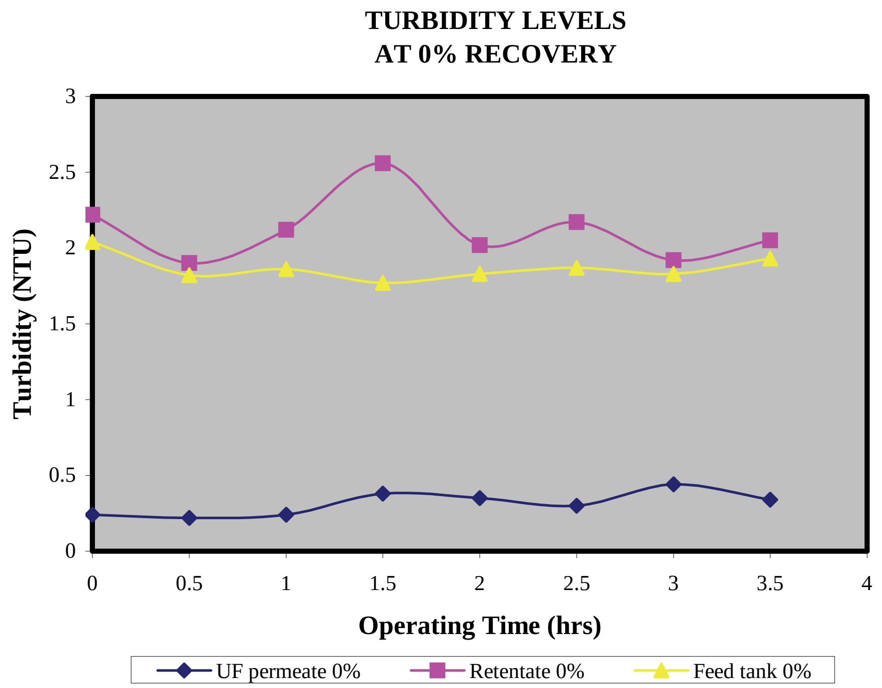


Figure 3.12: Second set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 0 percentage recovery

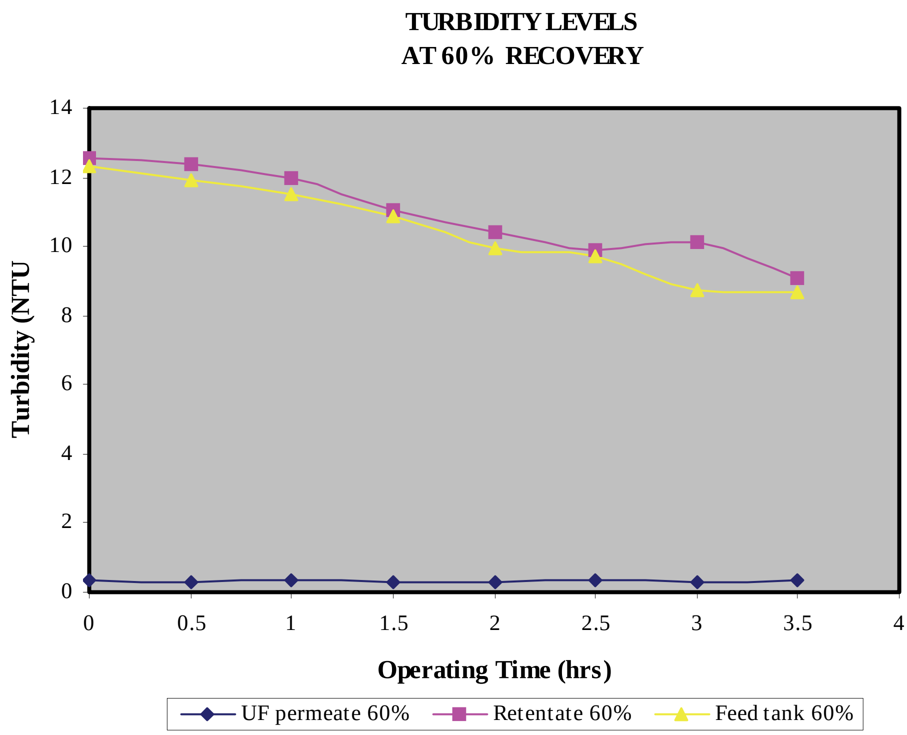


Figure 3.13: Second set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 60 percentage recovery

Figures A.25 and A.26 in Appendix A present flux variation with time, where the average flux decline for the different percentage recoveries is 17,16% on the first set and 4,45% on the second set. Initial average permeate fluxes of 77,50 l/m^2h and 54,17 l/m^2h were respectively identified in the first and second set of results. Initial and final permeate fluxes of 97,73 and 85,95 l/m^2h were achieved, respectively, after 4,78 hours of operation at 0% recovery in the first set.

Based on microbial analysis the raw water is by far unsuitable for human consumption (see table B.4) because of the high amount of Feacal Coliform and *Escherichia coli* bacteria in the feed. The turbidity of the product water was on average below 0,35 NTU. The analyses were done on the raw water, the retentate and the permeate as indicated in figures 3.10-3.13. It is very intresting to note that, the concentration of microbes in the raw water feed and the retentate streams do not differ much. It is possible that the microbial cells are damaged in the recirculation loop. This may be as a result of shear in the narrow flow paths of the membrane.

The raw water used for the study was sampled before the dosing of chlorine to find the true concentration of microbes in the water. The product waters at different water percentage recoveries were then taken to the lab for analysis. The analyses show high amount of FC and *E.coli* as $12x10^4$ per 100 ml and $10x10^4$ per 100 ml, respectively, in the raw water. An excellent reduction in FC and *E.coli* bacteria was observed with the product water reaching less than 10 per 100 ml concentrations. This shows that the UF membranes have disinfection capabilities, and with a final disinfection using chlorine, for example, the membrane process is effective for potable water treatment.

<u>Euthrophic Water</u>

The Voëlvlei treatment plant uses water from the Voëlvlei dam to supply the nearby areas. The water is characterised with high concentrations of algae species with *Melosira* species sometimes reaching as high as 867 filaments/ml (Scientific Services, CMC). The water quality from the dam changes from time to time and the analyses of the raw water sampled for the study did not show any concentrations of blue-green algae. The algae species detected in the raw water sample were *Carteria* species with a concentration of 98 cells/ml; Centric diatoms with a concentration of 49 cells/ml; *Melosira* with a concentration of 685 filaments/ml and lastly *Trachydomonas* species with a concentration of 49 cells/ml. The raw water turbidities were as high as 47 NTU.

Irrespective of the high raw water turbidities the filtration process was able to remove around 99% of the turbidity content in the feed. Figures 3.14-3.15 shows the turbidity of the feed, retentate and permeate at 0% and 60% recoveries. The overall turbidities of the raw water feed is high. Turbidities of both the feed and retentate are getting lower and lower during the filtration process. Initial and final turbidities in the feed water at 0% recovery are 51,6 and 30,9 NTU respectively. This is due to the cake layer build upon the membrane. Product water turbidities between 0,20-0,60 NTU were recorded.

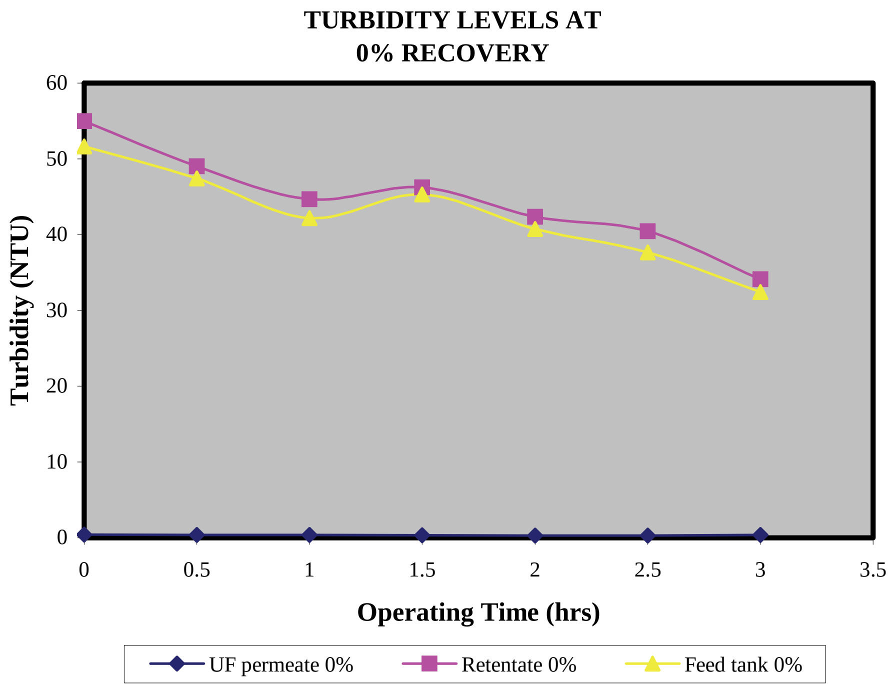


Figure 3.14: First set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 0 percentage recovery.

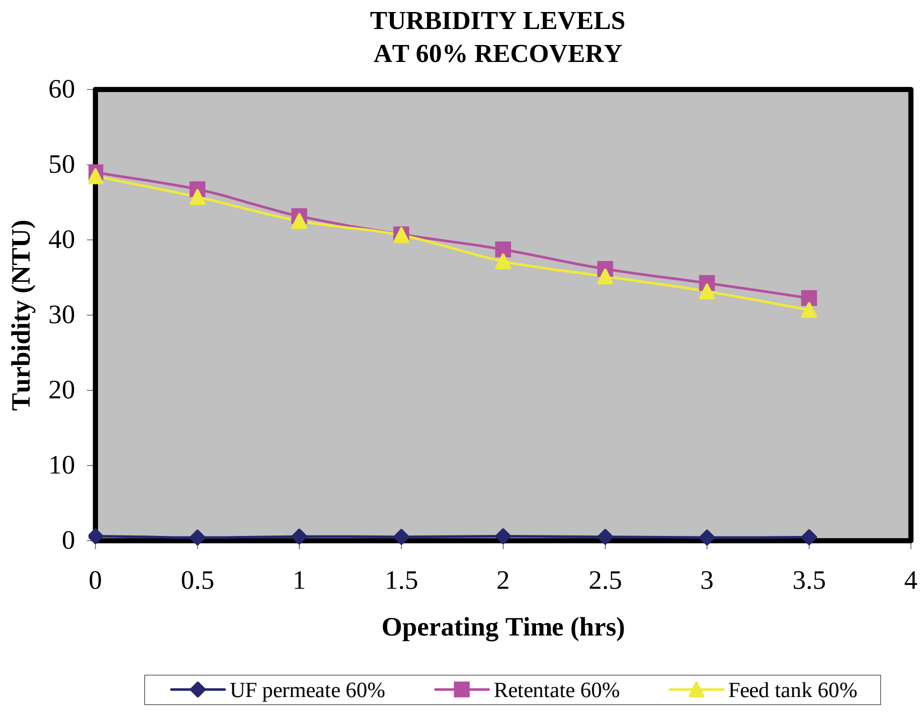


Figure 3.15: First set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 60 percentage recovery.

Initially, before the start of the experiment on the algae water, it was thought that the membrane was easily going to be fouled due to the high concentrations of the *Melosira* species in the water. For the two sets of results, there was a relative decline in the membrane flux during the filtration process. Figure 3.16 and 3.17 show flux variation with time at different percentage recoveries for the fisrt and the second set of results. In the first set the initial and final permeate fluxes are 114,47 and 78,96 l/m^2h, respectively, at 0% recovery. At 60% recovery the initial and final permeate fluxes are 56,75 and 49,64 l/m^2h respectively. It is clearly observed from the results that the cake layer actually builds up as filtration goes on, thus showing an influence on the membrane performance.

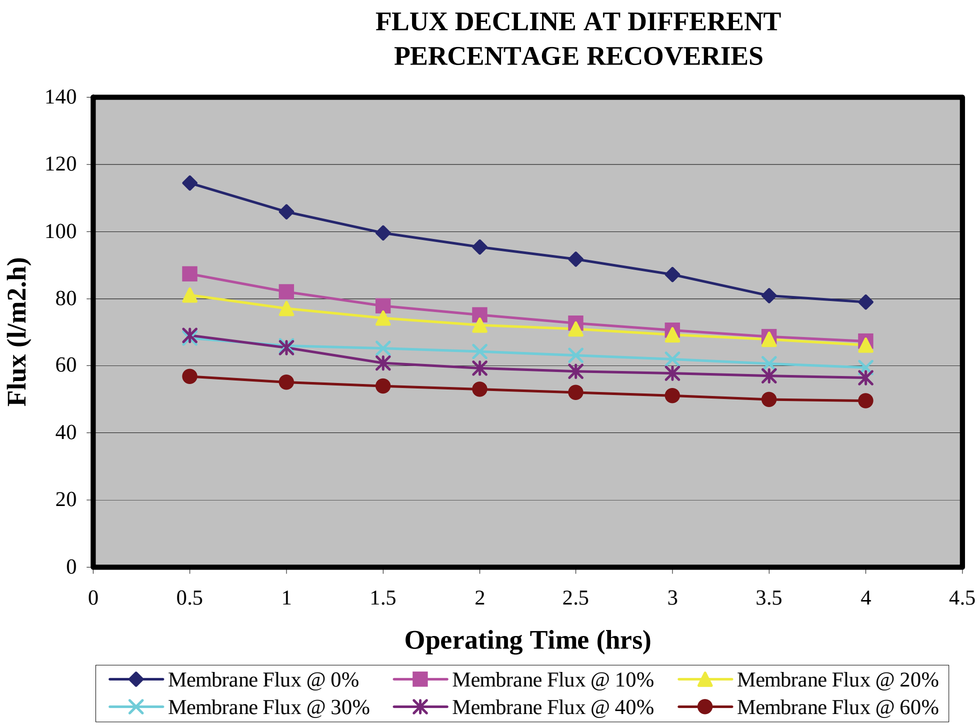


Figure 3.16: First set showing flux decline over time due to fouling at different percentage recoveries

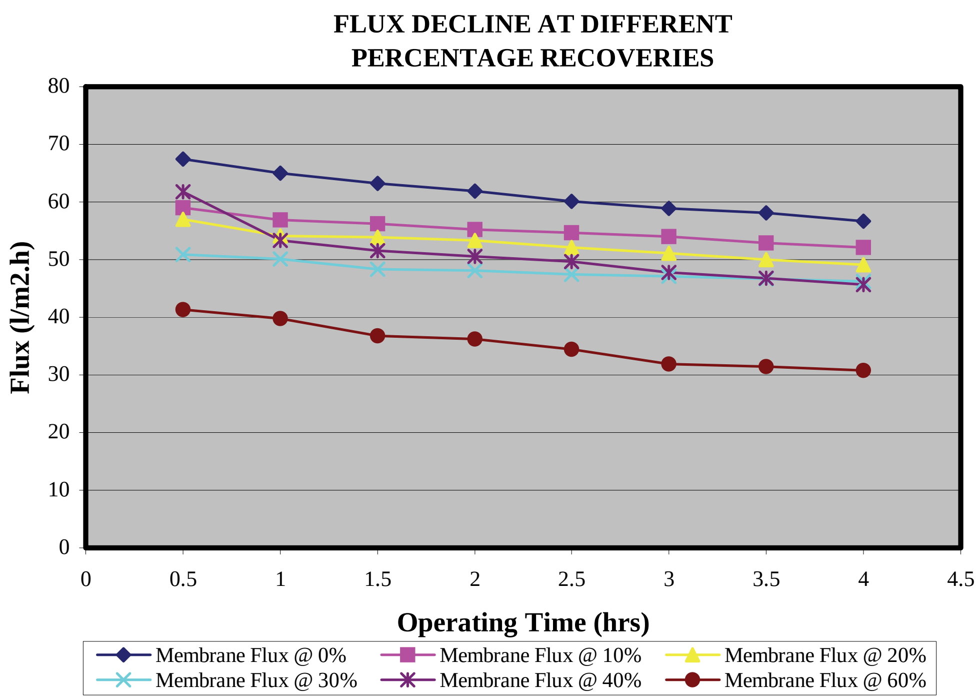


Figure 3.17: Second set showing flux decline over time due to fouling at different percentage recoveries

Analyses done on the product water shows a relatively high reduction in the algae species in the raw water. The analyses were done on samples at different percentage recoveries and the results were as follows (see table A.7)

- 0% recovery *Melosira* species with up to 98 cells/ml concentrations.
- 20% recovery *chlamydonomas* species with 49 cells/ml concentrations.
- 40% recovery, No algae present in the water.
- 60% recovery, No algae present in the water

General

As it was expected, the removal of suspended and colloidal solids on the UF membranes were excellent, *i.e.* **99%** as turbidity, for the majority of the experiments, reducing turbidity to less than 0,2 NTU. It was also observed that the suspended solids removal efficiency is constant, depending on the operating conditions. Certain differences observed in removal efficiencies of turbidity can be correlated with the change of the feed waters i.e. each raw water used in the study had different percentage removal on turbidity due to different raw water turbidities and characteristics.

Organic compounds, attached to suspended solids, have also not been removed to a certain extent. Dissolved organic materials can easily pass through the UF membranes depending on the molecular mass. On the other hand, the UF membranes do not retain dissolved inorganic compounds (such as iron) and these compounds should be removed by oxidation followed by membrane filtration.

CHAPTER 4

PILOT-PLANT STUDIES WITH MICROFILTRATION AND ULTRAFILTRATION MEMBRANES

4.1 Description of Pilot Treatment Plant

A pilot scale microfiltration and ultrafiltration treatment plant was constructed by Quality Filtration for the project team, for technical and social acceptance evaluation at rural communities. The plant has a capacity of 500 litres per hour, and can be operated on a semi-automated basis by PLC control. The MF module consists of hollow-fibre membranes, made of polyethersulfone, with MWCO of 0,2 micron and membrane area of 3,5 m^2. It is operated in the dead-end mode, with intermittent backflushing.

The ultrafiltration module consists of capillary membranes, also made of polyethersulfone, with a MWCO of 70-100 kD. The area of the UF membrane is 4,5 m^2. It is operated in crossflow filtration mode, and contains manual back pressure valve.

The lay-out of the pilot plant is shown in figure 4.1 below. The configuration of the pilot plant (flow diagrams) and a photo appear in Appendix B of the report.

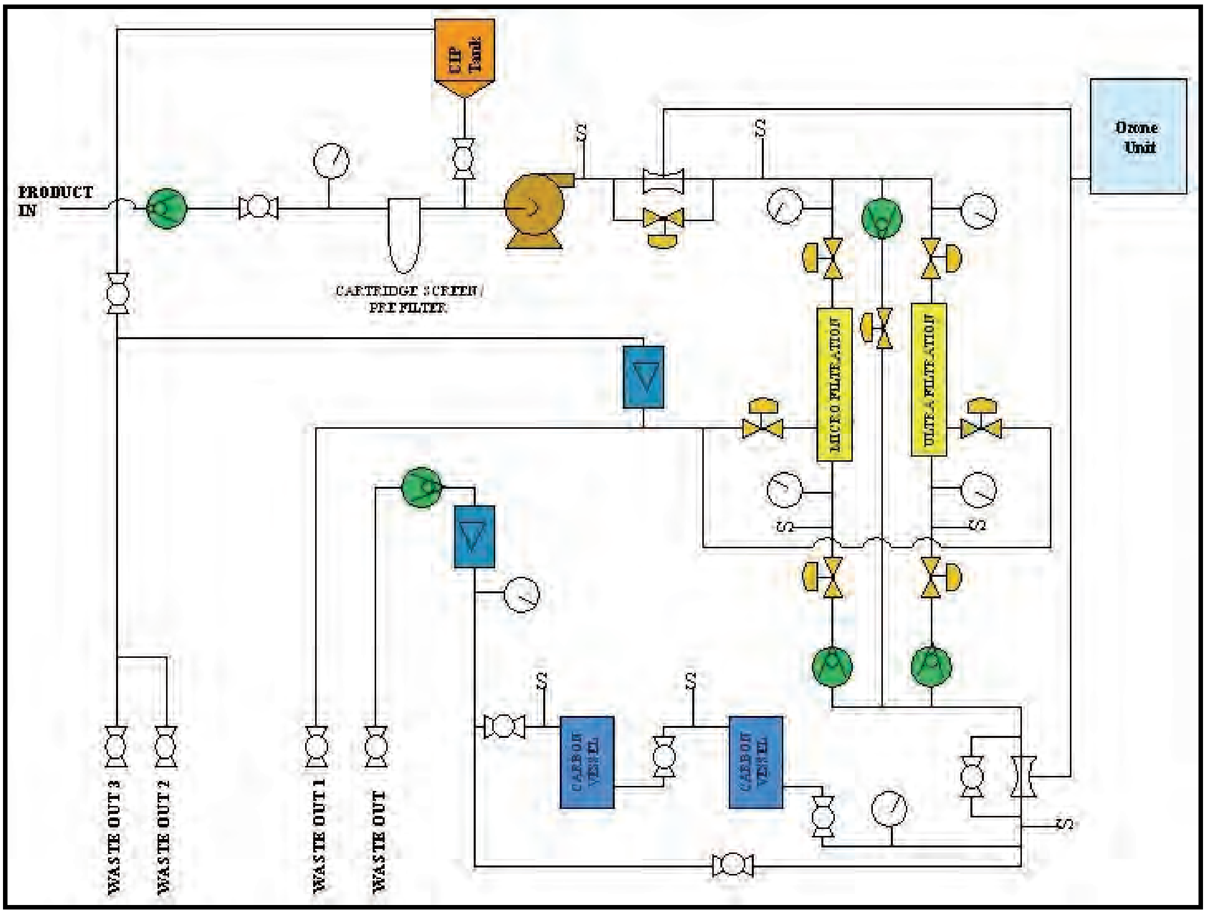


Figure 4.1(a): Flow diagram of Microfiltration / Ultrafiltration Mobile Pilot Plant

4.2 Selection of sites for the pilot-plant and socio-economic studies

It was decided that the two test sites should reflect not only different water qualities, but, importantly, supplying water to two communities with different socio-economic profiles and characteristics.

The site for the first pilot-plant study was selected to be at the Voorstekraal community in Genadendal, Western Cape Province. Genadendal is situated approximately 35 km to the north of Caledon. The second pilot study was performed at the Upper Mnyameni community in the Keiskammahoek-region in the Eastern Cape Province. Descriptions of the water supply schemes of these communities are given below.

4.2.1 Description of Voorstekraal water supply

The raw water supply to the Voorstekraal community is obtained from a weir in the foothills of the mountains directly to the north of the community. The raw water is normally of a fairly good quality, with low turbidity and moderately low colour levels. However, during periods of rain the quality of the raw water rapidly deteriorates, with increase in turbidity but in particular in dissolved organic matter, reflected as increasing brown colour in the water. During these periods, complaints about the quality of the raw water are frequently received from inhabitants by the municipality.

The raw water at Voorstekraal gravitates from the weir into a 50 000 L storage tank on the outskirts of the town. From here the water flows into two cement dams (these dams used to be slow sand filters but has not been in operation for many years) and then feeds into the town's distribution system. Before entering the two cement dams, the water is chlorinated, which is the only form of treatment of the water.

4.2.2 Description of Upper Mnyameni water supply

Upper Mnyameni is a rural village located in the Amatola Mountains in the Eastern Cape Province in South Africa. It is situated in the Keiskammahoek region which lies in a basin at the confluence of the Keiskamma and Gxulu rivers.

Water for the village is withdrawn from the Mnyameni Dam, which is in a tribituary (the Mnyameni River) of the Keiskamma river. The raw water is characterized by moderate turbidity levels (10 NTU), which can rise to high levels after rain storms.

Raw water gravitates from the dam to a balancing tank located on the slopes just above the Mnyameni water treatment plant. From here the water gravitates to the filtration room where 6 pressure sand filters are located. On the way to the filters a coagulant is dosed (a polymer blend) into the gravity line. Provision is also made for dosing of lime at an adjacent dosing point, but this is rarely used. The flocculated water is pumped by means of a booster pump through the pressure sand filters to a clean water reservoir on site. Chlorination is achieved through placing chlorine tablets in the inlet zone of the clean water reservoir.

4.3 Experimental Protocol

4.3.1 Voorstekraal methodology

The pilot-plant was set up at the medical clinic in the main road of the town (selected here as is a centrally-located point for the collection of treated water from the pilot-plant, and also because of the availability of lock-up facilities for test equipment, and security fencing around the facility.

Raw water was gravitated from a connection point before it enters the 50 000 L storage tank of the existing water supply system (see 4.2.1 above), to the pilot plant. Treated water from the pilot plant was pumped into a 5 000 L plastic tank next to the clinic building, where community members could collect the treated water in containers.

The pilot plant was operated by two students from the Cape Peninsula University of Technology, who also took samples and plant readings at regular intervals during the trials.

The pilot plant was operated at Voorstekraal with the microfiltration in dead-end mode and the ultrafiltration in cross-flow mode.

The following trials were performed:

a. Determination of optimal recovery on UF module for turbidity and colour removal

The cross-flow volumes were varied at the following percentages of maximum flow on the cross-flow rotameter:
- 0%
- 20%
- 40%
- 60%
- 80%

The optimisation of recovery was done for UF alone as well as UF preceded by MF.

b. Comparison of turbidity removal efficiency of MF alone, UF alone, and MF followed by UF at optimum recoveries for UF determined in (a) above

The following control parameters were monitored:
- Permeate Flowrate
- Cross-flow Flowrate
- Differential Pressures

The following water quality parameters were measured on samples that were taken on regular intervals of the feed water from feed tank, after microfiltration and after ultrafiltration:
- Turbidity
- Colour
- pH
- Conductivity
- Iron

More detailed chemical analysis was performed on the raw water feed to the pilot plant during the start of each of the trial periods.

4.3.2 Upper Mnyameni methodology

The pilot plant was positioned and commissioned within the existing Mnyameni Water Treatment Plant. The raw water feed was obtained from a sampling connection on the main raw water feed line. The treated water from the pilot plant was pumped into a 2 500 L plastic tank that was located next to the security fence around the plant, with the outlet tap protruding through the security fence so that community members were able to collect treated water from the membrane pilot-plant at any time of the day.

The pilot-plant was operated by the Process Controller and plant readings and samples taken at regular intervals over the two week period.

The plant was operated with the microfiltration in dead-end mode and the ultrafiltration in cross-flow mode. A cross-flow volume of 50% of the maximum flow on the cross-flow rotameter was maintained throughout the pilot trials at Upper Mnyameni, which was done over a period of two weeks.

Samples were taken by the Process Controller during the trials at the following points and the turbidity measured:

- raw water
- after microfiltration
- after ultrafiltration (final water)

A sample was also taken during the first week of the trials and submitted to the CSIR laboratory in Stellenbosch.

4.4 Results and Discussion

The results of preliminary trials that were performed at Caledon and the trials at Voorstekraal and Upper Mnyameni are given in Appendix C of the report.

4.4.1 Voorstekraal results

The typical quality of the Voorstekraal raw water is shown in table 4.1.

Table 4.1: Chemical quality of Voorstekraal raw water

Determinant	Taken on 23 August 2005	Taken on 19 October 2005
pH	4.5	5.3
Conductivity (*mS/m*)	7.6	6.7
Alkalinity (*mg/L* $CaCO_3$)	0	2.0
Chloride (*mg/L Cl*)	17.5	nd
Colour (*mg/L as Pt*)	20	50
Calcium (*mg/L Ca*)	0.5	0.3
Magnesium (*mg/L Mg*)	1.0	1.0
Hardness *(mg/L as CaCO3)*	5.4	4.8
Iron (*mg/L Fe*)	0.13	0.24
Potassium (*mg/L K*)	0.1	nd
Sodium (*mg/L Na*)	9.2	nd
Sulphate (*mg/L* SO_4)	1.2	nd
Dissolved organic carbon *(mg/L)*	2.7	3.5
Total suspended solids *(mg/L)*	< 5	nd
Nitrate/Nitrite (*mg/L* NO_3/NO_2)	< 0.1	nd
Turbidity (*NTU*)	0.57	1.1

nd: not determined

The results are shown graphically in figures 4.1-4.21 below, showing the turbidity and colour removal in the plant for different MF and UF configurations.

The turbidity of the raw water was low during the trial period, but the microfiltration membrane reduced the turbidity to around 0.2-0.6 NTU, while the ultrafiltration membrane reduced it further to 0.1-0.3 NTU.

Colour levels were reduced to less than 20 mg/L as Pt (the SABS 241 Class I limit), but could not be reduced to less than 10 mg/L as Pt, as expected. The exception was when ultrafiltration was operated without the preceding microfiltration step, in which case the colour levels were reduced to between 5 and 10 mg/L as Pt.

No specific conclusions are attempted here on the effect of varying cross-flow volumes on turbidity and colour removal, partially because this was not the main aim of the experimental work, but mainly because considerable research has already been done locally on the evaluation of microfiltration and ultrafiltration for the treatment of various raw water types.

Figure 4.1(b) Photo of Microfiltration / Ultrafiltration Mobile Pilot Plant

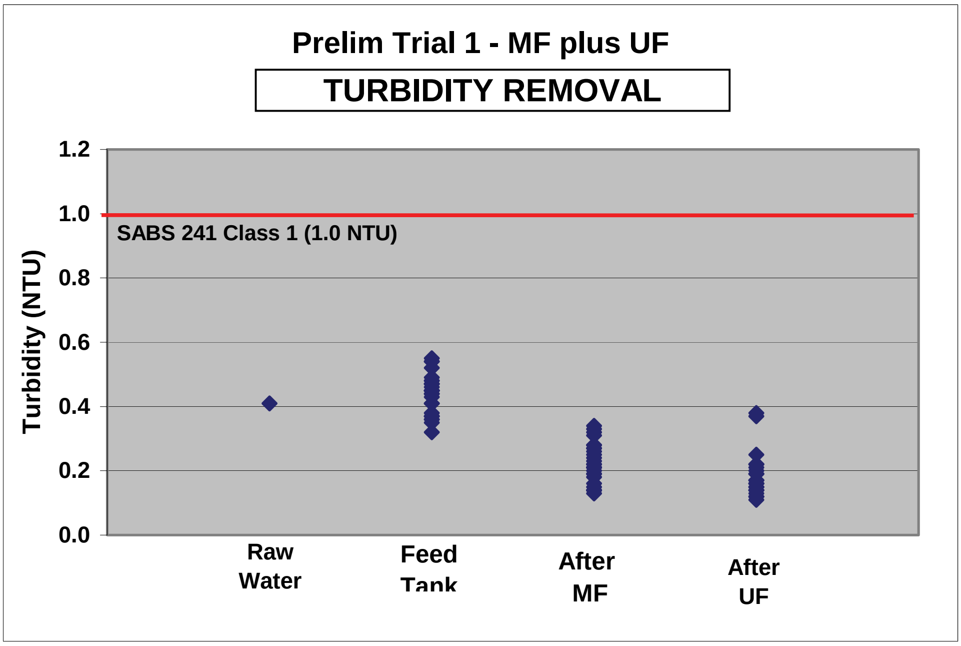


Figure 4.2: Preliminary Trial 1 – Turbidity removal with Microfiltration plus Ultrafiltration

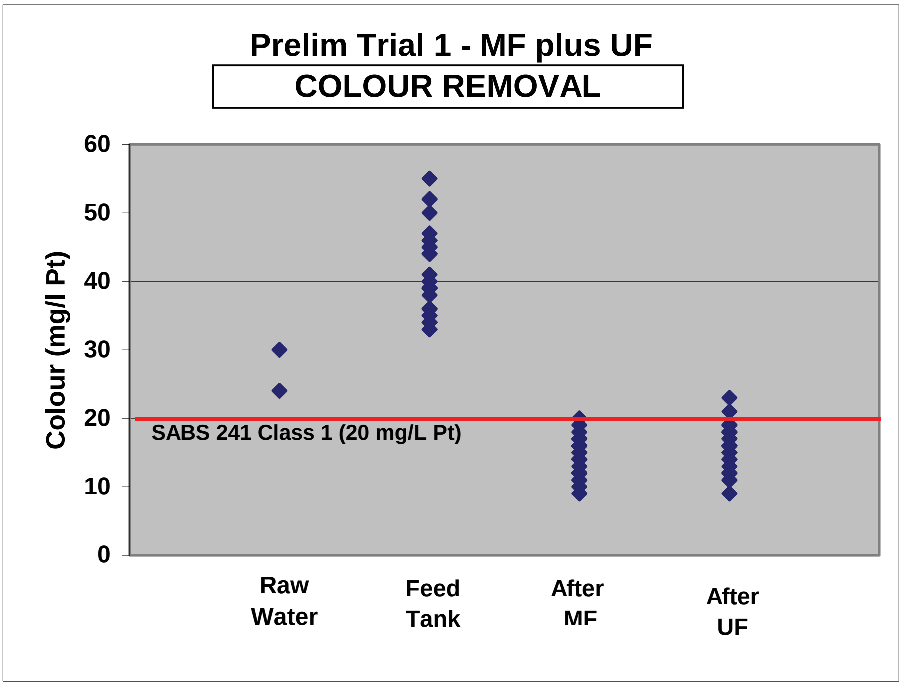


Figure 4.3: Preliminary Trial 1 – Colour removal with Microfiltration plus Ultrafiltration

