GUIDEBOOK FOR THE SELECTION OF SMALL WATER TREATMENT SYSTEMS FOR POTABLE WATER SUPPLY TO SMALL COMMUNITIES

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TT 319/07

Water Research Commission

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ABOUT THE GUIDEBOOK

The guidebook and the accompanying electronic decision-support system (on CD) comprises three sections. In Section 1 the scope and intended use of the guidebook is described, together with an emphasis on the important technological and socio-economic issues. This is followed by Section 2 in which the procedures to be followed for selecting appropriate or 'best' technologies for specific applications are described. This commences with establishing the need for a small water treatment system and information on the water source to be treated (raw water quality; possible variations in raw water quality). The user compiles a shortlist of available technologies that will meet these raw water treatment requirements, and these technologies are then evaluated and compared with each other by means of the technology information sheets that are provided in Annexure B of the guidebook. The different evaluation criteria are used to determine which treatment system(s) will be the most suitable for the user's specific needs. It also includes information on socio-economic aspects relevant to the selection of small water-treatment systems or technologies for small communities.

Section 3 provides the data necessary for performing the evaluation and selection procedure. It contains a comprehensive database of existing, new, and emerging small water treatment systems and technologies. A list of relevant research and evaluation reports is also included to enable the user to obtain more detailed information on the technologies contained in the technology information sheets.

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SECTION 1

SCOPE OF THE GUIDEBOOK

SECTION 2

SELECTION PROCESS FOR SMALL WATER TREATMENT SYSTEMS

SECTION 3

DETAILED INFORMATION AND REFERENCES

SECTION 1

SCOPE OF THE GUIDEBOOK

SECTION 2

SELECTION PROCESS FOR SMALL WATER TREATMENT SYSTEMS

SECTION 3

DETAILED INFORMATION AND REFERENCES

SECTION 1

SCOPE OF THE GUIDEBOOK

1.1 NEED FOR THE GUIDELINES

Small water treatment plants are defined as water treatment systems that have to be installed in areas which are not adequately serviced and do not normally fall within the confines of urban areas. They are therefore mostly used in rural and peri-urban areas and include chlorination plants for water supplies from boreholes and springs, small treatment systems for rural communities, treatment plants of small municipalities and treatment plants for establishments such as rural hospitals, schools, clinics, forestry stations, etc. Most of these applications require small plants of less than 2.5 ML/d (although plants of up to 25 ML/d may sometimes also fall into this category).

The decision-maker selecting one of these small water treatment plants has a great number of local and international system designs to choose from. Especially in the case of novel and emerging systems, very little may be known of these systems in terms of cost, efficiency and the applicability to the intended application. Supplier information may be sketchy, or promising new technologies have not yet been fully evaluated under South African conditions. Socio-economic factors are also very important and should be taken into account in the selection of small water treatment systems in order to ensure sustainability.

Although some evaluation of a selected number of small water treatment plants has taken place under previous WRC projects (WRC Report No 450/1/97: Package water treatment plant selection, and WRC Report No 828/1/01: Field evaluation of alternative disinfection technologies for small water supply technologies), a number of other small water treatment plants, available on the international market, have not yet been assessed in any way for possible (beneficial) application in South Africa. This guidebook is therefore seen as complementing existing guidelines in providing assistance in the selection and operation of specific small water treatment systems being marketed for the treatment of potable water for small communities.

A number of local and international studies have shown that the selection of the correct water treatment system is but a first step in ensuring a sustainable supply of potable water to small communities. Following of the correct operational and maintenance procedures is of even greater importance for ensuring sustainability of water supply. Although most suppliers of small water treatment systems provide their clients with some operational and maintenance guidelines, these may not be exhaustive, or certain important generic aspects may not be covered. Information on operation and maintenance aspects will be of significant value to the owners and operators of such small water treatment systems.

The guidebook aims to provide guidelines for the identification and optimal selection of available and emerging new water treatment systems, which are currently being marketed for the supply of potable water to small communities in South Africa.

1.2 INTENDED USE

This guidebook serves as a decision-making aid for water supply authorities and water service providers in the identification and selection of appropriate water treatment technologies for the supply of potable water to small communities. The guidebook aims to achieve this by providing a number of decision-making steps, based on raw water quality, which will lead the user to identify one or a number of appropriate potential water treatment option(s). These options are described in the database of existing and emerging water treatment technologies being marketed in South Africa, included as Annexure A of this guidebook. This database provides information on the applicability, efficiency, operational use and cost aspects of the water treatment technologies so that the guidebook user can make technical comparisons between different solutions that may exist. In addition, socio-economic guidelines, based on researched community experience with such, or similar, water treatment technologies, are provided to assist the guidebook user in determining the appropriateness of identified technologies for specific small community use.

Once the most appropriate water treatment technologies have been identified, a more detailed investigation of viable option(s) can be undertaken *e.g.* for project definition purposes.

1.3 TARGET AUDIENCE

The guidebook is aimed at the following groups wishing to plan, install, evaluate or select a small water treatment system or technology for a specific application(s):

- Water providers (regional authorities; water boards; Department of Water Affairs and Forestry)
- Water supply authorities (local authorities; water boards)
- Community-based decision-makers
- Funding organisations
- Consulting engineers.

The guidebook and accompanying electronic version have been prepared for use at management, engineering and technical level. It is assumed that the user already has at least a basic knowledge and experience of water treatment and an understanding of its underlying principles.

1.4 TECHNOLOGY CONCEPTS

The purposes of this sub-section is to:

- Provide a description of the concepts behind water treatment technology
- Highlight the fact that water treatment technology is governed by the quality of the raw water
- Highlight the need for minimum treatment technology for any raw water
- Highlight primary items and issues in comparing technologies.

Water treatment technology refers to practical processes used to produce potable water from *raw water*. Each of the processes performs a specific task, hence the use of the term '*Unit Process*'.

The quality of the *raw water* determines the type and number of unit processes to be chosen. One or several unit processes can be applied. Nevertheless, the ultimate goal is to produce water that does not cause health problems in humans. In addition, the unit process(es) must produce aesthetically acceptable water, which must also be stable such that it does not cause excessive scale deposition or corrosion of infrastructure.

No matter how good the raw water quality is, the minimum water treatment technology that must be applied to ensure that potable water reaches the consumer is disinfection. Raw water, such as groundwater, may exist of potable quality, but it would still be susceptible to pollution and/or contamination during transportation to consumers, hence the need for this minimum treatment.

The primary items of technology comparison are:

- Operation and maintenance (O & M) complexity
- Capital costs
- Operation and maintenance costs.

O & M complexity determines the capital costs and the O & M costs, hence it has a large influence in the comparison. It determines the sustainability of any technology after the implementation phase. Apart from comparing the technologies, site-specific issues, such as soil and groundwater conditions, must be taken into account. Other site-specific issues include the need for land acquisition, storage requirements, waste disposal, power availability, degree of automation, and pre-fabrication components.

1.5 SOCIO-ECONOMIC ISSUES

The technical selection of the appropriate water system is a crucial part of ensuring a sustainable supply of potable water for household usage, but generally socio-economic factors of recipients and beneficiaries are seldom considered when selecting a technology. It is therefore important to take into account the following guidelines (relating to socio-economic factors) when selecting/deciding on a water treatment technology for supply of potable household water to small communities.

a. Water demand management

Water demand is driven by the needs and type of activities of households. Women are responsible for managing water in households. This they do by deciding how water is used and how much water to use for household activities. In rural areas they monitor cost and prevent wastage of water, and also control water usage. Where water collection takes place, they decide on the frequency and quantity of water to be collected.

b. Education and training

The level of education of users, existing skills, and training needs should be considered from the outset. Where the general level of education ranges from none to primary school level of education, community members may be able to operate and maintain simple small water treatment systems that do not require complicated and in-depth technical knowledge. Technically complicated small water treatment systems, i.e. in terms of operation and maintenance, may be considered where a high level of technical skills is present within the community. In this instance additional training on the operation and maintenance of the plant is required based on the level of training and existing skills.

c. Hygiene and sanitation

Communities measure the success of health interventions in terms of disease incidence. Poor hygiene awareness and sanitation may impact on the success of the small water treatment systems. For this reason improvements in sanitation as well as hygiene awareness should be linked to improvements in water quality. It is therefore important to ensure that education around hygienic sanitation practices, especially in communities where sanitation is inadequate, is concentrated on.

d. Water payment

Payment for water services and water accounts go hand in hand with the community's understanding thereof. Service providers need to have informative sessions about service delivery and the payment thereof. The responsibilities of the local authority/government and community members need to be addressed and discussed in depth, so that communities understand and accept their responsibility to pay for services rendered. Through a better understanding of the process, appreciation of the service that is delivered will be reached. If this is achieved, sustainability of this service can be achieved.

e. Community involvement, participation and awareness

Participation refers to the sum of actions taken by ordinary community members in order to influence or attempt to influence an outcome. Appropriate development cannot take place without participation from local communities. Communities are eager to learn about, and be included in, decision-making on any venture that takes place within their area. Community participation will only be truly democratic if the community has the right and opportunity to participate in the decision-making process. It is therefore important for communities to be made aware of initiatives, especially those affecting them. To ensure sustainability of any intervention it is crucial that the community be consulted and participates in decision-making, implementation, evaluation, and maintenance of water systems. This needs to occur in order to avoid inappropriate services, conflict, and vandalism of water treatment equipment.

SECTION 2

SELECTION PROCESS FOR SMALL WATER TREATMENT SYSTEMS

2.1 DETERMINING THE WATER TREATMENT NEEDS

Before an evaluation of different small water treatment systems or technologies can commence, it is necessary to determine the water treatment needs as accurately and fully as possible, as this will greatly enhance the selection process. The following essential background information is important to the process of selecting treatment technologies. More detailed information on certain paragraphs appears in Annexure A in Section 3. It is advised that this be read, and data obtained where applicable, before proceeding to the selection procedure (paragraph 2.2):

2.1.1 Raw Water Sources

Background knowledge of raw water sources in South Africa is necessary in order to establish a classification system of raw water types, which will lead to the selection of appropriate treatment processes which should then be able to produce a product water complying with the drinking water specifications. An important aspect here is the hydrological cycle which provides information on how pollutants and impurities may find their way into water sources, thus providing a starting point for raw water classification based on the water quality. Equally important is the sustainability of the water sources, both in terms of quantity and quality. Typical water quality problems in South Africa provide a basis for a characterisation and classification of the raw water types that may be encountered, and on which main technology groupings (or classes) are founded. Detailed information on raw water types is given in Section 3, Annexure A.

2.1.2 Classification of Main Raw Water Types according to Treatability

Based on the treatability of the different main raw water types, a classification of the main raw water types and characteristics is given in Table 2.1 below.

The grouping of sets of raw water quality parameters in Groups A, B, C and D in Table 2.1 is based on the classification system suggested in the *Quality of Domestic Water Supply Guides - Volume 1: Assessment Guide* (WRC Report TT 101/98), and which comprises the following:

GROUP A	
Group A substances are indicators of potential problems and should be frequently tested at all points in the water supply system, irrespective of the source of the water. (Free available (or residual) chlorine has to be measured only if the water has been treated with chlorine-based disinfectants).	
Electrical conductivity (total dissolved salts)	Conductivity is an indicator of total dissolved salts (TDS), and also establishes if the water is drinkable and capable of slaking thirst.
Faecal coliforms	This is an indicator of the possible presence of disease-causing organisms. It establishes if water is polluted with faecal matter.
pH Value (1)	This has a marked effect on the taste of water and also indicates possible corrosion problems and potential copper, zinc and cadmium problems.
Turbidity (2)	This affects the appearance, and thus the aesthetic acceptability, of the water. Turbidity is commonly high in surface waters.
Free available chlorine (Residual chlorine)	This is a measure of effectiveness of the disinfection of the water. Residual chlorine is the chlorine concentration remaining at least 30 minutes after disinfection. There should be residual chlorine in the water, but if the concentrations are too high, it may impact an unpleasant taste and smell to the water.

(1) Correct pH range important for effective disinfection

(2) More importantly it effects the efficiency of chlorination

GROUP B	
The presence/concentration of Group B substances should be determined before the water is supplied. The frequency of testing depends on the source and the treatment applied. Note that substances of concern due to pollution sources in the area, may have to be added to Group B.	
Nitrate & Nitrite	These are common in groundwater (borehole) samples, particularly in areas of intensive agricultural activity, or where pit latrines are used. Severe toxic effects are possible in infants.
Fluoride	This is often elevated in groundwater in hot, arid areas. Can cause damage to the skeleton and the marking of teeth.
Sulphate	This is particularly common in mining areas. Causes diarrhoea, particularly in users not accustomed to drinking water with high sulphate concentrations.

Chloride	This is often elevated in hot, arid areas, and on the western and southern Cape coast (particularly in groundwater). May cause nausea and vomiting at very high concentrations.
Arsenic	This may be present in groundwater, particularly in mining areas. Can lead to arsenic poisoning.
Total coliforms	This provides an additional indicator of disease-causing organisms, and the effectiveness of disinfection.

GROUP C	
Group C substances should be tested for at point of use only in areas of the country where soft water of a low pH value is used.	
Cadmium	This usually occurs along with zinc in acidic waters where it may have been dissolved from appliances.
Copper	This affects the colour of the water and can cause upset stomachs. Normally occurs only when copper piping is used to carry water with a low pH value.

GROUP D	
The presence of Group D substances should be determined at least when assessing the water for the first time. Thereafter, they can be included when there is reason to believe that their concentrations may have changed.	
Manganese	This is common reason for brown or black discolouration of fixtures and for stains in laundry. Can be common in bottom waters of dams, or in mining areas.
Zinc	This affects the taste of water. Usual cause is acidic water dissolving zinc from galvanised pipes or from appliances.
Iron	This affects the taste of the water and may also cause a reddish brown discolouration. Can be common in bottom waters of dams, or in mining areas. Can cause growth of slimes of iron reducing bacteria that ultimately appear as black flecks in the water.
Potassium	This affects the taste of the water and is bitter at elevated concentrations.
Sodium	This affects the taste of water. Often elevated in hot, arid areas and on the western and southern Cape coasts (particularly in groundwater).

Calcium	This can cause scaling and can reduce the lathering of soap.
Magnesium	This affects the taste of water. It is bitter at high concentrations. Common in some areas it adds to the effect of calcium.
Hardness, Total	This is a combination of calcium and magnesium. It is associated with scaling and inhibition of soap lathering.