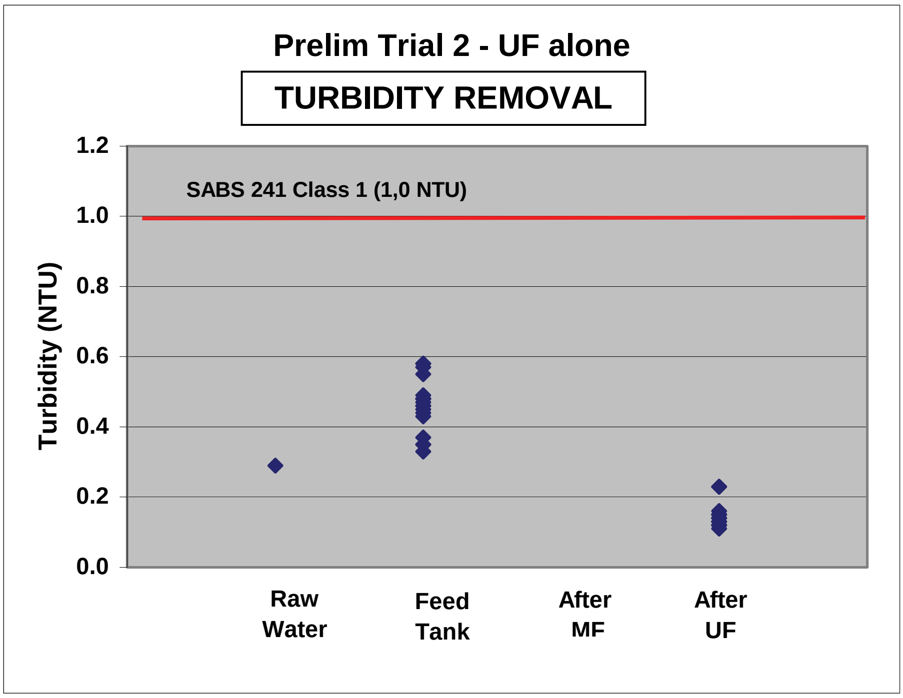


Figure 4.4: Preliminary Trial 2 – Turbidity removal with Ultrafiltration

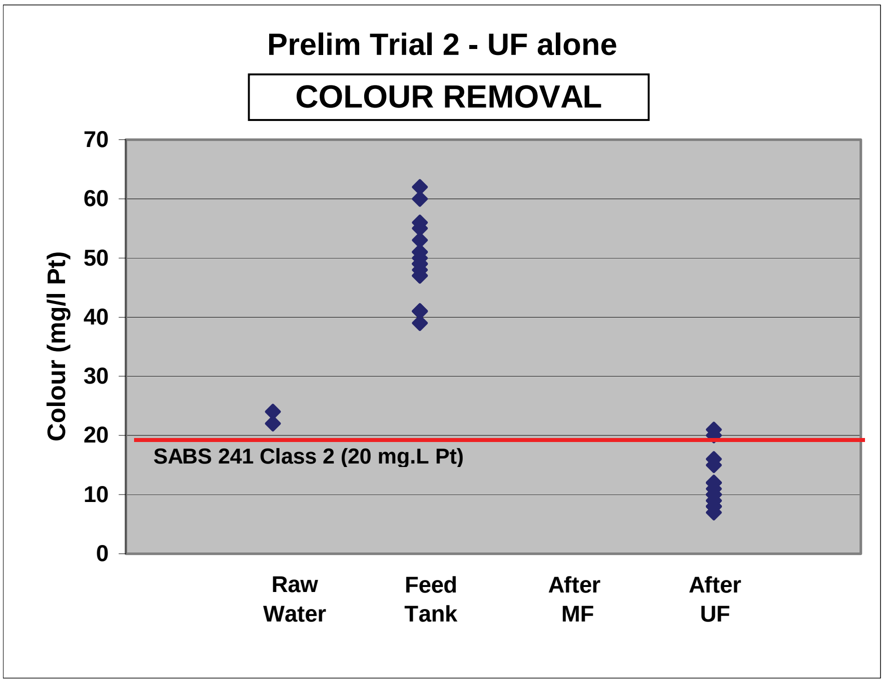


Figure 4.5: Preliminary Trial 2 – Colour removal with Ultrafiltration

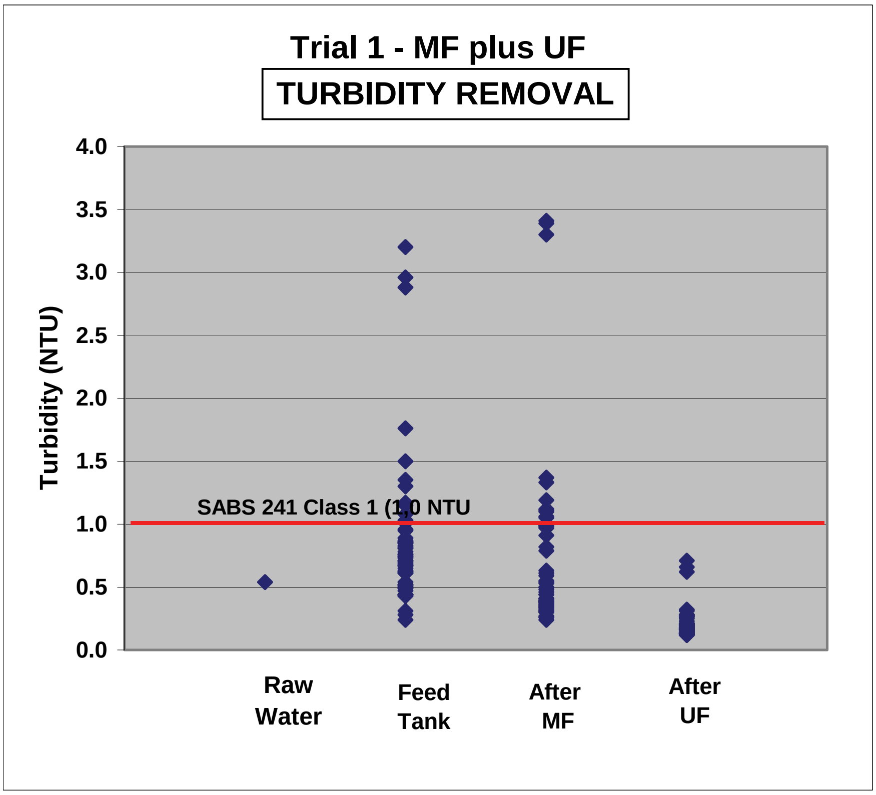


Figure 4.6: Trial 1 – Turbidity removal with Microfiltration plus Ultrafiltration

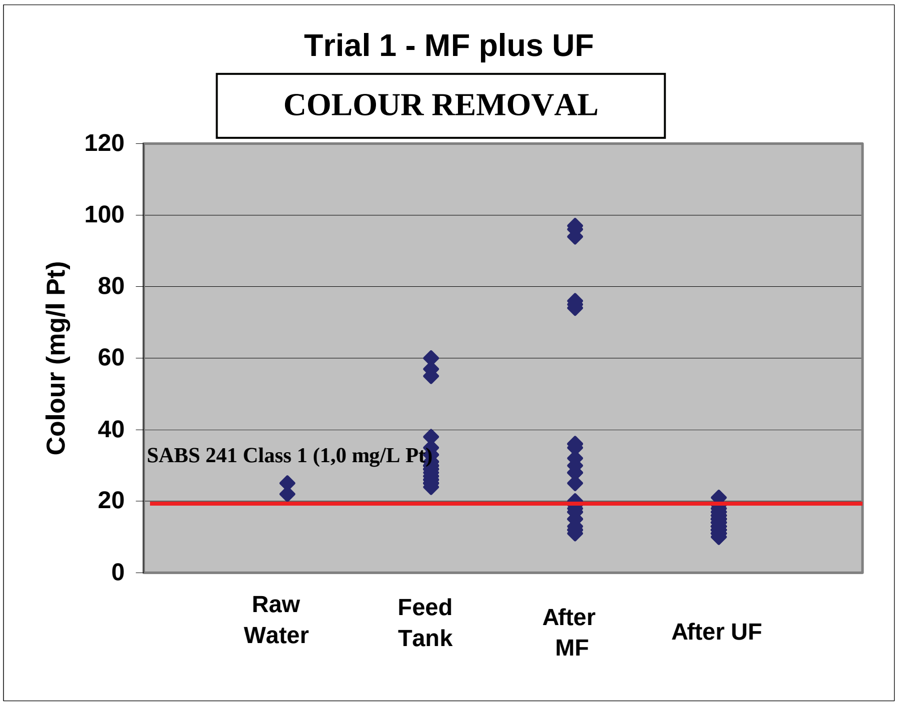


Figure 4.7: Trial 1 – Colour removal with Microfiltration plus Ultrafiltration

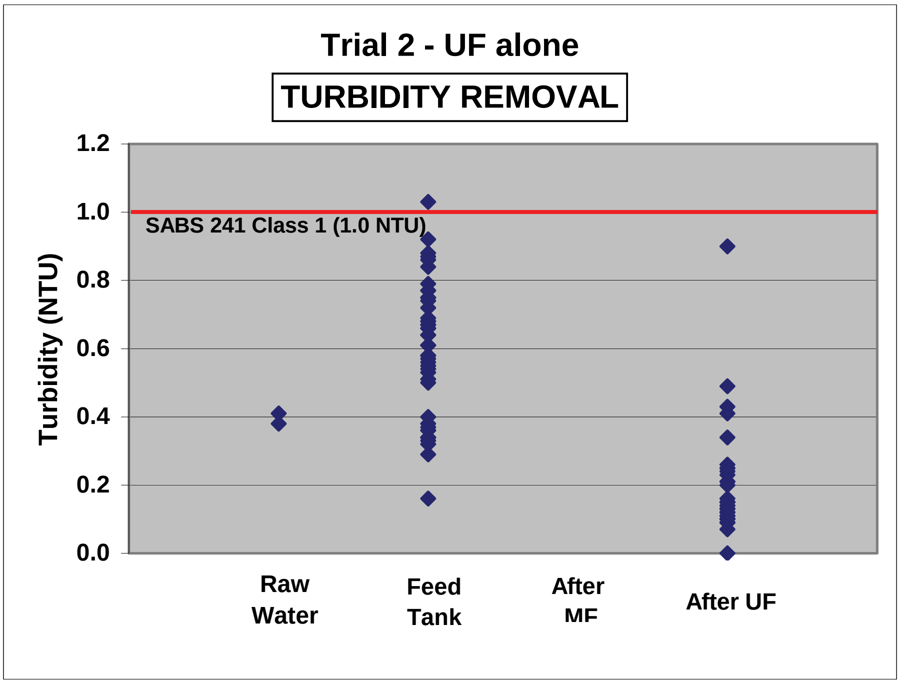


Figure 4.8: Trial 2 – Turbidity removal with Ultrafiltration

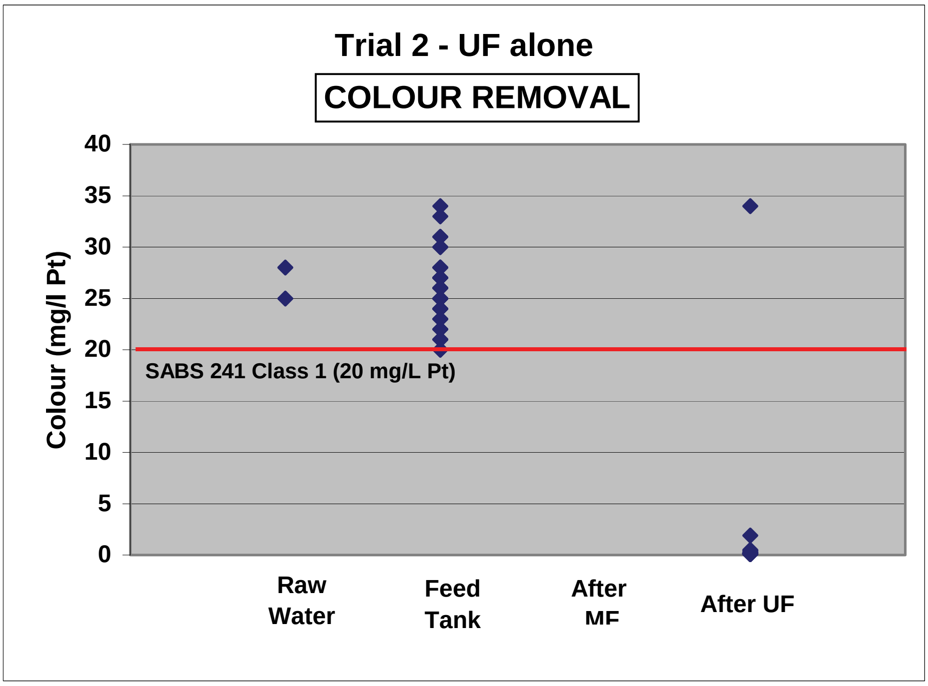


Figure 4.9: Trial 2 – Colour removal with Ultrafiltration

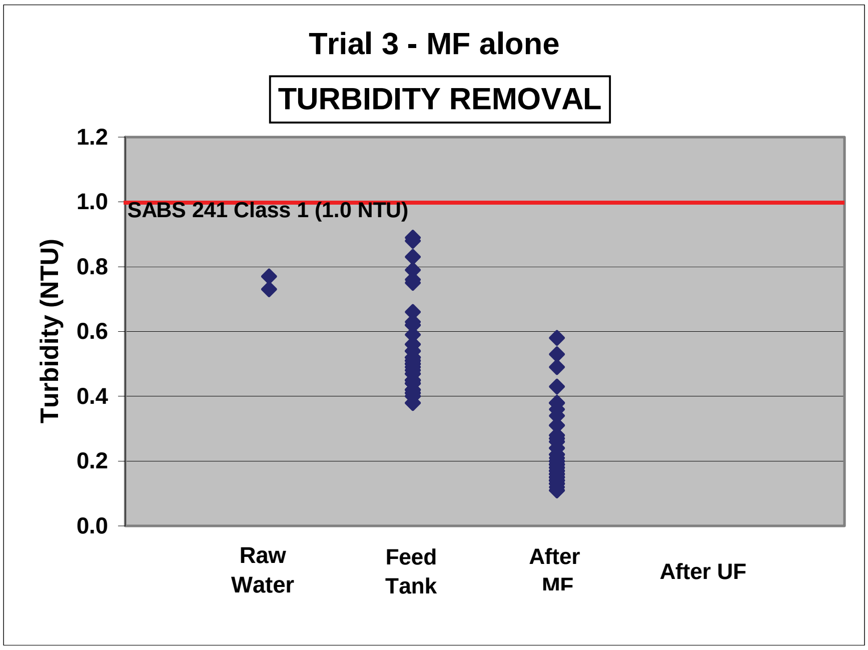


Figure 4.10: Trial 3 – Turbidity removal with Microfiltration

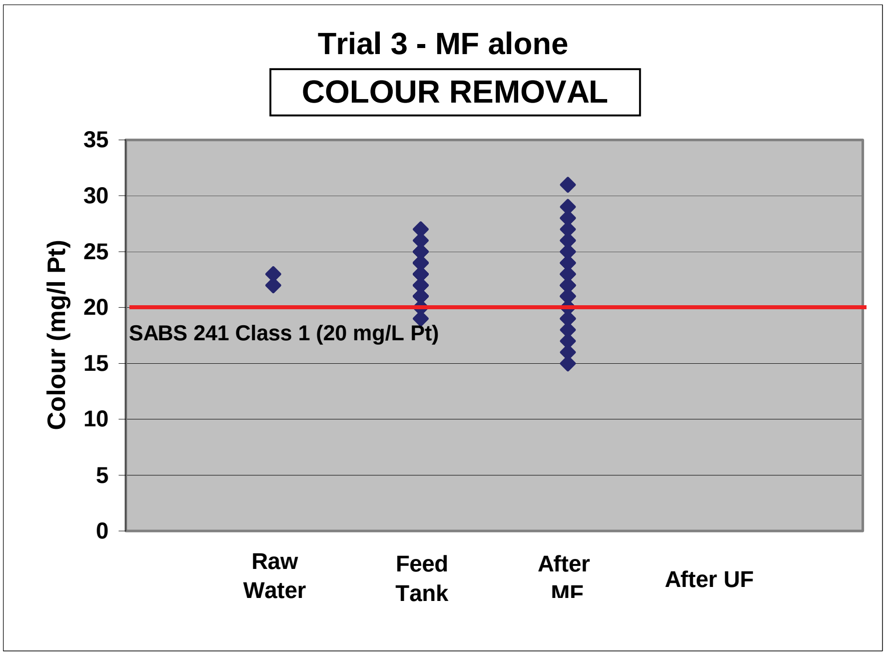


Figure 4.11: Trial 3 – Colour removal with Microfiltration

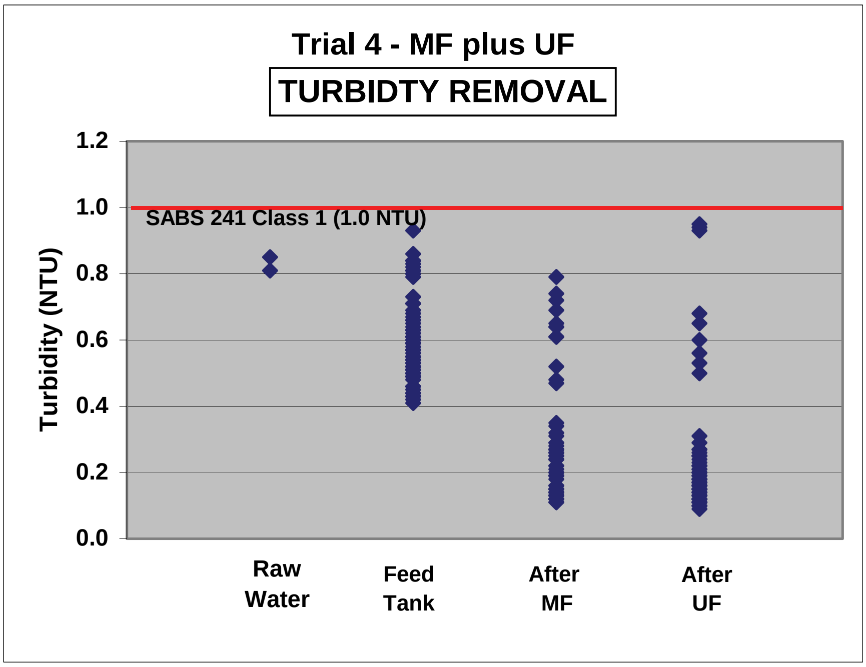


Figure 4.12: Trial 4 – Turbidity removal with Microfiltration plus Ultrafiltration

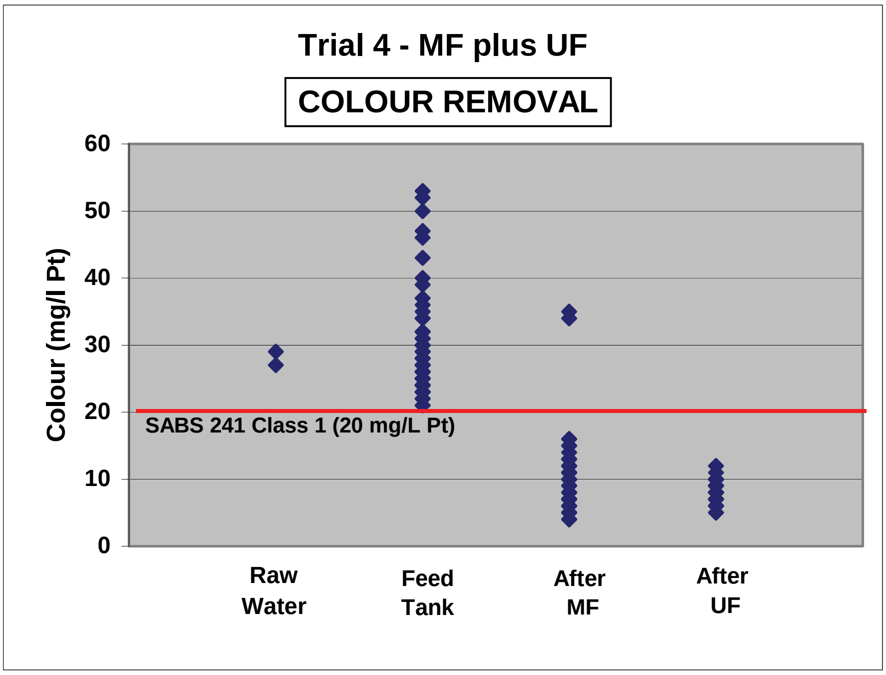


Figure 4.13: Trial 4 – Colour removal with Microfiltration plus Ultrafiltration

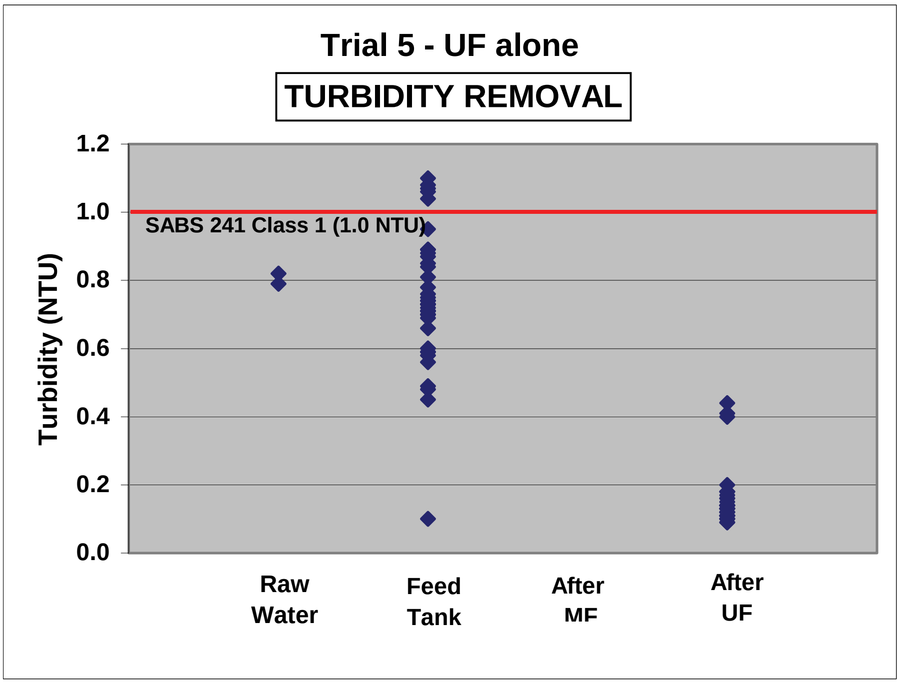


Figure 4.14: Trial 5 – Turbidity removal with Ultrafiltration

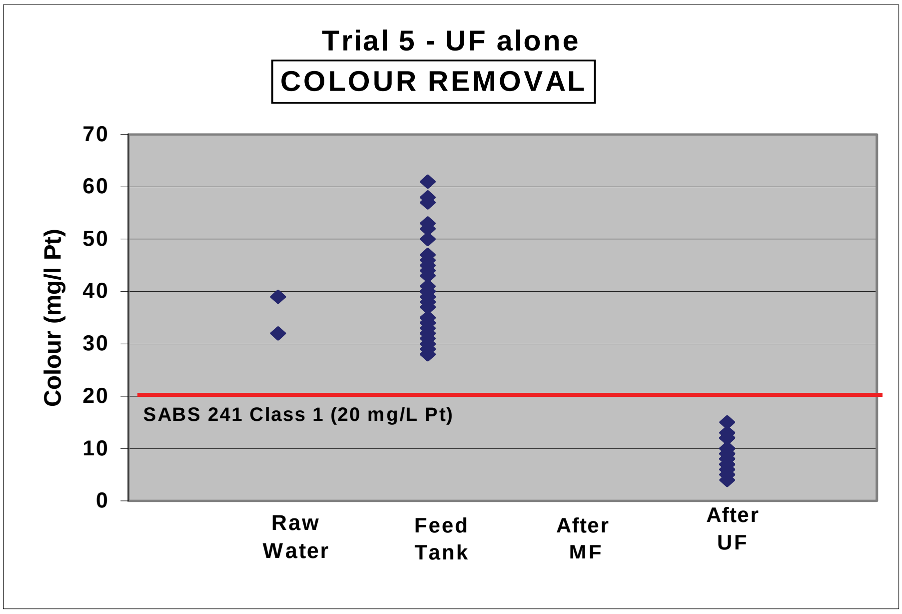


Figure 4.15: Trial 5 – Colour removal with Ultrafiltration

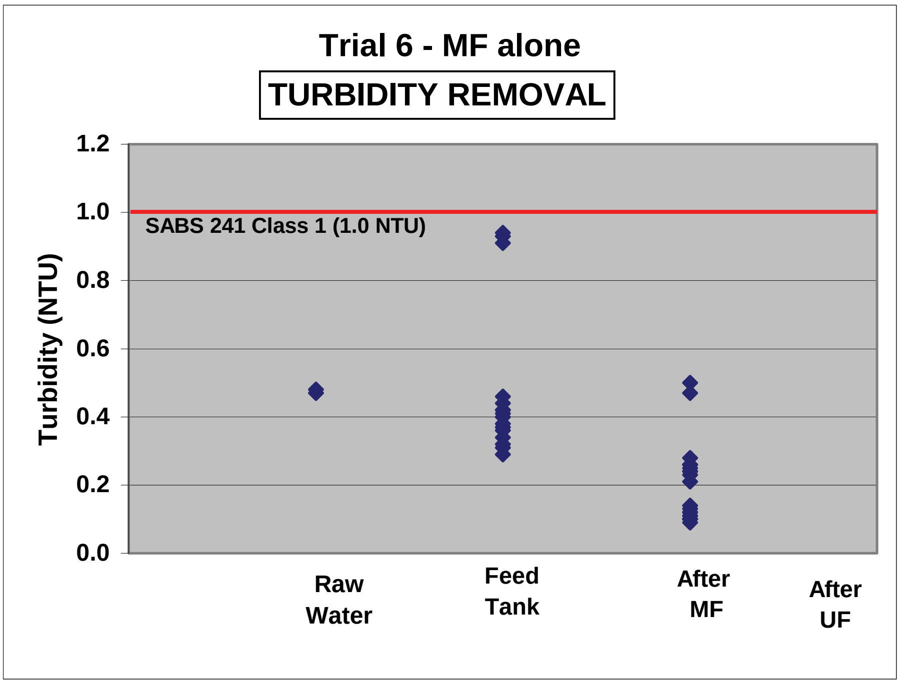


Figure 4.16: Trial 6 – Turbidity removal with Microfiltration

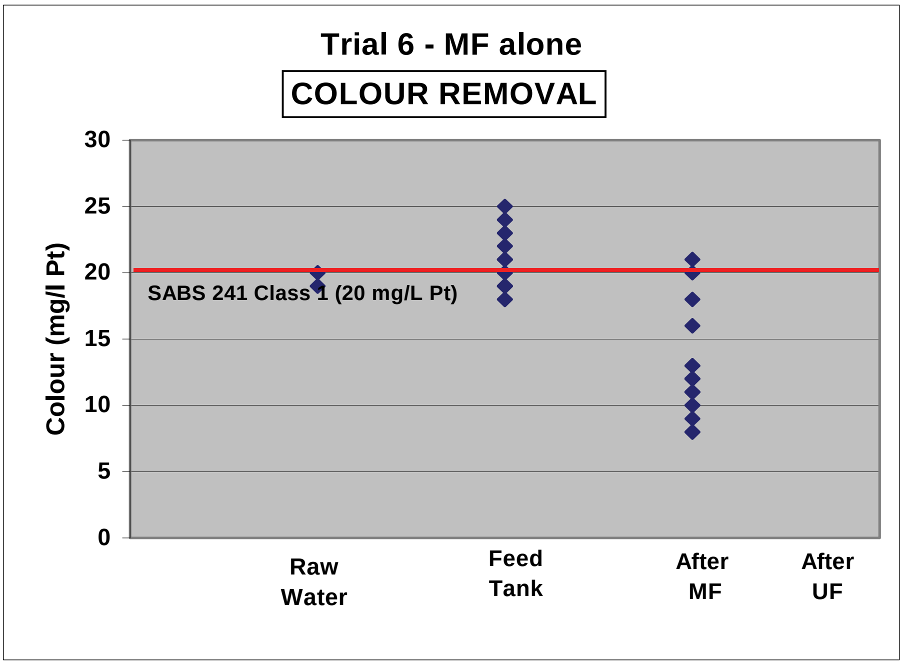


Figure 4.17: Trial 6 – Colour removal with Microfiltration

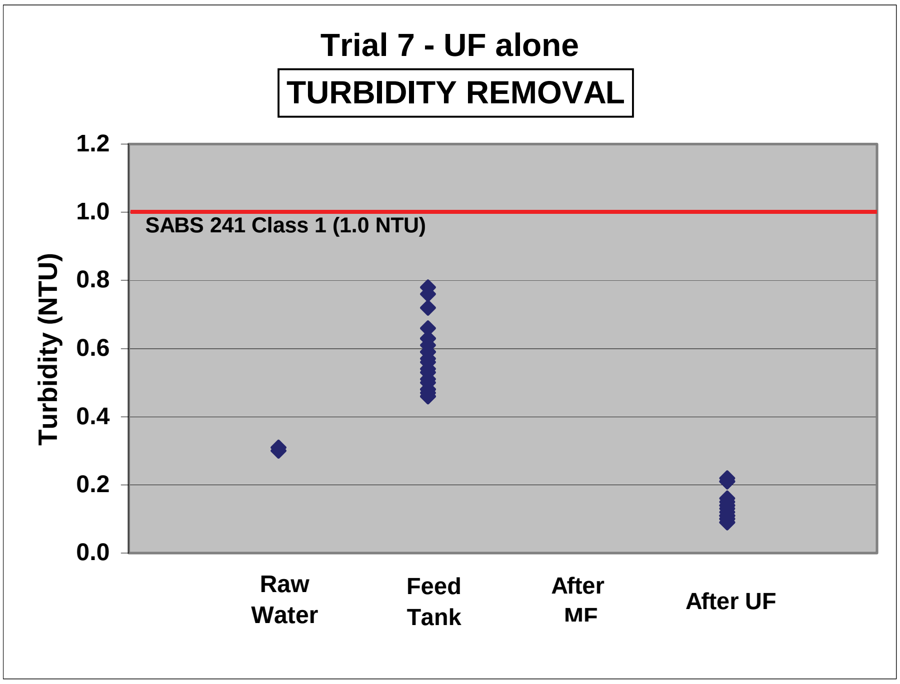


Figure 4.18: Trial 7 – Turbidity removal Ultrafiltration

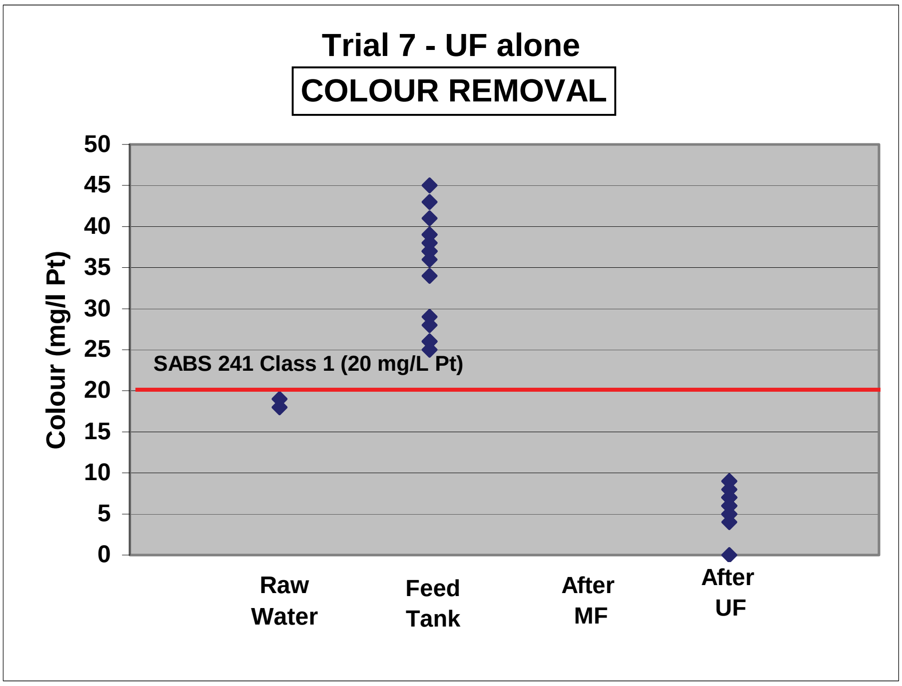


Figure 4.19: Trial 7 – Colour removal with Ultrafiltration

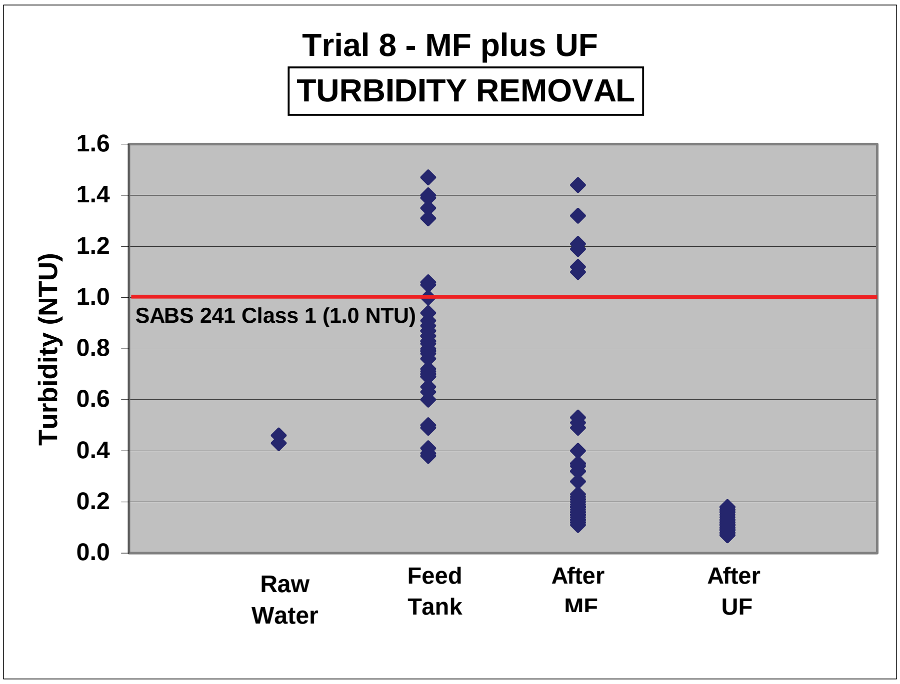


Figure 4.20: Trial 8 – Turbidity removal with Microfiltration plus Ultrafiltration

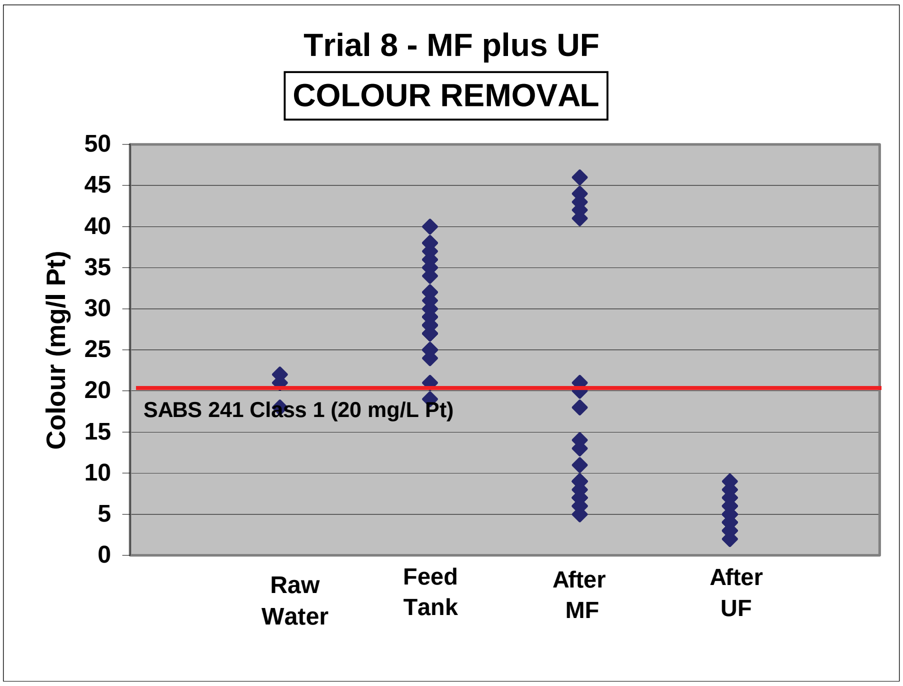


Figure 4.21: Trial 8 – Colour removal with Microfiltration plus Ultrafiltration

4.4.2 Upper Mnyameni results

The raw water quality from the Mnyameni Dam is given in Table 4.2.

Table 4.2: Chemical quality of Mnyameni raw water

Determinant	Taken on 14 November 2006
pH	6.9
Conductivity (*mS/m*)	5.4
Colour (*mg/L as Pt*)	80
Iron (*mg/L Fe*)	1.65
Turbidity (*NTU*)	27.4

The results of the trial period evaluation for turbidity removal are summarized graphically in Figure 4.22. The ultrafiltration membrane reduced the turbidity to less than 0.3 NTU.

The results of the sample that was submitted to the CSIR appear in Table 4.3.