Table 2.1 Classification of raw water types and characteristics

RAW WATER CHARACTERISTICS			TARGET VALUES SANS 241: 2005 Class I Recommended	TARGET VALUES SANS 241: 2005 Class II Max. allowable (Max consumption period)
Turbidity	Very high	> 500 NTU	< 1 NTU	1 – 5 NTU (No limit)
	High	50 - 500 NTU		
	Medium	5 – 50 NTU		
	Low	1 - 5 NTU		
Colour	Very high	> 300 mg/ℓ as Pt	< 20 mg/ℓ as Pt	20 – 50 mg/ℓ as Pt (No limit)
	High	100 - 300 mg/ℓ as Pt		
	Medium	20 - 100 mg/ℓ as Pt		
	Low	5 – 20 mg/ℓ as Pt		
Brackish water	Highly brackish	> 370 mS/m	< 150 mS/m	150 – 370 mS/m (7 years)
	Moderately brackish	150 – 370 mS/m		
	Low brackish	70 - 150 mS/m		
Hard water	Very hard water	TH > 200 mg/ℓ as $CaCO_3$ (*)	n.s.	n.s.
	Moderately hard water	TH 100 - 200 mg/ℓ as $CaCO_3$ (*)		
Soft water	Very soft water	TH < 10 mg/ℓ as $CaCO_3$	n.s.	n.s.
	Moderately soft water	TH 10 - 40 mg/ℓ as $CaCO_3$		
Microbiological (MB) contaminated	Highly MB contaminated	> 100 Faecal Coli/100 mℓ	*E.Coli* :not detected Faecal coli: not detected	*E.Coli* : not detected Faecal coli: 1/100 mℓ
	Moderately MB contaminated	5 - 100 Faecal Coli/100 mℓ		
	Low MB contaminated	< 5 Faecal Coli/100 mℓ		
Eutrophic water	Highly eutrophic	Chlorophyl a > 100 µg/ℓ	n.s.	n.s.
	Moderately eutrophic	Chlorophyl a 40 - 100 µg/ℓ		
	Low eutrophic	Chlorophyl a 10 - 40 µg/ℓ		
pH	Low pH	< 5.5	5,0 – 9,5	4,0 – 10,0 (No limit)
	Medium pH	5.5 – 9.5		
	High pH	> 9.5		
Nitrate and nitrite	Low	< 10 mg/ℓ as N	< 10 mg/ℓ as N	10 – 20 mg/ℓ as N (7 years)
	High	> 10 mg/ℓ as N		
Iron and manganese	Low	<0.3 mg/ℓ as Fe; <0.1 mg/ℓ as Mn	< 0,2 mg/ℓ as Fe <0,1 mg/ℓ as Mn	0,2 – 2 mg/ℓ as Fe 0,1 – 1 mg/ℓ as Mn (7 years)
	Medium	0.3–10 mg/ℓ Fe; 0.1–4 mg/ℓ Mn		
	High	>10 mg/ℓ as Fe; >4 mg/ℓ as Mn		
Fluoride	High	> 1.5 mg/ℓ as F	< 1,0 mg/ℓ as F^-	1,0 – 1,5 mg/ℓ as F (1 year)$^-$
	Medium	0.5 – 1.5 mg/ℓ as F		
	Low	< 0.5 mg/ℓ as F		
Other: Group B	Sulphate	See brackish water		
	Chloride	See brackish water		
	Arsenic	Requires specialist services (see Annexure D)		
	Total Coliforms	See MB contaminated water		
Other: Group C	Cadmium	Requires specialist services (see Annexure D)		
	Copper	Requires specialist services (see Annexure D)		
Other: Group D	Zinc	Requires specialist services (see Annexure D)		
	Potassium	See brackish water		
	Sodium	See brackish water		

(*) TH = Total Hardness n.s. = not specified

2.1.3 Characterization and Treatment Guidelines for main Raw Water Types

Characterisation information of the main raw water types and treatment guidelines that should be used when comparing water treatment alternatives, is provided in paragraph 2 of Annexure A (Section 3). Information is provided for the following main raw water types:

- Turbid Waters
- Coloured Water
- Brackish Water
- Water high in Iron and Manganese
- Hard and Soft Water
- Microbiologically Contaminated Water
- Eutrophic Water
- Acidic or Alkaline Water (pH outside specifications)
- Water high in Nitrates
- Water high in Fluorides

2.1.4 Water Quality Standards

Water quality standards set limits for the presence of physical, chemical and microbiological substances in water to be used for drinking purposes. In South Africa a set of standards has been compiled by Standards South Africa (a division of SABS), after consultation with all stakeholders. The World Health Organization's guidelines on water quality have served as basis for the development of many National Water Quality standards. Besides the presence of national standards, individual water supply organisations (e.g. Rand Water, Umgeni Water) and water services authorities (e.g. City of Cape Town Metropolitan Municipality) usually develop their own internal standards, which exceed national ones.

Therefore, when evaluating and selecting any water treatment technology water quality standards against which the technology performance shall be assessed must be known. ***The interpretation of water quality data and standards is critical as it determines the suitability of a given water quality for respective application and guides the extent of treatment to be applied to the available raw water***. As a decision maker, knowledge of water quality standards is therefore very important because it helps to classify the water for its suitability for either direct use or treatment by given technology options that can achieve the production of the desired final water that satisfies local water quality standards.

South African National Standard (SANS) for Drinking Water (SANS 241: 2005) classifies water into two main classes: Class I and Class II. A Class I water is of a quality complying with the given recommended upper limit, while the Class II water falls within the specified maximum allowable value for limited duration. The limits for Class I (recommended value) and Class II (maximum allowable) are shown as "target values" in Table 2.1.

2.1.5 Sampling and Analysis Requirements

The Department of Water and Forestry (DWAF), in conjunction with the Department of Health (DOH) and the Water Research Commission (WRC), have published ***Guidelines on the Quality of Domestic Water Supplies***, two of which deal with *Sampling (Volume 2)* and *Analysis (Volume 3)*. These guidelines are recommended references with respect to sampling and analysis requirements when evaluating various water treatment systems for the purpose of deciding on an appropriate option. Summaries of key issues to be considered when selecting water treatment technologies are presented in Section 3, Annexure A.

2.1.6 Plant Capacity and Storage Required

Plant capacity and storage required should be based on the number of persons to be supplied with water, and the level of service that will be provided, with due cognisance of the socio-economic level of the community under consideration. The following are important guidelines to consult:

- RDP guidelines (minimum of 25 litres per person per day, *i.e.* 6 000 litres of free water per month per household)
- Client-specific requirements
- Other non-domestic requirements; *e.g.* dairies on farms
- Future requirements (expansion possibilities/upgrading)
- Storage requirements (e.g. 24 hours) (in case of plant malfunctioning or raw water supply interruption)
- Plant operation time per day (8 hours; 12 hours; 24 hours)
- Seasonal variations (low flow out of season / high demand in season)
- Plant control / storage management.

2.1.7 Socio-Economic Guidelines

Important socio-economic guidelines for small water treatment systems were drawn up following the socio-economic studies in the various provinces of South Africa. These guidelines are presented in Appendix A Section 4 of the Guidebook and should be studied carefully before embarking on the technology selection process, so as to form a basis for the more specific guidelines that are presented as selection criteria in each of the Technology Information Sheets. The socio-economic guidelines appear under the following headings in Appendix A:

a. Educational Status

b. Willingness To Pay

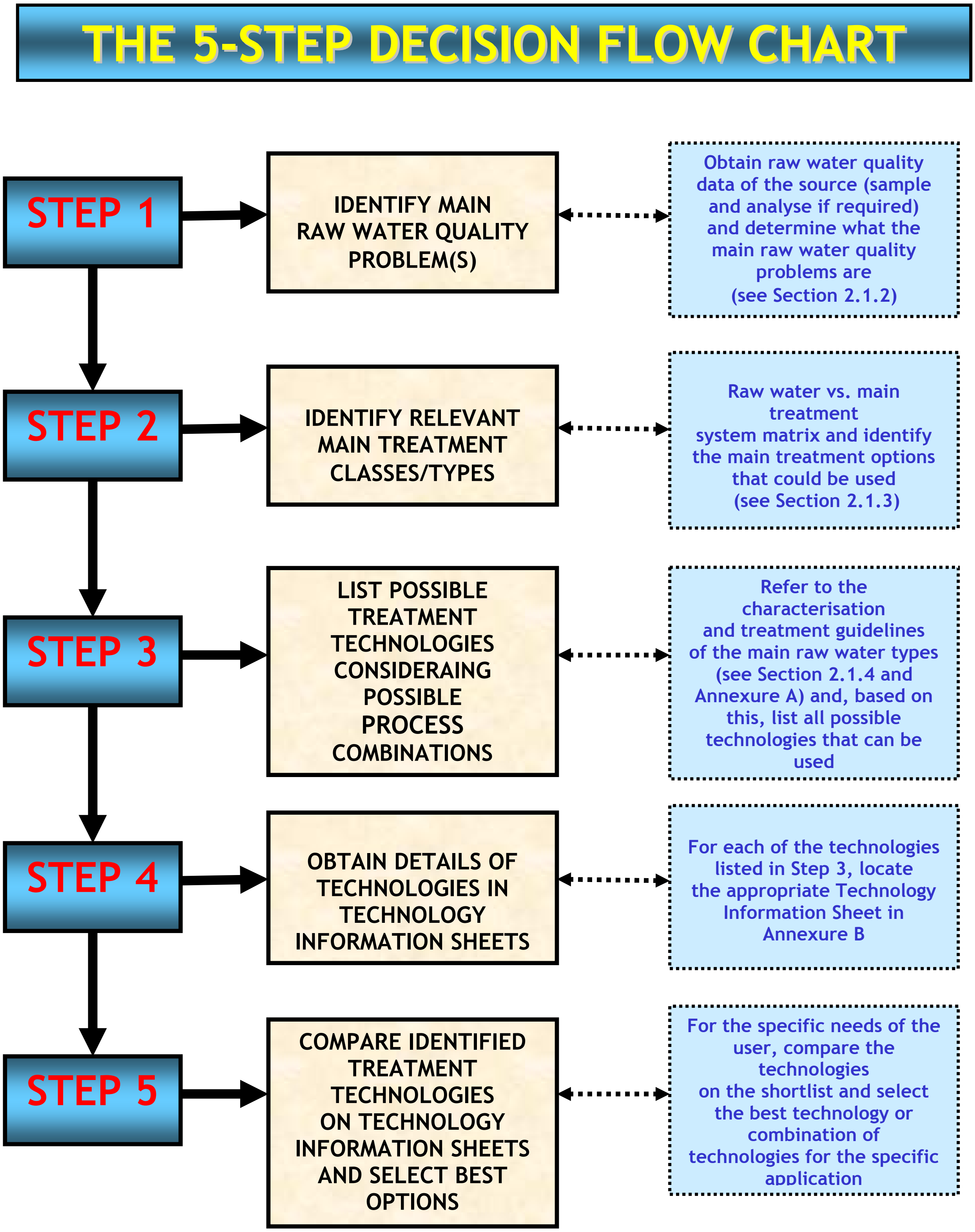
c. Impact of Human Activity on Water Quality

d. Community Participation

e. Water Demand and Management

2.2 SELECTION OF TREATMENT OPTIONS BASED ON RAW WATER QUALITY (Selection Procedure)

The steps to be followed to identify the possible treatment options for a given raw water source, are given schematically below. The position of the user on the flow diagram is also given at the start of each of the five steps.



STEP 1: IDENTIFY MAIN RAW WATER QUALITY PROBLEM(S)

1. ***Determine raw water quality as far as possible by sampling and analysing raw water source, and identify all raw water quality deviations from South African water quality standards (primarily based on values (blue; green; yellow), as contained in: Quality of Domestic Water Supplies, Volume 1: Assessment Guide, Second Edition, 1998). Refer to quality of final water aimed at (SANS 241).***

2. ***Table 2.1 in Section 2.1.2 may be used to assist the guidebook user. Users themselves should fill in all raw water quality values not complying with a SANS 241 Class II water (maximum allowable) in a column provided on the right hand side.***

Table 2.2 Table with column for raw water values filled in by user of the guidebook

RAW WATER CHARACTERISTICS			VALUE
Turbidity	Very high	> 500 NTU	
	High	50 - 500 NTU	
	Medium	5 - 50 NTU	
	Low	1 – 5 NTU	
Colour	Very high	> 300 mg/ℓ as Pt	
	High	100 - 300 mg/ℓ as Pt	
	Medium	20 - 100 mg/ℓ as Pt	
	Low	5 – 20 mg/ℓ as Pt	
Brackish water	Highly brackish	> 370 mS/m	
	Moderately brackish	150 - 370 mS/m	
	Low brackish	70 - 150 mS/m	
Hard water	Very hard water	TH > 200 mg/ℓ as $CaCO_3$	
	Moderately hard water	TH 100 - 200 mg/ℓ as $CaCO_3$	
Soft water	Very soft water	TH < 10 mg/ℓ as $CaCO_3$	
	Moderately soft water	10 - 40 mg/ℓ as $CaCO_3$	
Microbiological (MB) contaminated	Highly MB contaminated	> 100 Faecal Coli/100 mℓ	
	Moderately MB contaminated	5 - 100 Faecal Coli/100 mℓ	
	Low MB contaminated	< 5 Faecal Coli/100 mℓ	
Eutrophic water	Highly eutrophic	Chlorophyl a > 100 µg/ℓ	
	Moderately eutrophic	Chlorophyl a 40 - 100 µg/ℓ	
	Low eutrophic	Chlorophyl a < 40 µg/ℓ	
pH	Low pH	< 5.5	
	Medium pH	5.5 – 9.5	
	High pH	> 9.5	
Nitrate and nitrite	Low	< 10 mg/ℓ as N	
	High	> 10 mg/ℓ as N	
Iron and manganese	Low	<0.3 mg/ℓ as Fe; <0.1 mg/ℓ as Mn	
	Medium	0.3 – 10 mg/ℓ as Fe; 0.1 – 4 mg/ℓ as Mn	
	High	>10 mg/ℓ as Fe; >4 mg/ℓ as Mn	
Fluoride	High	> 1.5 mg/ℓ as F	
	Medium	0.5 – 1.5 mg/ℓ as F	
	Low	< 0.5 mg/ℓ as F	
Other: Group B	Sulphate	See brackish water	
	Chloride	See brackish water	
	Arsenic	Requires specialist services; not incl. in this Guide	
	Total Coliforms	See MB contaminated water	
Group C	Cadmium	Requires specialist services; not incl. in this Guide	
	Copper	Requires specialist services; not incl. in this Guide	
Group D	Zinc	Requires specialist services; not incl. in this Guide	
	Potassium	See brackish water	
	Sodium	See brackish water	
	Calcium	See hard / soft water above	
	Magnesium	See hard / soft water above	
	Total Hardness	See hard / soft water above	

STEP 2: IDENTIFY RELEVANT MAIN TREATMENT CLASSES / TYPES

For each of the raw water deviations, identify the relevant main treatment classes or types using the Table 2.3 on the next page (green shading indicates main treatment types that can be used)

PLEASE NOTE!

It is recommended that all waters receive some form of disinfection.

For surface waters, some form of fine filtration is always recommended.

Treatment priorities must be established based on primary, secondary and tertiary health concerns, in accordance with DWAF guideline documents.

Note that for use of Table 2.3 on the next page, the aim is to obtain a final water complying with the requirements of a Class I water of SANS 241 of 2005.
If the raw water already complies with a Class I water, then no treatment is required for that specific parameter.