Table 4.3: Results of pilot-plant results at Upper Mnyameni: 14 November 2006

Determinant	Raw water	After MF	After UF (final water)
pH	6.9	7.1	6.9
Conductivity (*mS/m*)	5.4	5.2	5.2
Colour (*mg/L as Pt*)	80	20	< 10
Iron (*mg/L Fe*)	1.65	0.08	< 0.05
Turbidity (*NTU*)	27.4	0.70	0.14

The performance of the membranes for turbidity and colour removal showed the same results as in the Voorstekraal trials, with turbidity of 0.14 NTU and colour of less than 10 mg/L as Pt in the final water. Excellent iron removal was also obtained; 95.2% removal with microfiltration and 99.5% with microfiltration followed by ultrafiltration.

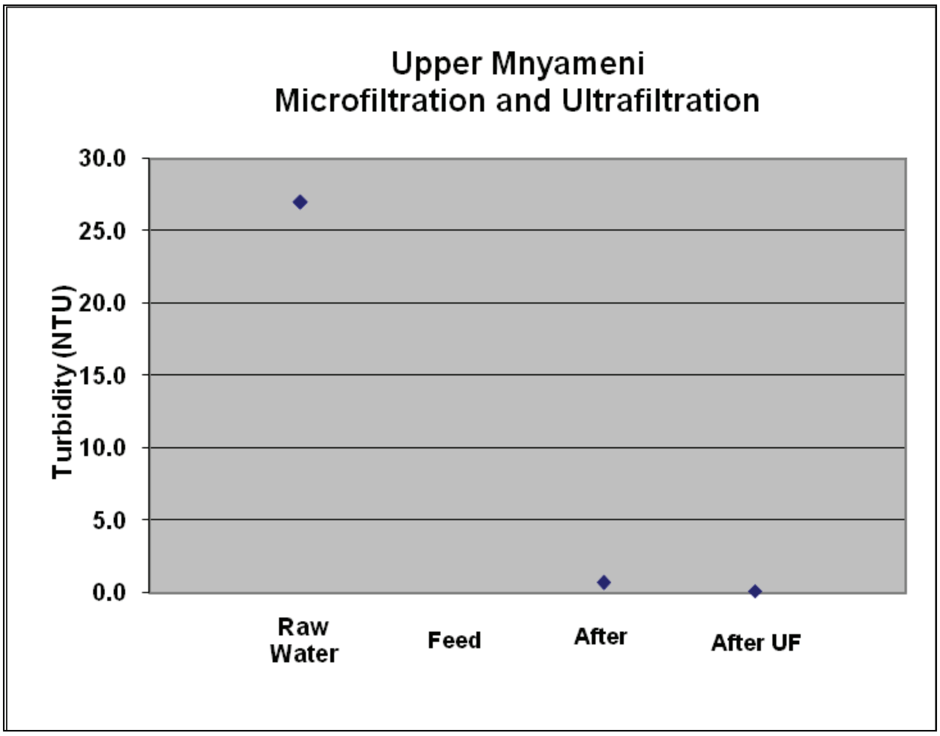


Figure 4.22: Upper Mnyameni – Turbidity removal with Microfiltration plus Ultrafiltration

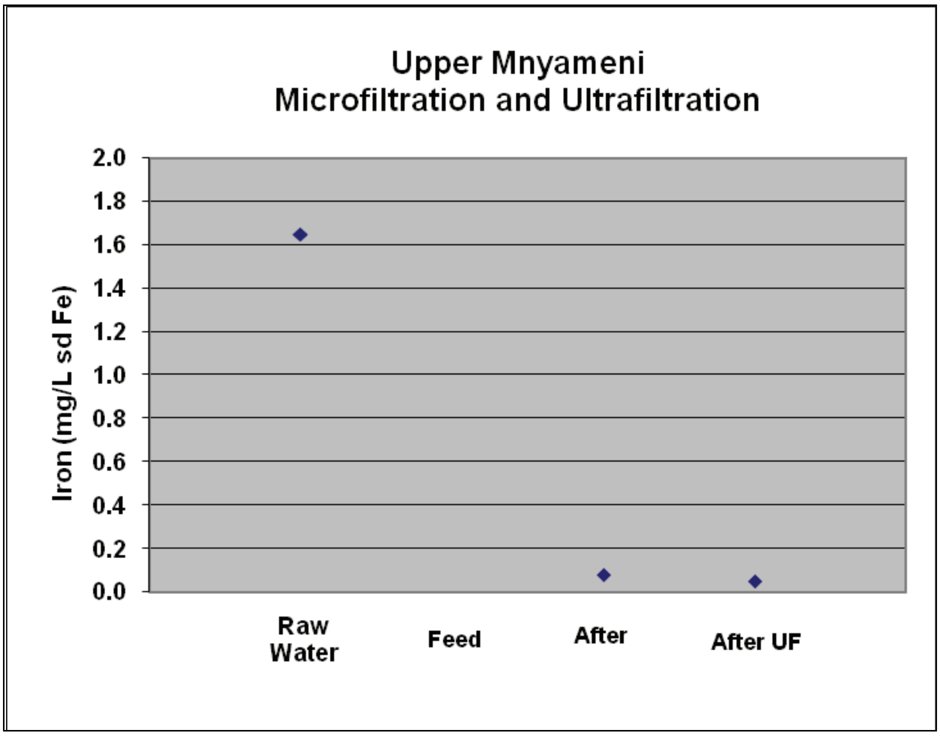


Figure 4.23: Upper Mnyameni – Iron removal with Microfiltration plus Ultrafiltration

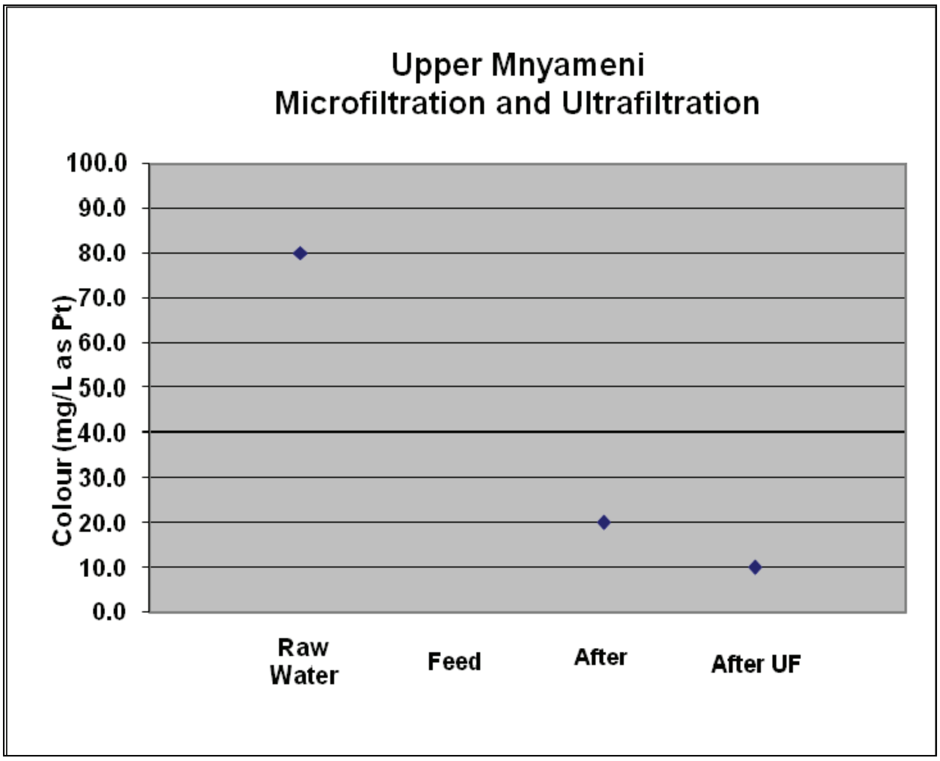


Figure 4.24: Upper Mnyameni – Colour removal with Microfiltration plus Ultrafiltration

CHAPTER 5

SOCIAL ACCEPTANCE EVALUATION

The social acceptance study was aimed at determining what social factors influences the acceptance of a new technology. It is envisaged that this study will contribute to a greater understanding of water technology acceptance and implementation, provide vital information for setting water related policies and giving communities access to clean water.

A cross-sectional descriptive study design aimed at collecting both qualitative and quantitative data was used. Voorstekraal in the Theewaterskloof Local Municipality and Upper Mnyameni in the Amahlathi Local Municipality were selected as study areas. Accidental non-probability sampling method was used. The target population was defined as households from small rural- or peri-urban communities whose potable household water is purified by a limited or no water treatment system. Data was collected during two phases: Phase 1, before implementation of the water purification plant and Phase2, post implementation, after the plant was removed from the community.

The following socio-economic factors were found to influence the acceptance of micro-filtration and ultra filtration membrane systems:

- Cost and willingness to pay
- Efficiency of the new technology
- Awareness raising/ informed Community
- Community Needs
- Job creation
- Assessment of existing infrastructure
- Security and location of the plant/unit
- Security and location of the plant/unit
- Functioning of the new technology
- Current community practices

The study concludes that:

- Acceptance does not necessarily mean usage.
- Communities will always revert to the water they are used to
- A non-cohesive community intensifies a lack of interest.
- Community meetings may not be a high quality way of informing households.
- Local government participation must incorporate involvement and commitment
- The safest location may not be the most appropriate, convenient or accessible

The full report on the social acceptance study appears in Part B of the project report.

Specific guidelines that were developed for social acceptance aspects of implementing advanced water treatment technologies are given in Chapter 9 of Part A of the report.

CHAPTER 6

COST COMPARISON STUDIES

This chapter outlines the economic comparisons of membrane water treatment technologies and conventional water treatment systems. The high quality of product water from membrane filtration processes makes them very attractive in the field of potable and wastewater treatment. In anticipation of future demands for high standards and reduced environmental impact, membrane processes are increasingly being considered as an alternative to conventional water and wastewater treatment methods. Unfortunately, the economics of these new technologies and the parameters that control costs are not well understood by researchers, process engineers and others who wish to assess the feasibility of these processes in comparison with alternative technologies or to improve the cost effectiveness of the processes (Pickering *et al.*, 1993).

The operation of membrane technologies for potable and wastewater treatment is currently limited by the high capital and operating cost with which they are associated. In extensive pilot plant studies carried out by Owen *et al.* (1995), it was found that the most significant factors influencing the overall cost in membrane process were, membrane cost, membrane replacement frequency and power consumption. The cost of membrane filtration is largely a function of the permeate flux. Therefore, estimates of the cost of membrane technologies require accurate estimates of the permeate rate. Furthermore, membrane fouling has a significant effect on the permeate flux and therefore membrane cost (Mark *et al.*, 1994).

6.1 Capital Cost of Membrane Systems

The capital costs can be divided into non-membrane costs and initial membrane unit costs (Owen *et al.*, 1995).

a. Non-membrane costs

Non-membrane costs include all equipment and facilities necessary to support the use of membranes, such as, pumps, monitoring equipment, automation and associated civil engineering costs. Capital costs for non-membrane plant are based on quotes from membrane plant suppliers. Costs of non-membrane plant items have been scaled according to the six-tenths power rule (Owen *et al.*, 1995).

$$C_a = C_b \left(\frac{Q_a}{Q_b} \right)^{0.6}$$

where, C_a and C_b are non-membrane capital costs of plants to treat flows of Q_a and Q_b, respectively.

b. Membrane costs

The membrane cost is dependent on the specific membrane cost, c_{memb}, permeate flux, J and the plant design capacity, $Q_{des.}$ For a constant permeate flux, J, the total membrane area required to produce a given flow of filtered water can be calculated by using the equation below (Weisner, 1995).

$$A_{memb} = \frac{(Q_{des} * t_{tot}) + (Q_{bw} * t_{bw})}{J\ t_o}$$

where:

- A_{memb} is the surface area of membrane required to provide the design capacity
- Q_{bw} is the flow rate during back flushing
- t_o is the operating time between flux enhancement cycles
- t_{tot} is total cycle time ($t_{tot} = t_{bw} + t_{cf} + t_o$)

The equation takes into consideration the volume of permeate wasted in hydraulic cleaning.

The capital cost can be expressed as an annualized sum. A series of equal annual payments, C_A, invested at a fractional interest rate, *I*, at the end of each year over *n* years may be used to build up a sum of money with present worth (C_{men} + C).

Annualized capital cost C_A is given by:

$$C_A(Rand / year) = \frac{(C_{mem} + C)^i}{\left[1-(1+i)^{-n}\right]}$$

where:

C_{mem} and *C* are capital costs of membrane and non-membrane components. An empirical expression for capital costs as a function of the number of installed membrane modules or pressure vessels, *n*, exclusive of the initial cost of the membrane modules was developed by Mark *et al.*, 1994. In his estimates he included the cost of buildings, chemical feed systems, control and instrumentation, site works, storage, process piping, yard piping, site electricity, pretreatment, cleaning and booster pump. The total capital costs are then calculated as: (Mark *et al.*, 1994).

$$CC_{tot} = \frac{\left[\left(150037\,(n_{\mathrm{mod}})^{0.74}\right) + C_{\mathrm{mod}}\,n_{\mathrm{mod}}\right]\frac{A}{P}}{Q_{design}}$$

where:

CC_{tot} – annualized capital cost
C_{mod} – cost per module or pressure vessel of the membrane
A/P – the amortisation factor

c. Depreciation

Allowance has been made for the cost of replacement of non-membrane plants at the end of their technical life. This cost is charged as depreciation on the equipment. This was estimated as the total end cost of non-membrane units expressed as annual cost, and is given as:

$$Depreciation = \frac{Total\ non\ memb.\cos t - memb.plant\ \cos t}{Technical\ life\ of\ the\ plant}$$

The sum of membrane and non-membrane capital costs is amortised over the design life of the plant to yield an annual cost by the equation below

$$C_{annual} = (C_{memb} + C_{non-memb}) * A$$

where *A* is the amortization factor given by the equation below

$$A = \frac{(1+i)^n * i}{(1+i)^n - 1}$$

where, *I* is interest rate and *n* is the plant life.

6.2 Operating Costs

Operating costs include membrane replacement cost, energy cost, labour cost, maintenance cost and the cost of cleaning chemicals. Membrane replacement costs are the total costs of all the replacement membranes distributed over the entire life of the plant as annual costs.

a. Membrane replacement

Membrane replacement costs are the total costs of all the replacement membranes distributed over the entire life of the plant as an annual cost. Membrane lifetimes estimated by manufacturers range from 3-5 years for polymeric membranes and up to 10 years for ceramic membranes. The actual lifetime achieved by a membrane can have substantial effect on the operating cost.

b. Energy

Energy costs are calculated from the applied feed pressure, the energy required to maintain a specific permeate flux and the energy required for flux enhancement or membrane cleaning. Feed pump power estimated from the equation below (Owen *et al.*, 1995).

$$Power(kW/d) = Q_l * P * \frac{24}{100}$$

where:

P = feed pressure (N/m^2)
Q = average permeate flow rate (m^3/s)

The cost of electricity depends on the locality and the supplier.

c. Labour cost

Initial estimates of labour requirements can be obtained from membrane system suppliers. The number of man-hours per week required to operate the plant can be assumed to be proportional to the size of the plant since a significant part of operator time is likely to be associated with membrane cleaning and maintenance (Owen *et a.l*, 1995). Labour costs are found to be low, compared to conventional treatment plants since there is much potential for automation compared with conventional process.

d. Maintenance

The maintenance cost of a plant is related to the capital cost of mechanical and electrical items. It is assumed that an annual sum of 1,5% of initial non-membrane capital cost can be used to obtain this maintenance cost (Owen *et al.*, 1995)

e. Chemicals

In order to determine optimum cleaning frequencies, prolonged trials over several months have to be carried out. Information gathered by (Owen *et al.*, 1995) from existing installations and suppliers give cleaning chemical costs as below 1 cent/m^3 of permeates produced. Concentrate disposal costs are calculated as the cost of energy and chemicals invested in the wasted concentrate.

6.3 Effect of Permeate Flux on Cost

The cost of constructing and operating UF system is extremely sensitive to the permeate flux (Mark *et al*., 1994). Higher permeate fluxes are achieved at higher pressure at the cost of higher energy consumption. However, less membrane area is required to produce the same design flow. Cost estimates calculated from the corresponding permeate flux data observed in pilot studies by (Mark *et al.*, 1994) indicated that the higher energy costs associated with increased pressures should be more than offset by the savings in capital costs and membrane replacement that result from a higher permeate rate. Reductions in cost achieved by increasing pressure are constrained by the mechanical strength of the membrane and potentially by an increase in mass transport of materials to the membrane surface at a higher permeate flux.

6.4 Costs of Ultrafiltration Membrane Treatment

Pillay and Jacobs (2004) reports in WRC Report No. 1070/1/04***: "The Development of Small-Scale Ultrafiltration Systems for Potable Water Production"*** as follows on the costs of ultrafiltration membrane systems:

a. Capital costs

They report that only an illustrative, or order of magnitude, capital cost can be stated. The final capital cost will depend on the pricing policy of the technology vendor, the expected market size, etc. Estimated capital costs are presented for a range of unit size, to illustrate the economies of scale.

The costs are for a capillary ultrafiltration unit consisting of feed and backwash pumps, membrane module banks, actuated valves, PVC piping, backwash and CIP tanks, and PLC, on steel structure.

The membranes are 110 mm modules (7 m^2 each) operated in dead-end filtration mode with intermittent backflushing. Chemical cleaning is performed manually.

The estimated capital costs for units ranging from 30 m^3/day to 120 m^3/day are shown in table 6.1 below. It is noted that the costs include materials and labour only, and excludes overheads, royalties, profit and VAT. Values in the table are scaled from the graph presented in the report.

Table 6.1: Estimated capital costs for UF membrane systems (Pillay and Jacobs, 2004)

Capacity (m^3/day)	Capital Cost (R)	Unit Capital Cost (R/m^3/day)
30	135 000	4 400
60	190 000	3 000
90	245 000	2 600
120	300 000	2 500

They report that "economy of scale" applies to the capital cost. As the production capacity increases, the number of modules required increases, but the cost of the control system, frame and actuated valves does not increase substantially. Hence, the capital cost per unit production decreases. Conversely, costs do not decrease linearly as production capacity decreases. Therefore, it may be found that a single module unit may not be economically cost effective, whereas larger units are.

It is stated that the above costing structure is based on prototype design, and cannot be extrapolated to large units. For large units that are to serve a large village, or a small municipality, more optimal geometric designs can be obtained, which will result in a lower cost structure.

b. Operating costs

Operating costs as a function of production capacity are presented as follows in the report by Pillay and Jacobs (2004). The assumptions in the determination are shown in the table below:

Table 6.2 Operating requirements

Power consumption	0.13 kW / (m^3/h) @ R 0,27 per kWh (based on pump and motor efficiencies of 0.4, pump discharge pressure of 2.5 bar)
Labour	
Daily monitoring	½ hour per day, at R 150 per month
Chemical cleaning and mechanical maintenance	1 day per month, at R 500 per day
Transport for technician	200 km per visit, at R 1,40 per km
Consumables for chemical cleaning	R 17 per module per month
Membrane replacement	Every four years, at R 7 000 per module

The estimated operating costs are summarized in table 6.3 (values scaled from graph presented in the report).

Table 6.3: Estimated operating costs for UF membrane systems (Pillay and Jacobs, 2004)

Capacity (m^3/day)	Operating costs (R/month)	Operating costs (R/m^3)
30	2 000	2.30
60	3 100	1.75
90	4 200	1.60
120	5 400	1.50

According to the authors, once again, economies of scale apply to the above operating costs. If the size of the unit increases, the power consumption, cleaning consumables and membrane replacement will increase. However, the costs of labour and transport will remain the same. Accordingly, the operating cost per unit will decrease as the higher capacity units are considered.

c. Operating cost per person per month

Currently each citizen in South Africa is entitled to 25 litres per day "free" potable water. The operating costs stated above have been forecast by Pillay and Jacobs (2004) to show what it would cost per person per month to provide this "free" water. The results are presented below (scaled from the graph provided in the report).

Table 6.4: Estimated operating costs per person per month for UF membrane systems (Pillay and Jacobs, 2004)

Production (m^3/day)	Number of people served at 25 litres per day	Operating cost per person per month (R/person/month)
30	1 200	1.70
60	2 400	1.30
90	3 600	1.15
120	4 800	1.10

6.5 Comparison of technological and financial sustainability of a membrane plant versus conventional treatment plant for rural water treatment

Mackintosh *et al.* (2002) describe the operation of a membrane-based plant at a small, rural town (approximately 250 km from Cape Town) in the Western Cape, South Africa. The raw water of the town is a highly coloured surface water (>200 mg Pt/L) with consistently very poor bacteriological quality. The assessment included comparison with a nearby conventional water treatment plant with regards to plant performance, and financial and technological sustainability.

6.5.1 Technological sustainability

Traditionally in South Africa, small water treatment systems have made use of conventional processes such as chemical pre-treatment, coagulation, settling and dual media filtration in a scaled-down manner. These unit processes, although effective on large-scale applications, inevitably prove troublesome for small-user systems, the result being production of sub-standard water, and non-sustainability with the plant eventually falling into disuse. This issue of non-sustainability of water supply schemes resulting from imposition of nonappropriate technologies on communities requires considered attention in South Africa. Paradoxically, a potentially attractive alternative is the use of semi-automated "high-tech" plants incorporating membrane technology for rural water treatment.

6.5.2 Financial sustainability

A significant influencing factor as to sustainability is community affordability in terms of the ongoing running costs of water treatment. In the case of considering membrane based water treatment, the operating costs are potentially lower than conventional processes; hence this is advantageous to the community that must guarantee payment thereof into the future. However, the funding organization that incurs the upfront capital costs is often discouraged by the usually significantly higher capital costs of membrane treatment. It is hence important that a clear and unambiguous financial comparison be carried out to enable informed decision-making. In this paper the Net Present Value (NPV) based approach considers operating costs/cash flow projection of a project over a ten-year period. This simple NPV assessment captures both the capital and operating costs for alternative technologies and relates these as one financial sum in terms of current monetary value. This approach clearly indicates which alternative is financially more viable, or the magnitude of any variation.

6.5.3 Evaluation of membrane-based treatment plant

The membrane-based plant considered is a movable package water treatment plant designed to condition surface water so as to comply with international water quality standards. The unit incorporates flocculation and pre-filtration, membrane filtration, adsorption and chemical disinfection and treats approximately 2,000 L/hr depending on the raw water characteristics. Chemicals used to treat the raw water included those required for aiding flocculation (poly aluminium chloride - PAC and polyelectrolyte), pH adjustment (soda ash) and disinfection (calcium hypochlorite - HTH). In addition, calciumhypochlorite and citric acid were used as cleaning chemicals for the membranes.

The membrane-based plant was installed and a community member with no previous water treatment training or experience was trained over 2 weeks in all aspects *of* plant operation. The results obtained during the trial period indicated that the plant performed well, consistently providing a high quality drinking water. During the eight-month assessment period, the plant failed on two occasions. On the first occasion, the problem was found to be a faulty relay, which was rapidly rectified with the assistance *of* a local electrician. In the second instance, the plant malfunctioned as a result of the failure of an air valve, which was subsequently replaced under specialist supervision. Hence, the only problems that occurred during the eight-month period were

trivial and easily rectified. However, in both cases plant downtime was approximately 1 week, which highlighted the requirement for adequate back-up service/support.

6.5.4 Comparative assessment of conventional water treatment plant performance

The performance of the membrane-based plant was compared to a nearby conventional plant, which treats essentially the same source. This existing water treatment system treats approximately 10,000 L/hr and employs conventional water treatment principles of coagulation, flocculation, sedimentation, sand filtration and disinfection.

The results obtained during the assessment period showed that the conventional plant is highly vulnerable to passing on contaminated treated water to the end user when not operating optimally. Frequent episodes of treated water quality failing *SABS 241-2001* Maximum Allowable standards (i.e. not fit for human consumption) occurred. Both the plant operator and the community confirmed that the plant did not continuously operate at an optimal level.

6.5.5 Cost comparison - membrane-based versus conventional water treatment plant

The cost comparison was based on a water treatment plant capacity of 10,000 L/hr operating for 20 hours/day (i.e. providing a community of 2,000 people with 100 L/person/day).

Total installed capital cost estimates were obtained from manufacturers of the different water treatment technologies. Operating costs included those related to chemicals, labour, electricity and maintenance and were based on required on-site inputs and information supplied by manufacturers ($1.00 = R8.00, April 2001).

The cost comparison shown in Table 6.4 shows that the total installed capital cost of the membrane based plant is significantly more expensive (- 1.9 times) than that of the conventional water treatment plant. Furthermore, the cost comparison showed that the membrane based plant shows significant operating cost savings over the conventional plant. This can mostly be attributed to lower labour and chemical requirements.

Meaningful comparison of the capital and running cost figures given above is difficult. A more useful manner of comparing the two processes is to use a Net Present Value (NPV) based approach. The NPV approach relates the cash flow projection of a project over a specific time period (in this case 10 years). The NPV assessment captures both the capital and operating costs for the two alternative technologies and relates these as one financial sum in terms of current money. An important aspect is the discount rate used. For this case study the total discount rate included: inflation (@ 7% in South Africa), required real return (@ 0%, as no return on investment required by government funders) and risk (@ 10%, as membrane based processes are less familiar for rural use in South Africa).

Table 6.5: Cost comparison input variables

	Membrane		Conventional	
Plant capacity	10 000 L/hr		10 000L/hr	
TIC cost	$ 75 000		$ 40 000	
Operating costs				
Chemicals	*Chemical dose*	*Cost ($/kL)*	*Chemical dose*	*Cost ($/kL)*
PAC @ $1.12/kg	35 mg/l	0.039	60 mg/l	0.067
Polyelectrolyte @ $1.12/kg	0., mg/l	0.0004	-	-
HTH @ $1. 75/kg	0.5 mg/l	0.0008	2 mg/l	0.003
Soda ash @ $0.30/kg	50 mg/l	0.015	50 mg/l	0.015
Citric acid (membrane cleaning) @ $3. 75/kg	0.1 mg/l	0.0004	-	-
HTH (membrane cleaning) @ $1.75/kg	0.01 mg/l	0.0001	-	-
Chlorine gas @$1.75/kg	-	-	2 mg/l	0.003
Chemical wastage @ 5 %	-	0.0028	-	0.0038
Electricity @ $0.025/kWh	*Power consumption*	*Cost ($/kl)*	*Power consumption*	*Cost ($/kl)*
Plant power consumption	8.5 kW	0.0150	10 kW	0.20
Labour @ $2.34/hr	*Time*	*Cost ($/kl)*	*Time*	*Cost ($/kl)*
Plant operation, maintenance, etc.	1 hr/day	0.012	4 hrs/day	0.047
Maintenance @ 5% of capital cost	*Cost ($/kl)*	0.0431	*Cost ($/kl)*	0.027

The NPV based cost comparison shown in Table 6.5 shows that the use of a membrane based plant (with higher capital costs and higher risk but lower running costs), yields a nominally negative NPV of $4 187 (and an Internal Rate of Return of 14%). This result shows that there is very little difference in financial performance between the two technologies when compared over ten years. It is important to note that this observation is contrary to conventional thinking in South Africa, where the initial significantly higher capital costs of membrane-based plants are considered to make the use thereof a non-option.

Table 6.6: NPV summary table - plant capacity 10 kL/hr

	Conventional	*Membrane*
Capital costs ($)	40 000	75 000
Operating cost ($/kL)	0.36	0.26
Discount rate		
• Average inflation	7%	7%
• Required real return	0%	0%
• Estimated risk	10%	10%
Internal Rate of Return	14%	14%
Net Present Value (NPV)		- $ 4 187.00

Discussion and conclusions for the study (Mackintosh *et al.*, 2002)

From analysis of both plant performance and the cost comparison, the following points should be noted:

- Considering that South African rural communities are required to guarantee the payment of the operational costs of water treatment whilst the capital costs are usually covered by a funding organisation, the membrane based approach makes sense from a perspective of community financial sustainability.
- The NPV based assessment shows that, despite the considerably higher capital cost of the membrane based process, there is very little difference in financial performance between the two technologies when compared over ten years and this should satisfy the concerns of those providing the capital funds.
- The proven ability of a previously "unskilled in water treatment" community member to operate the membrane-based plant, versus the regular malfunction of the conventional plant indicates superior technological sustainability of the membrane-based plant. (However, this is dependent on adequate back-up service should significant technical failures occur.)
- The principal advantage of the membrane based treatment process is that it provides consistently high quality drinking-water and it is not possible for the system to pass on partially treated water that fails bacteriological standards. This will ensure the sociopolitical sustainability of the membrane-based process. In comparison the regular failure of the conventional system is likely to lead to eventual rejection of the technology by the community, i.e. not socio-politically sustainable.

CHAPTER 7

GUIDELINES FOR APPLICATION OF MICROFILTRATION AND ULTRAFILTRATION TECHNOLOGIES FOR POTABLE WATER TREATMENT FOR RURAL COMMUNITIES

7.1 General Guidelines

a. Microfiltration and ultrafiltration treatment systems are rapidly gaining ground as best available technology for small water treatment systems because of the following main reasons:
   - production of high quality treated water
   - do not require chemical pre-treatment
   - provide a barrier against bacteria, viruses and parasites
   - offer competitive costs when considering life-cycle costing
   - can be operated by semi-skilled community members (but requires excellent technical back-up).

b. Design, choice of appropriate technology and operation and maintenance issues are identified as potential problems that need to be addressed in the technical evaluation processes.

c. Social and technical factors form a critical part of sustainability of rural water supply both in the short and long term.

d. ***Technical factors*** that determine sustainability include, *inter alia*:
   - construction costs
   - operation costs
   - performance
   - reliability of the service
   - provision for future upgrading
   - training of operators
   - community involvement.

e. ***Social factors*** that have a major impact on sustainability include:
   - needs assessment prior the starting of the project
   - community involvement
   - community participation
   - financial aspect of the project including costs.

f. The following factors need to be considered when planning the installation of a new water treatment unit for a rural community:
   - security of the plant/unit
   - location of the unit
   - cost
   - efficiency (ability to produce improved quality of drinking water)
   - awareness raising/community informed
   - community needs
   - job creation
   - replacement of existing water pipes

g. Communication forms part of infrastructure development including technological information and transfer of knowledge between communities and engineers. Partnership is seen as most viable for a sustainable operation, especially in filling gap and counter-acting areas of weakness from various role-players.

h. In the social process, inclusion of women in various ways for sustainability of a project is crucial. This includes decision-making, cultural issues, attitudes and awareness, roles and responsibilities, education and training.

i. The NGO approach to rural water supply, especially in South Africa confirmed that more emphasis is placed on customer-based (community), policy and procedure “enforcement”, capacity building (both community and institutional) and post-project support.

j. Though rural water supply is demand-driven, various methods are used to involve the community in the choice of technology to use.

k. Using the Net Present Value (NPV) based approach for costing of new treatment plants allows operating costs/cash flow projection of a project over a ten-year period to be made. This simple assessment captures both the capital and operating costs for alternative technologies and relates these as one financial sum in terms of current monetary value. This approach allows financial comparisons between technology options and clearly indicates which alternative is financially more viable, or the magnitude of any variation.

7.2 Guidelines from Socio-Economic Study

The following guidelines resulted out of the socio-economic factors that influence the acceptance of micro-filtration and ultra filtration membrane systems:

7.2.1 Cost and Willingness to Pay

Cost and affordability are important factors as most of the community members in rural areas are unemployed or they have a low income. Communities are willing to pay for the use of water but prefer that the installation of a new technology not interfere with the current water rates they are paying. Costs of water services should therefore not increase as a result of installation of the plant.

7.2.2 Efficiency of the New Technology

Communities need to have evidence that the new technology will really deliver an improved quality of water, and would want a sample of purified water first. In other words communities would want proof that the new technology adequately purifies the water. This would lead to easy acceptance after installation.

7.2.3 Awareness Raising/ Informed Community

If the community is not properly informed and made aware of the new technology they may not accept the unit. It is suggested that community members be thoroughly informed via a community meeting so that all may understand, or at least have an idea of how the unit works. This includes informing them of interruptions in the current water supply during installation of the pilot unit. If the community understands the unit and are adequately made aware thereof, installation will be easy. They should also be well informed of any increases in costs relating to the plant installation. In addition to making the community aware about the plant, the whole community must be part of decision-making and agree upon its installation.

The discussions and outcome of these meetings should be propagated to the rest of the community members who could not attend. Propagation should include vigorous door- to- door campaigning.

7.2.4 Community Needs

Community needs should be determined prior to implementing any project. This will encourage acceptance thereof amongst community members. The benefits of the new technology must coincide with and or meet the needs of the community.

7.2.5 Job Creation

As unemployment rates are high, the prospect of community members getting employment from the installation and operation of the new technology will be an encouraging factor. If employment opportunities are created as a result of the installation, locals should be considered for this purpose and be given adequate knowledge and skills should they lack these.

7.2.6 Assessment of Existing Infrastructure

Existing infrastructure such as pipes (because of their age) could greatly interfere with having water quality. The fear thus exists that these may constrict the true effects of the new technology. Existing infrastructure should be thoroughly and continuously assessed and replaced where necessary.

7.2.7 Security and location of the Plant/Unit

The new technology should be completely secured, because children, mischievous youth and vandals may interfere with or cause breakage to the unit. Rural areas, in most cases, have terrains that are quite uneven and mountainous. The location of the new technology must be selected carefully but community accessibility and convenience should not be compromised.

7.2.8 Performance and Involvement of Local Government

There seems to be a relationship between the performance of local government and the community's acceptance of a new technology. The community will be very sceptical about accepting new initiatives if local government does not perform on delivering essentials services to the community. Local government should commit themselves with the installation of the new technology by maintaining binding agreements and or a memorandum of understanding with the community.

7.2.9 Functioning of the New Technology

The new technology should function with limited or no interruptions to the supply of water. The community should be made aware of any interruptions that may result due to the maintenance and operations of such technology.

7.2.10 Current Community Practices

Communities are used to dealing with the problems of their existing water resource and will continue using it even if it means running the risk of contracting water related and water-borne diseases. The new technology must also use that specific water resource and in its operations.

CHAPTER 8

CONCLUSIONS

a. Acceptance does not necessarily mean usage. A large number of households indicated that they accepted the plant but not all of them used it. Usage rate was mainly influenced by the location of the plant, lack of community enthusiasm and drive, limited municipal involvement, misinformation and lack of awareness to use the plant.

b. Communities will always revert to the water they are used to. This is mainly because the alternative water (from purification plant) becomes a bother due to the fact that the water is not close at hand, and they are used to dealing with the problems of the original water.

c. A non-cohesive community intensifies a lack of interest.

d. Community meetings may not be a high quality way of informing households. People attend community meetings in their individual capacity and not necessarily representing their households. Whatever is discussed and decided at the meeting is not propagated to the rest of the households.

e. Local government participation must incorporate involvement and commitment. The Municipality participated fully in the planning stages but was not visible in the implementation phase. The limited involvement of the Municipality discouraged usage and created the perception that they disregard the community.

f. The safest location may not be the most appropriate, convenient or accessible place for the plant. In most instances water purification plants are placed at a location which is most secure irrespective of whether the community has easy access or not. Security concerns should therefore not determine the location of the plant. One needs to find the most convenient and or accessible location for the community and then secure the plant.

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APPENDIX A

RESULTS OF ULTRAFILTRATION BENCH SCALE STUDIES

The results are presented separately for each of the raw waters.