Table 2.3 Main treatment classes/types that could be used for different raw water groupings

RAW WATER CHARACTERISTICS		OXIDATION	CHEMICAL TREATMENT	PHASE SEPARATION	FILTRATION			DISINFECTION	ION EXCHANGE	BIOLOGICAL	DEMINERALISATION	ADSORPTION	ELECTRICAL / MAGNETIC
					COARSE	FINE	MEMBRANE						
Turbidity	Very high		♦	♦	♦	♦							
	High		♦	♦	♦	♦							
	Medium		♦			♦	♦						♦
	Low		♦			♦	♦						♦
Colour	Very high	♦	♦				♦		♦				♦
	High	♦	♦				♦		♦				♦
	Medium	♦	♦				♦		♦				♦
	Low	♦	♦				♦		♦				♦
Brackish water	Highly brackish						♦				♦		
	Moderately brackish						♦				♦		
	Low brackish						♦				♦		
Hard water	Very hard water		♦	♦			♦		♦		♦		
	Moderately hard water		♦	♦			♦		♦		♦		
Soft water	Very soft water		♦										
	Moderately soft water		♦										
Microbiological (MB) contaminated	Highly MB contaminated	♦	♦			♦	♦	♦					
	Moderately MB contaminated	♦	♦			♦	♦	♦					
	Low MB contaminated	♦	♦			♦	♦	♦					
Eutrophic water	Highly eutrophic	♦	♦	♦		♦						♦	♦
	Moderately eutrophic	♦	♦	♦		♦						♦	♦
	Low eutrophic	♦	♦	♦		♦						♦	♦
pH	High pH		♦										
	Medium pH		♦										
	Low pH		♦										
Nitrate and nitrite	High						♦		♦	♦			
	Low						♦		♦	♦			
Iron and manganese	High	♦	♦	♦	♦	♦				♦			
	Medium	♦	♦	♦	♦	♦				♦			
	Low	♦	♦	♦	♦	♦				♦			
Fluoride	High		♦						♦			♦	
	Medium		♦						♦			♦	
	Low		♦						♦			♦	

STEP 3: LIST POSSIBLE TREATMENT TECHNOLOGIES CONSIDERING POSSIBLE PROCESS COMBINATIONS (TRAINS)

For each of the raw water deviations, it is now possible to identify appropriate treatment technologies according to the treatment class or type identified in step 2, and the treatment guidelines and process combination (train) diagrams presented in Annexure A for that raw water type. All the technologies in each of the main treatment classes are listed in the contents table appearing before the Technology Information Sheets in Annexure B.

STEP 4: OBTAIN DETAILS OF TECHNOLOGIES IN TECHNOLOGY INFORMATION SHEETS

Locate the identified treatment technology information sheets in Annexure B.

The evaluation criteria that were used in developing the technology information sheets are given in Table 2.4 on the following page.

Table 2.4 Technology Information Sheet showing evaluation criteria that were used

NO	FIELD	INFORMATION
1	**Purpose and status**	What can be removed/reduced/adjusted/altered - as main application From what type of water For what subsequent process Proven Technology (in full-scale use for a period of time in water treatment) Emerging Technology (new in water treatment; gaining ground) Experimental/Novel Technology (needs to be proven in water treatment)
2	**Alternatives**	Other technologies that can achieve a similar purpose
3	**Summary of key features**	Brief summary of main features and attributes
4	**Description**	Process description should be sufficiently comprehensive so that it could be used as stand alone if needed, and at least include the following: Type of process (e.g. filtration or oxidation or adsorption, etc.) Purpose of treatment Position in treatment process Batch or continuous flow Force necessary to affect the process Mechanism (mechanical; chemical; physical; biological) Type of material(s)/compounds/state (e.g. gas; liquid) used in the process (including brief specs where important) Flow path (e.g. up-flow; down-flow; horizontal flow) Rate of flow/treatment (high rate; low rate)(including actual values)
5	**Technology illustration**	1/4 to 1/3 page
6	**Performance limitations**	No specific format Not suitable for treatment of ……. type of water Not suitable for removing/reducing/altering/adjusting ……. quality parameters Can remove/reduce/alter/adjust quality parameters to a maximum value of ….... Impact of raw water quality variations [same keywords as above]
7	**Recommended capacity**	Use the following classification as guidance, but describe suitable capacity applications and reasons. Household scale < 1 m^3/d Very small 1 – 10 m^3/d Small 10 – 500 m^3/d Medium 0,5 – 2,5 Mℓ/d Large > 2,5 Mℓ/d Ease of expansion: (easy [modular]; difficult [conventional])
8	**Operational requirements**	Provide details of requirements (use the following as guidance only): Operator skills required (trained/semi-trained/untrained); operator input man-hours required per day (numeric); chemical dosage required (yes; no); can alternative chemicals be used (yes; no); degree of automation (fully/semi-automated; manual); frequency of process and quality control monitoring tasks (4-hourly; 8-hourly; daily; twice weekly; weekly; monthly); availability of materials/chemicals for operation spares (readily available; long lead time)

9	**Maintenance requirements**	Provide details of requirements (use the following as guidance only): cost of servicing/repairs/replacement (high; medium; low); frequency of servicing/repairs/replacement (daily; weekly; monthly; annually); expert or skilled maintenance inputs (expert; skilled operator); availability of recommended spares and tools (readily available; long lead time)
10	**Infrastructure requirements**	Provide details of requirements (use the following as guidance only): State whether the following infrastructure plays an important role in selection: (yes/no): access roads; power, lighting; prefabricated/site-constructed; chemical storage; raw water storage; clean water storage; civil construction; sludge and waste disposal; availability of reticulation system
11	**Impact of failures**	Impact of operational, maintenance and infrastructural failures on the performance of the technology (electricity; operator presence; supply of chemicals; technical support) [keywords: critical; severe; limiting; negligible; none]
12	**Energy requirements**	Regular electricity supply; fossil fuel; renewable (solar; wind); alternate between two or more of the above; none (e.g. gravity feed can be used)
13	**Capital costs**	Comparative costs are provided at the end of each section, together with remarks on most important cost aspects
14	**Operating costs**	Comparative costs are provided at the end of each section, together with remarks on most important cost aspects
15	**Typical treatment process configuration (train) or example**	Block diagram with standard symbols and captions
16	**Examples of SA installations**	5 examples, with capacities, preferably spread over SA (name of plant; municipality; owner; town)
17	**Socio-economic impact**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of and manage this type of technology; ability and willingness to operate and maintain this type of system, impact of implementation on water services authority (costs, labour, training, maintenance)
18	**Research and evaluation in South Africa**	Relevant to this technology: WRC reports (report no.); current WRC projects (project no); other R&D reports from research institutions/suppliers of equipment/chemicals; other references; names of researchers/consultants working in this field

Technology Information Sheets were drawn up for the following technologies, and are presented in Annexure B:

MAIN TECHNOLOGY GROUPING	TECHNOLOGY
1. OXIDATION	1-1 Aeration 1-2 Chlorination for oxidation 1-3 Ozonation for oxidation 1-4 Greensand filtration for oxidation 1-5 Potassium permanganate oxidation 1-6 Chlorine dioxide
2. CHEMICAL TREATMENT	2-1 Chemical precipitation 2-2 Limestone stabilisation 2-3 Electrocoagulation
3. PHASE SEPARATION	3-1 Conventional sedimentation 3-2 Upflow blanket sludge clarifier 3-3 High-rate settling 3-4 Batch sedimentation 3-5 Plain sedimentation 3-6 Dissolved air flotation 3-7 Floating media separator 3-8 Solar distillation
4. COARSE FILTRATION	4-1 Upflow roughing filtration 4-2 Horizontal flow roughing filtration 4-3 Intake roughing filtration
5. FINE FILTRATION	5-1 Conventional rapid gravity sand filtration 5-2 Pressure sand filtration 5-3 Conventional slow sand filtration 5-4 Direct slow sand filtration 5-5 Autonomous backwash filtration 5-6 Bag filters 5-7 Cartridge filters 5-8 Direct upflow filtration 5-9 Direct and inline filtration 5-10 High-rate sand filtration 5-11 Direct series filtration 5-12 Diatomaceous earth filtration 5-13 Fabric enhanced slow sand filtration 5-14 Dynamic cross-flow sand filtration
6. MEMBRANE FILTRATION	6-1 Microfiltration membranes 6-2 Ultrafiltration 6-3 Reverse osmosis 6-4 Immersed microfiltration 6-5 Nanofiltration 6-6 Electrodyalisis (reversal)
7. DISINFECTION	7-1 Gas chlorine 7-2 Liquid chlorine 7-3 Granular chlorine 7-4 On-site chlorine generation 7-5 Mixed oxidants (MIOX) 7-6 Solar pasteurisation 7-7 Ultraviolet disinfection 7-8 Ozonation for disinfection (see 1.3) 7-9 Chlorine dioxide (see 1.6) 7-10 Chloramination 7-11 Bromine / iodine

8. ADSORPTION	**8-1 Granular activated carbon** **8-2 Powder activated carbon** **8-3 Activated alumina**
9. ION EXCHANGE	**9-1 Ion exchange softening** **9-2 Ion exchange for nitrate removal** **9-3 Magnetic Ion Exchange (MIEX)**
10. BIOLOGICAL TREATMENT	**10-1 Biological denitrification**
11. DEMINERALISATION	**11-1 Reverse osmosis (see 6.3)** **11-2 Electrodialysis (reversal) (see 6.6)** **11-3 Solar distillation (see 3.8)** **11-4 Carbon Aerogel desalination**
12. RADIATION	**12-1 Ultraviolet radiation (see 7.7)** **12-2 Solar pasteurisation (see 7.6)**
13. ELECTRICAL AND MAGNETIC TREATMENT	**13-1 Electrocoagulation (see 2.3)** **13-2 Magnetic Ion Exchange (MIEX) (see 9.3)**
14. PACKAGE PLANTS	**14-1 Conventional filtration package plants** **14-2 Alternative oxidation package plants** **14-3 Membrane filtration package plants**

STEP 5: COMPARE IDENTIFIED TREATMENT TECHNOLOGIES ON TECHNOLOGY INFORMATION SHEETS AND SELECT BEST OPTION(S)

Compare the available technology information sheets of the identified treatment technologies (Step 3) in terms of their potential to address the raw water deviation(s) identified in Step 1. Cost comparisons may be made by evaluating cost data in the comparative cost graphs at the end of each technology grouping.

2.3 EXAMPLES OF USING THE GUIDEBOOK TO PERFORM THE SELECTION PROCESS FOR SMALL WATER SYSTEMS

Example 1: Iron and Manganese

A raw water source (groundwater) was analysed and the chemical and microbiological quality found to be as follows:

Quality Determinant	Value
pH	6,2
Turbidity (NTU)	0,8
Conductivity (mS/m)	58
Colour (mg/ℓ as Pt)	< 5
Calcium (mg/ℓ as Ca)	20
Magnesium (mg/ℓ as Mg)	4
Alkalinity (mg/ℓ as CaCO3)	18
Iron (mg/ℓ as Fe)	4,5
Manganese (mg/ℓ as Mn)	0,24
Sulphate (mg/ℓ as SO4)	20
Chloride (mg/ℓ as Cl)	71
Nitrate + nitrite (mg/ℓ as NOx)	8,3
Fluoride (mg/ℓ as F)	0,8
Total coliforms (# per 100 mℓ)	0
Faecal coliforms (# per 10 mℓ)	0

STEP 1: IDENTIFY MAIN RAW WATER QUALITY PROBLEMS

Comparing all the raw water quality values with the local water quality standards, it is found that the only constituents exceeding acceptable limits are **iron and manganese**.

Therefore the main water treatment requirement is removal of iron and manganese (to the acceptable local water standard of 0,2 mg/ℓ as Fe and 0,1 mg/ℓ as Mn).

(The water should be disinfected as well - it is recommended that all waters receive some form of disinfection.)

The value for iron of 4,5 mg/ℓ as Fe and manganese of 0,24 mg/ℓ as Mn will hence be inserted into Table 2.2 (Section 2.1.2) as the only raw water deviation.

Quality Determinant	Value
PH	6,2
Turbidity (NTU)	0,8
Conductivity (mS/m)	58
Colour (mg/ℓ as Pt)	< 5
Calcium (mg/ℓ as Ca)	20
Magnesium (mg/ℓ as Mg)	4
Alkalinity (mg/ℓ as CaCO3)	18
Iron (mg/ℓ as Fe)	**4,5**
Manganese (mg/ℓ as Mn)	**0,24**
Sulphate (mg/ℓ as SO4)	20
Chloride (mg/ℓ as Cl)	71
Nitrate + nitrite (mg/ℓ as NOx)	8,3
Fluoride (mg/ℓ as F)	0,8
Total coliforms (# per 100 mℓ)	0
Faecal coliforms (# per 10 mℓ)	0

The raw water will therefore be classified as:

Medium iron; medium manganese water
(0,3 - 10 mg/ℓ as Fe; 0,1 - 4 mg/ℓ as Mn)

STEP 2: IDENTIFY RELEVANT MAIN TREATMENT CLASS / TYPE

From the Table 2.3, and for a medium iron/medium manganese water, the following main treatment classes/types may be used to treat this water:

Oxidation
Chemical treatment
Fine filtration
Membrane treatment
Biological treatment

STEP 3: LIST POSSIBLE TREATMENT TECHNOLOGIES

From Annexure B (Technology Groupings) contents pages (Table B.1), the following technologies may all be used to remove iron and manganese from the given raw water:

Oxidation:

Aeration
Ozonation and combinations with other technologies
Potassium Permanganate for Oxidation
Greensand Filtration
Chlorination for Oxidation
Chlorine Dioxide for Oxidation

Chemical treatment:

Coagulation / Flocculation
Stabilisation
Lime Softening

Fine filtration:

Bag Filtration
Cartridge Filtration
Conventional Slow Sand Filtration
Fabric Enhanced Slow Sand Filtration
Dynamic Cross-Flow Sand Filtration
Conventional Rapid Gravity Sand Filtration
Direct Rapid Gravity Sand Filtration
Direct Up-flow Filtration
High-rate Sand Filtration (Deep-Bed or Multi-Media)
Autonomous Valveless Rapid Sand Filtration
Direct Series Filtration

Pressure Sand Filtration
Diatomaceous Earth Filtration
Biological Enhanced Filtration
Rapid Gravity Sand Filtration with Granular Activated Carbon

Membrane treatment:

Immersed Microfiltration
Microfiltration Membrane Filtration
Ultrafiltration
Electrodialysis
Nanofiltration
Reverse Osmosis

Biological treatment:

Biological Nitrate Removal
Biological Iron Removal

Using background information on removal of iron and manganese which appears in Annexure A (section on ***Characterisation and Treatment Guidelines for Main Raw Water Types***), the following processes can be selected as appropriate possible treatment processes/technologies for this specific raw water:

Main processes: Oxidation (aeration; chlorination; ozone; etc.) followed by fine filtration (sand filtration; bag filtration, etc) or membrane filtration (MF; UF; etc), or the two processes (oxidation and fine filtration) combined (e.g. greensand filtration; biological filtration).

These main treatment processes also appear in the process combination diagram for high iron and manganese waters at the end of paragraph 2.4, Annexure A.

STEP 4: OBTAIN DETAILS OF TECHNOLOGIES IN TECHNOLOGY INFORMATION SHEETS

Consult the Technology Information Sheets in Annexure B for possible treatment processes selected in Step 3 above.

STEP 5: COMPARE IDENTIFIED TREATMENT TECHNOLOGIES ON TECHNOLOGY INFORMATION SHEETS AND SELECT BEST OPTION(S)

Compare all these technologies on the basis of all the selection criteria given in the technology information sheets, and select the best available technology for the site-specific circumstances.