Ground Water

Ground water used was pumped from a borehole at the Peninsula Technikon lake on the main campus. The results of full analysis done are, as follows:

TableA.1 *Typical Water quality of the Ground Water at Peninsula Technikon Lake*

Determinant	Raw	Final Product		
		0% Recovery	30% Recovery	60% Recovery
PH	6.78	7.71	8.20	8.72
Conductivity (*mS/m*)	152	148	155	150
Alkalinity (*mg/l* $CaCO_3$)	214	167.8	259.4	261.20
Chloride (*mg/l Cl*)	nd	281	315	307
Colour (*mg/l as Pt/Co*)	120	30	40	40
Calcium (*mg/l Ca*)	73.5	74.3	72.6	71.8
Magnesium (*mg/l Mg*)	37.0	36.5	36.2	35.8
Aluminum (*mg/l Al*)	0.182	0.027	0.033	0.060
Iron (*mg/l Fe*)	1.667	0.450	0.057	0.046
Manganese (*mg/l Mn*)	0.014	0.20	0.017	0.012
Sodium (*mg/l Na*)	177	185	180	178
Potassium (*mg/l K*)	4.48	6.80	6.97	7.74
Sulphate (*mg/l* SO_4)	123.2	105	121	120
UV 4cm at 300nm	nd	0.590	0.661	0.732
Total Dissolved Solids	1000	1000	1100	1000
Nitrate/Nitrite (*mg/l* NO_3/NO_2)	nd	0.08	0.08	0.09
Turbidity (*NTU*)	11.9	0.31	0.29	0.2

nd: not determined

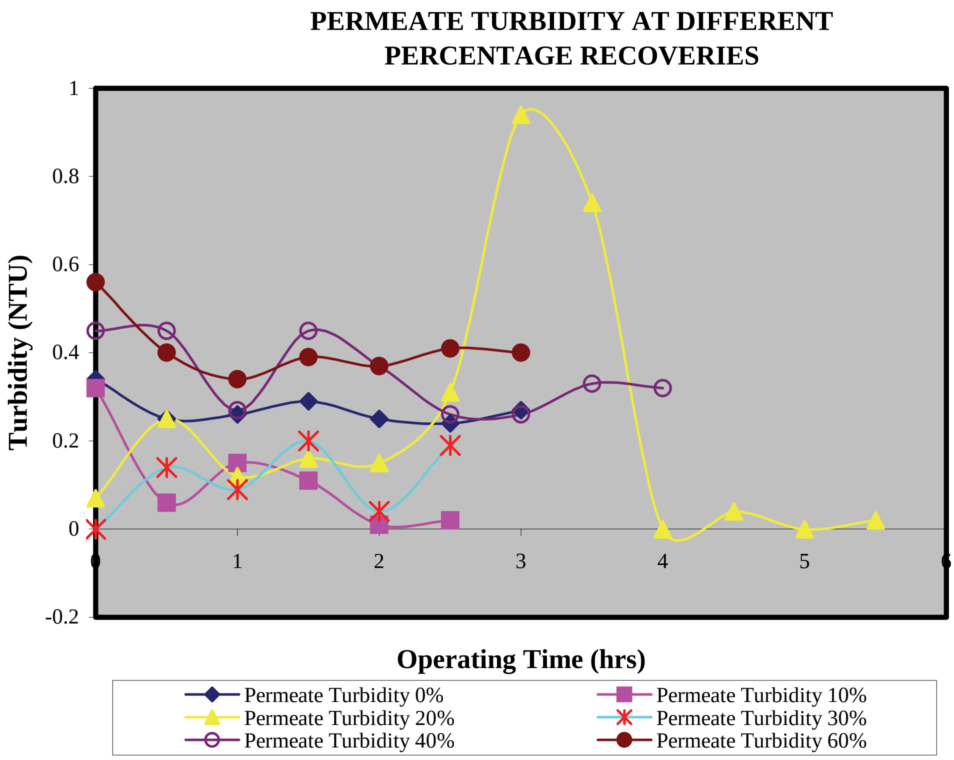

Figure A.1 *First set showing permeate turbidities at different percentage recoveries over the operating period*

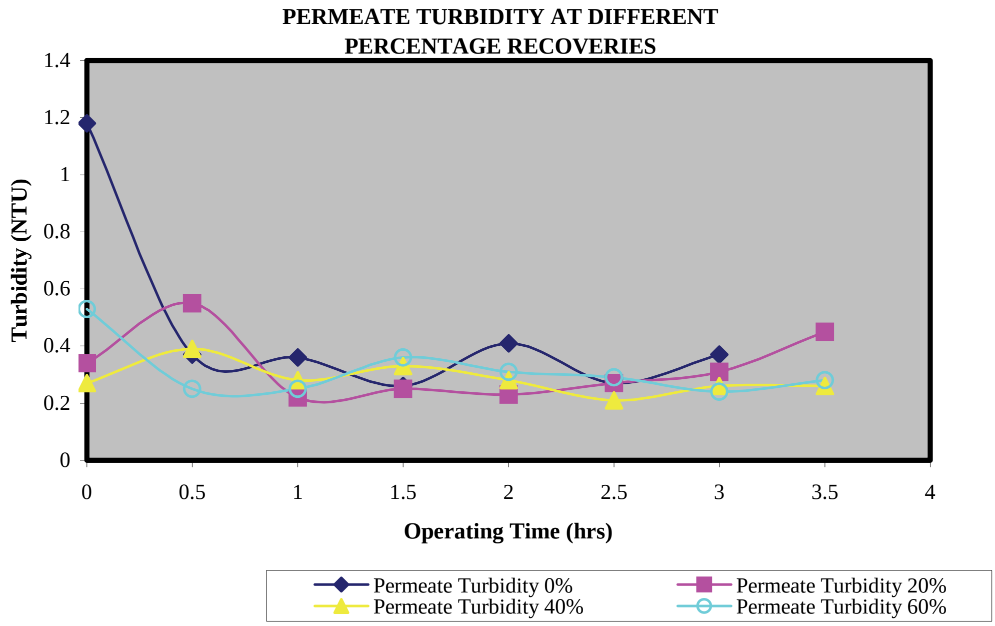

Figure A.2 *Second set showing permeate turbidities at different percentage recoveries over the operating period*

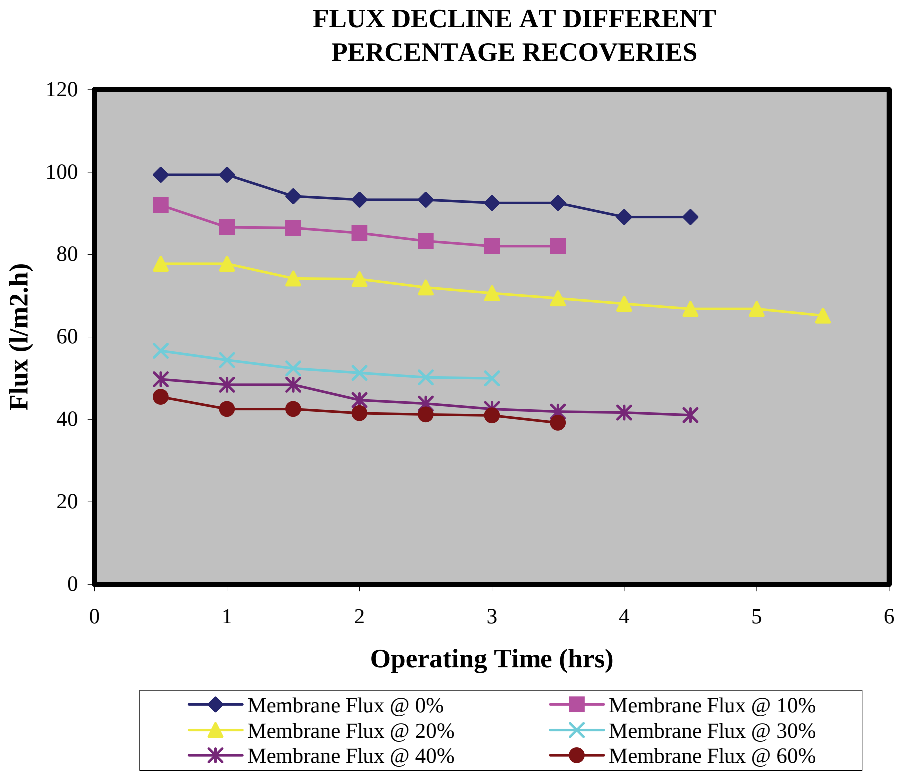

Figure A.3 *First set showing flux decline over time at different percentage recoveries.*

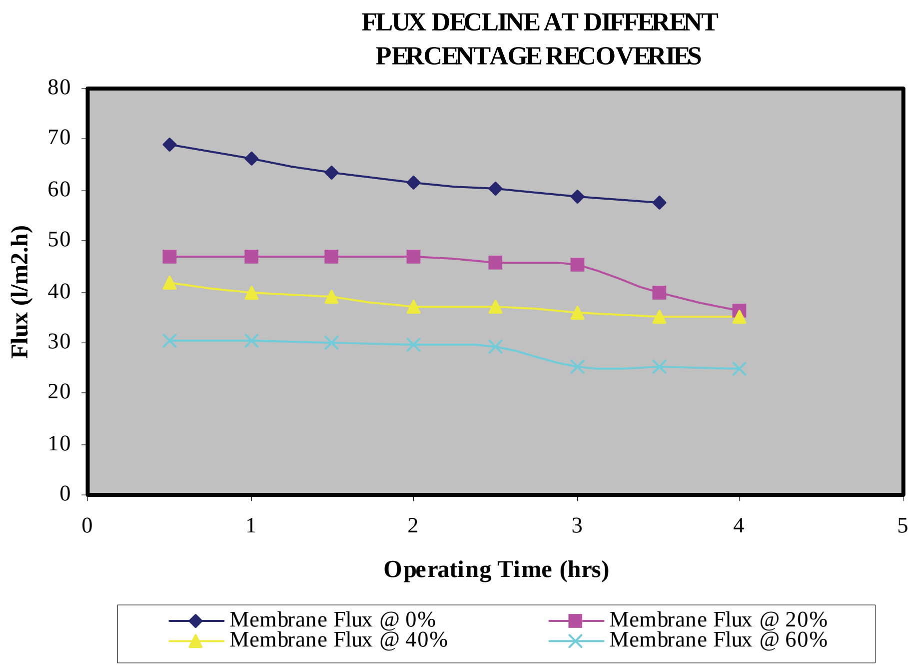

Figure A.4 *Second set showing flux decline over time at different percentage recoveries*

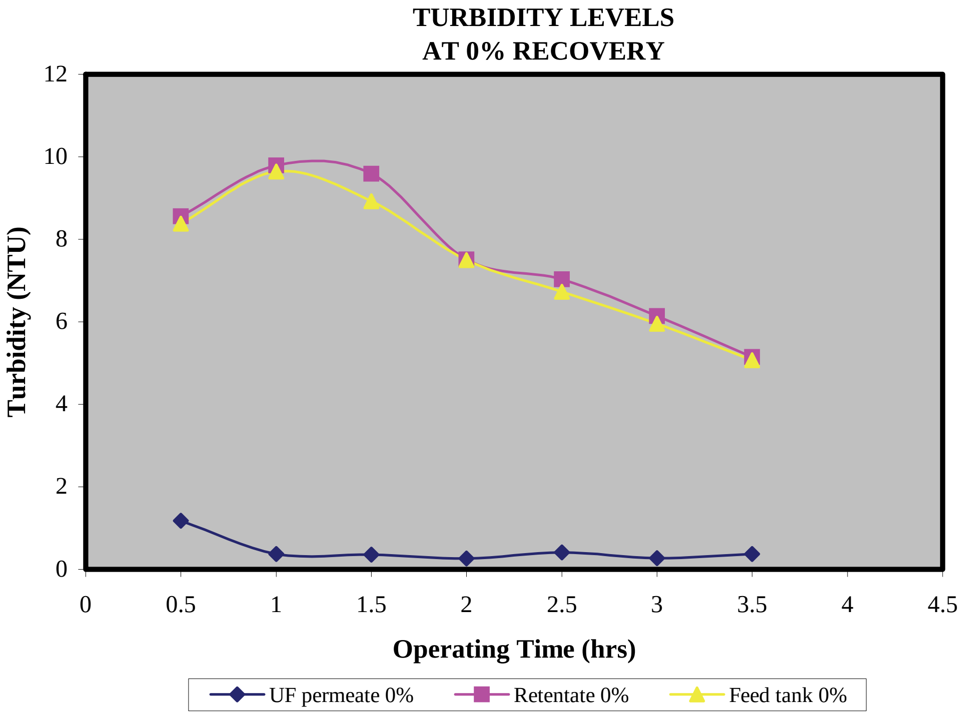

Figure A.5 *First set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 0 percentage recovery.*

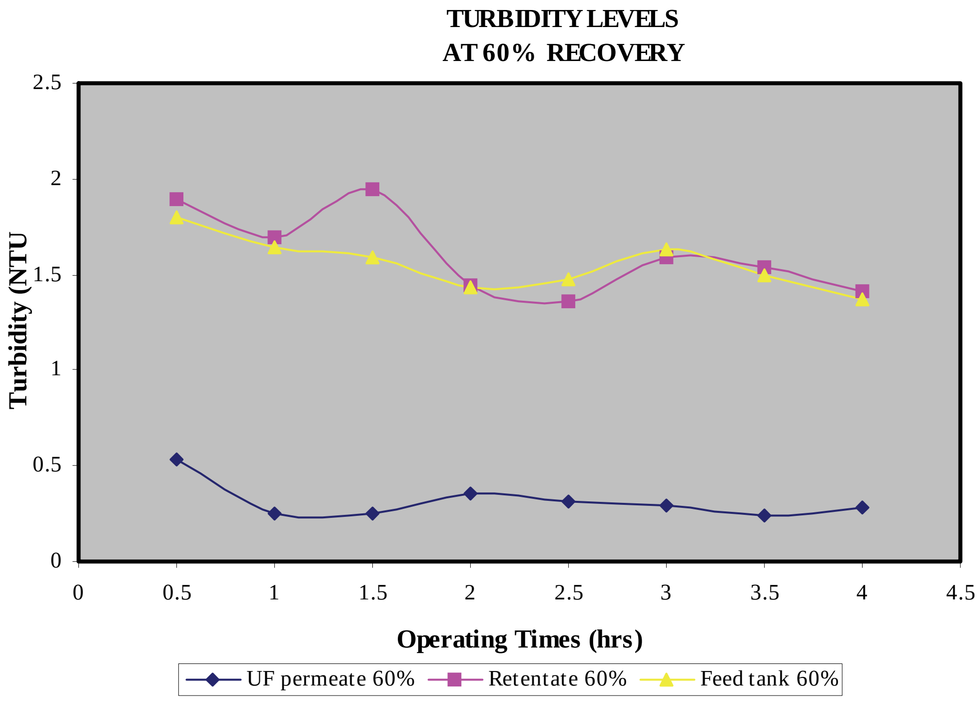

Figure A.6 *First set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 60 percentage recovery*

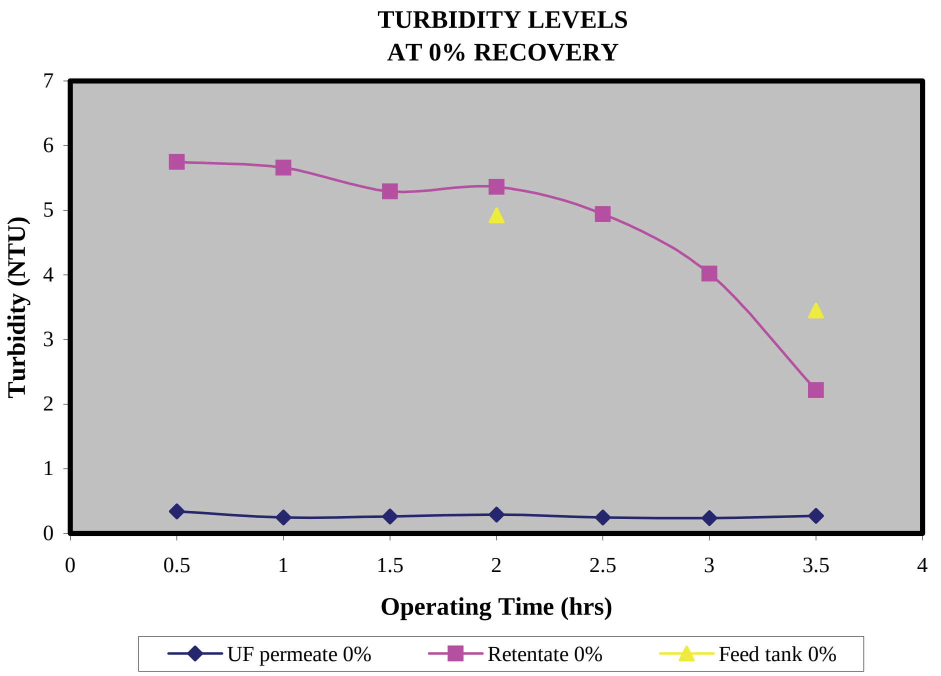

Figure A.7 *Second set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 0 percentage recovery*

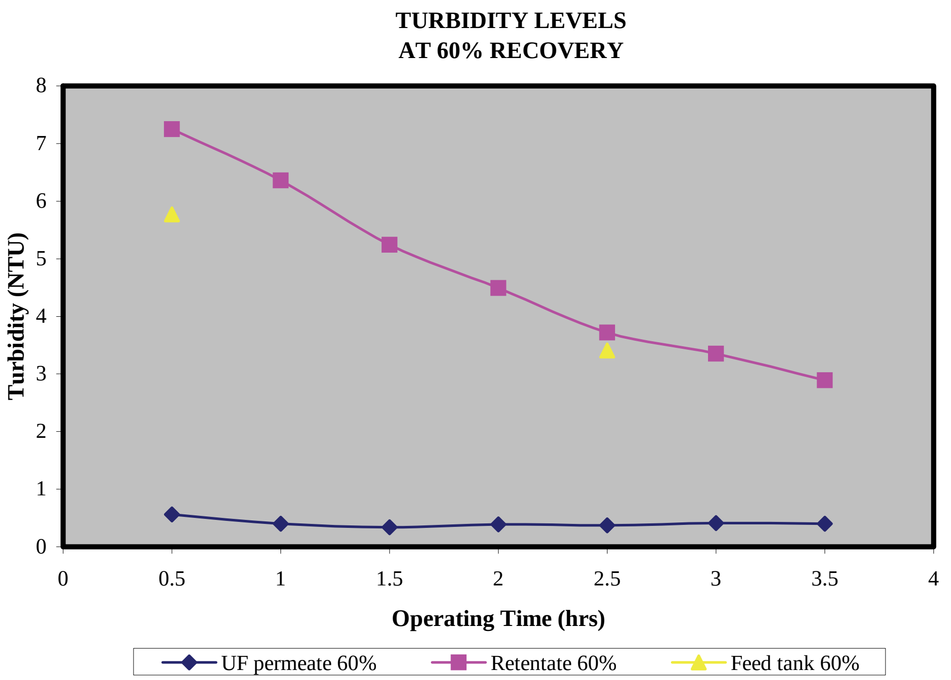

Figure A.8 *Second set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 60 percentage recovery*

Coloured Water

The Coloured water used for this study was sampled from Duivenhoks River. The water from this river is characterized by a high amount of colour and a relatively high amount of iron. Typical raw and ultrafiltered water analyses results are presented in table A.2.

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Table A.2 *Typical raw and ultrafiltered water qualities of the coloured water from Duivenhoks River.*

Determinant	Raw	Ultrafiltered water		
		0% Recovery	30% Recovery	60% Recovery
PH	6.82	6.83	6.74	6.76
Conductivity (*mS/m*)	25.0	16.20	16.50	17.80
Alkalinity (*mg/l* *$CaCo_3$*)	9.5	5.80	6.60	6.8
Chloride (*mg/l Cl*)	61.0	46.0	45.0	49
Colour (*mg/l as Pt/Co*)	160	10	20	30
Calcium (*mg/l Ca*)	5.49	1.99	2.00	2.34
Magnesium (*mg/l Mg*)	5.70	3.42	3.42	3.74
Aluminum (*mg/l Al*)	nd	0.034	0.038	0.042
Iron (*mg/l Fe*)	1.286	0.031	0.025	0.031
Manganese (*mg/l Mn*)	nd	0.003	0.003	0.015
Sodium (*mg/l Na*)	36.8	22.9	23.70	25.50
Potassium (*mg/l K*)	5.77	1.00	1.70	1.37
Sulphate (*mg/l* *SO_4*)	10.0	5.90	7.07	7.47
UV 4cm at 300nm	2.418	0.301	0.364	0.531
Total Dissolved Solids	162.50	100	100	100
Nitrate/Nitrite (*mg/l* *NO_3/NO_2*)	0.359	0.123	0.178	0.065
Turbidity (*NTU*)	12.3	0.25	0.15	0.28

nd: not determined

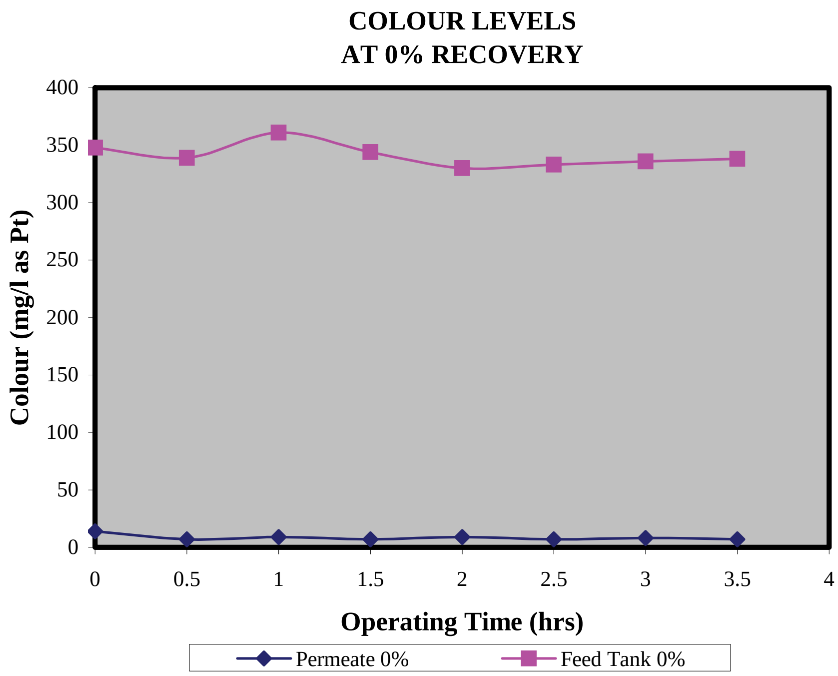

Figure A.9 *First set showing colour retention capabilities of the UF membranes over the operating time at 0 percentage recovery*

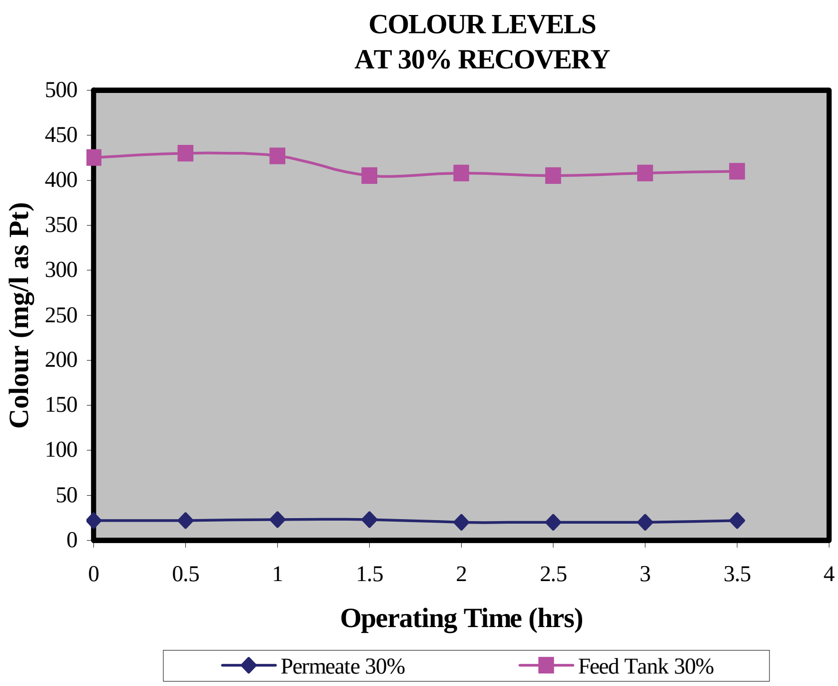

Figure A.10 *First set showing colour retention capabilities of the UF membranes over the operating time at 30 percentage recovery.*

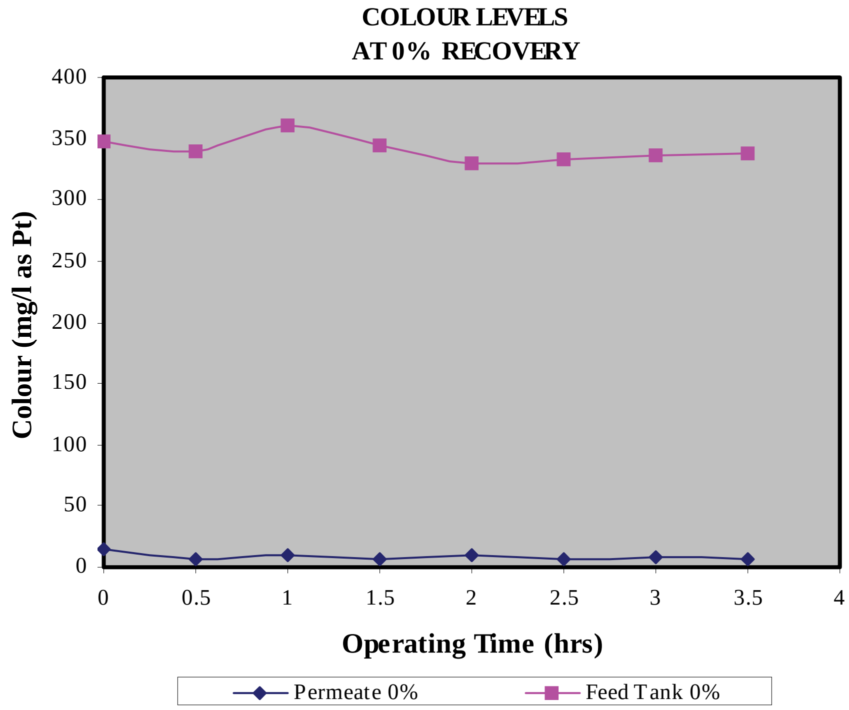

Figure A.11 *Second set showing colour retention capabilities of the UF membranes over the operating time at 0 percentage recovery*

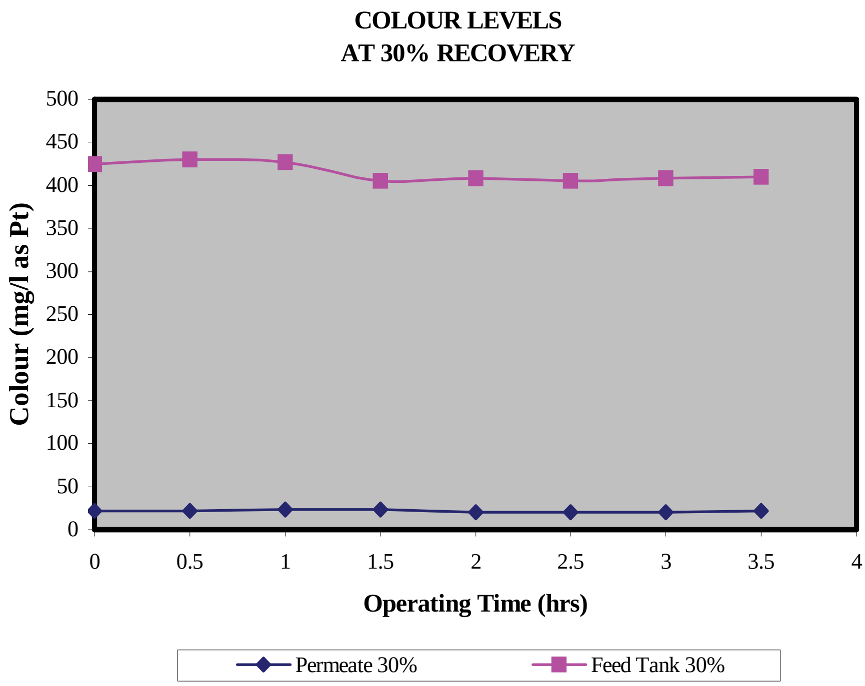

Figure A.12 *Second set showing colour retention capabilities of the UF membranes over the operating time at 30 percentage recovery.*

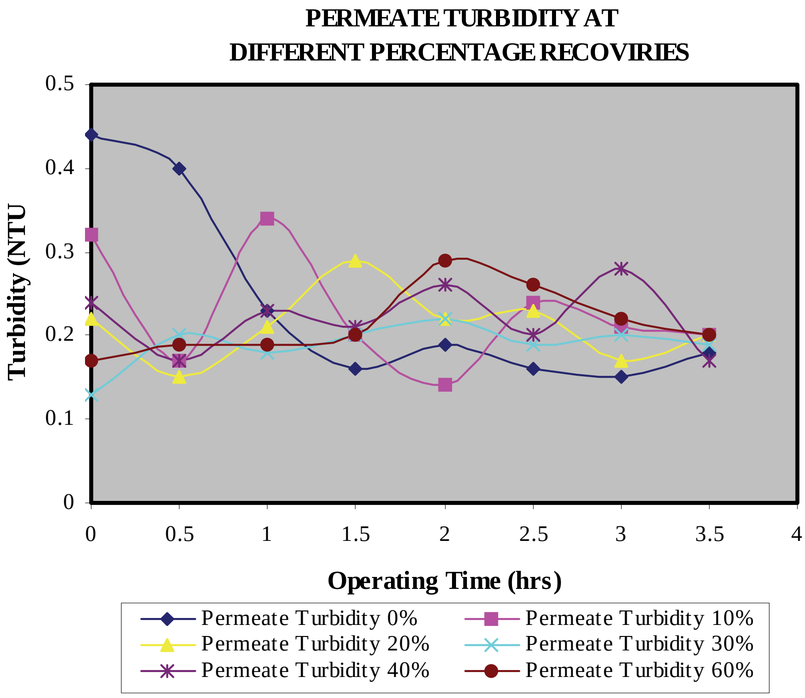

Figure A.13 *First set showing permeate turbidities at different percentage recoveries over the operating period*

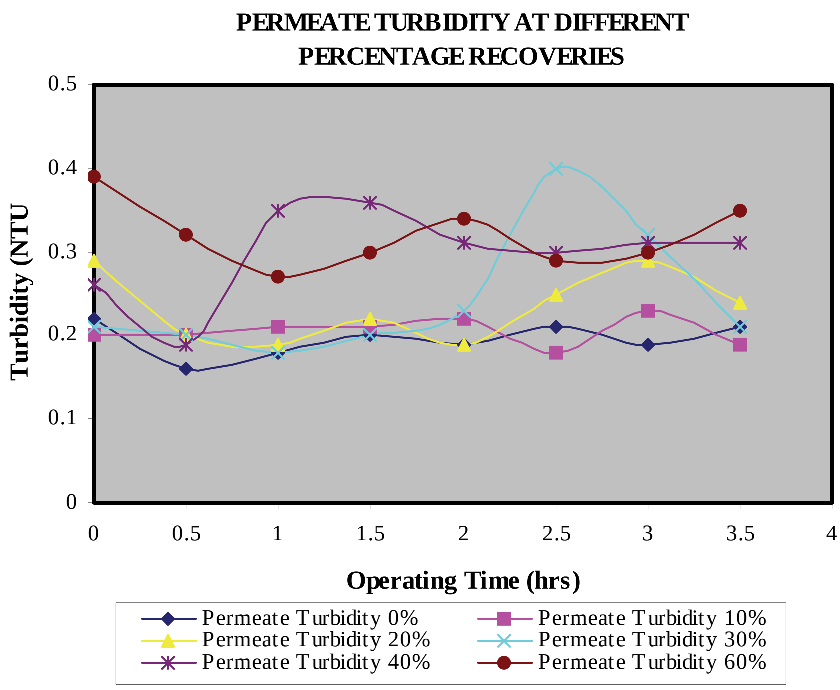

Figure A.14 *Second set showing permeate turbidities at different percentage recoveries over the operating period*

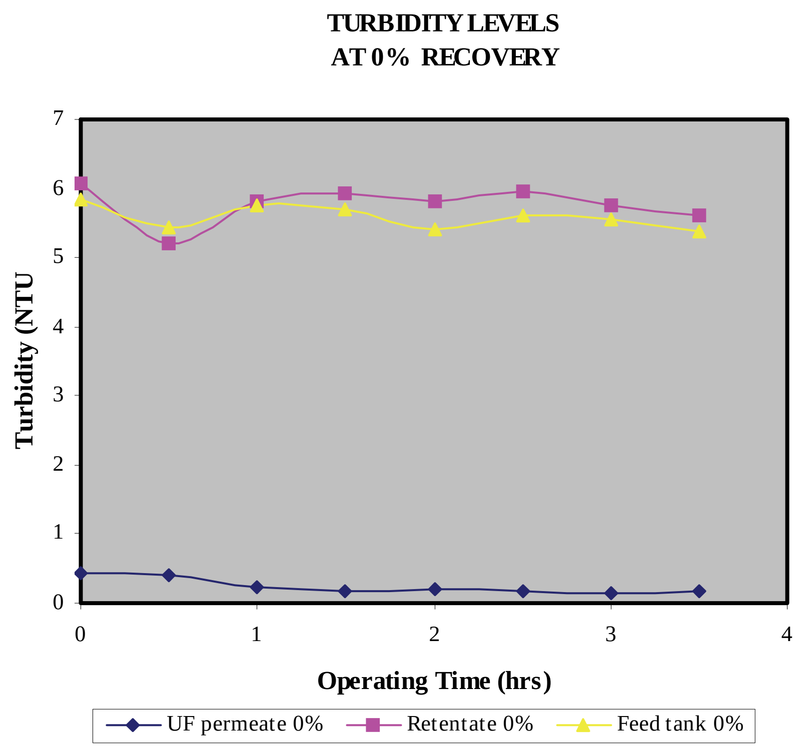

Figure A.15 *First set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 0 percentage recovery*

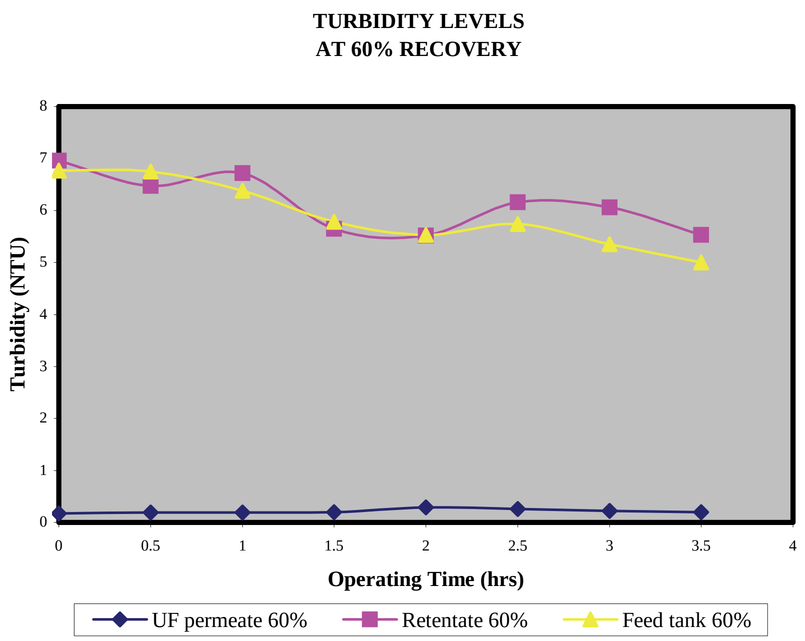

Figure A.16 *First set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 60 percentage recovery*

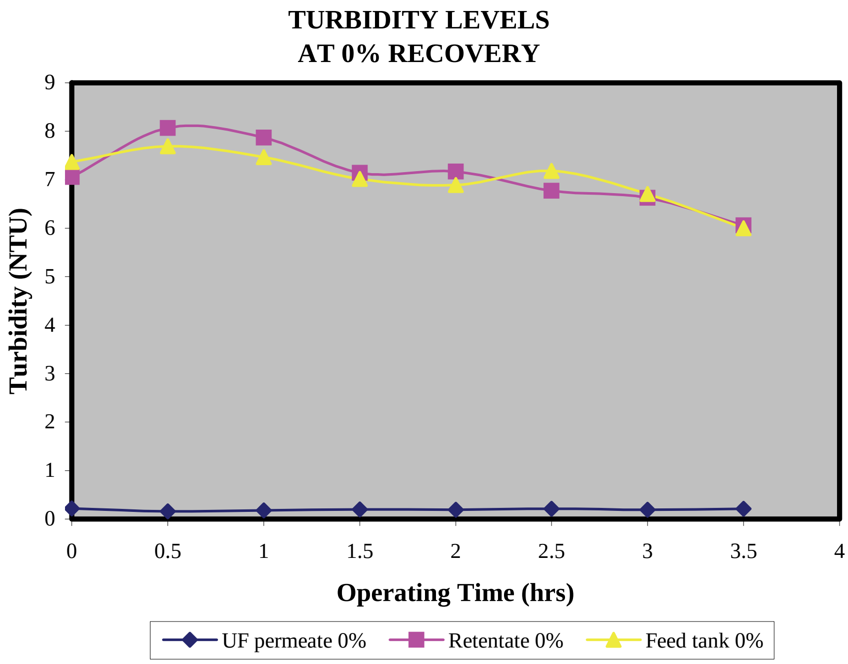

Figure A.17 *Second set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 0 percentage recovery*

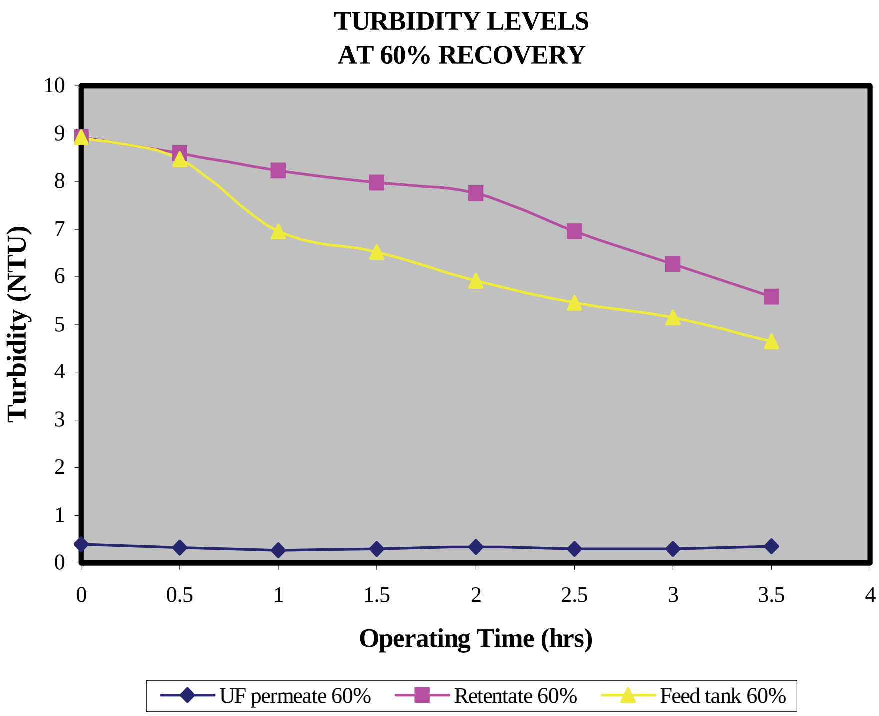

Figure A.18 *Second set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 60 percentage recovery*

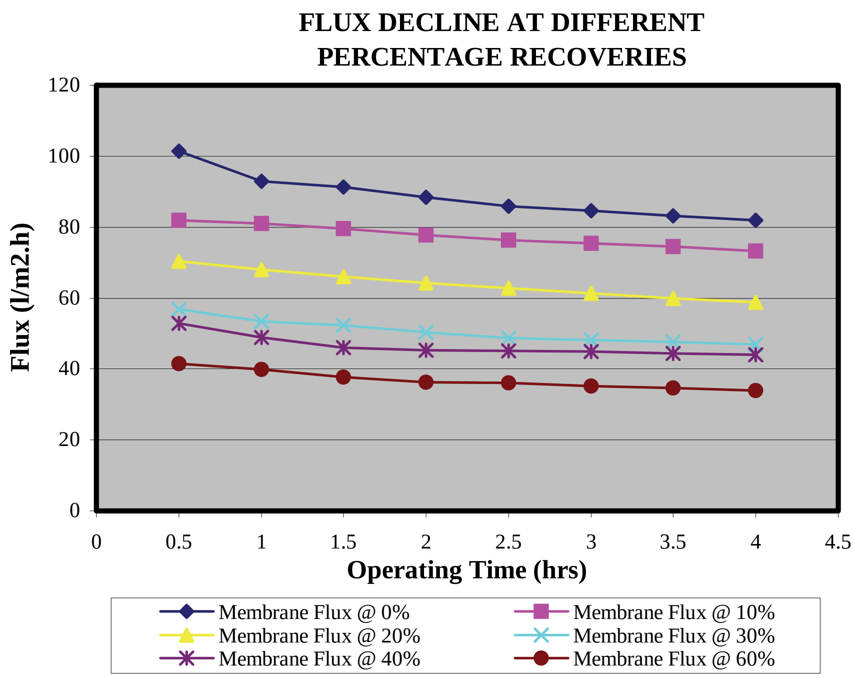

Figure A.19 *First set showing flux decline over time due to fouling at different percentage recoveries*

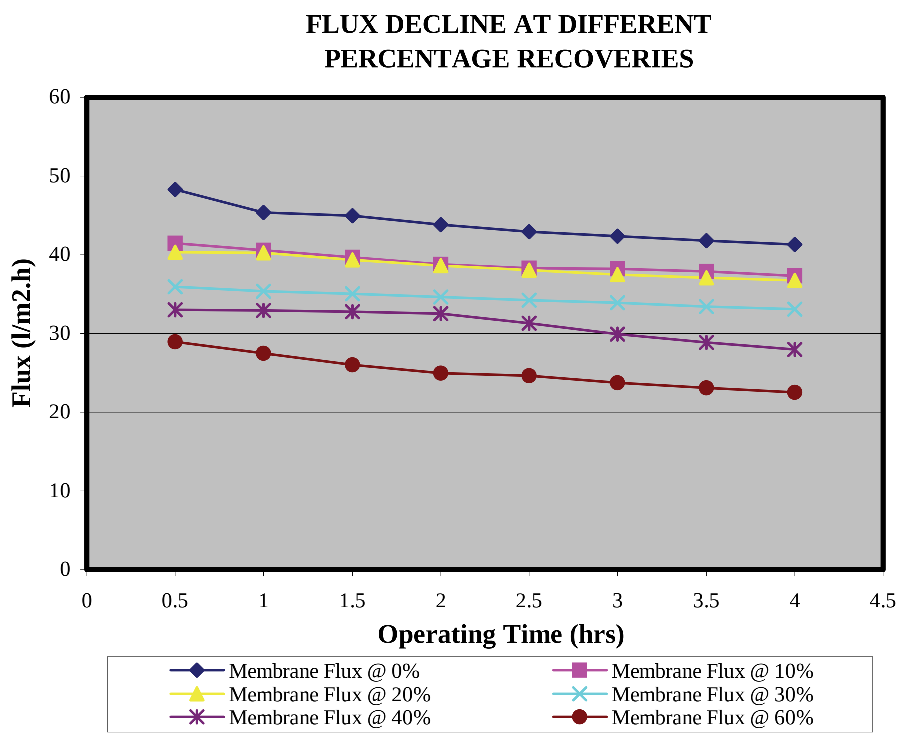

Figure A.20 *Second set showing flux decline over time due to fouling at different percentage recoveries*

Tertiary Treated Wastewater Effluent

The raw water is treated at the plant to a quality that permits discharge into the Elsies River and to adjacent industries for further treatment and re-use. The table below gives the full analysis done on the tertiary wastewater effluent.

Table A.3 *Full analysis and characterization results of tertiary treated wastewater effluent.*

Determinant	Tertiary treated wastewater effluent
Total Suspended Solids (*mg/l*)	1
COD (*mg/l*)	31
TKN (*mgN/l*)	12.4
NH_3 (*mgN/l*)	11.9
Organic Nitrogen (*mgN/l*)	0.5
NO_3/NO_2 (*mgN/l*)	6.6
Ortho-phosphate (*mgP/l*)	4.7
PH	7.0
Conductivity (*mS/m*)	66
Cl^- (*mg/l*)	79
Alkalinity (*mgCaCo$_3$/l*)	118

Microbiological results of the tertiary treated wastewater and ultrafiltered tertiary wastewater effluent are presented below.

TableA.4 *Microbiological results of the raw and ultrafiltered tertiary wastewater effluent.*

Determinant	**Tertiary treated wastewater effluent**	**Ultrafiltered tertiary wastewater effluent**
Feacal Coliform (*per 100 ml*)	$12x10^4$	<10
Escherichia Coli (*per 100 ml*)	$10x10^4$	<10

NB. No chlorine dosage to the raw water.

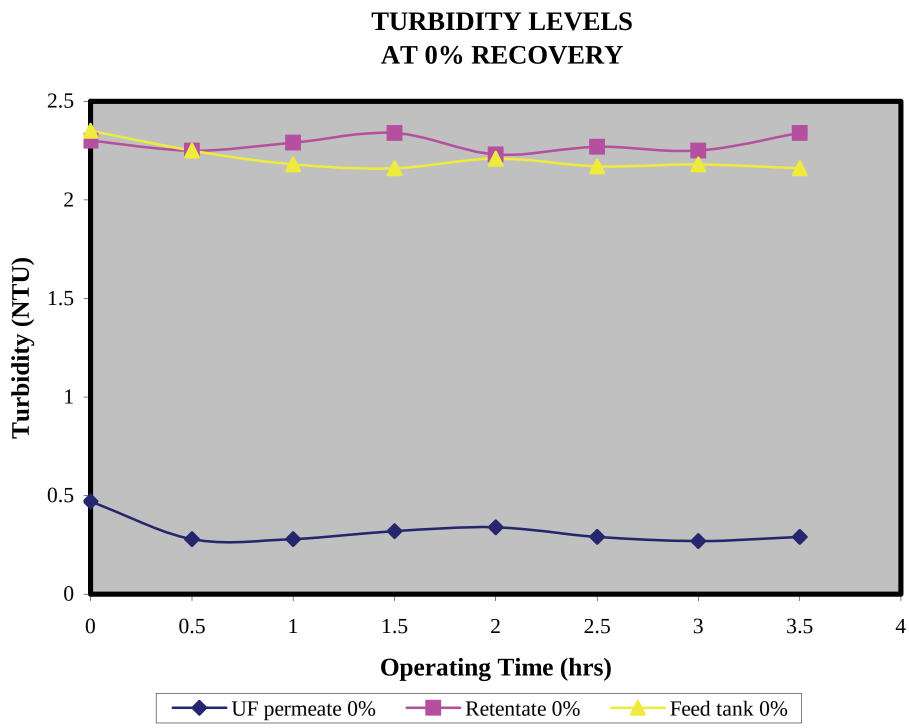

Figure A.21 *First set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 0 percentage recovery*

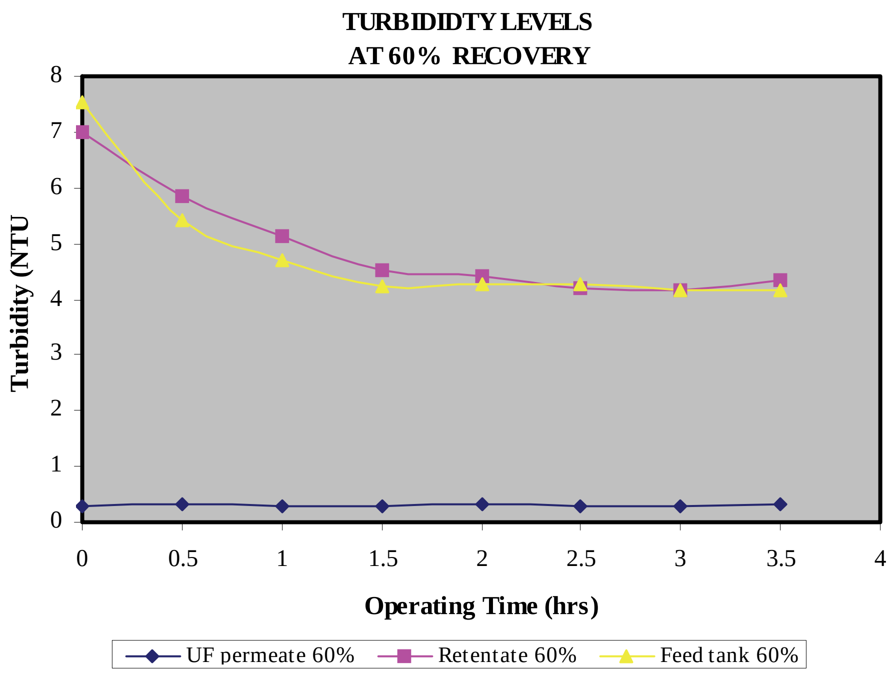

Figure A.22 *First set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 60 percentage recovery*

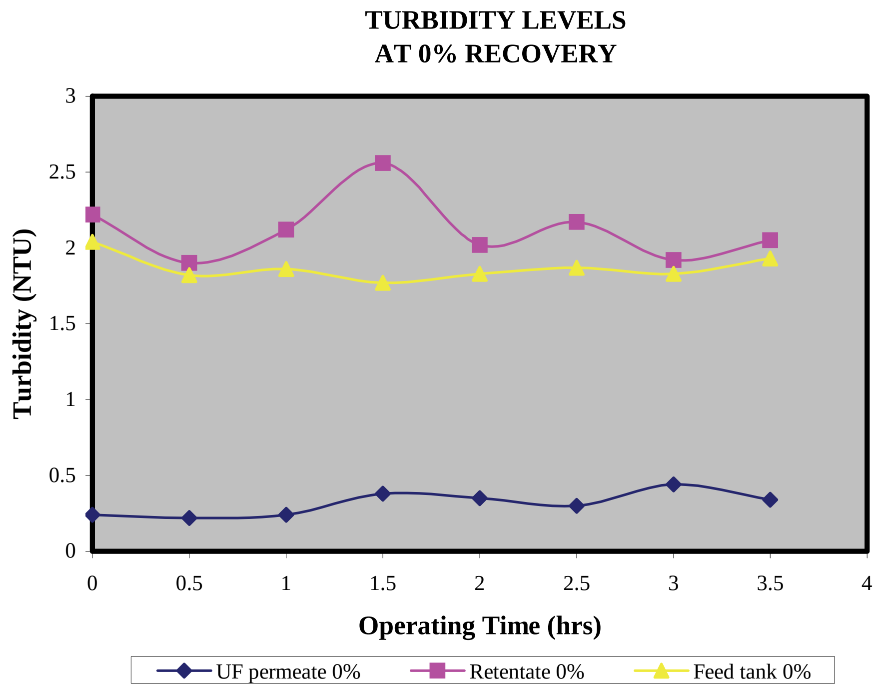

Figure A.23 *Second set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 0 percentage recovery*

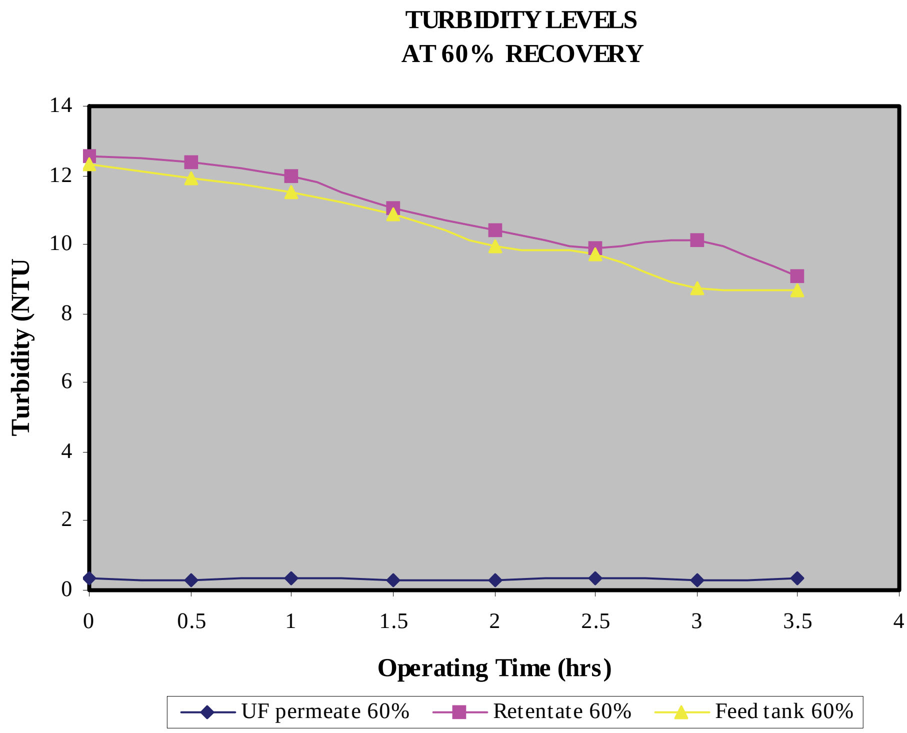

Figure A.24 *Second set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 60 percentage recovery*

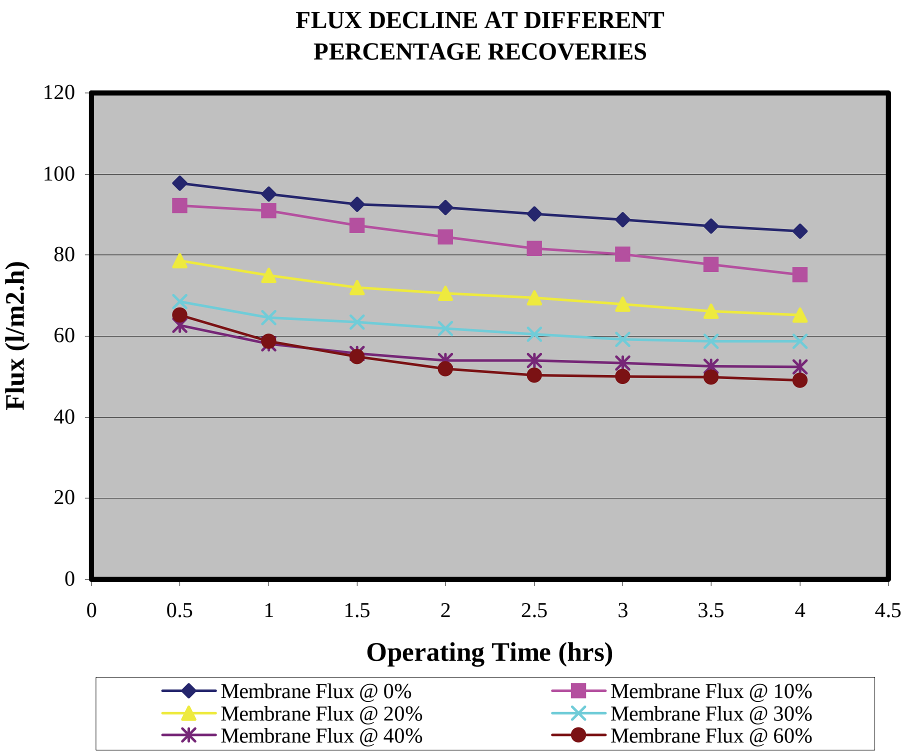

Figure A.25 *First set showing flux decline over time due to fouling at different percentage recoveries*

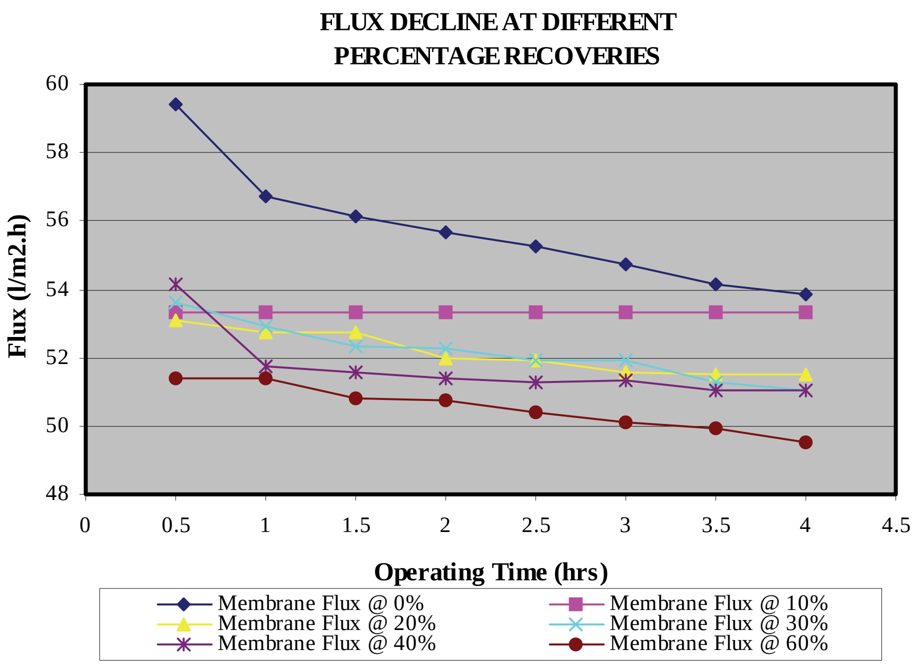

Figure A.26 Second *set showing flux decline over time due to fouling at different percentage recoveries*

Eutrophic Water

Eutrophic water used in this study comes from the Voëlvlei dam. The raw water is characterized with a high number of algae species. The full raw water characterization, algae identification and enumeration determinations were done by CMC Scientific services. The results are presented below.

Table A.5 *Physico-chemical results of Eutrophic water from Voëlvlei Dam.*

Determinant	Raw
PH	7.16
Conductivity (*mS/m*)	7.4
Alkalinity (*mg/l* $CaCO_3$)	12.0
Chloride (*mg/l Cl*)	19.9
Colour (*mg/l as Pt/Co*)	10
Calcium (*mg/l Ca*)	4.14
Magnesium (*mg/l Mg*)	nd
Aluminum (*mg/l Al*)	nd
Iron (*mg/l Fe*)	nd
Manganese (*mg/l Mn*)	nd
Sodium (*mg/l Na*)	nd
Potassium (*mg/l K*)	nd
Sulphate (*mg/l* SO_4)	3.20
UV 4cm at 300nm	0.19
Total Dissolved Solids	48.1
Nitrate/Nitrite (*mg/l* NO_3/NO_2)	0.007
Turbidity (*NTU*)	13.5

nd: not determined

ALGAE IDENTIFICATION AND ENUMERATION DETERMINATIONS

Table A.6 *Raw water results on algae identification and enumeration determinations on Eutrophic water*

Sample sites	Identified Algae Species	Concentration
Voëlvlei Raw Dam	*Carteria sp.*	98 cells/ml
	Centric Diatoms	49 cells/ml
	Melosira sp.	685 filaments/ml
	Trachledomonas sp.	49 cells/ml

Sample type: Raw water
Raw water source: Voëlvlei dam
REMARKS: No Blue-green algae were detected in the sample.

Table A.7 *Ultrafiltered water results on algae identification and enumeration determinations on Eutrophic water*

Sample sites	Percentage Recovery	Identified Algae Species	Concentration
Voëlvlei Treated	0%	*Melosira sp.*	98 filaments/ml
	20%	*Chlamydomonas sp.*	49 cells/ml
	40%	*No algae present*	-
	60%	*No algae present*	-

Sample type: Ultrafiltered water
Raw water source: Voëlvlei dam
REMARKS: No algae were detected in the 40% and 60% samples.

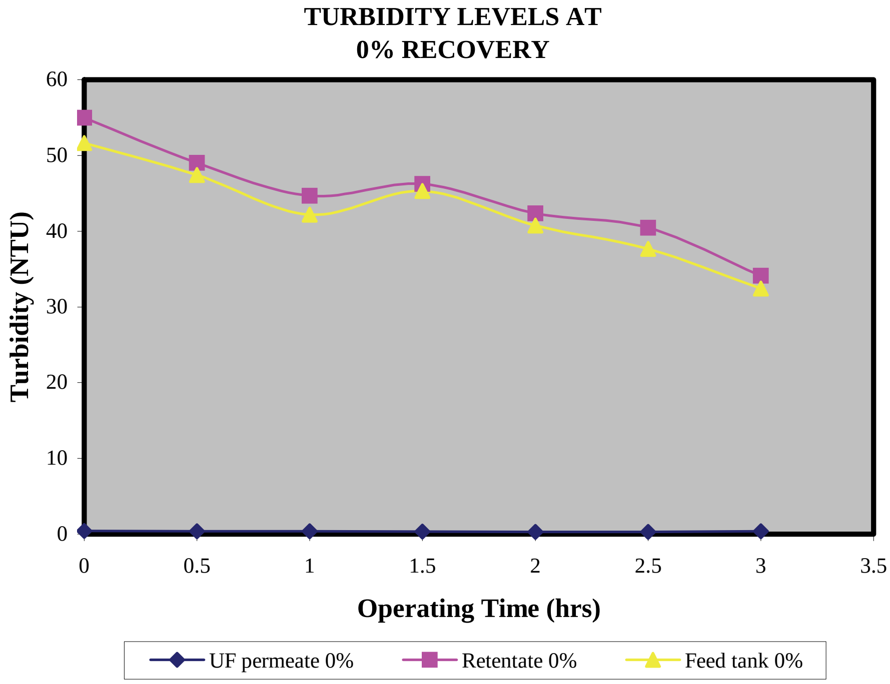

Figure A.27 *First set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 0 percentage recovery.*

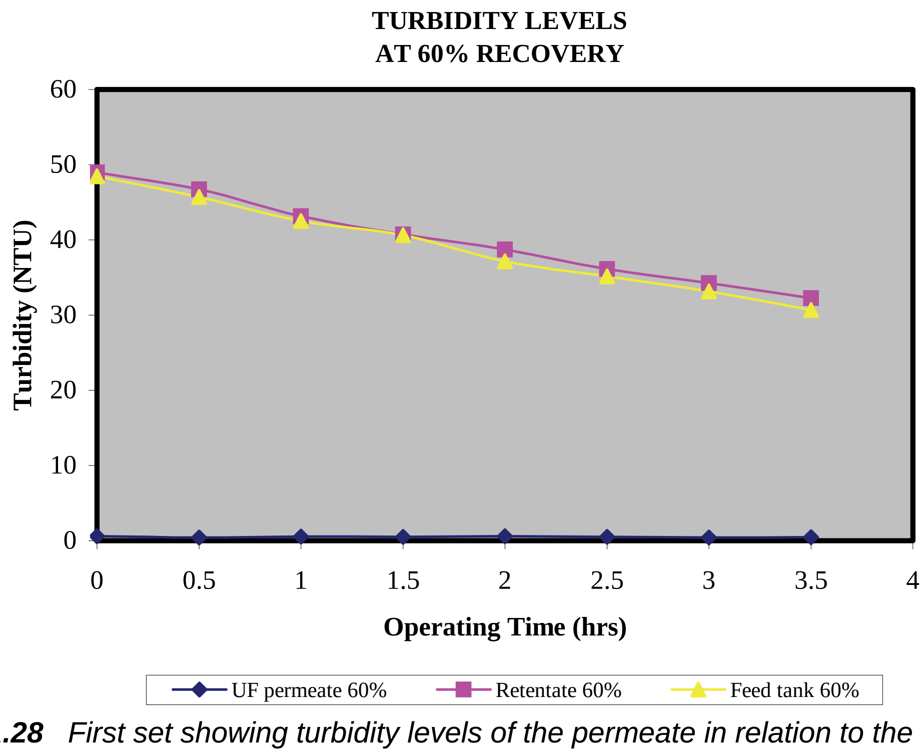

Figure A.28 *First set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 60 percentage recovery.*

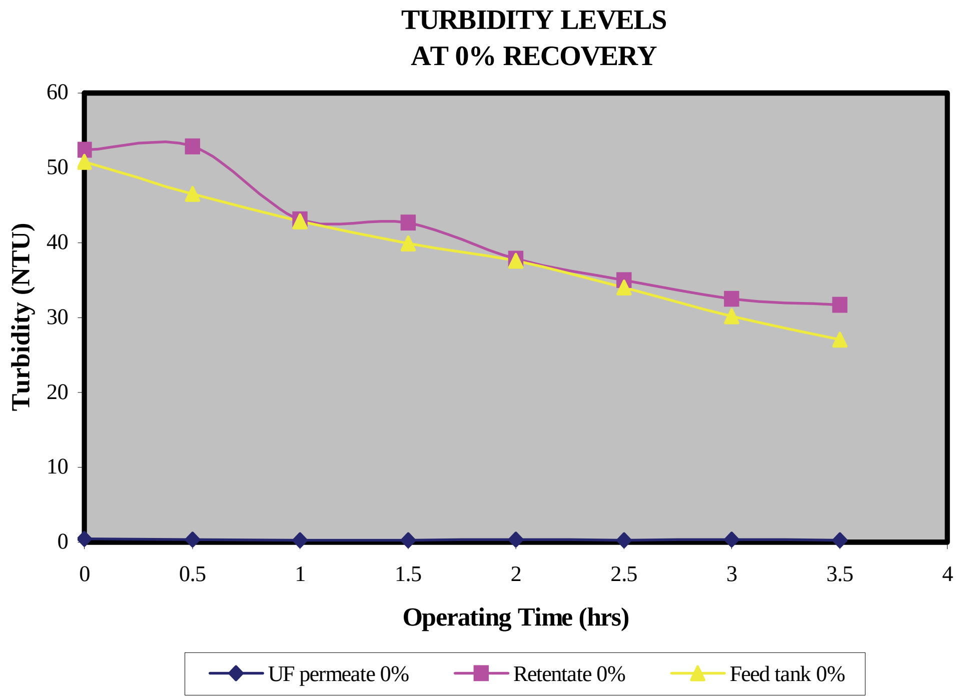

Figure A.29 *Second set showing turbidity levels of the permeate in relation to the feed and*
retentate streams over the operating period at 0 percentage recovery

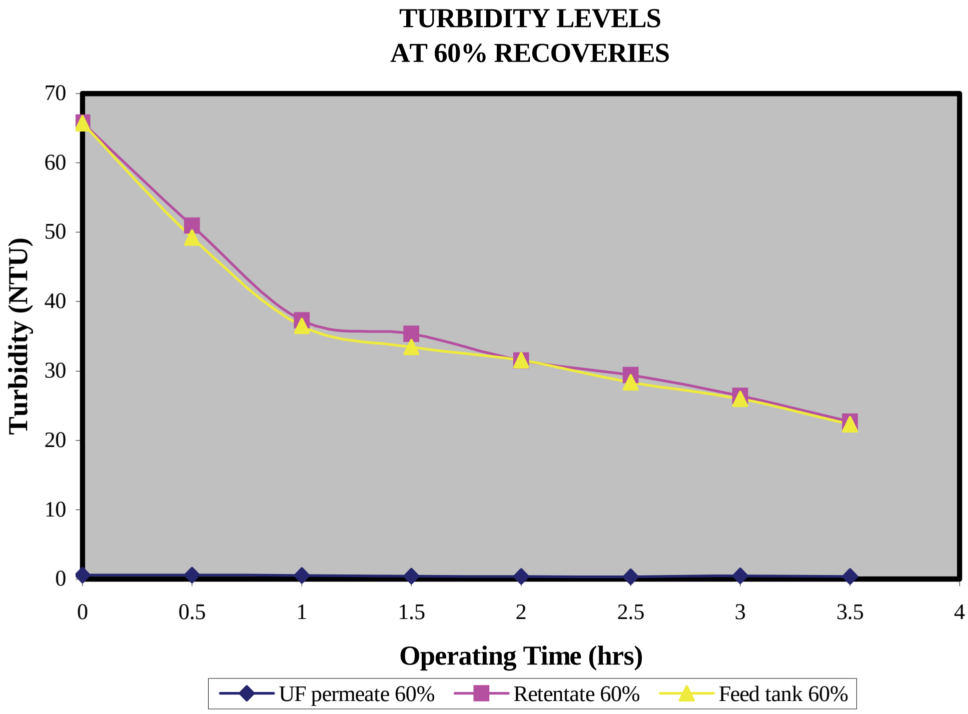

Figure A.30 *Second set showing turbidity levels of the permeate in relation to the feed and retentate streams over the operating period at 60 percentage recovery.*

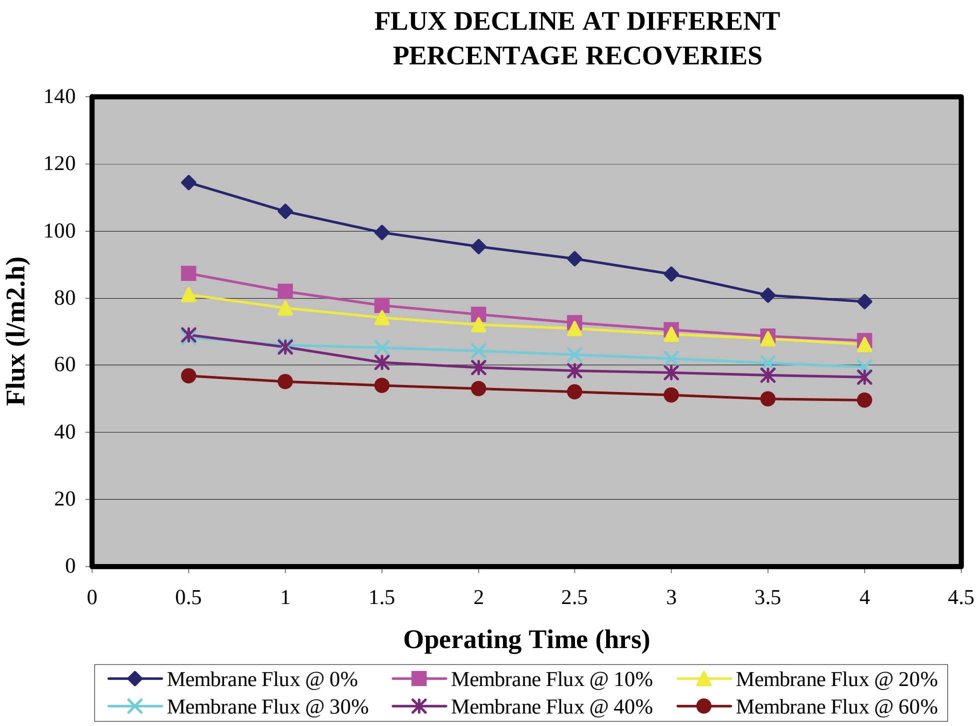

Figure A.31 *First set showing flux decline over time due to fouling at different percentage recoveries*