Example 2: High turbidity and Microbiological Contamination

A raw water source (surface water) was analysed and the chemical and microbiological quality found to be as follows:

Quality Determinant	Value
pH	8,1
Turbidity	47
Conductivity	41
Colour	< 15
Calcium	35
Magnesium	12
Alkalinity	37
Iron	0,15
Manganese	< 0,05
Sulphate	28
Chloride	28
Nitrate + nitrite (as NOx)	2,1
Fluoride	0,7
Total coliforms	1 500
Faecal coliforms	450

STEP 1: IDENTIFY MAIN RAW WATER QUALITY PROBLEMS

Comparing all the raw water quality values with the local water quality standards (SANS 241 of 2005), it is found that the constituents exceeding acceptable limits are turbidity and microbiological quality (total coliforms and faecal coliforms).

Therefore the main water treatment requirement is turbidity removal and disinfection (to the acceptable local water standard of 1,0 NTU (for turbidity) and zero (no detection of) total coliforms and faecal coliforms).

The value for turbidity of 47 NTU and total coliforms (1 500 per 100 mℓ) and faecal coliforms (450) will hence be inserted into Table 2.2 (Section 2.1.2) as the raw water deviations.

(Treatment priorities must be established based on primary, secondary and tertiary health concerns, in accordance with DWAF guides.)

For this example, thus, both microbiological contamination (direct) and turbidity (indirect) are primary quality (health) concerns, and need to be addressed.

Quality Determinant	**Value**
pH	8,1
Turbidity	**47**
Conductivity	41
Colour	< 15
Calcium	35
Magnesium	12
Alkalinity	37
Iron	0,15
Manganese	< 0,05
Sulphate	28
Chloride	28
Nitrate + nitrite (as NOx)	2,1
Fluoride	0,7
Total coliforms	**1 500**
Faecal coliforms	**450**

The raw water will therefore be classified as:

Medium turbidity; highly microbiologically contaminated water
(10 - 50 NTU; > 100 per 100 mℓ)

STEP 2: IDENTIFY RELEVANT MAIN TREATMENT CLASS / TYPE

From Table 2.3, for a medium turbidity, highly microbiologically contaminated water, the following main treatment classes/types may be used to treat this water:

Chemical treatment
Phase separation
Fine filtration
Membrane treatment
Disinfection

STEP 3: LIST POSSIBLE TREATMENT TECHNOLOGIES

From the technology grouping contents pages, the following technologies may all be used to remove turbidity and microbiological contamination from the given raw water:

Chemical treatment:

Coagulation / Flocculation
Stabilisation
Lime Softening

Phase separation:

Batch Sedimentation
Dissolved Air Flotation
Floating Media Separation
High-rate Settling
Conventional Sedimentation
Up-flow Sludge Blanket Clarification

Fine filtration:

Bag Filtration
Cartridge Filtration
Conventional Slow Sand Filtration
Fabric Enhanced Slow Sand Filtration
Dynamic Cross-Flow Sand Filtration
Conventional Rapid Gravity Sand Filtration

Direct Rapid Gravity Sand Filtration
Direct Up-flow Filtration
High-rate Sand Filtration (Deep-Bed or Multi-Media)
Autonomous Valveless Rapid Sand Filtration
Direct Series Filtration
Pressure Sand Filtration
Diatomaceous Earth Filtration
Biological Enhanced Filtration
Rapid Gravity Sand Filtration with Granular Activated Carbon

Membrane treatment:

Electrodialysis
Immersed Microfiltration
Microfiltration Membrane Filtration
Ultrafiltration
Nanofiltration
Reverse Osmosis

Disinfection:

Chlorination for Disinfection
Chloramination
Ozonation for Disinfection
Chlorine Dioxide for Disinfection
Other: Bromine
Other: Iodine
Ultrasound Treatment

Using background information on removal of turbidity and microbiological contamination, which appears in Annexure A (section on ***Characterisation and Treatment Guidelines for main Raw Water Types***), the following processes can be selected as appropriate possible treatment processes/technologies for this specific raw water:

Main processes: Filtration (sand filtration; microfiltration) followed by disinfection (chlorination or UV if water is consumed at point of treatment).

These main treatment processes also appear in the process combination diagram for high turbidity waters at the end of paragraph 2.1, Annexure A.

STEP 4: OBTAIN DETAILS OF TECHNOLOGIES IN TECHNOLOGY INFORMATION SHEETS

Consult the Technology Information Sheets in Annexure B for possible treatment processes selected in Step 3 above.

STEP 5: COMPARE IDENTIFIED TREATMENT TECHNOLOGIES ON TECHNOLOGY INFORMATION SHEETS AND SELECT BEST OPTION(S)

Compare all these technologies on the basis of all the selection criteria given in the technology information sheets, and select the best available technology for the site-specific circumstances.

Example 3: Nitrate

A raw water source (groundwater) was analysed and the chemical and microbiological quality found to be as follows:

Quality Determinant	Value
pH	6,8
Turbidity	0,6
Conductivity	40
Colour	< 5
Calcium	15
Magnesium	3
Alkalinity	14
Iron	< 0,1
Manganese	< 0,05
Sulphate	27
Chloride	91
Nitrate + nitrite (as N)	20,5
Fluoride	1,0
Total coliforms	0
Faecal coliforms	0

STEP 1: IDENTIFY MAIN RAW WATER QUALITY PROBLEMS

Comparing all the raw water quality values with the local water quality standards, it is found that the only constituents exceeding acceptable limits are **nitrate and nitrite**.

Therefore the main water treatment requirement is removal of nitrate and nitrite (to the acceptable local water standard of less than 10 mg/ℓ as N).

(The water should be disinfected as well - it is recommended that all waters receive some form of disinfection.)

The value for nitrate + nitrite will hence be inserted into Table 2.2 (Section 2.1.2) as the only raw water deviation.

Quality Determinant	Value
pH	6,8
Turbidity	0,6
Conductivity	40
Colour	< 5
Calcium	15
Magnesium	3
Alkalinity	14
Iron	< 0,1
Manganese	< 0,05
Sulphate	27
Chloride	91
Nitrate + nitrite (as N)	**20,5**
Fluoride	1,0
Total coliforms	0
Faecal coliforms	0

The raw water will therefore be classified as:

High nitrate + nitrite
(>20 mg/ℓ as N)

STEP 2: IDENTIFY RELEVANT MAIN TREATMENT CLASS / TYPE

From Table 2.3, and for high nitrate + nitrite water, the following main treatment classes/types may be used to treat this water:

Membrane treatment
Ion exchange
Biological treatment

STEP 3: LIST POSSIBLE TREATMENT TECHNOLOGIES

From the technology grouping contents pages, the following technologies may all be used to remove nitrate from the given raw water:

Membrane treatment:

Electrodialysis
Immersed Microfiltration
Microfiltration Membrane Filtration
Ultrafiltration
Nanofiltration
Reverse Osmosis

Ion exchange:

Ion-exchange nitrate removal
MIEX
Manganese zeolite
Ion-exchange softening

Biological treatment:

Biological Nitrate Removal
Biological Iron Removal

Using background information on nitrate removal, which appears in Annexure A (section on ***Characterisation and Treatment Guidelines for Main Raw Water Types***), the following processes can be selected as appropriate possible treatment processes/technologies for this specific raw water:

Main processes: Reverse osmosis OR Ion exchange OR Biological nitrate removal.

These main treatment processes also appear in the process combination diagram for high nitrate waters at the end of paragraph 2.8, Annexure A (Figure A.9).

STEP 4: OBTAIN DETAILS OF TECHNOLOGIES IN TECHNOLOGY INFORMATION SHEETS

Consult the Technology Information Sheets in Annexure B for possible treatment processes selected in Step 3 above.

STEP 5: COMPARE IDENTIFIED TREATMENT TECHNOLOGIES ON TECHNOLOGY INFORMATION SHEETS AND SELECT BEST OPTION(S)

Compare the technologies on the basis of all the selection criteria given in the technology information sheets, and select the best available technology for the site-specific circumstances.

SECTION 3

DETAILED INFORMATION AND REFERENCES

ANNEXURE A

BACKGROUND INFORMATION ON WATER TREATMENT REQUIREMENTS

CONTENTS

1. RAW WATER SOURCES

1.1 Raw Water Sources of Southern Africa

a. The hydrological cycle

Water moves continuously through the natural cycle of transpiration, evaporation, condensation and precipitation as rain and snow, infiltration into the soil, emergence in the form of fountains and run-off, and storage in dams. The source of supply for human consumption is that point in the cycle where water is withdrawn for use. Such sources should be protected against pollution at all times.

b. Surface waters

The natural surface water of South Africa can be divided into two main groups:

- Water with a low colour intensity, but which contains solids in suspension. Most inland water falls in this category; for example, the Vaal, Orange, Tugela and Umkomaas rivers.

  Most inland rivers carry large quantities of material in suspension during floods; most of this material is fairly coarse and mainly inorganic, and will settle out of suspension as soon as the rate of flow decreases, but some is of colloidal and semi-colloidal size, and can remain in suspension for extended periods, as is the case with the water of the Vaal Dam.

  It has been shown that the surface water of South Africa can be classified on a regional basis according to the composition of the suspended material it contains.

- Water of low turbidity, but usually coloured as a result of organic matter in solution or in colloidal suspension, such as the water in the southern coastal regions of South Africa. These waters usually contain a low concentration of inorganic salts, which causes chemical instability and imparts corrosive properties to the water. The treatment process should, therefore, include a step for increasing the carbonate species in order to stabilize the water.

  Underground waters

  A comprehensive survey has been made of the underground water of South Africa and the information transferred to a series of water maps. If the mineral content of underground supplies lies within the limits of the standards, disinfection is usually sufficient to ensure that the water is potable.

  The sea

  Sea water contains such a high concentration of dissolved salts (35 000 mg/ℓ) that it cannot be consumed by humans or land-based animals as drinking water, or be used for irrigation. Elaborate and relatively expensive equipment is required to desalinate sea water in quantities sufficient to support communities of any size.

  The concentration of dissolved salts in sea water in the open seas is fairly constant. Sodium chloride is the salt present in the greatest proportion.

1.2 Sustainability of Raw Water Sources

The quality and quantity of water from any source invariably change with time. These changes can either be short-term fluctuations, seasonal, or long term.

As a water treatment plant must be designed to cater for these fluctuations it is essential that they be monitored adequately over a period of time to establish the variability of all the essential design parameters. These data are necessary for the initial concept design as well as for the detailed design stages. It speaks for itself that the monitoring programme should be devised or tailored around the ultimately required needs and final water quality irrespective of whether the source(s) is surface, underground or effluent water.

a. Quantity

Should the rate of water supply from a source not be compatible with the required demand, the source is either inadequate and has to be augmented, or its yield might have to be adapted to suit the needs of the demand, *i.e.* storage of run-off must be provided from a rainfall catchment, etc.

The inconvenience and damage that severe restrictions on water use may cause to different consumer sectors is being evaluated at present. In the interim, assurances of supplies that are regarded as appropriate for various consumers or use sectors vary from practically 100% for strategic industries, to the provision of the full long-term demand 98% of the time for domestic and normal industrial requirements.

b. Quality

As is the case for quantity, the designer must decide what provisions, if any, are to be built into a treatment scheme, and how predictable future fluctuations in quality must be addressed.

Relatively small seasonal algal blooms, for example, can be dealt with by killing off the algae in the raw water by pre-chlorination and allowing them to settle out in the clarifier. High loads of algae might, however, have to be dealt with differently, i.e. by flotation, screening, etc. If this provision is not required in the early life span of a treatment scheme, provision for future incorporation thereof can be considered.

Criteria for monitoring the quality parameters of a source are recommended in Table A.1.

Table A.1 Monitoring of Source Water Quality (adapted Van Duuren, 1997)

Application and type of monitoring	Recommended frequency	Minimum period of monitoring
1. **Health & pollution** . Bacteriological analysis . BOD, COD, NH_3, PO_4	Monthly	At least one year
2. **Aesthetic reasons** . Turbidity . Colour . Treatability	Monthly	At least one year
3. **Economical reasons** . Chemical analysis - pH / acidity - alkalinity / hardness - corrosivity - Fe, Mn - algae or chlorophyll	Monthly	At least one year

1.3 Typical Water Quality Problems in South Africa

a. Common water quality problems in South Africa

The most important water quality problem in surface water in South Africa is most likely to be faecal pollution, together with the associated disease-causing organisms. However, elevated salt concentrations (TDS, sodium and chloride) are also common in many parts of the country. In groundwater, common problems are high nitrate/nitrite and fluoride concentrations.

b. Problems in surface water

Most of the surface water in South Africa is of good quality and requires only clarification and disinfection. There are, however, a few notable exceptions:

- **Faecal pollution**
  High faecal and total coliform counts (used as indicator organisms to indicate recent faecal pollution) occur in most surface waters near dense human settlements.

- **Colour and stability**
  The rivers that drain the mountain catchments along the southern coastline have waters that are highly coloured due to organic acids. These waters have characteristically low TDS (electrical conductivity (EC)) concentrations and a low pH. Colour removal requires precise chemical dosing. This treatment, together with the stabilisation of the water, is neither cheap nor easy.

- **Salt concentrations (TDS or EC, sodium, chloride and sulphate)**
  The rivers that drain the dry interior regions carry water that may have a high

TDS concentration, mostly resulting from high sulphate and chloride concentrations. This means that the water is corrosive and has a distinctly salty taste. Salt removal by means of reverse osmosis or ion exchange is expensive, and most communities accept the water after clarification and disinfection.

The rivers that drain the northern and eastern parts of South Africa generally carry good-quality water, unless it has been contaminated due to human activity. A prime example of this is the Vaal River downstream of the Vaal Dam, which has a high TDS due to effluent from the Witwatersrand area and from the gold mines. Treatment is expensive and the consumers normally accept the high salinity.

- **Euthrophication (high algal concentrations)**
  Some reservoirs in South Africa have high algal concentrations. Water from these water bodies may have taste and odour problems. In many cases authorities have implemented treatment options such as powdered activated carbon or processes such as dissolved air flotation instead of the more conventional sedimentation in the clarification process. In some cases algae may produce toxins that are of concern to human health. Generally, however, these toxins are also removed by the above processes.

c. Problems in groundwater

The most common problems in groundwater are:

- **Salinity**
  Many groundwaters have high TDS concentrations, especially those in the drier regions of the country where the predominant geological formations are sedimentary rocks of marine origin. The Karoo shales are a prime example of this. Salinity can be removed only at high cost and by means of, for instance, reverse osmosis, electrodialysis or deionisation.

- **Fluoride**
  Fluoride concentrations in groundwater in some areas tend to be high, especially in the central and western parts of the country. In the coal-bearing regions of the country fluoride concentrations tend to be very high. Fluoride removal is expensive.

- **Sulphate and chloride**
  Water with high TDS concentrations tends to also have high sulphate concentrations. Sulphate removal is expensive (desalination or ion exchange) and normally not considered viable.

- **Calcium and magnesium**
  The groundwater in the dolomitic areas and the northern parts of the country tends to be very hard. This usually has no health implications, except where concentrations are extremely high. It does, however, lead to clogging of pipes and scaling of the elements in hot water appliances. The cost of replacement and maintenance of these appliances may make it cheaper to treat the water. For small communities, or single households, water softening by means of ion exchange is recommended. For larger communities, chemical dosing, settling and filtration will be more economical.

  It is important to note that water softening by means of ion exchange will add sodium to the water. This could prove problematic if the sodium concentration is already high.

- **Iron and/or manganese**
  Iron and manganese commonly occur in high concentrations in groundwater. Treatment for both of these problems is cheap and easy; it involves oxidation by means of aeration, or by adding chlorine.

1.4 Evaluation of Raw Water Quality

Over and above the indicative maps on surface and underground water qualities given in this annexure, the Department of Water Affairs and Forestry, through its Directorate of Hydrology and the Institute for Water Quality Studies (Roodeplaat Dam, Pretoria), monitors the quality of South Africa's surface water resources. The objectives of the national monitoring programme, which was started in the late 1960s, were essentially to provide:

- Ambient water quality data, and
- Interpretative information for water resource planning, management and pollution control.

This programme primarily focuses on inorganic chemical quality determinants such as the major ions (calcium, magnesium, sodium, potassium, sulphate, chloride, and alkalinity), pH, conductivity, fluoride and plant nutrients such as inorganic phosphorous, nitrate and ammonium. A synthesis of the data is often also synoptically presented in the form of a water quality map, giving an overall catchment perspective. These data are also processed to evaluate changes with time. Further monitoring of organic pollution and other toxic matter is being done on an *ad hoc* basis in certain catchment areas, i.e. total phosphorous, organic nitrogen and trace metals.

All these data sources are stored on the Department of Water Affairs and Forestry's Hydrological Information System's (HIS) data bank and can be accessed via the Computing Centre for Water Research (CCWR).

2. CHARACTERIZATION AND TREATMENT GUIDELINES FOR THE MAIN RAW WATER TYPES

The following paragraphs provide essential background information on the characterisation of, and treatment options for, the different main raw water types, in order to obtain Class 1 treated water (see Table 2.2).

2.1 Turbid Waters

Suspended solids that occur in raw water give it a turbid or murky appearance. These solids (usually measured as turbidity) and the appearance they cause are undesirable for aesthetic reasons. The objective of treating turbid raw water is therefore to reduce turbidity levels (clarification) so that the water appears clear, aesthetically acceptable and good enough to ensure effective disinfection.

The reduction of turbidity (or treatment of turbid raw water) always involves fine sand filtration (FSF) preceded by a variety of combinations of other unit processes. Therefore, the reduction of turbidity in medium- to very high-turbidity raw water can be divided into two main stages:

STAGE 1: Reduction of turbidity (to < 10 NTU) to protect fine sand filters from frequent clogging and ensure effective operation. This is achieved either by conventional processes such as chemical coagulation, flocculation and sedimentation, or non-conventional methods such as plain sedimentation and roughing (gravel) filtration. Some treatment at the raw water intake may be necessary for very high-turbidity raw water in order reduce the suspended load to the above processes.

The main challenge at this stage is to ensure that fine sand filters receives low-turbidity water continuously. Careful withdrawal and disposal of the sludge must be considered in this stage.

STAGE 2: Reduction of turbidity, by fine sand filters, to levels that are aesthetically acceptable and which also ensure effective disinfection. Of the different types of fine sand filters, rapid gravity sand filtration and pressure filtration are the most commonly used. Slow sand filtration is also applied where pressure filtration and rapid gravity sand filtration are applicable in Stage 1. However, if slow sand filtration is used in combination with chemical coagulation, flocculation and sedimentation, then sustainable resources/skills for their stringent operation and maintenance must be available.

In small/rural water supply systems, the reduction of turbidity in low-turbidity raw water (< 10 NTU) can be achieved by either slow sand filtration alone or by direct filtration and in-line filtration. In both cases the annual raw water turbidity variations must remain within the low limits to prevent frequent clogging of the filtration process.

Filter media cleaning is the most critical operation and maintenance activity in fine sand filtration. Hence this aspect must be carefully considered in the selection of the sand filtration process.

The types of sand filtration and its relation are shown in Figure A.1.

Figure A.1 Types of sand filtration processes

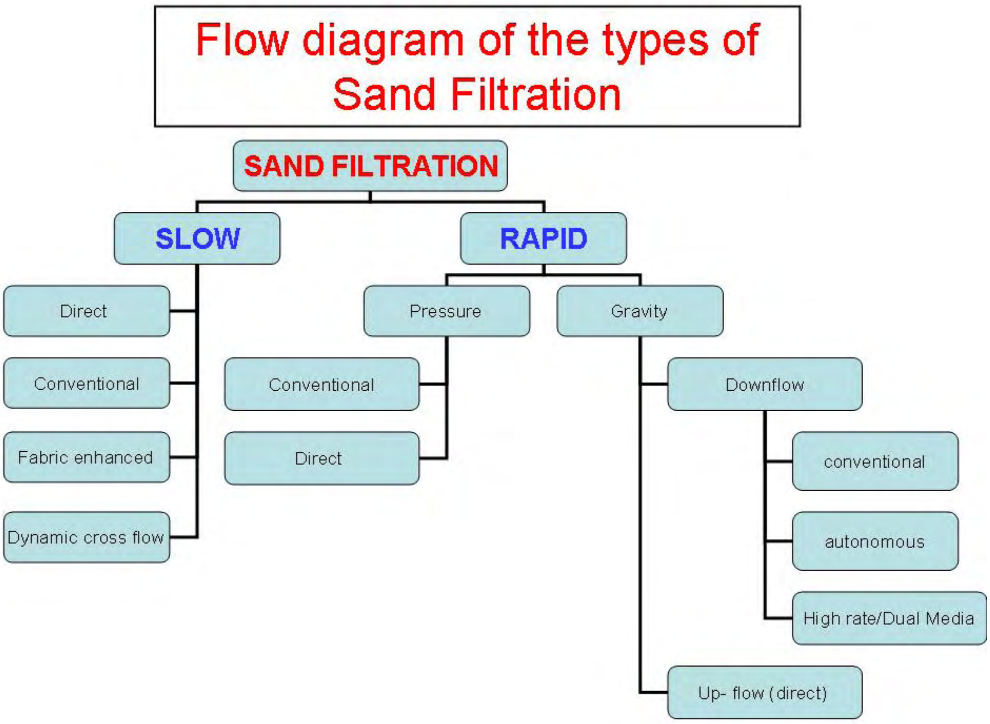


Figure A.2 Process Combinations for medium to high turbidity waters

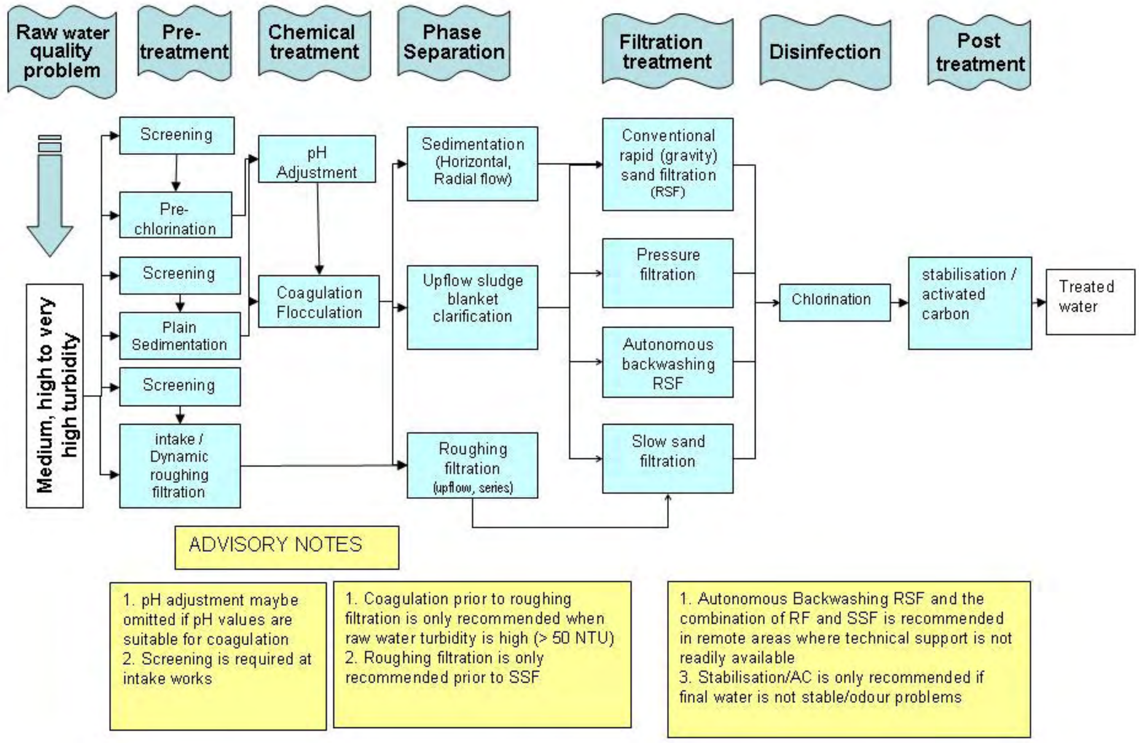
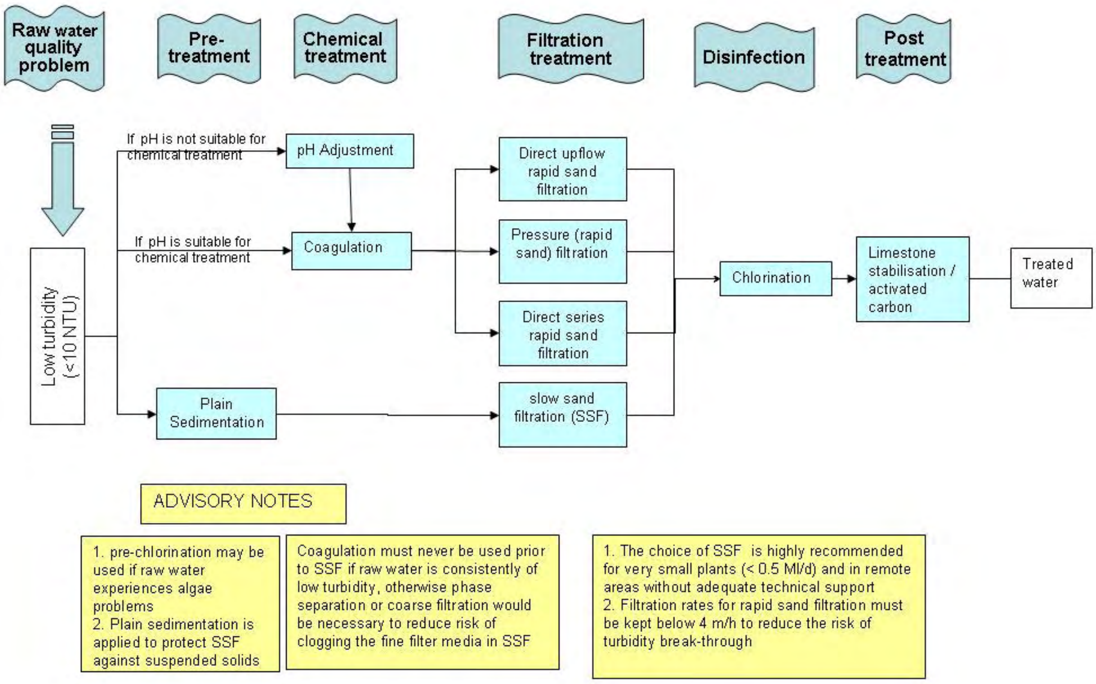


Figure A.3 Flow diagram for low turbidity waters



2.2 Coloured Water

Coloured water is defined as any natural water containing organic matter that gives it a yellow to brown colour. It therefore refers to organically coloured surface water, and excludes any coloured water arising from industrial activities.

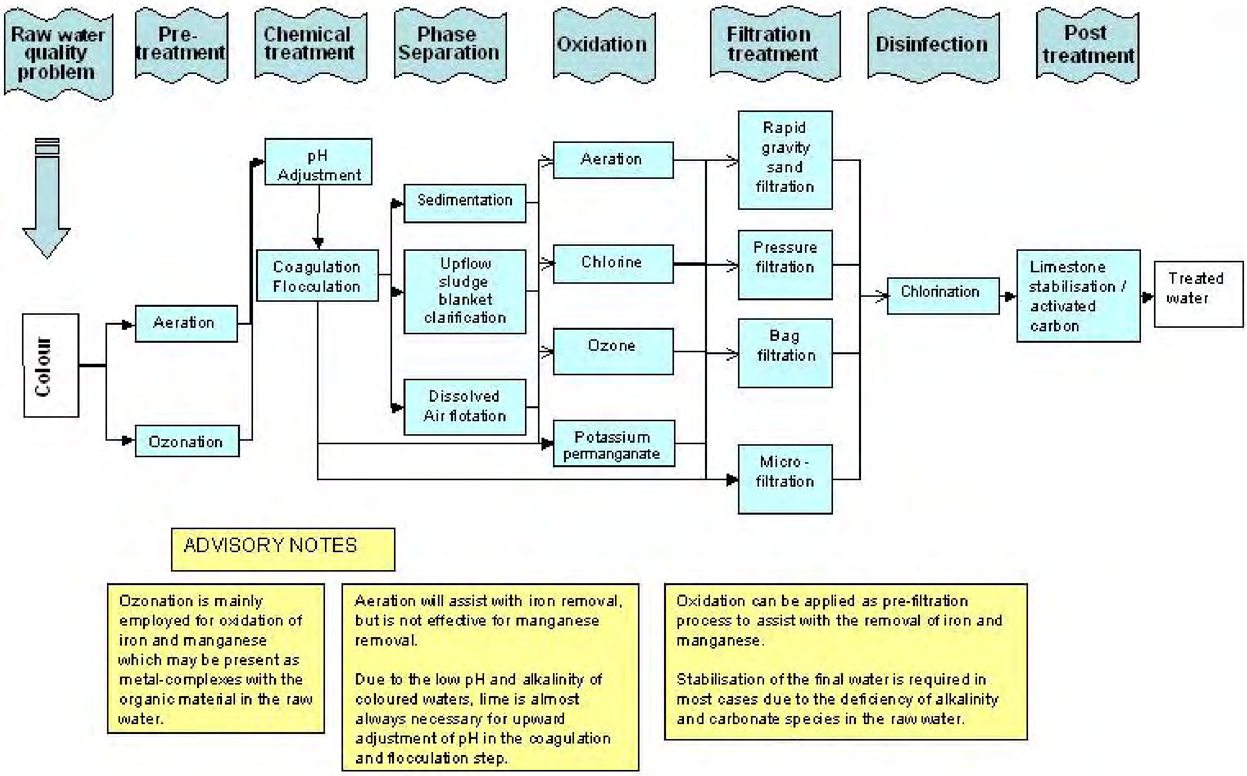
Most natural surface water contains a certain amount of organic matter. The organic matter may be grouped into humic substances and non-humic substances, the former making up the larger part. If these humic substances are present in high concentrations in the water they give rise to a yellow-brown colour (because the humic materials absorb light at short wavelengths). They are resistant to microbial degradation and have the ability to form stable, water-soluble and water-insoluble salts, as well as soluble complexes with metal ions and hydrous oxides, making them particularly difficult to remove from surface waters.

Colour, as is the case with taste, odour and turbidity, forms a primary quality parameter when water is supplied from any raw water source for human consumption. Humans consider clear and colourless water as the minimum requirement when the water is to be used for drinking purposes. This is the case regardless of whether the colour or turbidity has any health implications or not. Organic colour in water is therefore aesthetically unacceptable to the consumer.