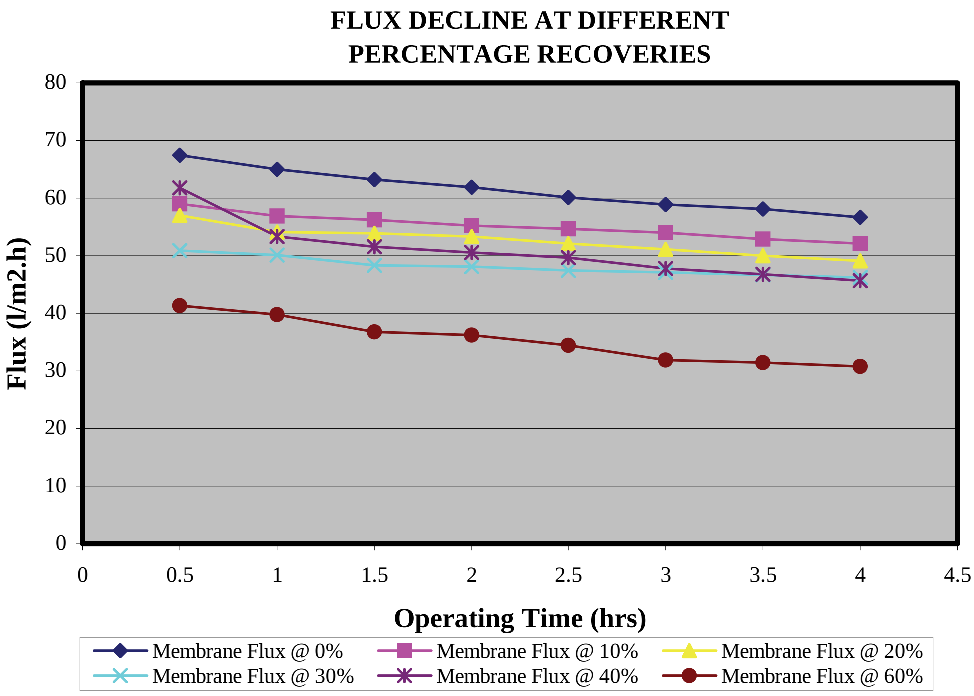

Figure A.32 *Second set showing flux decline over time due to fouling at different percentage recoveries*

APPENDIX B

DETAILS OF MOBILE MICROFILTRATION AND ULTRAFILTRATION PILOT PLANT

Figure B.1 *Schematic Lay-out of Microfiltration / Ultrafiltration Mobile Pilot Plant*

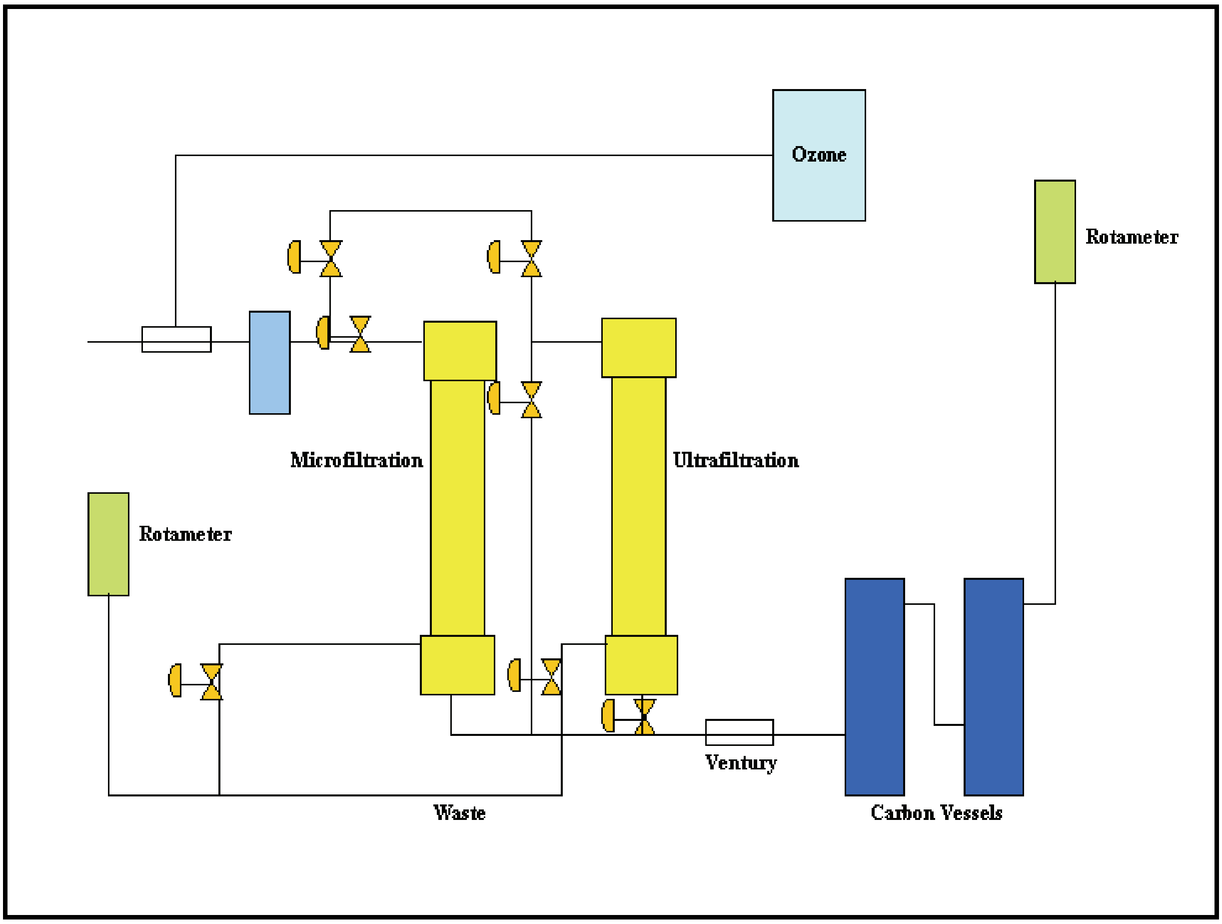

Figure B.2 *P&I Diagram of Microfiltration / Ultrafiltration Mobile Pilot Plant*

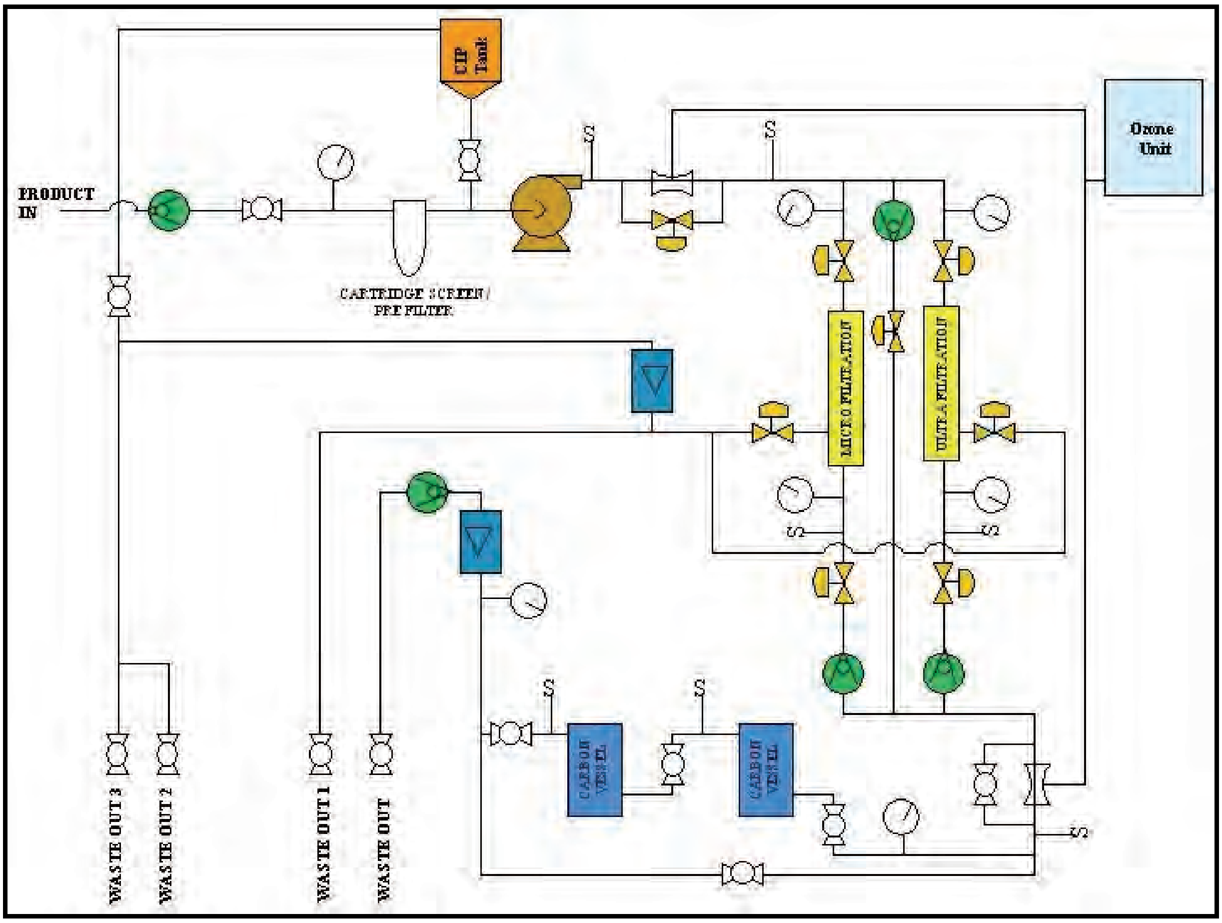

Figure B.3 *Photo of Microfiltration / Ultrafiltration Mobile Pilot Plant*

APPENDIX C

RESULTS OF MICROFILTRATION / ULTRAFILTRATION PILOT SCALE STUDIES

PRELIMINARY TRIALS AT CALEDON

RUN 1

RAW WATER

DATE	TIME	P1	P2	P3	RAW WATER				FLOW RATE	REMARKS
					TEMP	PH	TURB	COLOUR		
14/06/05	10H00	-	-	-	15.3	7.77	3.44	177/182/181	-	Rainy

AFTER MICROFILTATION

DATE	TIME	P1	P2	P3	MICROFILTATION				FLOW RATE	REMARKS
					TEMP	PH	TURB	COLOUR		
14/06/05	10H00	180	140	0	16.2	5.65	1.02	65/68/66	110	Rainy
14/06/05	12H30	190	150	0	16.0	5.70	0.52	91/96/96	130	
14/06/05	15H30	190	150	0	16.0	6.20	0.48	90/91/90	130	

AFTER ULTRAFILTRATION

DATE	TIME	P1	P2	P3	ULTRAFILTATION				FLOW RATE	REMARKS
					TEMP	PH	TURB	COLOUR		
14/06/05	10H00	180	140	0	16.3	5.85	0.55	42/41/43	110	Rainy
14/06/05	12H30	190	150	0	16.2	5.83	0.43	57/55/55	130	
14/06/05	15H30	190	150	0	16.4	6.09	0.54	62/64/62	130	

RUN 2

RAW WATER

DATE	TIME	P1	P2	P3	RAW WATER				FLOW RATE	REMARKS
					TEMP	PH	TURB	COLOUR		
15/06/05	10H00	-	-	-	13.3	5.81	1.73	102/105/103	-	Rainy

AFTER MICROFILTRATION

DATE	TIME	P1	P2	P3	MICROFILTRATION				FLOW RATE	REMARKS
					TEMP	PH	TURB	COLOUR		
15/06/05	10H00	190	150	0	13.7	6.82	0.71	76/76/74	140	Windy
15/06/05	11H00	190	150	0	15.5	6.93	0.47	94/96/95	140	
15/06/05	12H00	180	140	0	16.0	6.63	0.65	87/92/88	120	
15/06/05	13H00	190	140	0	16.4	6.34	0.46	118/116/115	130	
15/06/05	14H00	190	140	0	16.3	6.28	0.42	97/96/98	130	
15/06/05	15H00	180	140	0	16.9	6.20	0.33	109/115/111	120	

AFTER ULTRAFILTRATION

DATE	TIME	P1	P2	P3	ULTRAFILTRATION				FLOW RATE	REMARKS
					TEMP	PH	TURB	COLOUR		
15/06/05	10H00	190	150	0	14.3	6.76	0.70	55/55/58	140	Rainy
15/06/05	11H00	190	150	0	14.6	6.54	0.31	48/51/52	140	
15/06/05	12H00	180	140	0	16.9	6.70	0.30	68/63/62	120	
15/06/05	13H00	190	140	0	16.4	6.74	0.32	50/51/49	130	
15/06/05	14H00	190	140	0	16.2	6.72	0.33	66/67/66	130	
15/06/05	15H00	180	140	0	16.7	6.80	0.39	68/67/66	120	

RUN 3

RAW WATER

DATE	TIME	P1	P2	P3	RAW WATER				FLOW RATE	REMARKS
					TEMP	PH	TURB	COLOUR		
16/06/05	11H00	-	-	-	16.0	6.86	5.50	232/229/231	-	

AFTER MICROFILTRATION

DATE	TIME	P1	P2	P3	MICROFILTRATION				FLOW RATE	REMARKS
					TEMP	PH	TURB	COLOUR		
16/06/05	11H00	180	140	0	17.3	6.52	0.53	90/94/98	95	
16/06/05	12H00	180	140	0	16.5	6.62	0.54	89/91/88	100	
16/06/05	13H00	180	140	0	19.0	6.61	0.37	108/114/113	100	
16/06/05	14H00	180	140	0	18.6	6.50	0.47	129/126/130	100	
16/06/05	15H00	175	130	0	20.0	6.59	0.30	122/125/125	95	

AFTER ULTRAFILTRATION

DATE	TIME	P1	P2	P3	ULTRAFILTRATION				FLOW RATE	REMARKS
					TEMP	PH	TURB	COLOUR		
16/06/05	11H00	180	140	0	16.4	6.67	0.60	32/35/33	95	
16/06/05	12H00	180	140	0	16.3	6.71	0.24	40/37/39	100	
16/06/05	13H00	180	140	0	18.7	6.78	0.33	49/52/50	100	
16/06/05	14H00	180	140	0	17.3	6.78	0.26	48/48/45	100	
16/06/05	15H00	175	130	0	19.7	6.73	0.27	62/61/66	95	

RUN 4

RAW WATER

DATE	TIME	P1	P2	P3	RAW WATER				FLOW RATE	REMARKS
					TEMP	PH	TURB	COLOUR		
17/06/05	11H00	-	-	-	15.0	6.83	2.08	115/114/116	-	

AFTER MICROFILTATION

DATE	TIME	P1	P2	P3	MICROFILTRATION				FLOW RATE	REMARKS
					TEMP	PH	TURB	COLOUR		
17/06/05	11H00	180	140	0	14.6	6.51	0.70	99/98/94	98	
17/06/05	12H00	170	130	0	16.2	6.62	0.35	106/106/104	95	
17/06/05	13H00	180	140	0	17.1	6.11	0.45	122/122/121	100	
17/06/05	14H00	170	130	0	19.3	6.35	0.33	117/119/118	90	
17/06/05	15H00	170	130	0	18.7	6.44	0.37	126/127/127	100	

AFTER ULTRAFILTRATION

DATE	TIME	P1	P2	P3	ULTRAFILTRATION				FLOW RATE	REMARKS
					TEMP	PH	TURB	COLOUR		
17/06/05	11H00	180	140	0	14.8	6.67	0.24	30/34/38	98	
17/06/05	12H00	170	130	0	16.9	6.61	0.32	55/42/48	95	
17/06/05	13H00	180	140	0	17.0	6.42	0.32	49/45/46	100	
17/06/05	14H00	170	130	0	17.9	6.47	0.31	60/62/59	90	
17/06/05	15H00	170	130	0	17.7	6.42	0.28	55/51/52	100	

FIRST SET OF PILOT PLANT TRIALS AT VOORSTEKRAAL, GENADENDAL

Trial No.: **PRELIM TRIAL 1** MF or MF plus UF: **MF plus UF** Date: **20 October 2005**

Raw water: pH **8.35** Turbidity **0.41** Colour **24/30** Conductivity **59.2**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
09:00	P1: 260 P2: 215 P3: 20	220	650	0.54 0.45	34/38	60.7	8.10	-	0.27 0.28	10/12	59.9	7.95	-	0.25 0.21	14/12	59.3	8.08	-
09:30	P1: 250 P2: 205 P3: 20	210	650	0.54	39/40	-	7.90	-	0.34 0.31	14/14	-	8.03	-	0.15 0.14	16/15	-	8.00	-
10:00	P1: 250 P2: 205 P3: 15	210	650	0.52 0.49	41/39	61.2	7.68	-	0.33 0.32	12/13	61.4	7.74	-	0.22 0.19	12/11	56.9	7.82	-
10:30	P1: 250 P2: 225 P3: 20	210	520	0.47 0.47	47/46	-	7.75	-	0.24 0.21	17/16	-	7.86	-	0.37 0.38	19/18	-	7.78	-
11:00	P1: 255 P2: 220 P3: 20	240	520	0.45 0.41	36/35	60.7	7.90	-	0.13 0.14	11/09	60.5	7.93	-	0.19 0.16	14/15	57.9	7.85	-
11:30	P1: 240 P2: 200 P3: 15	170	520	0.45 0.41	45/44	-	7.69	-	0.21 0.22	12/11	-	7.82	-	0.19 0.17	13/12	-	7.82	-
12:00	P1: 255 P2: 225 P3: 15	200	390	0.48 0.44	52/55	62.9	7.71	-	0.20 0.26	12/14	60.9	7.81	-	0.14 0.13	16/18	59.3	7.89	-

12:30	P1: 260 P2: 220 P3: 15	200	390	0.37 0.37	39/39	-	7.65	-	0.14 0.14	18/17	-	7.79	-	0.17 0.16	16/14	-	7.70	-
13:00	P1: 240 P2: 195 P3: 15	170	390	0.46 0.43	52/50	61.7	7.81	-	0.21 0.14	15/16	60.8	7.79	-	0.12 0.11	15/15	57.8	7.67	-
13:30	P1: 260 P2: 230 P3: 15	200	260	0.44 0.45	46/44	-	7.61	-	0.19 0.18	16/16	-	7.82	-	0.16 0.16	18/19	-	7.71	-
14:00	P1: 260 P2: 230 P3: 15	220	260	0.35 0.32	33/34	60.4	7.76	-	0.19 0.22	19/20	60.8	7.71	-	0.22 0.22	16/18	57.9	7.89	-

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
14:30	P1: 250 P2: 210 P3: 15	210	260	0.55 0.48	36/39	-	7.44	-	0.16 0.15	15/14	-	7.75	-	0.14 0.15	19/17	-	7.69	-
15:00	P1: 275 P2: 240 P3: 15	220	130	0.47 0.45	45/44	61.1	7.57	-	0.28 0.27	15/17	59.7	7.72	-	0.17 0.20	23/21	59.1	7.79	-
15:30	P1: 275 P2: 240 P3: 15	205	130	0.38 0.36	35/36	-	7.65	-	0.21 0.23	14/16	-	7.50	-	0.14 0.15	16/17	-	7.69	-
16:00	P1: 260 P2: 220 P3: 15	185	130	0.36 0.37	34/33	60.1	7.62	-	0.22 0.25	16/17	60.0	7.61	-	0.12 0.12	9/11	57.6	7.57	-

Trial No.: **PRELIM TRIAL 2** MF or MF plus UF: **UF ALONE** Date: **20 October 2005**

Raw water: pH **7.89** Turbidity **0.29/0.29** Colour **22/24** Conductivity **59.5**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
09:00	P1: 260 P2: 215 P3: 20	150	650	0.55 0.58	51/53	65.1	7.84	-	-	-	-	-	-	0.14 0.12	10/8	57.6	7.86	-
09:30	P1: 255 P2: 210 P3: 15	110	650	0.58 0.57	49/47	-	7.81	-	-	-	-	-	-	0.13 0.14	9/7	-	7.87	-
10:00	P1: 250 P2: 220 P3: 15	125	520	0.49 0.48	55/56	65.2	7.72	-	-	-	-	-	-	0.13 0.14	8/8	59.5	7.78	-
10:30	P1: 250 P2: 210 P3: 15	145	520	0.44 0.43	49/51	-	7.58	-	-	-	-	-	-	0.13 0.12	9/10	-	7.76	-
11:00	P1: 250 P2: 220 P3: 10	160	390	0.46 0.48	49/50	63.1	7.51	-	-	-	-	-	-	0.15 0.16	16/15	59.2	7.62	-
11:30	P1: 250 P2: 220 P3: 10	150	390	0.46 0.47	48/47	-	7.45	-	-	-	-	-	-	0.23 0.23	12/8	-	7.61	-
12:00	P1: 260 P2: 235 P3: 10	160	260	0.48 0.45	60/62	65.3	7.37	-	-	-	-	-	-	0.15 0.15	20/21	61.1	7.48	-
12:30	P1: 240 P2: 205 P3: 10	130	260	0.35 0.33	41/39	-	7.46	-	-	-	-	-	-	0.15 0.11	11/12	-	7.56	-

13:00	P1: 220 P2: 180 P3: 5	120	130	0.35 0.37	41/41	62.0	7.44	-	-	-	-	-	-	0.12 0.12	12/10	59.7	7.37	-

SECOND SET OF PILOT PLANT TRIALS AT VOORSTEKRAAL, GENADENDAL

Trial No.: **TRIAL # 1** MF or UF plus UF: **MF plus UF** Date: **22 November 2005**

Raw water: pH **6.11** Turbidity **0.56/0.51** Colour **25/22** Conductivity **61.8**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
15:00	P1: 210 P2: 180 P3: 25	620	650	2.88 3.20 2.96	60/57/55	67.2	6.21	-	1.11 1.10 0.99	36/36/28	70.04	5.84	-	0.31 0.32 0.28	15/17/18	62.3	5.92	-
15:30	P1: 210 P2: 170 P3: 22	600	650	1.17 1.50 1.35	38/33/35	63.2	5.71	-	1.06 1.12 1.05	32/35/30	64.3	5.37	-	0.19 0.21 0.27	21/17/19	62.2	5.59	-
16:00	P1: 220 P2: 180 P3: 20	590	650	0.75 0.74 0.68	29/29/29	62.1	5.81	-	3.30 3.41 3.39	75/76/74	64.6	5.51	-	0.23 0.26 0.19	16/15/15	61.1	5.90	-
16:30	P1: 225 P2: 180 P3: 20	560	520	0.86 1.15 0.85	30/30/31	63.6	5.85	-	4.27 4.27 4.26	96/94/97	66.2	5.52	-	0.20 0.15 0.17	19/15/15	62.2	5.72	-
17:00	P1: 220 P2: 170 P3: 15	540	520	0.62 0.67 0.78	31/26/30	64.2	5.51	-	0.50 0.40 0.44	18/17/20	67.3	5.72	-	0.14 0.18 0.19	15/15/16	61.8	6.02	-

Trial No.: **TRIAL # 1** MF or UF plus UF: **MF plus UF** Date: **23 November 2005**

Raw water: pH **5.56**Turbidity **0.83/0.42**Colour **21/22** Conductivity **61.8**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
09:00	P1: 245 P2: 195 P3: 25	470	650	1.03 0.86 1.30	30/29/30	61.7	5.74	-	1.37 1.19 1.33	28/27/27	65.4	5.29	-	0.66 0.71 0.62	16/15/17	61.3	5.65	-
09:30	P1: 240 P2: 195 P3: 20	440	650	0.76 0.73 0.85	26/27/30	61.6	5.75	-	0.91 0.79 082	25/17/17	62.2	5.60	-	0.17 0.16 0.19	11/14/12	59.7	5.64	-
10:00	P1: 245 P2: 200 P3: 20	430	650	0.82 1.08 0.81	26/28/33	61.9	5.60	-	0.53 0.46 0.55	13/13/14	68.2	5.29	-	0.21 0.21 0.17	12/10/13	60.6	5.44	-
10:30	P1: 249 P2: 200 P3: 15	549	520	0.83 0.89 0.85	27/25/25	61.3	5.62	-	0.41 0.39 0.38	12/11/9	63.6	5.54	-	0.16 0.13 0.18	12/10/13	60.6	5.44	-
11:00	P1: 249 P2: 200 P3: 10	435	520	0.81 1.76 0.67	25/24/25	61.9	5.40	-	0.99 0.97 0.98	17/17/16	62.9	5.46	-	0.20 0.12 0.13	12/12/12	60.9	5.49	-
11:30	P1: 249 P2: 200 P3: 5	418	520	0.65 0.74 0.69	27/24/25	61.5	5.59	-	0.39 0.38 0.41	15/14/14	80.2	5.63	-	0.12 0.12 0.13	15/13/15	61.3	5.75	-
12:00	P1: 249 P2: 210 P3: 10	425	390	0.31 0.24 0.28	11/9/9	62.5	5.74	-	0.31 0.31 0.35	12/13/12	80.2	5.63	-	0.12 0.12 0.13	14/15/11	61.0	5.67	-
12:30	P1: 249 P2: 210 P3: 5	410	390	0.71 0.76 0.62	25/23/27	61.7	5.79	-	0.37 0.34 0.36	15/15/10	62.8	5.66	-	0.17 0.14 0.13	15/13/15	61.3	5.75	-

13:00	P1: 249 P2: 210 P3: 10	395	390	0.71 0.70 0.87	26/24/26	62.6	5.77	-	0.61 0.63 0.59	14/14/15	62.5	5.54	-	0.18 0.13 0.14	12/11/12	61.0	5.84	-
13:30	P1: 249 P2: 210 P3: 10	400	260	0.44 0.47 0.44	23/22/23	61.4	5.84	-	0.48 0.50 0.54	15/12/10	61.9	5.80	-	0.16 0.13 0.14	12/11/12	60.4	5.82	-
14:00	P1: 249 P2: 210 P3: 10	380	260	0.49 0.44 0.49	24/26/23	61.0	5.79	-	0.32 0.34 0.30	12/13/11	62.4	5.63	-	0.16 0.15 0.14	11/11/12	60.6	5.82	-
14:30	P1: 210 P2: 180 P3: 5	310	260	0.61 0.51 0.52	22/23/25	61.9	5.95	-	0.34 0.38 0.39	10/9/13	62.2	5.68	-	0.27 0.25 0.27	13/14/18	60.9	5.85	-

Trial No.: **TRIAL # 1** MF or UF plus UF: **MF plus UF** Date: **23 November 2005**

Raw water: pH **5.56** Turbidity **0.38/0.42** Colour **21/22** Conductivity **61.8**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
15:00	P1: 230 P2: 190 P3: 5	325	130	0.61 0.63 0.52	23/24/22	61.4	5.84	-	0.33 0.24 0.26	7/12/10	62.3	5.80	-	0.18 0.16 0.15	14/13/13	60.9	5.67	-
15:30	P1: 230 P2: 190 P3: 5	325	130	1.01 0.96 0.95	26/30/29	61.9	5.91	-	0.36 0.44 0.30	16/11/11	62.8	5.65	-	0.28 0.21 0.20	16/14/16	61.3	5.83	-
16:00	P1: 220 P2: 180 P3: 5	340	130	0.43 0.43 0.54	25/26/24	61.6	5.79	-	0.27 0.39 0.26	10/9/12	63.0	5.62	-	0.16 0.13 0.12	15/14/13	61.3	5.66	-

Trial No.: **TRIAL # 2** MF or UF plus UF: **UF ALONE** Date: **24 November 2005**

Raw water: pH **6.70** Turbidity **0.41/0.38** Colour **18/18/23** Conductivity **22.9**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
09:00	P1: 249 P2: 200 P3: 15	280	650	0.86 0.74 0.76	28/25/27	23.3	6.53		-	-	-	-	-	1.91 1.90 1.89	25/23/24	22.1	6.50	
09:30	P1: 249 P2: 200 P3: 15	305	650	0.77 0.61 0.84	24/26/28	23.3	6.37		-	-	-	-	-	0.34 0.26 0.25	12/11/13	22.6	6.36	
10:00	P1: 249 P2: 200 P3: 10	305	650	0.87 0.75 0.75	25/25/26	23.6	6.39		-	-	-	-	-	0.41 0.43 0.49	11/10/10	22.7	6.38	
10:30	P1: 249 P2: 210 P3: 5	310	520	0.61 0.57 0.67	27/25/26	23.5	6.32		-	-	-	-	-	0.10 0.11 0.11	15/28/10	22.7	6.12	
11:00	P1: 249 P2: 210 P3: 5	300	520	0.77 0.68 0.79	23/24/27	23.3	6.26		-	-	-	-	-	0.10 0.10 0.07	9/10/12	22.6	6.16	
11:30	P1: 249 P2: 210 P3: 5	250	520	0.66 0.67 0.72	34/31/30	23.5	6.16		-	-	-	-	-	0.12 0.16 0.14	4/7/9	22.5	6.17	
12:00	P1: 249 P2: 210 P3: 5	260	390	0.64 0.65 0.69	26/27/30	23.8	6.03		-	-	-	-	-	0.15 0.12 0.09	11/10/9	23.1	6.12	
12:30	P1: 220 P2: 190 P3: 5	225	390	0.58 0.50 0.58	25/24/25	23.5	6.14		-	-	-	-	-	0.10 0.15 0.13	9/8/12	23.0	5.88	

13:00	P1: 230 P2: 200 P3: 5	250	390	0.88 1.03 0.92	33/28/28	24.1	5.94		-	-	-	-	-	0.10 0.15 0.13	9/8/12	23.0	5.88	
14:30	P1: 230 P2: 200 P3: 5	280	260	0.53 0.68 0.56	26/27/25	23.8	5.79		-	-	-	-	-	0.14 0.09 0.09	9/11/11	23.1	5.86	
15:00	P1: 230 P2: 200 P3: 5	250	260	0.29 0.32 0.34	31/21/21	23.5	5.86		-	-	-	-	-	0.11 0.10 0.10	11/9/12	22.8	5.78	
15:30	P1: 220 P2: 190 P3: 5	255	260	0.55 0.51 0.60	24/27/23	23.6	5.72		-	-	-	-	-	0.25 0.24 0.20	11/12/9	22.9	5.64	

Trial No.: **TRIAL # 2** MF or UF plus UF: **UF ALONE** Date: **24 November 2005**

Raw water: pH **6.70** Turbidity **0.41/0.38**Colour **18/18/23** Conductivity **22.9**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
16:00	P1: 220 P2: 190 P3: 5	250	130	0.54 0.34 0.34	21/20/20	23.1	5.39		-	-	-	-	-	0.13 0.12 0.12	12/6/11	22.9	5.64	
16:30	P1: 230 P2: 200 P3: 5	260	130	0.36 0.38 0.37	21/22/22	22.9	5.40		-	-	-	-	-	0.23 0.21 0.21	13/10/11	22.7	5.49	
17:00	P1: 240 P2: 200 P3: 5	265	130	0.40 0.33 0.39	24/23/22	22.9	5.56		-	-	-	-	-	0.13 0.15 0.15	11/9/11	22.5	5.52	

Trial No.: **TRIAL** # 3 MF or UF plus UF: **MF ALONE** Date: **25 November 2005**

Raw water: pH **5.20** Turbidity **0.77/0.73**Colour **22/23** Conductivity **22.8**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
11:00	P1: 160 P2: 130 P3: 20	>650	>650	0.66 0.79 0.75	27/23/24	22.6	5.52		4.16 4.24 4.31	29/29/31	22.5	5.54		-	-	-	-	-
11:30	P1: 160 P2: 130 P3: 30	>650	>650	0.41 0.44 0.44	25/21/20	22.5	5.49		4.71 4.57 4.89	39/38/33	22.6	5.45		-	-	-	-	-
12:00	P1: 160 P2: 130 P3: 30	>650	>650	0.52 0.56 0.62	25/22/23	22.6	5.56		0.17 0.13 0.14	14/15/12	22.6	5.40		-	-	-	-	-
12:30	P1: 160 P2: 130 P3: 30	>650	>650	0.50 0.47 0.54	24/24/20	22.6	5.85		0.21 0.19 0.17	16/15/15	22.7	5.77		-	-	-	-	-
13:00	P1: 155 P2: 120 P3: 10	>650	>650	0.76 0.52 0.45	23/22/21	22.7	5.72		0.15 0.13 0.11	14/11/13	22.7	5.69		-	-	-	-	-
13:30	P1: 155 P2: 120 P3: 10	>650	>650	0.38 0.47 0.38	19/24/20	22.6	5.74		0.19 0.24 0.19	13/13/13	22.6	5.75		-	-	-	-	-
14:00	P1: 230 P2: 200 P3: 5	>650	>650	0.49 0.47 0.51	24/21/23	22.8	5.74		0.38 0.28 0.26	19/12/10	22.8	5.72		-	-	-	-	-
14:30	P1: 160 P2: 130 P3: 10	>650	>650	0.48 0.50 0.45	24/21/23	22.8	5.74		0.38 0.28 0.26	19/12/10	22.8	5.72		-	-	-	-	-

Trial No.: **TRIAL # 3** MF or UF plus UF: **MF ALONE** Date: **26 November 2005**

Raw water: pH **5.14** Turbidity **0.54/0.48/0.55**Colour **17/21/21** Conductivity **23.5**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
09:30	P1: 200 P2: 150 P3: 20	650	>650	0.54 0.45 0.50	21/23/24	22.5	5.31		0.38 0.43 0.36	13/14/12	22.5	5.31		-	-	-	-	-
10:00	P1: 200 P2: 130 P3: 30	640	>650	0.44 0.62 0.50	22/21/22	22.5	5.14		0.16 0.16 0.18	15/13/12	22.5	5.40		-	-	-	-	-
10:30	P1: 190 P2: 150 P3: 15	615	>650	0.40 0.42 0.51	25/26/21	22.6	5.55		0.14 0.15 0.14	17/9/13	22.7	5.52		-	-	-	-	-
11:00	P1: 200 P2: 150 P3: 10	600	>650	0.44 0.44 0.41	21/21/25	22.6	5.54		0.18 0.22 0.13	17/15/11	22.6	5.54		-	-	-	-	-
11:30	P1: 190 P2: 150 P3: 10	600	>650	0.52 0.52 0.50	24/22/19	22.6	5.59		0.16 0.13 0.13	12/10/12	22.5	5.54		-	-	-	-	-
12:00	P1: 190 P2: 150 P3: 10	590	>650	0.52 0.52 0.56	22/20/19	22.6	5.44		0.20 0.14 0.15	15/11/9	22.6	5.40		-	-	-	-	-
12:30	P1: 190 P2: 150 P3: 5	570	>650	0.51 0.41 0.42	21/22/20	22.6	5.40		0.22 0.27 0.20	13/13/13	22.7	5.37		-	-	-	-	-
13:00	P1: 190 P2: 150 P3: 5	560	>650	0.88 0.83 0.89	28/29/31	22.5	5.29		0.31 0.22 0.18	15/14/17	22.6	5.48		-	-	-	-	-