Organically coloured waters usually have a low alkalinity and low pH, making them corrosive to metal pipes and materials, even to normally corrosion-resistant piping such as copper and galvanised pipes and fittings. The deficiency of carbonate species also makes the water aggressive and leads to increased rates of deterioration of concrete pipes and structures. Stabilisation of these waters is essential to protect the water supply network.

Organic compounds in water also serve as a nutrient source for micro-organisms, which can lead to bacterial growth in water purification plants and distribution systems. This results in deterioration of the water quality and slime formation in tanks and pipes, and also leads to biological corrosion.

Figure A.4 Flow diagram for coloured waters



2.3. Brackish Water

For raw waters with high salinity, such as seawater or brackish water, treatment processes must remove most of the dissolved salts (desalinate) in order to make the water potable (i.e. reduce the TDS to less than 1000 mg/ℓ or EC to less than 150 mS/m).

Reverse osmosis (RO) is the most common desalination (or demineralisation) technology in use for small communities. It is a pressure-driven membrane separation process capable of treating raw water with a TDS of up to 45 000 mg/ℓ at efficiencies of up to 99% (depending on the salinity). Apart from rejecting typical brackish water salts (e.g. as Na, Cl and Ca), as well as nitrates and fluorides, it is also effective for rejecting metals, microbiological compounds and organics. Other advantages of RO systems include their small space requirements and modular construction, allowing easy expansion. Disadvantages include high capital costs, pre- and post-treatment requirements and the corrosivity of the product water. Brine disposal also requires special attention.

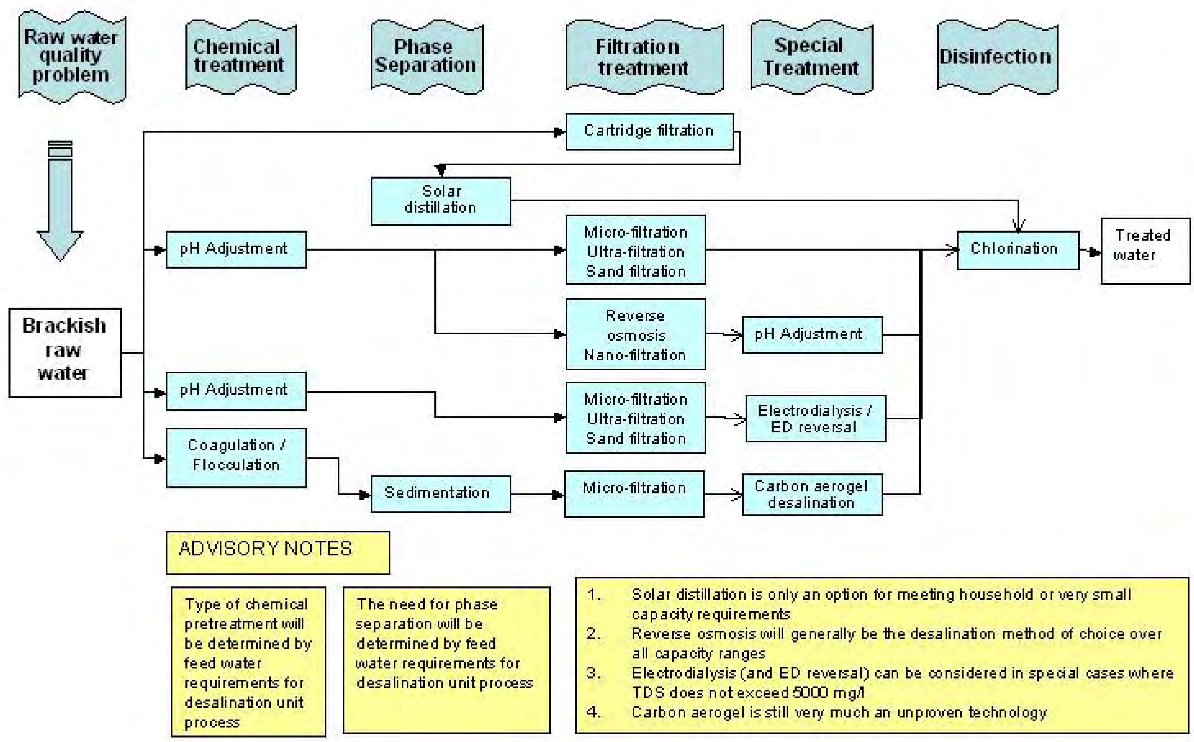
Other membrane processes that can be used for the desalination of brackish water are electrodialysis or electrodialysis reversal (ED/R). These processes can be used for the desalination of brackish water with TDS less than 10 000 mg/ℓ. The infrastructure requirements in terms of pre- and post-treatment are similar to those of RO.

Capital and running costs of membrane plants vary significantly as a result of site-specific factors such as raw water quality (e.g. dissolved solids content, pH, suspended solids, microbiological growth), brine disposal requirements and other infrastructure as determined by pre- and post-treatment requirements. Pre-treatment processes for membrane demineralisation include the removal of suspended solids and pH adjustment, in order to improve performance or/and to protect the membranes against fouling and/or clogging, e.g. through conventional pre-treatment or fine filtration, such as ultrafiltration. Post-treatment processes normally involve the pH stabilisation of the treated water to ensure that it is not overly aggressive on the distribution system, as well as chemical disinfection. Product water costs have in the past nearly always been higher for these processes than for conventional treatment processes, with ED/R being nearly always more expensive than RO under similar conditions. (The past few years, however, have seen a steady decrease in both the capital and running costs associated with RO treatment.)

Trained operating personnel and technical back-up specialists are normally essential for sustainable plant operation.

Other emerging demineralisation technologies include solar powered distillation (for very small rural communities) and carbon aerogel desalination (new technology) – see technology information sheets for more detail.

Figure A.5 Flow diagram for brackish waters



2.4 High Iron and Manganese

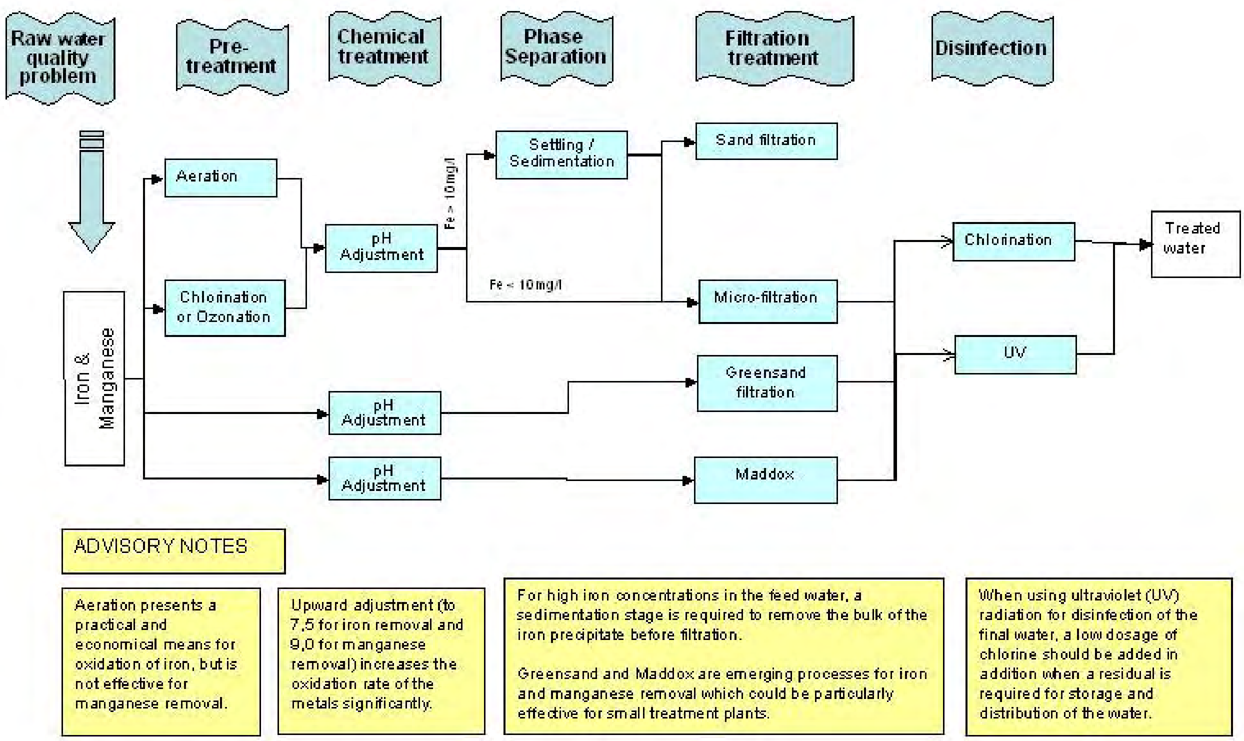
Iron and manganese sometime occur in groundwater and some polluted surface waters in relatively high concentrations. These substances are soluble and invisible and are not removed by conventional treatment processes. However, during treatment and distribution iron and manganese may be oxidised and cause problems in the distribution systems and in the home. The iron and manganese products precipitate and settle in the system and may cause discolouration of water and staining of clothes. It is therefore necessary to remove iron and manganese when they occur in higher concentrations than recommended for domestic use.

Dissolved iron and manganese occur in reduced form in some waters (*i.e.* they can be oxidised). It is therefore necessary to oxidise the iron and manganese to forms that can subsequently b precipitated and removed during filtration. Oxidation can be achieved by means of oxidants such as chlorine, ozone, potassium permanganate or air. The iron is normally precipitated as ferric hydroxide, while manganese is precipitated as the oxide.

Dissolved iron occurs as Fe^{2+} and is readily oxidised to Fe^{3+}which can be precipitated as $Fe(OH)_3$ and be removed during sedimentation and sand filtration. Iron can be oxidised by aeration of the water, but sometimes a stronger oxidant such as chlorine may be necessary when the iron occurs in complexed form.

Manganese is not readily oxidised by air and stronger oxidants are required. Potassium permanganate is an effective oxidant for the oxidation of Mn^{2+} to Mn^{4+} that precipitates as MnO_2. The sand in a sand filter that is used for the removal of iron and manganese get coated with a layer of manganese dioxide and this coated sand (green sand) assists in the removal of iron and manganese.

Figure A.6 Flow diagram for high iron and manganese waters



2.5 Hard and Soft Water

Hardness in water is caused by the presence of any polyvalent metal cation. The principle cations are: calcium, magnesium, strontium, iron and manganese, with calcium and magnesium being the most prevalent. The associated anions are normally bicarbonate, sulphate, chloride, nitrate, and silicate.

Public acceptance of hardness varies from community to community; consumer sensitivity is related to what the consumer is accustomed to. Hard water (150-300 mg/ℓ $CaCO_3$) and very hard water (> 300 mg/ℓ $CaCO_3$) result in high soap consumption and the scaling of pipelines, boilers, geysers and kettles.

Total hardness represents the sum of the multivalent metallic cations, normally considered to be only calcium and magnesium concentrations - expressed as mg/ℓ $CaCO_3$. *Carbonate hardness* is caused by cations from the dissolution of calcium and magnesium carbonate and bicarbonate in the water. Most of the alkalinity in natural water is caused by bicarbonate and carbonate ions. *Non-carbonate hardness* is equal to total hardness minus carbonate hardness, and is caused by cations of calcium and magnesium with sulphate, chloride or silicate dissolved in water.

Hard water, in terms of non-carbonate hardness, presents different problems to water that is hard, over saturated, in terms of carbonate hardness. In the former the most significant problem would be the excessive use of soap and the potential to increase the corrosivity of the water due to the presence of high sulphate and chloride concentrations. High concentrations of carbonate hardness cause scaling in pipelines and water heating devices, and may also reduce corrosivity and aggressiveness towards concrete due to protective layers.

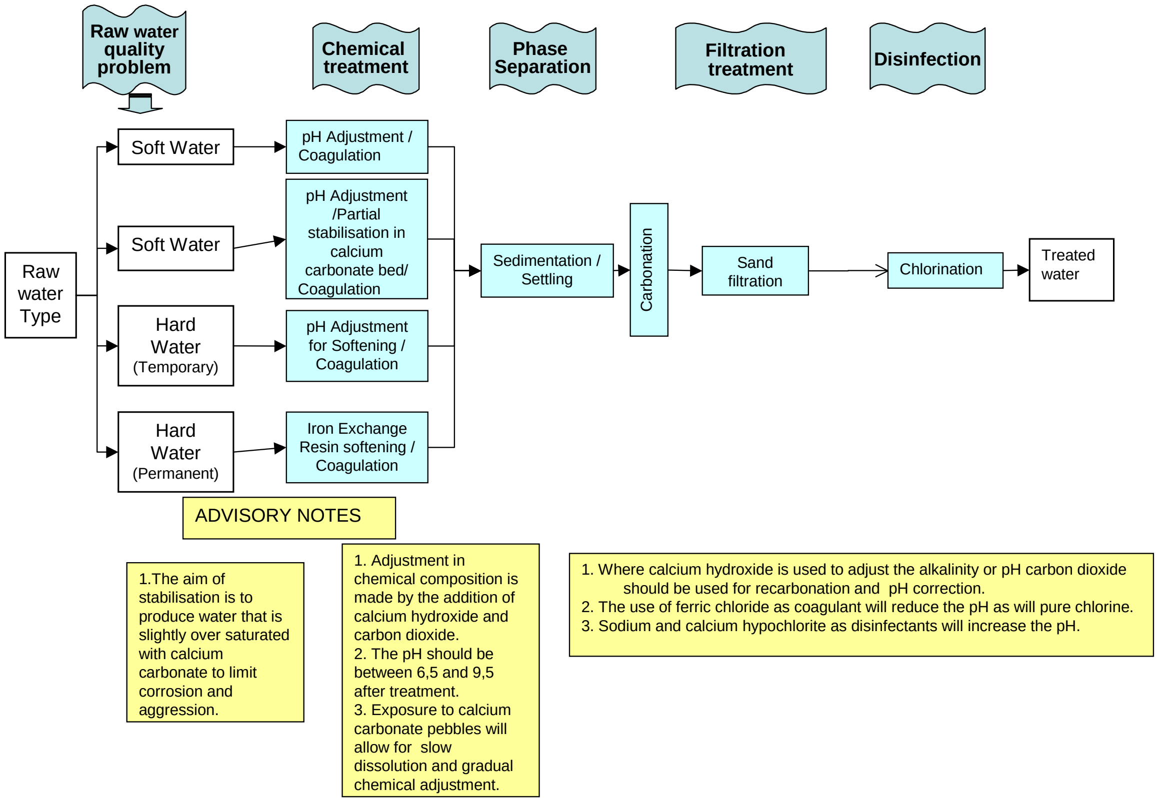
Both carbonate and non-carbonate hardness can be removed by precipitation of the calcium and/or magnesium through the addition of hydrated lime [$Ca(OH)_2$] and sodium carbonate [Na_2CO_3] (soda ash). For removal of carbonate hardness, lime is used, and for the removal of carbonate and non-carbonate hardness, lime/soda-ash softening processes may be used. High levels of carbonate hardness can also be removed effectively in calcium carbonate pellet-bed reactors by the addition of hydrated lime.

With proper pre-treatment, nanofiltration or ion exchange may also be used to reduce non-carbonate hardness.