13:30	**P1: 190** **P2: 150** **P3: 5**	**550**	**>650**	**0.44** **0.45** **0.40**	**17/17/20**	**22.7**	**5.50**		**0.18** **0.19** **0.16**	**16/13/10**	**22.6**	**5.49**		**-**	**-**	**-**	**-**	**-**
14:00	**P1: 200** **P2: 150** **P3: 5**	**545**	**>650**	**0.63** **0.59** **0.54**	**22/23/21**	**22.8**	**5.62**		**0.16** **0.13** **0.15**	**8/11/9**	**22.3**	**5.55**		**-**	**-**	**-**	**-**	**-**
14:30	**P1: 200** **P2: 150** **P3: 5**	**520**	**>650**	**0.48** **0.51** **0.51**	**16/19/22**	**22.6**	**5.57**		**0.19** **0.14** **0.12**	**15/16/11**	**22.6**	**5.53**		**-**	**-**	**-**	**-**	**-**
15:00	**P1: 200** **P2: 150** **P3: 5**	**520**	**>650**	**0.45** **0.49** **0.42**	**20/20/25**	**22.7**	**5.61**	**0.08**	**0.17** **0.18** **0.18**	**12/11/13**	**22.3**	**5.60**	**0.31**	**-**	**-**	**-**	**-**	**-**

Trial No.: **TRIAL # 3** MF or UF plus UF: **MF ALONE** Date: **26 November 2005**

Raw water: pH **5.14** Turbidity **0.54/0.48/0.55**Colour **17/21/21** Conductivity **23.5**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
15:30	P1: 200 P2: 150 P3: 5	515	>650	0.52 0.50 0.44	27/23/24	22.6	5.66		0.58 0.49 0.53	14/12/12	22.3	5.52		-	-	-	-	-
16:00	P1: 200 P2: 150 P3: 5	505	>650	0.59 0.56 0.51	23/21/21	22.7	5.61		0.14 0.14 0.11	11/11/11	22.5	5.55		-	-	-	-	-
16:30	P1: 200 P2: 150 P3: 15	500	>650	0.44 0.55 0.49	15/18/18	22.7	5.65		0.17 0.20 0.15	13/10/14	22.7	5.59		-	-	-	-	-
17:00	P1: 200 P2: 150 P3: 5	480	>650	0.99 0.99 0.94	26/28/28	22.7	5.74		0.34 0.34 0.30	15/17/19	22.3	5.60		-	-	-	-	-
17:30	P1: 200 P2: 150 P3: 5	470	>650	0.49 0.51 0.52	22/22/21	22.8	5.64		0.31 0.27 0.24	10/10/11	22.6	5.54		-	-	-	-	-
18:00	P1: 200 P2: 150 P3: 5	460	>650	0.79 0.82 0.86	23/26/24	22.7	5.56		0.20 0.16 0.16	12/11/12	22.7	5.43		-	-	-	-	-

Trial No.: **TRIAL # 4** MF or UF plus UF: **MF plus UF** Date: **27 November 2005**

Raw water: pH **5.24** Turbidity **0.85/0.81** Colour **27/29** Conductivity **24.3**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
09:00	P1: 230 P2: 190 P3: 5	240	260	0.93 0.84 0.86	28/26/27	22.9	5.21		1.76 1.60 1.67	35/34/34	22.8	5.24		0.68 0.60 0.65	10/10/11	22.3	5.18	
09:30	P1: 200 P2: 180 P3: 5	195	260	0.82 0.84 0.81	24/25/27	22.9	5.19		0.26 0.19 0.27	16/15/12	22.8	5.21		0.15 0.16 0.15	9/7/5	22.2	5.21	
10:00	P1: 200 P2: 180 P3: 5	180	260	0.73 0.80 0.73	26/24/25	23.1	5.18	0.09	0.12 0.13 0.12	11/8/8	22.8	5.15	0.04	0.18 0.20 0.18	7/8/8	22.3	5.13	0.03
10:30	P1: 200 P2: 180 P3: 5	180	260	0.61 0.63 0.66	23/23/22	23.0	5.29		0.65 0.64 0.61	11/12/12	22.9	5.27		0.29 0.25 0.31	8/8/8	22.2	5.26	
11:00	P1: 200 P2: 180 P3: 5	180	260	0.67 0.62 0.63	22/24/25	23.1	5.30		0.29 0.24 0.20	7/6/4	22.9	5.24		0.16 0.15 0.15	6/7/7	22.2	5.26	
11:30	P1: 200 P2: 180 P3: 5	185	260	0.66 0.57 0.61	23/24/25	23.2	5.34		0.12 0.12 0.12	7/5/7	23.1	5.31		0.17 0.12 0.16	8/7/8	22.3	5.29	
12:00	P1: 200 P2: 180 P3: 5	205	260	0.52 0.50 0.55	24/24/23	23.2	5.38		0.19 0.21 0.25	8/7/5	23.3	5.30		0.25 0.17 0.22	12/10/8	22.3	5.34	
12:30	P1: 200 P2: 170 P3: 5	185	260	0.79 0.71 0.83	26/28/26	23.4	5.26		0.79 0.74 0.72	15/12/12	23.3	5.28		0.16 0.15 0.16	7/10/8	22.6	5.26	

13:00	P1: 200 P2: 180 P3: 5	195	260	0.51 0.55 0.57	22/23/22	23.1	5.32	0.07	0.15 0.12 0.11	10/7/6	23.2	5.25	0.03	0.16 0.15 0.15	8/8/9	22.3	5.24	0.01
13:30	P1: 200 P2: 180 P3: 5	195	260	0.55 0.55 0.59	23/26/27	23.5	5.27		0.35 0.32 0.27	8/8/7	23.2	5.21		0.22 0.22 0.22	9/9/10	22.7	5.19	
14:00	P1: 210 P2: 190 P3: 5	215	260	0.49 0.57 0.52	29/24/24	23.4	5.26		0.16 0.16 0.19	8/8/8	23.3	5.10		0.27 0.21 0.20	10/9/8	22.8	5.02	
14:30	P1: 200 P2: 180 P3: 5	190	260	0.55 0.58 0.53	21/25/23	23.3	5.04		0.47 0.47 0.48	13/14/14	23.5	4.94		0.23 0.25 0.24	7/8/8	22.1	4.92	

Trial No.: **TRIAL # 4** MF or UF plus UF: **MF plus UF** Date: **27 November 2005**

Raw water: pH **5.24** Turbidity **0.85/0.81**Colour **27/29** Conductivity **24.3**

TIME	PRESSURE	PERMEATE	CROSS	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
(hrs)		FLOW	FLOW	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
15:00	P1: 200	190	260	0.55	24/23/24	23.5	4.95	0.09	0.69	11/11/11	23.4	4.91	0.08	0.56	8/10/10	22.5	4.94	0.09
	P2: 170			0.60					0.61					0.53				
	P3: 5			0.61					0.64					0.50				
15:30	P1: 230	220	260	0.85	26/27/27	23.5	4.89		0.26	9/10/10	23.5	4.82		0.22	9/8/10	22.6	4.93	
	P2: 200			0.80					0.26					0.27				
	P3: 5			0.81					0.22					0.26				
16:00	P1: 230	220	260	0.63	25/24/24	23.3	4.97		0.28	13/12/11	23.5	4.89		0.19	10/8/6	22.3	4.91	
	P2: 200			0.54					0.22					0.16				
	P3: 5			0.59					0.24					0.16				

Trial No.: **TRIAL # 4** MF or UF plus UF: **MF plus UF** Date: **28 November 2005**

Raw water: pH **7.17** Turbidity **0.51/0.52**Colour **20/23** Conductivity **23.9**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
09:00	P1: 220 P2: 190 P3: 10	140	260	0.60 0.51 0.54	21/22/22	23.1	6.51		0.27 0.24 0.25	16/15/15	23.0	6.63		0.94 0.93 095	9/10/10	21.9	6.41	
09:30	P1: 200 P2: 170 P3: 10	120	260	0.65 0.71 0.63	28/25/25	23.4	6.73		0.52 0.52 0.52	13/13/13	23.1	6.46		0.25 0.21 0.18	6/8/8	22.0	6.58	
10:00	P1: 200 P2: 170 P3: 5	120	260	0.51 0.46 0.44	27/26/26	23.5	6.51		0.13 0.12 0.14	4/4/4	23.2	6.46		0.15 0.13 0.11	6/6/7	22.2	6.65	
10:30	P1: 200 P2: 180 P3: 5	120	260	0.52 0.48 0.50	29/32/29	23.9	6.63		0.13 0.13 0.14	5/6/4	23.3	6.70		0.13 0.15 0.12	6/6/5	22.5	6.70	
11:00	P1: 190 P2: 180 P3: 0	120	260	0.59 0.50 0.54	30/31/32	24.0	6.58		0.16 0.14 0.11	7/6/6	23.5	6.53		0.12 0.10 0.10	7/6/7	22.4	6.67	
11:30	P1: 200 P2: 180 P3: 0	150	260	0.42 0.41 0.43	24/24/24	23.3	6.62		0.13 0.12 0.11	7/6/5	23.6	6.63		0.10 0.10 0.10	6/8/9	22.3	6.61	
12:00	P1: 200 P2: 180 P3: 0	150	260	0.59 0.56 0.57	25/26/24	23.3	6.65		0.14 0.15 0.14	6/6/5	23.5	6.53		0.11 0.09 0.12	8/8/8	22.2	6.58	
12:30	P1: 200 P2: 180 P3: 0	150	260	0.45 0.51 0.49	27/31/30	23.6	6.22		0.20 0.24 0.19	11/8/7	23.6	6.28		0.15 0.10 0.09	10/7/10	22.3	6.30	

13:30	P1: 200 P2: 180 P3: 0	150	260	0.43 0.49 0.49	26/25/24	23.5	6.28		0.34 0.27 0.31	10/8/9	23.7	6.22		0.16 0.10 0.11	9/7/8	22.2	6.25	
14:00	P1: 220 P2: 190 P3: 0	140	260	0.44 0.53 0.46	25/25/27	23.7	6.07		0.13 0.15 0.14	10/13/11	23.7	6.03		0.11 0.12 0.13	10/10/9	22.5	5.97	
15:00	P1: 210 P2: 190 P3: 0	120	260	1.45 1.61 1.67	36/36/36	24.2	6.29		0.18 0.14 0.15	9/8/8	23.7	5.93		0.19 0.17 0.15	9/7/7	22.7	5.85	
15:00	P1: 210 P2: 190 P3: 0	180	260	0.69 0.68 0.64	26/24/25	24.0	5.99	0.19	0.26 0.29 0.27	12/11/11	23.8	5.81	0.01	0.19 0.15 0.16	10/9/7	22.6	5.65	0.01

Trial No.: **TRIAL # 5** MF or UF plus UF: **UF ALONE** Date: **29 November 2005**

Raw water: pH **5.11** Turbidity **0.79/0.82**Colour **32/29** Conductivity **23.8** Iron **0.07**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
09:00	P1: 249 P2: 200 P3: 5	150	520	0.95 0.88 0.89	32/31/30	23.5	5.07		-	-	-	-	-	0.18 0.12 0.17	9/9/8	21.6	5.15	
10:00	P1: 249 P2: 200 P3: 5	160	520	0.71 0.71 0.70	34/34/32	24.3	5.23		-	-	-	-	-	0.17 0.14 0.15	12/7/7	22.4	5.22	
11:00	P1: 240 P2: 200 P3: 0	155	520	0.81 0.87 0.84	39/40/40	25.4	5.22		-	-	-	-	-	0.13 0.18 0.14	10/8/8	23.1	5.21	
12:00	P1: 230 P2: 200 P3: 0	160	520	0.78 0.73 0.75	28/30/29	24.0	5.26		-	-	-	-	-	0.13 0.11 0.11	8/7/8	22.1	5.27	
13:00	P1: 240 P2: 200 P3: 0	160	520	0.49 0.45 0.48	28/29/29	23.9	5.26		-	-	-		-	0.12 0.11 0.10	7/7/8	21.8	5.22	
14:00	P1: 230 P2: 200 P3: 0	160	520	0.59 0.60 0.56	37/35/34	24.9	5.18		-	-	-	-	-	0.14 0.14 0.16	6/7/6	22.6	5.11	
15:00	P1: 240 P2: 200 P3: 0	150	520	1.91 1.85 2.00	50/52/53	25.7	5.14	0.27	-	-	-	-	-	0.20 0.18 0.18	9/15/12	23.1	5.11	0.01
16:00	P1: 250 P2: 210 P3: 5	150	520	0.58 0.59 0.59	43/46/47	25.7	5.06		-	-	-	-	-	0.13 0.11 0.14	11/10/10	23.0	4.89	

Trial No.: **TRIAL # 5** MF or UF plus UF: **UF ALONE** Date: **30 November 2005**

Raw water: pH **5.03** Turbidity **0.64/0.67**Colour **29/30** Conductivity **24.3**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
09:00	P1: 240 P2: 190 P3: 5	100	520	0.71 0.74 0.74	34/35/33	24.0	5.11		-	-	-	-	-	0.12 0.13 0.12	5/5/4	21.6	5.05	
10:00	P1: 240 P2: 190 P3: 5	100	520	0.89 0.89 0.85	41/41/40	24.8	5.09		-	-	-	-	-	0.16 0.14 0.13	7/5/6	22.3	5.10	
11:00	P1: 249 P2: 200 P3: 5	145	520	1.08 1.06 0.10	57/61/58	26.5	5.08		-	-	-	-	-	0.14 0.14 0.11	13/12/12	23.7	5.05	
12:00	P1: 250 P2: 210 P3: 0	140	520	0.71 0.69 0.66	38/38/39	24.3	5.06		-	-	-	-	-	0.14 0.10 0.10	9/9/8	21.8	5.10	
13:00	P1: 250 P2: 210 P3: 0	140	520	0.70 0.72 0.73	34/35/32	24.3	5.17		-	-	-	-	-	0.10 0.09 0.10	10/10/12	21.9	5.17	
14:00	P1: 250 P2: 210 P3: 0	135	520	0.73 0.74 0.73	37/38/38	24.4	5.15		-	-	-	-	-	0.11 0.11 0.11	8/10/9	22.5	5.13	
15:00	P1: 260 P2: 220 P3: 0	130	520	0.70 0.73 0.76	39/40/40	24.8	5.13		-	-	-	-	-	0.44 0.40 0.41	13/13/13	23.0	5.11	
16:00	P1: 260 P2: 220 P3: 0	125	520	1.04 1.10 1.07	44/40/45	25.0	5.11		-	-	-	-	-	0.11 0.10 0.09	12/10/9	22.2	5.08	

Trial No.: **TRIAL # 6** MF or UF plus UF: **MF ALONE** Date: **01 December 2005**

Raw water: pH **5.03** Turbidity **0.47/0.48**Colour **20/19** Conductivity **22.4**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
09:00	P1: 230 P2: 180 P3: 5	575	-	0.46 0.42 0.44	20/19/21	22.5	5.08		0.14 0.11 0.10	9/12/8	22.4	5.07		-	-	-	-	-
10:00	P1: 220 P2: 180 P3: 5	580	-	0.36 0.36 0.38	21/22/19	22.4	5.09		0.12 0.10 0.11	13/11/13	22.4	5.13		-	-	-	-	-
11:00	P1: 220 P2: 180 P3: 0	555	-	0.34 0.32 0.34	20/21/18	22.5	5.16		0.13 0.09 0.10	11/10/11	22.5	5.16		-	-	-	-	-
12:00	P1: 220 P2: 180 P3: 0	545	-	0.34 0.34 0.34	23/24/24	22.5	5.17		0.26 0.24 0.28	16/18/16	22.4	5.17		-	-	-	-	-
13:00	P1: 220 P2: 180 P3: 0	535	-	0.94 0.93 0.91	25/22/23	22.6	5.18		0.26 0.25 0.21	13/10/12	22.6	5.13		-	-	-	-	-
14:00	P1: 220 P2: 180 P3: 0	520	-	0.31 0.29 0.29	19/19/19	22.6	5.10		0.24 0.23 0.26	12/11/11	22.4	5.06		-	-	-	-	-
15:00	P1: 220 P2: 180 P3: 0	515	-	0.42 0.42 0.42	21/18/19	22.7	5.13		0.10 0.12 0.10	8/12/11	22.8	5.08		-	-	-	-	-
16:00	P1: 220 P2: 180 P3: 0	505	-	0.40 0.37 0.41	21/24/19	22.8	5.06		0.47 0.47 0.50	20/20/21	23.0	5.02		-	-	-	-	-

Trial No.: **TRIAL # 7** MF or UF plus UF: **UF ALONE** Date: **02 December 2005**

Raw water: pH **4.77** Turbidity **0.31/0.30**Colour **18/19** Conductivity **23.1**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
09:00	P1: 260 P2: 230 P3: 0	140	520	0.48 0.46 0.50	28/26/25	23.7	4.87		-	-	-	-	-	0.21 0.22 0.21	7/4/5	21.1	4.92	
10:00	P1: 210 P2: 180 P3: 0	95	520	0.46 0.48 0.47	29/29/26	24.4	4.94		-	-	-	-	-	0.14 0.16 0.14	6/5/5	21.9	4.96	
11:00	P1: 220 P2: 190 P3: 5	110	520	0.76 0.72 0.78	37/39/37	25.1	4.98		-	-	-	-	-	0.12 0.14 0.10	7/6/5	23.2	4.98	
12:00	P1: 220 P2: 180 P3: 0	110	520	0.66 0.59 0.63	43/45/45	26.1	4.97		-	-	-	-	-	0.14 0.11 0.11	9/8/8	23.3	4.96	
13:00	P1: 220 P2: 190 P3: 0	110	520	0.54 0.56 0.54	36/37/34	25.0	4.98		-	-	-	-	-	0.11 0.09 0.09	7/7/6	22.1	4.99	
14:00	P1: 220 P2: 190 P3: 0	105	520	0.63 0.59 0.61	38/39/41	25.5	4.97		-	-	-	-	-	0.11 0.13 0.15	8/5/7	23.1	4.98	
15:00	P1: 220 P2: 185 P3: 0	110	520	0.53 0.57 0.51	41/38/37	25.9	4.93		-	-	-	-	-	0.09 0.11 0.10	6/9/7	23.2	4.98	

Trial No.: **TRIAL # 8** MF or UF plus UF: **MF plus UF** Date: **07 December 2005**

Raw water: pH **---**Turbidity **0.46/0.46/0.43**Colour **22/21/18**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
09:00	P1: 240 P2: 200 P3: 5	120	260	0.60 0.54 0.49	19/21/19				1.21 1.32 1.44	41/41/42				0.12 0.13 0.11	4/6/5			
10:00	P1: 240 P2: 200 P3: 5	100	260	1.47 1.31 1.38	36/37/35				0.40 0.34 0.32	14/13/13				0.17 0.18 0.17	5/4/6			
11:00	P1: 240 P2: 200 P3: 5	130	260	0.91 0.83 0.94	28/29/30				0.23 0.28 0.20	7/7/9				0.11 0.10 0.10	4/5/5			
12:00	P1: 240 P2: 200 P3: 5	140	260	0.80 0.83 0.79	29/29/30				0.35 0.32 0.35	7/9/6				0.09 0.10 0.08	5/6/7			
13:00	P1: 210 P2: 180 P3: 0	100	260	0.71 0.70 0.69	29/31/29				0.15 0.14 0.11	6/7/11				0.12 0.14 0.10	3/2/5			
14:00	P1: 240 P2: 200 P3: 5	140	260	0.63 0.65 0.65	34/32/34				0.18 0.13 0.12	7/9/6				0.11 0.12 0.11	5/8/6			
15:00	P1: 215 P2: 180 P3: 5	110	260	0.41 0.39 0.39	25/27/25				0.16 0.15 0.17	6/6/8				0.12 0.11 0.09	5/4/5			
16:00	P1: 200 P2: 180 P3: 5	105	260	0.82 0.85 0.87	28/25/27				0.15 0.13 0.12	6/7/5				0.10 0.08 0.09	6/3/4			

Trial No.: **TRIAL # 8** MF or UF plus UF: **MF plus UF** Date: **08 December 2005**

Raw water: pH **---**Turbidity **0.50/0.48/0.45**Colour **25/27/29**

TIME (hrs)	PRESSURE	PERMEATE FLOW	CROSS FLOW	INFLOW FROM FEED TANK (S1)					AFTER MF (S2)					AFTER UF (S3)				
				Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe	Turb	Colour	Cond	PH	Fe
09:00	P1: 250 P2: 200 P3: 5	130	260	1.05 1.00 1.06	38/32/35				1.12 1.19 1.10	43/46/44				0.17 0.16 0.18	8/7/5			
10:00	P1: 255 P2: 200 P3: 5	110	260	1.39 1.35 1.40	40/36/38				0.51 0.53 0.49	18/20/21				0.16 0.15 0.13	6/7/9			
11:00	P1: 240 P2: 200 P3: 5	125	260	0.89 0.85 0.87	28/25/24				0.21 0.22 0.22	9/8/8				0.10 0.10 0.09	5/4/5			
12:00	P1: 245 P2: 200 P3: 0	100	260	0.79 0.76 0.78	28/29/27				0.21 0.19 0.18	9/7/9				0.08 0.09 0.08	5/3/4			
13:00	P1: 220 P2: 180 P3: 0	105	260	0.69 0.70 0.72	28/27/28				0.16 0.18 0.18	7/9/6				0.07 0.08 0.07	3/2/2			

TECHNICAL AND SOCIAL ACCEPTANCE EVALUATION OF MICROFILTRATION AND ULTRAFILTRATION MEMBRANE SYSTEMS FOR POTABLE WATER SUPPLY TO RURAL COMMUNITIES

PART B
Socio-economic Factors Influencing the Acceptance of Advanced Water Treatment Technologies

Report compiled by

BA Delcarme
LM Daries
JD Seconna

EXECUTIVE SUMMARY

In order to understand the factors that influence the acceptance of technology, one needs to look beyond the specific technology and consider the socio-economic influences. Understanding technology means more than understanding its technicalities; it also means making sense of the technology in its human environment.

This study is therefore aimed at determining what social factors influences the acceptance of a new technology. It is envisaged that this study will contribute to a greater understanding of water technology acceptance and implementation, provide vital information for setting water related policies and giving communities access to clean water.

The primary research question asked by this study is:

> *Having introduced a micro-filtration and ultra-filtration membrane water purification plant in a poor rural community, what socio-economic factors influence the acceptance thereof?*

A cross-sectional descriptive study design aimed at collecting both qualitative and quantitative data was used. Voorstekraal in the Theewaterskloof Local Municipality and Upper Mnyameni in the Amahlathi Local Municipality were selected as study areas. Accidental non-probability sampling method was used. The target population was defined as households from small rural- or peri-urban communities whose potable household water is purified by a limited or no water treatment system. Data was collected during two phases: Phase 1, before implementation of the water purification plant and Phase 2, post implementation, after the plant was removed from the community.

The following socio-economic factors influence the acceptance of micro-filtration and ultra filtration membrane systems:

- Cost and willingness to pay
- Efficiency of the new technology
- Awareness raising/ informed Community
- Community Needs
- Job creation
- Assessment of existing infrastructure
- Security and location of the plant/unit
- Security and location of the plant/unit
- Functioning of the new technology
- Current community practices.

The study concludes that:

a. Acceptance does not necessarily mean usage.
b. Communities will always revert to the water they are used to
c. A non-cohesive community intensifies a lack of interest.
d. Community meetings may not be a high quality way of informing households.
e. Local government participation must incorporate involvement and commitment
f. The safest location may not be the most appropriate, convenient or accessible.

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1. INTRODUCTION

In order to understand the factors that influence the acceptance of technology one needs to look beyond the specific technology and consider the socio-economic influences. Timely and comparable socio-economic information plays a vital role in establishing linkages between the provision and the acceptance of a technology.

Understanding technology means more than understanding its technicalities (Du Plooy & Roode, 1999), it also means making sense of the technology in its human environment. It is not easy to reach consensus on the role of technology and the task mastering the future. However, public acceptance has become an important but not an automatic condition for successful research and technology (TAB, 1994).

Relatively little work has been done to explore how social aspects influence the acceptance and implementation of water technologies. Fundamental questions, which are largely unanswered, are: "What social factors influence technology acceptance?"; "How is social information utilized?"; "If not utilized, what reasons are evident?", and "If utilized, does it lead to the outcomes in a stated plan?"

This study is therefore aimed at determining what social factors influence the acceptance of a new technology. It is envisaged that this study will contribute to a greater understanding of water technology acceptance and implementation, provide vital information for setting water related policies and giving communities access to clean water.

2. METHODOLOGY

2.1 Research Question

The primary research question asked by this study is:

> *Having introduced a micro-filtration and ultra-filtration membrane water purification plant in a poor rural community, what socio-economic factors influence the acceptance thereof?*

2.2 Study Design

A cross-sectional descriptive study design aimed at collecting both qualitative and quantitative data was used. Descriptive studies address a wide range of topics (Stone and Clements, 1998) and cross sectional studies captures the research scene at a given moment (True, 1989).
Burns and Grove (2005) states that descriptive research provides an accurate portrayal or account of the characteristics of a particular individual, event or group in real life situations.

2.3 Study Sites

The research budget and time-frame could not accommodate data collection in all areas of South Africa. Two sites were agreed upon by the research team and review committee using the criteria of (1) rural communities experiencing problems with water quality rather than quantity and (2) must be in the framework of large environmental programmes. The acceptance of the technology is enhanced if the introduction of the plant takes place within the framework of large environmental programmes (Kalker et al., 1999).

Voorstekraal in the Theewaterskloof Local Municipality and Upper Mnyameni in the Amahlathi Local Municipality were selected as study areas.

A meeting was held with community leaders and the municipality and after detailed discussion, the research team was requested to use the Voorstekraal community as the study site. Voorstekraal is within the framework of the Greater Genadendal's environmental programme because it has the biggest water quality problem and the laying of new pipes was budgeted for and scheduled to be installed prior to the research study.

Upper Mnyameni (with a contrasting ethnic community to that of Voorstekraal) also has a major water quality problem and the Amatola Water Board is planning to address this problem.

2.4 Sampling

The social construction of technology advises that sampling and data collection is conducted amongst relevant social groups rather than aiming at a representative sample of the total population (Sahay et al., in Du Plooy and Roode, 1999).

Accidental non-probability sampling method was used. The target population was defined as households from small rural- or peri-urban communities whose potable household water is purified by a limited or no water treatment system. A respondent is defined as one representative per household.

2.5 Data Collection

Data was collected during two phases: Phase 1, before implementation of the water purification plant and Phase 2, post implementation, after the plant was removed from the community.

Data was collected from individuals using the survey method and structured questionnaires as the data collection tool.

Babbie (2004: 243) writes:

> "Surveys are chiefly used in studies that have individual people as unit of analysis and would be considered best method of collecting original data for describing a population too large to observe directly and are excellent vehicles for measuring attitudes and orientations in large populations"

Reliable respondents were regarded as a person per household over the age of 16 years, present during the time of the interview.

The Voorstekraal community consists of approximately 104 households and Table 1 illustrates the amount of questionnaires administered during the relevant phases.

TABLE 1: Total Questionnaires Administered.

PHASE 1	PHASE 2
Voorstekraal **98** **Upper Mnyameni**	 **92** (88 Responded, 3 Refused, 1 Spoilt) **91** (88 Responses and 3 refusals)

Data collection in Upper Mnyameni only took place in phase two, approximately 2 weeks after the pilot water purification unit was placed within the community.

3. ETHICAL CONSIDERATIONS

Community entry was obtained after consultation with the municipality, community structures and leaders. The community was briefed during community meetings and informed consent was obtained from respondents. Confidentiality was granted throughout the study. Respondents' names were captured for record and verification purposes and only the researchers had access to these names.

The layout, operation and purpose of the purification plant were explained to the respondents and respondents were informed that they had the right not to participate in the study.

4. DELIMITATIONS

We acknowledge that the data from only two sites cannot be tested statistically but that was not the purpose of this study.

The study did not determine the respondent's status within the household, i.e. whether the respondent was the breadwinner or not.

Data was only collected in Upper Mnyameni during the post implementation phase. This was largely due to budget and time constraints.

The researchers used interpreters during data collection in Upper Mnyameni.

5. RESULTS AND FINDINGS

5.1 Demography

The Voorstekraal Community is a rural Coloured community within the Theewaterskloof Local Municipality situated in the Western Cape. The age and gender distribution are summarised in Table 2

TABLE 2: Theewaterskloof Local Municipality Age Group, Population Group and Gender

Ages	African/Black		Coloured		Indian/Asian		White	
	Male	Female	Male	Female	Male	Female	Male	Female
0-4	1 138	1 108	3 043	3 003	10	6	316	262
5-9	854	790	3 151	3 138	9	6	361	336
10-14	560	571	3 229	3 109	7	9	408	420
15-19	671	765	3 042	3 164	7	5	432	438
20-24	1 527	1 229	2 664	2 548	4	9	245	176
25-29	2 081	1 404	2 764	2 582	3	8	284	300
30-34	1 726	891	2 806	2 739	3	3	356	375
35-39	1 364	655	2 583	2 548	12	12	426	441
40-44	866	563	2 205	2 038	5	5	446	452
45-49	640	302	1 477	1 670	3	0	380	420
50-54	421	228	1 291	1 319	0	3	337	326
55-59	257	98	892	892	0	0	288	307
60-64	201	86	681	693	3	0	250	286
65-69	92	37	462	507	0	0	211	238
70-74	49	33	244	311	0	4	158	209
75-79	23	10	140	190	0	0	105	169
80-84	12	11	77	91	0	0	70	104
85+	5	8	34	77	0	0	36	93

Source: Census 2001

The respondents describe the Voorstekraal community as follows:

- Peaceful Community: Respondents felt that this is a humble, peace-loving and helpful community. They stressed that they are a simple and friendly community, willing to help where they can.
- Religious Community: The Moravian church plays a big role in this community and the culture of attending church services is strong in the community. Given this, family ties are strong in this community.
- No Cooperation: Respondents felt that a culture of non-cohesiveness is present within this community and that they do not work together well. Community members are envious of one another and most of them do not get along well with others. Community members do not stand together and each one sees only to themselves.
- Scandalous Community: It was the opinion of some respondents that the Voorstekraal community has a culture of substance abuse, scandalous behaviour – gossiping, fighting and arguing- and promiscuity.

The Upper Mnyameni Community is an African community within the Amahlathi Local Municipality situated in the Eastern Cape. The age and gender distribution of this community are summarised in Table 3

TABLE 3: Amahlathi Local Municipality, Age Group, Population Group and Gender

Ages	African/Black		Coloured		Indian/Asian		White	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
0-4	5 796	5 657	59	100	0	0	60	60
5-9	8 152	7 929	89	105	0	0	95	74
10-14	9 557	9 250	95	93	4	0	85	81
15-19	9 036	8 585	82	72	0	0	78	85
20-24	5 712	5 421	73	56	0	0	56	51
25-29	4 053	4 334	54	50	0	0	63	65
30-34	3 269	3 993	58	70	3	0	92	78
35-39	3 189	4 334	44	58	0	0	101	81
40-44	3 091	4 123	64	54	6	3	87	108
45-49	2 608	3 418	48	38	3	0	92	110
50-54	2 119	2 392	24	27	0	0	98	94
55-59	1 565	2 139	16	22	0	4	81	94
60-64	1 773	2 757	24	26	0	0	94	117
65-69	1 174	1 995	13	21	0	0	91	86
70-74	1 042	1 745	6	13	0	0	71	63
75-79	632	1 204	14	10	0	0	40	47
80-84	547	1 099	6	6	0	0	19	48
85+	226	411	3	0	0	0	17	43

Source: Census 2001

Respondents summarise the Upper Mnyameni community as follows:

- A simple farming community, who have a culture of farming, working the land.
- A community who is generally unemployed and poor.
- A peaceful, non-violent community.
- A community who does not work together and therefore will not improve: "…we do not really work together, we experience conflicts every now & then, there's no progress…"

The census data (Tables 4 and 5) supports the community's claim of being generally unemployed.

TABLE 4: Amahlathi Local Municipality Economically Active Population Amongst those aged 15 to 65 years, Population group and Gender

Economic Activity	African/Black		Coloured		Indian/Asian		White	
	Male	Female	Male	Female	Male	Female	Male	Female
Employed	7 101	5 279	245	196	4	3	649	460
Unemployed	10 253	11 755	110	131	0	0	27	30
Scholar or student	9 530	8 808	42	43	5	0	66	74
Homemaker or housewife	95	3 972	0	35	0	0	6	171
Pensioner or retired person	1 806	3 436	45	39	0	0	71	117
Unable to work due to illness or disability	1 762	1 648	12	11	0	0	30	14
Seasonal worker not working presently	247	223	8	3	0	0	3	0
Does not choose to work	1 709	1 983	22	8	0	0	6	19
Not applicable	4 231	4 838	6	15	0	0	17	15

Source: Census 2001

29% of interviewees in Voorstekraal are currently employed while a further 65% are unemployed. The rest (6%) are either pensioners or obtain a disability grant, as they are too sickly to work or are retired.

Both Voorstekraal and Upper Mnyameni are located in municipalities where the bulk of the working people have an income that ranges between R1 – R 800.00 (Tables 6 and 7) per month. This data also supports the community's description of "generally poor".

TABLE 5: Theewaterskloof Local Municipality Economically Active Population Amongst those aged 15 to 65 years, Population group and Gender

Economic Activity	African/Black		Coloured		Indian/Asian		White	
	Male	Female	Male	Female	Male	Female	Male	Female
Employed	6 424	2 065	2 909	9 440	20	27	2 573	1 607
Unemployed	1 684	1 888	2 258	2 020	7	4	96	77
Scholar or student	351	380	1 853	1 838	4	5	405	414
Homemaker or housewife	5	657	34	3 230	0	4	9	916
Pensioner or retired person	69	77	508	810	0	0	303	342
Unable to work due to illness or disability	109	111	721	522	4	0	46	45
Seasonal worker not working presently	625	655	445	1 098	0	0	4	13
Does not choose to work	275	157	1 211	771	3	4	35	115
Not applicable	239	244	581	589	3	0	20	43

Source: Census 2001

TABLE 6: Amahlathi Local Municipality Individual Monthly Income for the Employed aged 15-65 years, population group and gender

Income (Rand)	African/Black		Coloured		Indian/Asian		White	
	Male	Female	Male	Female	Male	Female	Male	Female
No income	194	176	41	26	0	0	26	27
R1-R400	1 703	1 772	28	41	0	0	10	11
R401-R800	2 008	1 333	72	53	0	0	23	32
R801-R1600	1 619	801	73	50	0	0	59	63
R1601-R3200	966	601	19	10	0	0	123	131
R3201-R6400	449	464	8	9	4	3	176	137
R6401-R12 800	129	110	3	0	0	0	136	30
R12 801-R25 600	19	9	0	0	0	0	48	14
R25 601-R51 200	8	7	0	0	0	0	24	3
R51 201-R102 400	3	3	0	3	0	0	13	9
R102 401-R204 800	3	0	0	4	0	0	7	3
R 204801 or more	0	5	0	0	0	0	3	0
Not applicable	29 633	36 663	244	285	0	5	226	440

Source: Census 2001

Table 7: Theewaterskloof Local Municipality Individual Monthly Income for the Employed aged 15-65 years, Population group and Gender

Income (Rand)	African/Black		Coloured		Indian/Asian		White	
	Male	Female	Male	Female	Male	Female	Male	Female
No income	56	18	142	144	0	5	42	56
R1-R400	740	283	1 213	1 136	0	0	45	39
R401-R800	3 546	1 340	4 022	4 559	3	10	57	82
R801-R1600	1 720	305	4 753	2 525	8	9	168	255
R1601-R3200	185	68	1 824	653	3	4	386	526
R3201-R6400	119	46	705	326	5	0	808	469
R6401-R12 800	46	4	209	79	0	0	727	134
R12 801-R25 600	8	0	29	4	0	0	221	24
R25 601-R51 200	0	0	7	8	0	0	60	18
R51 201-R102 400	0	0	3	3	0	0	39	3
R102 401-R204 800	0	0	0	0	0	0	13	0
R204 801 or more	4	0	4	0	0	0	8	0
Not applicable	3 358	4 168	7 613	10 877	20	17	918	1 966

Source: Census 2001

5.2 Usage and Acceptance Rates

In Voorstekraal, only 24 households (27% of respondents) indicated that they made use of the purified water while 64 households (73%) indicated that they did not use the purified water.