Soft water is unsaturated in terms of carbonate hardness. It will be aggressive towards concrete and will not form a protective layer in pipelines. The concentration of dissolved carbonate hardness, or alkalinity, can be adjusted by the addition of hydrated lime to the water and the subsequent conversion of the hydroxide and carbonate to bicarbonate by the addition of carbon dioxide, to produce chemically stable water that will be neither corrosive nor aggressive or too scale-forming, by controlling the calcium carbonate precipitation potential (CCPP) to a slightly positive value.

Where no carbon dioxide is available, the aggressiveness or corrosiveness of the water can be partially stabilised by passing the water through calcium carbonate beds in which the alkalinity is increased and the very negative CCPP values are reduced to only slightly negative.

Figure A.7 Flow diagram for hard and soft waters



2.6 Microbiologically Contaminated Water

Most waters, natural or treated without any disinfection, usually have some extent of contamination that does not render the water potable. This contamination can be reduced by most filtration processes, especially by slow sand filtration, but not completely. Disinfection by chlorination is widely used to treat microbiological contamination. The disinfection applied must also be able to adequately protect the water throughout its pathways to the furthest consumer. Hence, the addition of disinfectants is necessary even for waters that are not contaminated, in order to protect the water from contamination during the distribution.

Water to be disinfected must always be clear enough in terms of turbidity levels (WHO guideline is < 1 NTU) in order to prevent disinfectants from reacting with, or being consumed by, turbidity particles to form disinfectant by-products. Where chlorination is applied, care must be taken not to overdose and impair the taste of the final water.

2.7 Eutrophic Water

The deterioration of surface water quality due the pollution from point source discharges (waste water treatment works and industrial effluent) and diffuse surface run-off (modern agriculture, industrialisation and urbanisation) has been recognised as a major global water resource concern. One of the primary effects of pollution is nutrient enrichment of receiving waters, commonly referred to as eutrophication. This results in the stimulation of an array of symptomatic changes, amongst which the increased production of algae, cyanobacteria and aquatic macrophytes, deterioration of water quality and other symptomatic changes are found to be undesirable, and interfere with water uses.

The proliferation of algae and cyanobacteria in eutrophied source water causes problems such as ineffective coagulation, flocculation and sedimentation, penetration of sand filters, clogging of sand filters, an increase in organic loading of the water and the release of taste and odour compounds, and sometimes toxic compounds.

The taste and odour problems in drinking water can, either directly or indirectly, be linked to cyanobacteria, which can produce compounds such as geosmin and 2-MIB in the spring, summer and autumn months in South Africa. It causes the drinking water to have an earthy-muddy-musty taste and odour. Although not toxic to the consumers, it tends to generate suspicion with regard to the quality and health effects of the drinking water, which leads to customer complaints and encourages consumers to seek alternative sources of drinking water.

Many cyanobacterial genera (for example *Microcystis, Anabaena, Planktothrix, Oscillatoria, Cylindrospermopsis, Nodularia*) synthesise toxins as secondary metabolites within the cells. These cyanotoxins are a diverse group of chemical compounds, which can broadly be grouped into cyclic peptides, alkaloids and lipopolysaccharides. The many reported mammalian health effects of these cyanotoxins range from being neurotoxic or hepatotoxic to inflammatory or irritants. The provisional guideline set by the World Health Organisation for microcystin–LR, which is the most toxic variant of microcystins, is 1 $\mu g/\ell$.

It is important to stress that many, if not most, of the freshwater bodies where cyanobacteria are observed in South Africa are also sources of water for drinking water purification plants. There is thus a real possibility that most of the drinking water treatments plants could be confronted by the challenges of treating source water that contains high concentrations of cyanobacteria.

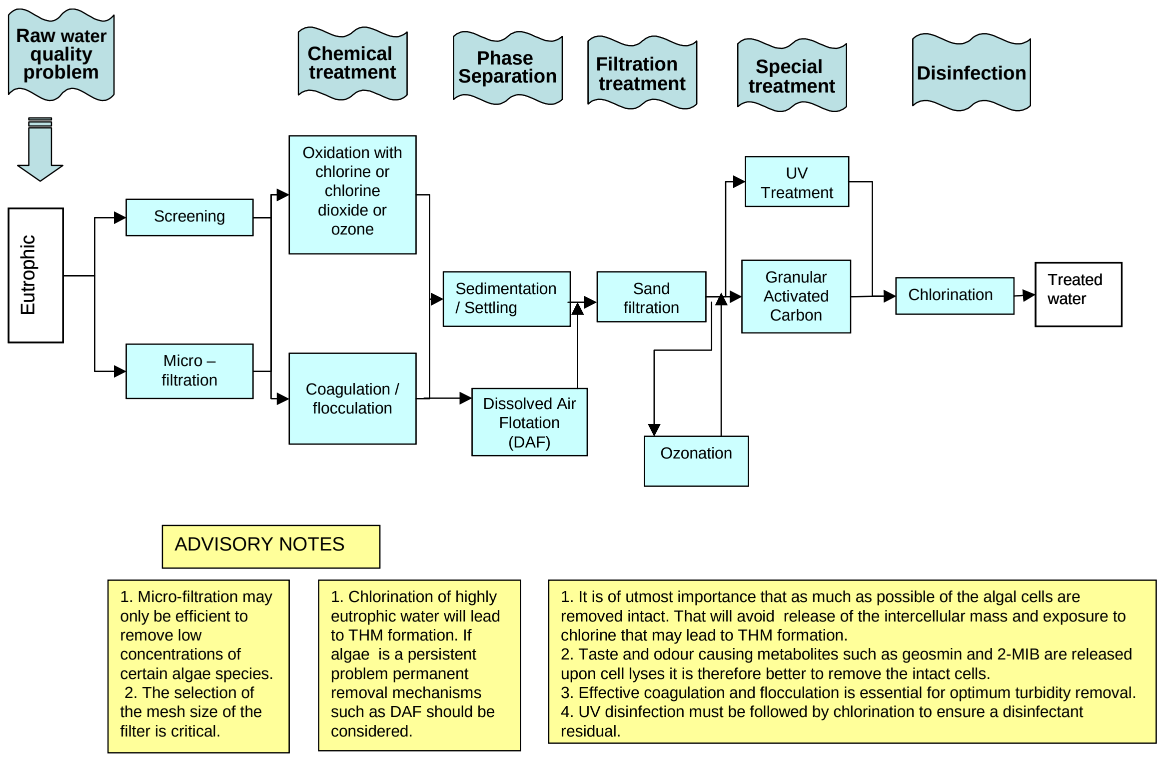
The locus of toxins, dissolved, internal, or external to the cell, is very important to decide on an effective purification process. Conventional treatment processes are not suitable for the removal of dissolved toxins or those that occur on the exterior of the cells. During the active growth phase (generally during the warmer spring and summer months) it can be expected that the toxins will be primarily located within the cyanobacteria cell (intracellular). With the onset of winter (or when an algaecide is added to the water) the cyanobacteria cells die and release the toxins so that by the end of the growing season (usually autumn and early winter) most toxins would be extracellular or dissolved in the water.

To reduce the risks of cyanotoxins in drinking water actions can broadly be grouped into those focusing on: 1) protecting the source water before abstraction, 2) abstracting the best quality source water, 3) optimising conventional treatment processes, and 4) advance treatment.

Effective methods to remove intact algal cells before releasing metabolites are coagulation, sedimentation, flotation and filtration.

Dissolved metabolites such as geosmin and algal toxins are best removed by activated carbon or destroyed by strong oxidants such as chlorine and ozone.

Figure A.8 Flow diagram for eutrophic waters



2.8 High Nitrate Water

High concentrations of nitrates in raw water can be reduced by a number of technologies. These include membrane desalination, ion exchange and biological nitrate removal (also called biodenitrification).

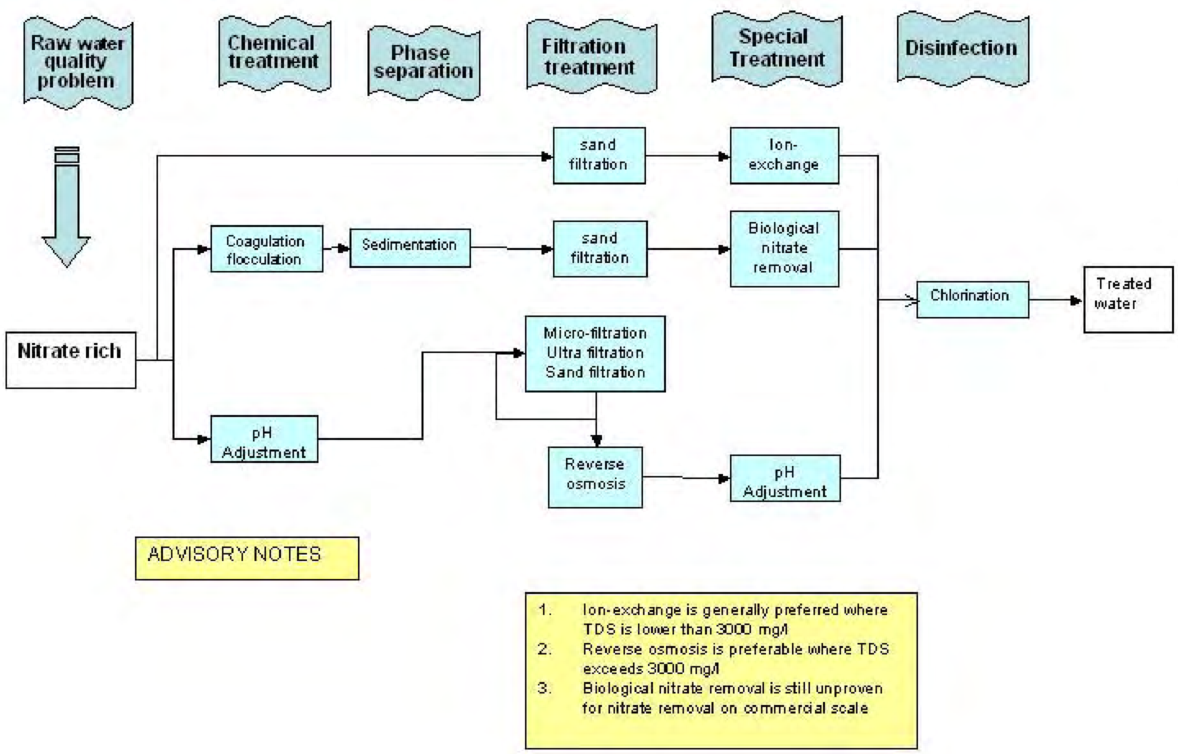
Membrane nitrate removal involves the use of pressurised reverse osmosis (RO) membranes to reduce the nitrate concentration in feed water by up to 90% (see par 2.3 for process description). The correct selection of the membranes is essential, and it is recommended that expert advice be obtained in this regard.

Ion-exchange nitrate removal employs a strong-base anion resin that exchanges chloride ions for nitrate (and sulphate) ions in the feed water. Such resins need to be regenerated to replace the chloride ions (typically with sodium chloride). Failure to frequently regenerate the resin can lead to nitrate leakage into the treated water, especially where a high sulphate concentration is present in the raw water (newer nitrate-specific resins can eliminate this problem). The backwash rate needs to be carefully controlled to prevent resin loss. It is also necessary to monitor and control the pH of the treated water, especially where the TDS is high and chlorides may be released from the resin. It is normally beneficial to soften the raw water prior to nitrate removal, while the product water may be corrosive, requiring pH adjustment before disinfection and storage. Special attention must be given to brine disposal, as it will be high in nitrates. Ion-exchange nitrate removal is effective where the TDS of the feed water is < 1500 mg/ℓ. At higher TDS levels, RO should be considered.

Nitrate removal by means of biological denitrification is an elegant solution for nitrate removal because it is transformed into gaseous nitrogen with a very high yield and low process cost. A biological denitrification plant basically comprises an injection well for adding nutrients, a biological reactor, and a pumping well for the abstraction of treated water. The process requires an adequate supply of nitrate, which serves as the oxygen source for the organic (heterotrophic) reaction, plus an energy source (often organic matter such as methanol or ethanol), plus anaerobic conditions (dissolved oxygen below 0.5 mg/ℓ). Further advantages include the generation of only small amounts of wastewater and the fact that that nitrate is not returned to the water. Biological denitrification, however, has serious drawbacks in terms of process control, while output water quality and fluctuations in product water quality can be expected. Nitrites are formed if insufficient carbon or energy is available and the substrate is in excess. Therefore, post-treatment, disinfection and oxygenation of product water are generally needed. Biological treatment is preferred for large wastewater treatment plants; it is generally not suitable for the production of potable water for smaller communities.

All nitrate removal technologies are expensive and require well-trained operators and specialised maintenance. Ion exchange and reverse osmosis may have a lower efficiency compared with biological denitrification, but they seem to be more suitable for medium and small applications. Better economics, larger automation possibilities, reduced feed concentrations, process control and no need for extensive post-treatment (as in the case of RO) are advantages of ion exchange and reverse osmosis for nitrate removal.

Figure A.9 Flow diagram for high nitrate waters



2.9 High Fluoride Water

High concentrations of fluoride in raw water can be reduced by a number of technologies. These include membrane desalination (reverse osmosis, see section 2.3 on brackish water), flocculation and adsorption.

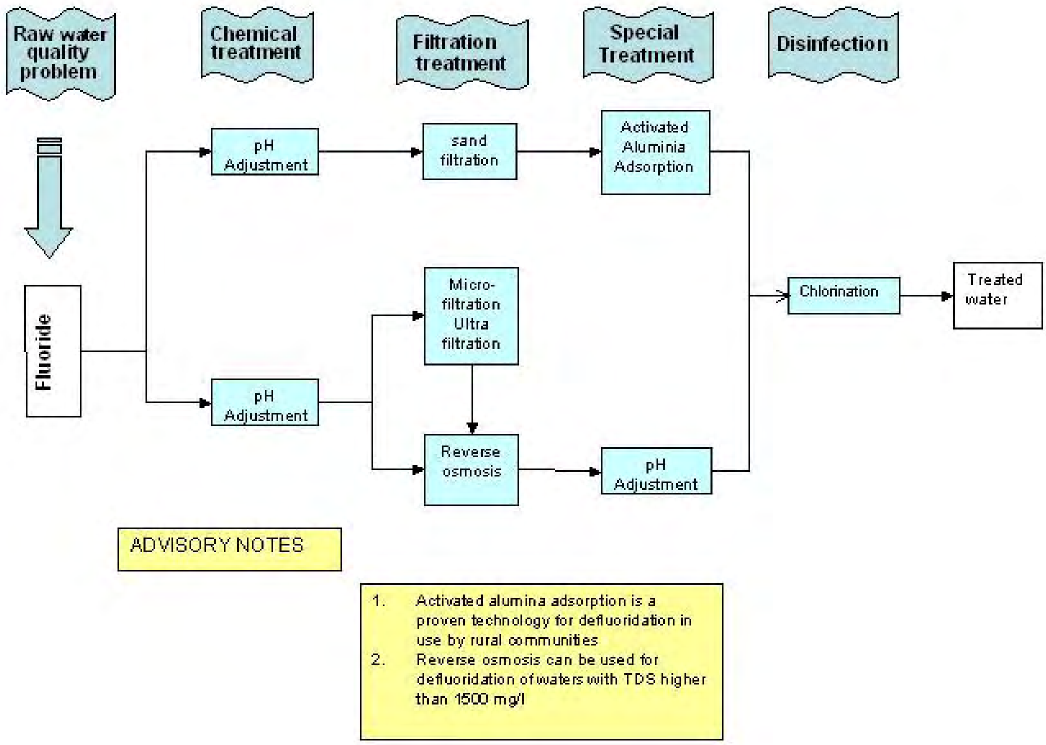
Membrane defluoridation involves the use of pressurised RO membranes to reduce the fluoride concentration in feed water by up to 90% (see par 2.3 for process description). The correct selection of membranes is essential, and it is recommended that expert advice be obtained in this regard.