TABLE 8: Voorstekraal Usage Rate and Plant Acceptance

Purified Water	Accept Plant	Do Not Accept Plant	N/A
Did not use	48 (55%)	10 (11%)	6 (7%)
Used	24 (27%)	0	
Total	72 (82%)	10 (11%)	6 (7%)

As for Upper Mnyameni, 51 households (64% of respondents) indicated that they made use of the purified water while 31 households (37%) indicated that they did not use the purified water.

TABLE 9: Upper Mnyameni Usage Rate and Plant Acceptance

Purified Water	Accept Plant	Do Not Accept Plant	N/A
Did not Use	29 (35%)	02 (2%)	0 (0%)
Used	48 (58%)	0	3 (6%)
Total	77 (93%)	02 (2%)	3 (6%)

Those who did not use the purified water from the plant still indicate that they accepted the plant. The low usage rate in the Voorstekraal community could be attributed to the fact that the community representatives were not that active in promoting the purification plant as was in the case of the Upper Mnyameni community where community representatives actively promoted the purification plant.

The respondents from the Voorstekraal community gave the following reasons for not using the water from the purification plant:

- Distance:
  - Distance from homes to plant are too far to carry bulky heavy containers of water.
- Not Informed:
  - Many respondents said that they were not aware that they may use the water.
  - They were under the impression that the water is strictly for use by the clinic staff and clients.
  - Those who knew something about the plant from Phase I of this project, was not aware that this unit was part of it.
  - They were not informed of collection times: "…unsure whether gate would be open or whether someone would be there to open it…"
  - As a result of not being informed, some respondents were under the impression they had to pay for the water: "…the tap is very far, I'm unsure about costs involved and I did not care to find out more about the project…"
- Constant Current Supply:
  - Respondents also indicated that as they lived far from the unit, and as they currently did not experience any water shortages, or interruptions in supply, the need to fetch water at the unit did not arise.
- Misinformed: Some of the respondents said that they were told they had to pay for the purified water, and rather did not use it as they are already paying for water.

- Some respondents indicated that they were simply not interested to find out what the project is about, or to taste the water: "…I was not interested in tasting it and assumed it tasted the same as our usual water…"

The respondents from the Upper Mnyameni who did not use the water from the purification plant did so for the following reasons:

- Were not around at the time of the meeting and therefore not informed.
- Have no interest in using "the machine water" as they are used to using water from the river.
- Collection point located too far from their homes.
- Respondents said that they do not accept the purification unit as with new.
- Technology brings costs and that they would eventually have to pay for the water.

Tables 8 & 9 also indicate that although the usage rate was much higher in the Upper Mnyameni community, the acceptance rate was similar. Reasons for accepting the purification plant were also similar and include:

- Appearance:
  - The water is clear and is not discoloured.
  - The water does not contain any bugs, insects, snakes or frogs.
  - It is not as muddy and dusty as the tap water.
- Taste:
  - The water tastes good.
  - It is fresh and colder than normal tap water.
  - The water does not have a chlorine taste.
- Health Benefits:
  - Water is purified and therefore will not make anyone ill.
- Alternative Supply:
  - Respondents felt that water from the purification unit could be an alternative 'source' of water during times when their usual supply is interrupted.
- Technology:
  - This machine is new technology and the community is open to new things.

5.3 Benefits of the Water Purification Plant

Respondents said a water purification unit could benefit the community as follows:

- Because it will be pure water it will improve health of the community.
- Laundry will be cleaner.
- Water will be cleaner.
- Will help with other problems which may arise later, e.g. when the new sanitation (toilet) system is implemented.
- Community will be happier.
- Community will grow and be uplifted.
- May bring community members closer together.
- Purified water provides 'good health' and it prevents ill effects as it is properly purified: "…benefit is health …" and "…river water is not healthy, you must use 'Jik' to clean river water…";
  "…good… as many people have stomach ailments caused by the dirty water…it is also good for health reasons…"
- The water from the purification unit prevents ill health: "…we will be protected from waterborne diseases and will get good health…"
- Purified water has plenty healthy benefits and it prevent ill effects:

- "…good… as many people have stomach ailments caused by the dirty water…it is also good for health reasons…"
- Could be used as alternative water during times when tap water is not clean (rainy periods): "…many people have no water and at such times can use machine water…" and "…good for health reasons, water is pure, can be used as alternative when usual water is 'dirty'…"
- This water does not contain sediments of dirt and debris and therefore does not have to settle before usage which saves time.
- Can be used for all household usages unlike their current tap water.
- Taste is more palatable than current water as it does not have a strong 'chlorine' taste.

5.4 Disadvantages of the Water Purification Plant

Respondents felt that in general the purification unit does not really hold any negative impacts for the community, but some of them did raise the following concerns:

- High installation and running costs – community will be unable to afford this as most people do not have employment "if the financial implications are beyond the means of the community.
- The bulk of respondents felt that it would not be of a disadvantage to the community.
- The distance from some homes to the collection point:"… some people are not used to this taste in water and the distance is too far to walk and fetch water..."
- Others felt that the unit was placed in isolation and therefore not completely accessible to all "…tank should not have been as isolated as it is now…"
- Respondents were unclear of costs involved and were concerned that they would have to pay large amounts of money for the unit: "…in future, when the plant is permanently installed, it will be too costly…Voorstekraal is full of poor people who earn little money…"

5.5 Water Quality

a. Before Plant Implementation

Before the implementation of the water purification plant, the people were generally satisfied with the supply and quality of their water for the following reasons:

- Currently clean water.
- Clean water is not brackish.
- The water is clean and runs 'strongly'.
- Forced to be satisfied as they have no other choice.
- Not many problems…"…only here and there…"
- Only unhappy when supply is interrupted.
- Grew up with the water and there's nothing wrong with it.

Those who were not satisfied with their water indicated that:

- Water quality is not good.
- Water has a lot of sediment and is discolored.
- Cannot use water for cooking.
- Frogs, snakes and other sediment in water.
- Supply is interrupted frequently.

b. Difference in Quality: Purified v/s Current Tap Water

This question was posed to all respondents, regardless of whether they made use of the water from the plant or not. More persons (49%) of those who did use the water, said there was no difference in taste, while 45% said there was. The rest could not say whether a difference was present or not.

Those who said there is a difference responded as follows:

- The water has a better quality in terms of purity and palatability: "…purity of water… unlike tap water the dosage of chlorine is correct as people were trained, tap water people are not trained about amount of chlorine to add, therefore sometimes too much chlorine…"
- It does not contain any impurities (visible) such as the frogs, snakes, insects, sand and debris that the normal tap water contains.
- Because of above, it is not time-consuming to use as there is no settlement time involved.;
- Others felt that there is no difference between the two.

c. Influence of Water Quality on Usage:

Only respondents who did not make use of the purified water were asked whether the quality of the water had any influence on their decision not to use water from the unit. Their responses are as follows:

- Water quality did not influence use (56%)
  - Because they never tasted the water and therefore are not aware of the quality.
  - They did not hear of anything negative relating to the water;
  - They were told that it is good, clean, pleasant-tasting.
  - They heard that it is purified.
  - The main reason for not using the water is because of the long distance from their homes to the plant.
- Water quality did influence use (2%). They said that they have been drinking water from the mountain for years and do not see any reason why they should now use purified water.

5.6 Fear of the Plant

82**%** of respondents from the Voorstekraal and 76% of the Upper Mnyameni respondents said they have no fears of the water purification plant.

Reasons given for not having any fears of the unit are as follows:

- Sure that the unit will provide clean water:
  - Respondents feel that the purification unit will filter out all sediment and this will make it easier to use the water. Health will improve as a result of clean, pure water: "…the machine will give me cleaner water which will improve my lifestyle..." and "...it will purify the water and that will benefit my health..."
- Lack of knowledge and understanding about the unit:
  - Respondents also indicated that they have limited, or no knowledge about the pilot unit and can therefore not relate any fears regarding it: "…I do not know enough to be scared…" and "…one cannot fear that which you now nothing about…"
- Trust in those involved in the project:

- Respondents said they had full trust in the engineers and the project as they felt these parties would not endanger the community: "…I do not think you would put up a danger here…" and "…the engineers know what they are doing…"
- Unit poses no danger to community:
  - Respondents felt that this unit will provide more benefits than dangers and concerns to the community: "… (the unit) can't be dangerous…can only be good…"

16% of Voorstekraal and 22% of Upper Mnyameni respondents indicated that they fear the unit.

Reasons for these fears are:

- The possibility that users might have to pay for water.
- During machine failure or breakdown they would have water interruptions for long periods of time.

Overall, 90% of respondents indicated that they liked the water purification unit.

5.7 Fear of the Plant and Water Usage

Respondents who did not use the purified water indicated that the machine did not influence their decision not to use the water as they felt it:

- Is safe and secured with a fence.
- Provides clean and healthy water.;
- Provides water which is much needed.
- Is safe and does not pose harm.
- Is not unsightly.
- Does not affect aesthetics of the surrounding environment.
- Simply did not see the unit/machine yet.

Of those who did not use the water from the machine, indicated that they do not like the machine and relate this to the following:

- Distance to the machine too far.
- Do not trust the machine.
- Possibility that they may have to pay for the water.
- They are used to drinking water from the mountain and have water on their property.
- therefore have no need to use the purified water.

5.8 Project Implementation Process

The project was introduced through a series of community meetings and those who attended these meetings were encouraged to inform those who did not attend. Respondents were asked their opinions regarding the extent to which this implementation process contributed to the usage of the water from the purification plant. Their responses are summarized as follows:

Those who made use of the purified water did so as they:

- attended meetings and were thus informed.
- heard from others that they could use the water for free.
- wanted to try it for themselves as they were inquisitive and wanted to find out how the water tastes.
- It did not contribute much as they do not know anything about it.
- They only used it as they wanted to taste the water and observe its quality.
- Regardless of who placed it there, or process that was followed, they will still use it.

Those who did not use the purified water said they were not informed about the project, or that they could obtain water there for free.

Some respondents in Upper Mnyameni (71% of those who did not attend the meetings) accounted to the fact that “They make their own decisions” and that they “…did not attend the meeting but heard from others in the community…”

5.9 Individual Influences

a. Impact of Water purification unit on the individual:

Respondents said the water purification unit would help them as follows:

- They will experience health benefits of clean, purified water.
- Uses of the water can be expanded to all household activities as well as for personal use.
- Time will be saved as now they do not have to wait for sediment to sink to the bottom before the water can be used.
- Money will be saved as their electrical appliances will now last longer, e.g. no more break-downs of washing machines and kettles as result of sediments in pipes.
- They will be ensured of a constant and clean supply of water.
- Become more aware of water quality and saving clean water.

b. Individual Values:

45% of respondents say that their values are different to that of the rest of the community. This, they say, is because everyone’s values and norms are not the same and that they would never agree with the alcohol abuse that is common in this community. When under the influence “…they do bad things that I will never accept…” They also feel the community is divided and does not stand together on issues that affect them as a whole. Others say they do not mix with the community frequently, or at all, as they do not agree with their lifestyle. This they relate to the fact not all community members are religious: “…there are few church going people – most people drink, smoke and do bad things…”

48% say theirs are not. They say they are all simple, impoverished people and that no differences exist between them. They are all part of this community with the aim to be happy. Others say they have adapted to this community’s way of life since retiring and coming to live here, or coming here to live with family. Because they are the same, they help each other wherever they can. They also feel that communications between community members are good.

6% say they do not know whether their values are different or not from those of the rest of the community.

c. Conforming to Community Decisions Not Part of Individual Values:

51% of respondents said they would accept things that are in line with the community values but not with their own individual values. Reasons given for this are as follows:

- Majority rules : if the majority of community members feel it’s the correct decision to take, they have no choice but to accept the decision.
- They have the same values as the rest of the community.
- Unaware of what the values of others in the community are.
- Each person has a right to make his or her own decision, as long as they stand up for what they believe in.

- Community decision outweighs that of the individual.
- Will accept if only if it's to the advantage of the community.

48% say they will not accept things that are in line with the community values but not their own. Reasons for this are as follows:

- There is no unity within the community.
- Will not follow poor judgment when decisions are made.
- Respect, but not necessarily agree with majority decision if its against values.
- Unaware of the values of the rest of the community.
- Depends on the issue at hand and the decision taken.

d. Community Confidence in individual:

59% of individuals interviewed said they would be given a hearing when giving advice to others for the following reasons:

They are longstanding members of the community and people respect them and look up to them. They are community leaders and people commonly turn to them for advice:
- At meetings each one who has something to say will be given a hearing.
- Good advice is commonly given and therefore people frequently visit (me/us) for advice.
- Trusted by community members therefore they give me a hearing.

25% said they would not be given a hearing when giving advice, because:
- People are stubborn and don't want to listen to others.
- Do not belong to any organization nor hold a leadership position.
- Not in nature to give advice.
- Community members are jealous and backstabbers therefore will not listen.
- Mistrust exists between community members.

14% were unsure and 2% did not know whether people would listen when they gave advice.

e. Individual Influence and Water Usage

Those who did not use the water (78% in Voorstekraal and 80% in Upper Mnyameni) said that they were hardly influenced by others within the community. Of the respondents who did not use the purified water, only 3% in Voorstekraal and 20% in Upper Mnyameni, were influenced by others. In particular by family, friends and plant operators who encouraged them to taste and collect the water for household usage.

54% of respondents who did use the water were influenced by others.

5.10 Cultural Influences

a. Respondent's Culture

66% of the Voorstekraal and 97% of the Upper Mnyameni respondents who did not use purified water said their culture had no impact on the decision not to use the purified water. They accounted non-usage as their own personal decision.

The amount of those who used the purified water and who felt that own culture did influence usage stands, at 8% of the total number of respondents (29%) of those who did use the purified water. This, they say, is because they have a culture of being inquisitive and wanting to find things out for themselves.

Those whose own culture had an influence on them not using the water, said it is because:

- They were not aware that they could use the water.
- Not aware what the 'tank' is all about and did not enquire about it.
- Were simply not interested in finding out about it.

b. Community's Culture

63% of respondents who did not use, and 100% of those who did use the purified water, felt that the culture of the community did not influence their decision regarding using the purified water. A smaller number, only 1%, indicated that the community culture influenced their decision on water usage.

Reasons given for culture not bearing influence on neither usage nor non-usage of the purified water are as follows:

- Distance main reason for not fetching water.
- Uninformed about availability of water and accessibility to all.
- Own personal decision to either use or not.
- Everyone in the community uses the water.
- Some of them do not follow a strict culture.
- Nothing in their culture prevents them from using purified water.

c. Culture Within the Household

89% of respondents indicated that the culture that exists in their homes does not prevent them from using the purified water. Only 5% indicated that it does; for the rest, (6%), no information regarding this was provided.

5.11 Community Influences

a. Groups

Respondent's in Voorstekraal said the following groups were present within their community:

- Women's Group
- Youth Group
- Church Group
- Rate Payers' Group.

(i) Trust in group to make decision:

32% of respondents said they would not allow any of the above organization's to make decisions on their behalf. 6% would allow the church to decide for them, 6% would allow the Women's group, 5% the youth group, 4% the welfare group, 2% the clinic group, 2% the municipality and a smaller percentage, 1%, would allow the DOTS group to decide for them. Some respondent's also said the groups are already making decisions for them *(unclear which groups)* while others felt they wanted to make their own decisions, or that: "…people should decide for themselves…"

Reasons given for allowing / not allowing specific groups to decide on their behalf are as follows:

- Trust in the judgment of the group:
  - Respondent's felt that groups would act in the favor of the community, especially relating to water and said: "…if they decide it will be a good decision…"
- Not part of the group/Powerlessness:
  - Respondents are aware of the groups but do not belong to the group and therefore feel that they cannot be allowed to decide for individuals or for the community as a whole: "…I am not part of the group and (they) cannot decide for me…" and "…we are outsiders who do not meddle in church decisions…"
- Want to be involved and make own decision:
  - The bulk of community members, roughly a third, want to learn more about the decision to be made. They trust only their own judgment and would therefore want to make their own decision: "…I want to be there to make my own decisions…" and "I want to know what is happening before I decide yes or no…"
- Mistrust in organizations:
  - Respondents said the groups have only their own (group's) interest at heart: " …have only their own interests and comfort in mind…"

(ii) Community Groups Influence on Water Usage

55% of Voorstekraal and 82% of Upper Mnyameni respondents who did use the purified water say they were not influenced by community groups, while 8% of those who used the water in Voorstekraal and 12% of those in Upper Mnyameni say they were influenced by such groups.

Reasons for not being influenced by community groups are related as follows:

- People make their own decisions.
- They heard from others, friends and family, and decided to try the water.
- "…no one stopped me from drinking the water, mother told me to drink water after they spoke to friends (about the purified water)…"
- They do not allow others to, and are not easily influenced: "…groups have no influence over my decision…"

Reasons for being influenced by community groups are related as follows:

- Feel that community groups had an obligation to inform them of the water.
- "…we are living so divided here, I can't blame anyone, but those who knew should've informed us…" and: "…the group who came with the first forms did not tell us when we could use the water…"
- People are only interested in themselves.

b. Community Politics

In Voorstekraal, 56% of those who did not use, 100% of those who did use the purified water, indicated that they were not all influenced by the politics of the community. 2% of those who did not use the purified water said they were influenced by politics in the community. The rest, both groups felt that this question was not applicable to them as they have previously indicated that decisions are based on their own opinions about things. Respondents who did make use of the purified water were asked whether they would still have used the water if any the political parties implemented the project. 67% said yes, they would use the water regardless, while the rest, 33%, said they would not.

In Upper Mnyameni, 58% of those who did not use, and 80% of those who did use the purified water, indicated that they were not all influenced by the politic of the community. None of those who did not use the purified water said they were influenced by politics in the community. Respondents who did make use of the purified water were asked whether they would still have used the water if any the political parties implemented the project. 75% said yes, they would use the water regardless, while the rest, 25% said they would not.

They responded as follows:

- Regardless of who is involved, the only thing they are concerned about is having access to clean and pure water: "…health risks, benefits are too great health-wise to consider politics…"and "…regardless of the political organization I will still use the water…"
- Political parties have no influence over them.

Others felt that they would not use the water had there been political party involvement because:

- They do not trust these: "…I don't have a lot of trust in them… no trust…"
- Clean drinking water is more important than community differences.
- Want to find out for themselves whether the water is better and how it tastes.
- It was available for free.

Respondents who made use of the water were further asked questions relating to their perception of whether outside people care about their community. 5% of respondents feel that outside people care about their community, this being so because:

- They too are dependent on the water purified by the unit in Upper Mnyameni.
- Tourists regularly visit their village.

33% said that outsiders do not care about their community because:
Outsiders often make promises, but these never materialize: "…because people do come and promise us things but they never happen …" and "…because nothing is going forward, no opportunities, no infrastructure …"

c. Community Organisations

Table 10 illustrates that in general few (2%) respondents, regardless of whether they used the purified water or not, are influenced by community organizations.

TABLE 10: Voorstekraal Community Organisation's Influence on Water Usage:

Purified Water	**Were you influenced by a community organisation to use or not use the water?**				**Total**
	NO	**YES**	**N/A**		
Did not use	**35** (40%)	**2** (2%)	**27** (31%)		**64** (73%)
Used	**23** (26%)	0	1 (1%)		**24** (27%)
TOTAL	**88** (100.0%)				

TABLE 11: Upper Mnyameni Community Organisation's Influence on Water Usage:

Use Purified water	Community Organization Influence			Total
	Yes	No	Missing	
Yes	(6) 7%	(42) 51%	(3) 4%	61%
No	(1) 1%	(22) 27%	(8)7%	37%
Missing	0	(1) 1%	0	1%
Total	**(7) 8%**	**(65) 78%**	**(11) 13%**	**100%**

Table 11 illustrates that in general few respondents, (8%), regardless of whether they used the purified water or not, are influenced by community organizations.

Both groups gave their reasons for the above as follows:

- It was their own decision.
- They simply saw the tank while visiting the clinic and wanted to find out more about it.
- Community organizations were not involved with the project.

Respondents who felt influenced by community groups say so because:

- They feel community organisations are responsible for informing them and they did not do so.

5.12 Water Payment:

Respondents were asked their opinion on the amount of money they thought would be reasonable to pay for water. Table 12 illustrates their responses:

TABLE 12: Water Usage vs. Payment (Voorstekraal)

Use machine water	Prepared to pay		Total
	Yes %	No%	
Yes	(18)20%	(6) 7%	(24) 27%
No	0	(12)14%	(12)14%
Missing	0	(52)59%	(52)59%
Total	**(18)20%**	**(60) 80%**	**(88) 100%**

This question was posed to respondents who made use of the purified water. 75% of respondents who used the water indicated that they would still do so even if they were charged for it, whereas 25% said they would not. Their responses are as follows:

- They are already paying for water: "…currently I'm paying for dirty water…" and "…we are already paying the same rates for water as Caledon and they are supplied with cleaned water…"
- They want better quality water than the water currently received: "…will rather pay extra money to ensure health which is important for children as they stay behind and will then have clean water…"

In terms of payment, there were also concerns:

- Actual costs involved and it affordability: "…it (water) must be available at a reasonable price, we are struggling with water and must pay for what we use…"
- Others felt that they are not willing to pay extra for something they already have.

5.13 Factors Causing Individual's Acceptance of the Unit:

Respondent's said they would accept the unit if it does the following (summary):

- The plant is efficient and effective in cleaning the water.
- Health benefits are experienced.
- It carries the approval of the council and municipality.
- Community members were all part of decision making.
- There is proper functioning of the unit with limited interruptions.
- The water quality is better than current water.
- The water is affordable after installation of the unit.

The following factors will hinder the individual's acceptance of the unit:

- The cost of water increases making it unaffordable.
- Water quality remains poor or it worsens resulting in a poor end-product.
- More illnesses are experienced by community members.
- If the unit is non-beneficial to community members.
- Used to the raw mountain water and prefer the taste thereof.
- Will have to abide by what the decision-makers decide.
- If the unit is damaging to nature or compromises safety of the community it will not be accepted.

5.14 Payment:

TABLE 13: WATER USAGE VS PAYMENT (Upper Mnyameni)

Use machine water	Prepared to pay		Total
	Yes %	No%	
Yes	(14)17%	(37) 45%	(51) 62%
No	(10)12%	(21)25%	(31)37%
Missing	(1) 1%	0	(1) 1%
Total	**(25) 30%**	**(58) 70%**	**(83) 100%**

Only 17% of respondents who used the water indicated that they would still do so even if they were charged for it, whereas 45% , of that same group, said they would not. Their responses are as follows:

- They have never had to pay for water: "…I am not paying for water for a long time, we are in a village, not location (township) …"
- They are unemployed and thus cannot afford to pay for water: "…we do not have permanent jobs so we cannot afford to pay for water"

Those who are prepared to pay for the purified water, 30%, will do so because:

- They will follow what the community as a whole decides : "…because we need clean water and more importantly, (we would pay) if the whole community agrees I would not object …"
- They have no other choice but to pay for water: "…because we need clean water, if I had no choice, then I would (pay for water), if (located) in my yard, R2/litre…"

6. DISCUSSION

Many technically sound schemes internationally have failed simply because communities have rejected them. Relatively little was known of how people make their decisions to accept or reject schemes and there have been no systematic programmes of social investigation to identify the different factors that might influence public perception or mediate their decision making (Po et al., 2005). Despite good design and techniques, many water conservation projects have failed because of the failure to investigate their social and economic aspects (Botha et al., 2005)

The acceptance of a new technology must take place on various levels, amongst technical professionals, municipal and government policy makers as well as the general public (Kalker et al., 1999). The success of projects is greatly increased if the community has a major input into which projects are chosen and how information is delivered to the community on the performance of these projects (Gibbon & Apostolidas, 2001). Ease of access and the level of acceptance of the product influences compliance with recommended hand hygiene practices (Boyce, 2001). Wieneke and Kutsch (2005) further states that technology deployment takes place within a human society which may or not adopt the innovation. The economic circumstances, formal or informal moral attitudes also playan important part in the success or failure of a technological deployment. The ongoing advance of the technology as well as the growing needs and demands of consumers, creates forces that affect a society's adoption choice.

7. GUIDELINES

The following guidelines resulted out of the socio-economic factors that influence the acceptance of micro-filtration and ultra filtration membrane systems:

7.1 Cost and Willingness to Pay

Cost and affordability are important factors as most of the community members in rural areas are unemployed or they have a low income. Communities are willing to pay for the use of water but prefer that the installation of a new technology not interfere with the current water rates they are paying. Costs of water services should therefore not increase as a result of installation of the plant.

7.2 Efficiency of the New Technology

Communities need to have evidence that the new technology will really deliver an improved quality of water, and would want a sample of purified water first. In other words communities would want proof that the new technology adequately purifies the water. This would lead to easy acceptance after installation.

7.3 Awareness Raising/ Informed Community

If the community is not properly informed and made aware of the new technology they may not accept the unit. It is suggested that community members be thoroughly informed via a community meeting so that all may understand, or at least have an idea of how the unit works. This includes informing them of interruptions in the current water supply during installation of the pilot unit. If the community understands the unit and are adequately made aware thereof, installation will be easy. They should also be well informed of any increases in costs relating to the plant installation. In addition to making the community aware about the plant, the whole community must be part of decision-making and agree upon its installation.

The discussions and outcome of these meetings should be propagated to the rest of the community members who could not attend. Propagation should include vigorous door- to- door campaigning.

7.4 Community Needs

Community needs should be determined prior to implementing any project. This will encourage acceptance thereof amongst community members. The benefits of the new technology must coincide with and or meet the needs of the community.

7.5 Job Creation

As unemployment rates are high, the prospect of community members getting employment from the installation and operation of the new technology will be an encouraging factor. If employment opportunities are created as a result of the installation, locals should be considered for this purpose and be given adequate knowledge and skills should they lack these.

7.6 Assessment of Existing Infrastructure

Existing infrastructure such as pipes (because of their age) could greatly interfere with having water quality. The fear thus exists that these may constrict the true effects of the new technology. Existing infrastructure should be thoroughly and continuously assessed and replaced where necessary.

7.7 Security and location of the Plant/Unit

The new technology should be completely secured, because children, mischievous youth and vandals may interfere with or cause breakage to the unit. Rural areas, in most cases, have terrains that are quite uneven and mountainous. The location of the new technology must be selected carefully but community accessibility and convenience should not be compromised.

7.8 Performance and Involvement of Local Government

There seems to be a relationship between the performance of local government and the community's acceptance of a new technology. The community will be very sceptical about accepting new initiatives if local government does not perform on delivering essentials services to the community. Local government should commit themselves with the installation of the new technology by maintaining binding agreements and or a memorandum of understanding with the community.

7.9 Functioning of the New Technology

The new technology should function with limited or no interruptions to the supply of water. The community should be made aware of any interruptions that may result due to the maintenance and operations of such technology.

7.10 Current Community Practices

Communities are used to dealing with the problems of their existing water resource and will continue using it even if it means running the risk of contracting water related and water-borne diseases. The new technology must also use that specific water resource and in its operations.

8. CONCLUSION

The study concludes that:

a. Acceptance does not necessarily mean usage. A large number of households indicated that they accepted the plant but not all of them used it. Usage rate was mainly influenced by the location of the plant, lack of community enthusiasm and drive, limited municipal involvement, misinformation and lack of awareness to use the plant.

b. Communities will always revert to the water they are used to. This is mainly because the alternative water (from purification plant) becomes a bother due to the fact that the water is not close at hand, and they are used to dealing with the problems of the original water.

c. A non-cohesive community intensifies a lack of interest.

d. Community meetings may not be a high quality way of informing households. People attend community meetings in their individual capacity and not necessarily representing their households. Whatever is discussed and decided at the meeting is not propagated to the rest of the households.

e. Local government participation must incorporate involvement and commitment. The Municipality participated fully in the planning stages but was not visible in the implementation phase. The limited involvement of the Municipality discouraged usage and created the perception that they disregard the community.

f. The safest location may not be the most appropriate, convenient or accessible place for the plant. In most instances water purification plants are placed at a location which is most secure irrespective of whether the community has easy access or not. Security concerns should therefore not determine the location of the plant. One needs to find the most convenient and or accessible location for the community and then secure the plant.

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APPENDIX B1: QUESTIONNAIRE USED IN SOCIAL ACCEPTANCE EVALUATION STUDIES

Technical and Social Acceptance Evaluation of Micro filtration and Ultra filtration Membrane Systems for Potable Water Supply to Rural and Remote Communities

Date:…………… Interviewer………………………… Ref No……………
Location……………………………… Address….………………………..

Goeie dag.

My naam is ………….. van die Skeireilandse Technikon. Ons is tans besig met navorsing met die doel om die sosiale faktore te bepaal wat die aanvaarbaarheid van 'n nuwe tegnologie beinvloed. Die tegnologie, in hierdie geval, is 'n watersuiweringseendheid.
Ek wil graag 'n paar vrae aan u stel waarvoor daar geen REGTE of VERKEERDE antwoorde is nie, net u EERLIKE opinie. Die informasie wat u verskaf sal gebruik word om 'n gids op te stel vir die implementering van kleinskaalse watertegnologie.

U het die reg om nie deel te neem aan hierdie navorsing nie, maar ek moedig u aan om deel te neem aangesien die informasie voordelig vir u gemeenskap sal wees. Die informasie wat u verskaf sal konfidensieel gehou word en slegs saamgevat word in 'n algemene verslag. Niemand sal weet WIE WATTER informasie veskaf het nie.

Willig u in om deel te neem aan die navorsing? *JA* *NEE*

Signature of Respondent…………………………………………………………

Name and *Good day. My name is …..… from Peninsula Technikon. We are currently conducting research that is aimed at determining what social factors which influences the acceptance of a new technology. The technology in this project is a water purification unit.*

We will ask you questions to which there is no right or wrong answers, just honest responses. The information that you provide will be used to develop guidelines for implementing small scale water technologies.

You have the right not to participate in this research but we would encourage you to do so because the information will benefit your community. Your identity will be kept secret and all information will be generalised in a report. Nobody will know who gave what information.

Do you agree to participate in this research? *YES* *NO*

Signature of Witness…………………………………………………….

1. Demography

Name:……………………………………….…..

Gender: Female Male

Age / Date of Birth………………………………

Marital Status……………………………………

Do you hold any position in the community?

Yes No

If Yes, What position do you hold?

………………………………………………………………………………………

2. Environmental Context

2.1 Which organizations are present in this community?

………………………………………………………………………………………

..……………………………………………………………………...………………

………………………………………………………………………………………

2.2 In your opinion which of these organizations benefit the community?

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..……………………………………………………………………...………………

………………………………………………………………………………………

2.3 Which beneficial organization/s' advice will you follow?

………………………………………………………………………………………

..……………………………………………………………………...………………

………………………………………………………………………………………

2.4 If the organization/s advise you to accept or not accept the water purification unit, Will you follow this advice?

Yes No

2.5 Why do you say so?
…………………………………………………………………………………………

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…………………………………………………………………..………………

3 Community Context

3.1 How would you describe Voorstekraal's culture?

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…………………………………………………………………..………………

…………………………………………………………………………………………

3.2 What is valued by the Voorstekraal's community?

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…………………………………………………………………..………………

…………………………………………………………………………………………

3.3 Is there anything in the community's culture that will prevent them from accepting the water purification unit?

Yes No

3.4 Why do you say so?
…………………………………………………………………………………………

…………………………………………………………………..………………

…………………………………………………………………………………………

3.5 Is there anything in the community's culture that will encourage them to accept the water purification unit?

Yes No

3.6 Why do you say so?

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…………………………………………………………………..………………

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3.7 Do you abide with the community culture of Voorstekraal?

Yes No

3.8 Why do you say so?

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…………………………………………………………………………………………

4 Group Context

4.1 Which group/s are present in your community?

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…………………………………………………………………………………………

4.2 Which of those groups will you allow to decide on your behalf?

…………………………………………………………………………………………

…………………………………………………………………..………………

…………………………………………………………………………………………

4.3 Why do you say so?

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……………………………………………………………………...………………

…………………………………………………………………………………………

4.4 Do you belong to any of those groups?

Yes No

4.5 If Yes, What position do you hold in the group?
………………………………………………………………………………………..

4.6 Why do you / don’t you belong to those groups?

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……………………………………………………………………...………………

…………………………………………………………………………………………

4.7 Who or what, in your opinion, has a positive influence on these groups?

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……………………………………………………………………...………………

…………………………………………………………………………………………

4.8 Who or what, in your opinion, has a negative influence on these groups?

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……………………………………………………………………...………………

…………………………………………………………………………………………

4.9 Which group/s are the most influential in the community?

……………………………………………………………………...………………

…………………………………………………………………………………………

5 Task Context

5.1 Are you willing to help with the promotion of this water purification unit?

Yes No

5.2 Why do you say so?
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…………………………………………………………………………………………

5.3 How do you think a water purification unit can benefit this community?

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…………………………………………………………………...………………

…………………………………………………………………………………………

5.4 How do you think a water purification unit can disadvantage this community?

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…………………………………………………………………...………………

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5.5 Will you use the water from this water purification unit?

Yes No

5.6 If Yes, What will you use it for?
…………………………………………………………………………………………

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…………………………………………………………………………………………

5.7 If No, why not?
…………………………………………………………………………………………

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6 Innovation Related Context

6.1 In your opinion, what must we consider when implementing this water purification unit?

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6.2 What will make it difficult for us to implement this water purification unit?

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…………………………………………………………………...………………

…………………………………………………………………………………………

6.3 What will make it easy for us to implement this water purification unit?

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6.4 Do you have a "fear" for this water purification unit?

Yes No

6.5 Why Do you say so?

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…………………………………………………………………...………………

…………………………………………………………………………………………

6.6 Do you think that the water purification unit will change the way the community operates/function?

Yes No

6.7 Why do you say so?

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7 Individual Context

7.1 In your opinion, how would the water purification help you personally?

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……………………………………………………………………...………………

………………………………………………………………………………………

7.2 Are your values different to those of the community?

Yes No

7.3 Why do you say so?

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……………………………………………………………………...………………

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7.4 Will you accept something that is in line with the community values but not in line with yours?

Yes No

7.5 Why do you say so?

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……………………………………………………………………...………………

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7.6 If you give advice to the community will they listen to it?

Yes No

7.7 Why would they listen/ not listen?

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………………………………………………………………………...………………

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7.8 If you have no choice in paying for water, How much will you be prepared to pay for water?

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7.9 What will cause you to accept the water purification unit?

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………………………………………………………………………...………………

………………………………………………………………………………………

7.10 What will make you reject the water purification unit?

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………………………………………………………………………...………………

………………………………………………………………………………………

Thank you very much for your time and assistance