The flocculation method involves the use of alum (commonly used in conventional water treatment) to flocculate fluoride ions in the raw water under alkaline conditions, normally by the addition of lime. After thorough stirring, the flocs settle to the bottom of the container or vessel, and the treated water can be removed from the top of the container. It is suitable for fluoride concentrations of 10 mg/ℓ and below, limiting its potential use for the more fluoride-rich ground waters occurring in Southern Africa.

Adsorption is more suited towards local application. It involves the downward flow of raw water through a column packed with a strong adsorbent, typically activated alumina, but activated charcoal or ion-exchange resins are also used (the latter when the fluoride concentration is less than 10 mg/ℓ). [There are different grades of activated alumina available and the suitability for defluoridation depends upon the porosity and surface area of the alumina. Other parameters, which are also of importance, include the life of the activated alumina for defluoridation purposes]. When the adsorbent becomes saturated with fluoride ions, it has to be backwashed with a mild acid or alkali solution to clean (hourly to daily) and regenerate (daily to monthly) the adsorbent. This effluent is rich in accumulated fluoride and must be disposed of carefully. Water quality monitoring is essential to ensure that breakthrough of fluoride ions into the product water does not occur. This technology can be employed on household to large scale. Pre-treatment can include the removal of suspended solids and pH adjustment, while post-treatment normally involves pH adjustment and disinfection. Activated alumina can reduce the fluoride concentration from more than 20 mg/ℓ to less than 1,5 mg/ℓ in raw water with a TDS of less than 1500 mg/ℓ. A disadvantage associated with activated alumina is the adsorption of fluoride in a specific pH range, thus requiring pre-and post-pH adjustment of water — a regeneration process that generates a concentrated fluoride solution, causing disposal problems and a reduction in adsorption efficiency of the activated alumina with an increasing number of usage-regeneration cycles. Feed water with high fluoride content (> 4 mg/ℓ) as well as high TDS (> 1500 mg/ℓ) should be treated with RO.

Economy of scale normally exists so that community-based defluoridation plants are normally cheaper per capita than the installation of household units (RO and activated alumina seem most appropriate). The technological and financial constraints of defluoridation specifically in rural areas must be kept in mind, e.g. the handling of dangerous chemicals and proper routine maintenance.

Figure A.10 Flow diagram for high fluoride waters



3. SAMPLING AND ANALYSIS REQUIREMENTS

A good understanding of what needs to be sampled, sampling frequency, approved or recommended sampling techniques, storage of samples with respect to time and care, and transportation of samples are essential prior to commissioning a sampling programme. The objectives of the sampling and analysis programme are determined by information that is required from the anticipated water quality analysis results. Such information includes:

(i) Final water quality to be achieved by a given treatment method in comparison to existing local standards

(ii) Efficiency of the treatment method

(iii) Levels of contamination in distribution systems

(iv) Impacts of the water quality on fixtures and infrastructure such as pipes, concrete reservoirs, etc.

Sampling of raw water must cover all periods or seasons in which the quality of water changes widely and comparatively.

Analysis of samples must preferably be conducted by laboratories accredited by the South African National Accreditation System (SANAS). Trained personnel can conduct in-house analysis with basic equipment for process monitoring and control purposes. It is important that analytical results can be practically interpreted and that trends are observed and recorded for easier extrapolations, as necessary.

Water treatment systems are characterised by different sampling and analysis needs. These needs will determine the operational and complexity levels (skills). Therefore, careful consideration of operation and maintenance needs to be taken in account when selecting a water treatment technology. Such considerations are determined by the number of samples, and the frequency and the level of required analyses (physical, chemical, microbiological, or combinations of these).

4. SOCIO-ECONOMIC ASPECTS

4.1 Educational Status

Adults of employable age have at least a primary school level of education. All children of primary school age are at school; in most instances age corresponds with the grade (standard). This, combined with a willingness to learn, indicates that communities can be trained, and access and communication to parents can take place via the primary schools.

a. Literacy levels and trainability

Illiteracy is more prevalent amongst older adults, i.e. senior citizens, as in this group little to no schooling is reported. For this reason, where training takes place, the levels of training, a well as the type of training materials and training aids, should be appropriate to the literacy levels of the group being trained. The focus of the training could also be varied between these groups.

Given the current low education status of communities in general, as well as an eagerness to learn and develop skills, communities can be trained, educated and made aware of aspects relating to basic aspects in health, the environment, water purification, etc.

b. Education status of women

Women's education levels usually vary from primary school to high school; in limited instances tertiary levels of education are present. Training, education and awareness of women, as family and household managers, and subsequently managers of household water supply, is recommended.

c. Training needs

In all communities a need to be educated on water issues is evident. This includes improving general knowledge on all aspects of water purification to learning how the water is piped from the raw source into the home.

4.2 Willingness to Pay

a. Operation and maintenance costs

Levels of income should be taken into account when a technology is selected, as affordability is important. In general, communities are willing to pay for water as it is a basic necessity, however the current costs of water should not escalate excessively.

b. Sophistication of technology

Some technologies do have varying degrees of sophistication. In spite of this communities express a need to know the basic operation of the plant and are willing to learn about it. If community members are aware of basic aspects regarding the plant this should limit costly tampering with the plant during interruptions. If some/one person is trained on maintaining the plant, it should further reduce it being tampered with.

c. Skills required from operators

Communities are prepared to be trained in all aspects regarding the supply of potable and palatable water to their homes. One must be aware that the skills required for operating the plant could be found within the community, based on their level of education and their diverse experiences. It most cases it is not necessary to appoint an operator from outside the community.

d. Frequency of water supplied

Frequent interruptions in the water supply system cause frustrations to households, even more so if the community is not informed about these in advance. A reliable supply with limited interruptions is also welcomed.

e. Quality of water

Communities are willing to pay for water if the quality thereof is acceptable. Any technology selected should thus adequately treat and purify water to a level that the community finds acceptable in terms of appearance, odour and palatability.

f. Level of income

The levels of income as well as those people with water payment arrears should be considered, with special regard to pensioners, the unemployed and low-income groups. When selecting a technology the current income levels as well as payment history of respective communities should be taken into account.

g. Local authority function/duty

In most communities where water payment occurs this is so because of the receipt of an account/water bill from the local authority (LA). Communities will also not pay for water if there is no evidence of water meters. Visible billing, in the form of water accounts, water meters, and readers of water meters encourages payment.

4.3 Impact of Human Activity on Water Quality

When selecting a specific technology it is important to be clear on the activities that take place in and around the entire water supply chain. Activities may impact on both the water treatment plant and water supply chain in the sense that they may damage the plant, or cause unexpected pollution. These activities may include, amongst others, domestic, mining, agricultural and industrial activities, from which emanate a variety of run-offs. The selected technology should be capable of safely and efficiently removing all hazards in such run-off, making it aesthetically acceptable to the communities who are its users.

4.4 Community Participation

Community members are often regarded as change agents and they therefore play a vital role in empowerment and development. Community participation on the other hand is a process, where members have the right to be actively part of any development that affects their lives and livelihood.

Favourable consideration has been given to the notion of local participation and more and more local authorities are actively engaging themselves in these processes. However, the following socio-economic aspects need to be considered when dealing with the aspect of community participation:

a. Process to be followed

Involving the community in certain activities does not signify participation. The processes of engagement, empowerment, participation and phasing-out need to be strictly adhered too.

Community structures vary throughout and different levels of authorities exist. In some communities one may find two-tier levels of authority while in other there are up to four.

b. Inclusiveness

Communities are eager to learn about, and be included in, any venture that takes place within their area. Communities need to be included in the programme by means of collaborative partnerships between individuals, groups, organisations and the local authority/ies.

c. Transparency

Transparency breeds trust. Communities demand that community structures, processes and the local authority maintain a high degree of openness, truth and honesty, and vice versa.

d. Public responsiveness

It must be accepted that communities do respond to what is said and done. A high degree of flexibility and open-mindedness facilitates greater responsiveness. Communities should be given the opportunity to debate and select between different options.

e. Tradition

The belief system and traditions of communities need to be respected. Common ground needs to found between tradition and new initiatives that bring about change. This identified common ground will form the basis of the change process.

f. Community perceptions and expectations

A community's expectations of water quality and how it impacts on quality of life often differ from those shared by officials. Communities tend to concentrate on tangible aspects such as colour and taste of water rather than on microbial counts. Issues such as the impact of water treatment facilities on the economic status and job creation are high on their agendas.

g. Delivery

Delivery is a critical element in the participation process. Non-delivery leads to dissatisfaction, suspicion and distrust.

4.5 Water Demand

a. Expectancy of sustainability

Community growth and activities increase the demand for water. However, quantity/provision should not be seen as meeting this demand. Water quality and the selection of the appropriate water system are crucial in ensuring usage and sustainability.

b. Present and future source

Present and future sources should not only take community growth into consideration but also the aspects of supply and reliability. Consistent water supply and plant reliability is often associated with satisfaction.

c. Projected plant and alternative

The projected plant should satisfy current and future needs. Communities also need to be made aware of and educated on activities and practices that unnecessarily increase the demand for water. The daily output should be consistent with, and reflect, the capacity of the plant. If current plants do not satisfy community's needs and expectations then suitable alternatives must be found.

4.6 Water management

There is a clear distinction between water supply management and household water management. On community level supply is often managed on organisational and/or committee level, whereas household water is managed mainly by women.

ANNEXURE B

TECHNOLOGY INFORMATION SHEETS

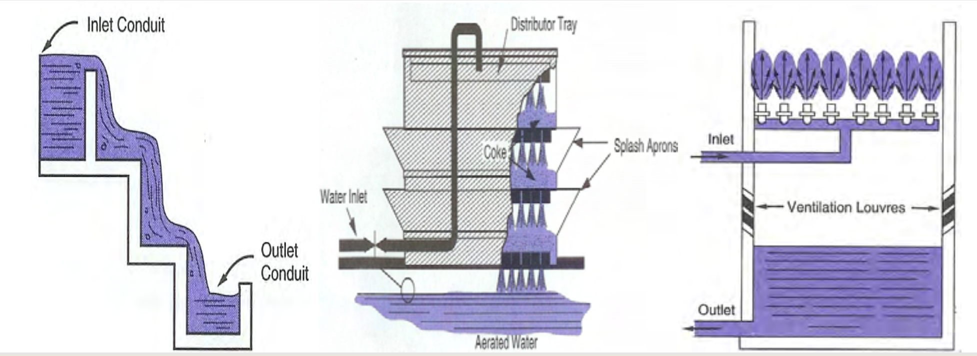
TECHNOLOGY INFORMATION SHEETS

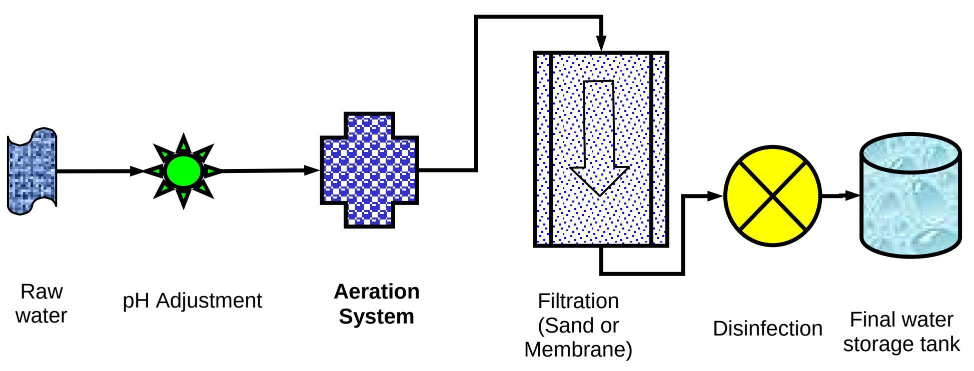
MAIN TECHNOLOGY GROUPING	TECHNOLOGY
1. OXIDATION	1-1 Aeration 1-2 Chlorination for oxidation 1-3 Ozonation for oxidation 1-4 Greensand filtration for oxidation 1-5 Potassium permanganate oxidation 1-6 Chlorine dioxide
2. CHEMICAL TREATMENT	2-1 Chemical precipitation 2-2 Limestone stabilisation 2-3 Electrocoagulation
3. PHASE SEPARATION	3-1 Conventional sedimentation 3-2 Upflow blanket sludge clarifier 3-3 High-rate settling 3-4 Batch sedimentation 3-5 Plain sedimentation 3-6 Dissolved air flotation 3-7 Floating media separator 3-8 Solar distillation
4. COARSE FILTRATION	4-1 Upflow roughing filtration 4-2 Horizontal flow roughing filtration 4-3 Intake roughing filtration
5. FINE FILTRATION	5-1 Conventional rapid gravity sand filtration 5-2 Pressure sand filtration 5-3 Conventional slow sand filtration 5-4 Direct slow sand filtration 5-5 Autonomous backwash filtration 5-6 Bag filters 5-7 Cartridge filters 5-8 Direct upflow filtration 5-9 Direct and inline filtration 5-10 High-rate sand filtration 5-11 Direct series filtration 5-12 Diatomaceous earth filtration 5-13 Fabric enhanced slow sand filtration 5-14 Dynamic cross-flow sand filtration

6. MEMBRANE FILTRATION	6-1 Microfiltration membranes 6-2 Ultrafiltration 6-3 Reverse osmosis 6-4 Immersed microfiltration 6-5 Nanofiltration 6-6 Electrodyalisis (reversal)
7. DISINFECTION	7-1 Gas chlorine 7-2 Liquid chlorine 7-3 Granular chlorine 7-4 On-site chlorine generation 7-5 Mixed oxidants (MIOX) 7-6 Solar pasteurisation 7-7 Ultraviolet disinfection 7-8 Ozonation for disinfection (see 1.3) 7-9 Chlorine dioxide (see 1.6) 7-10 Chloramination 7-11 Bromine / iodine
8. ADSORPTION	8-1 Granular activated carbon 8-2 Powder activated carbon 8-3 Activated alumina
9. ION EXCHANGE	9-1 Ion exchange softening 9-2 Ion exchange for nitrate removal 9-3 Magnetic Ion Exchange (MIEX)
10. BIOLOGICAL TREATMENT	10-1 Biological denitrification
11. DEMINERALISATION	11-1 Reverse osmosis (see 6.3) 11-2 Electrodialysis (reversal) (see 6.6) 11-3 Solar distillation (see 3.8) 11-4 Carbon Aerogel desalination
12. RADIATION	12-1 Ultraviolet radiation (see 7.7) 12-2 Solar pasteurisation (see 7.6)
13. ELECTRICAL AND MAGNETIC TREATMENT	13-1 Electrocoagulation (see 2.3) 13-2 Magnetic Ion Exchange (MIEX) (see 9.3)
14. PACKAGE PLANTS	14-1 Conventional filtration package plants 14-2 Alternative oxidation package plants 14-3 Membrane filtration package plants

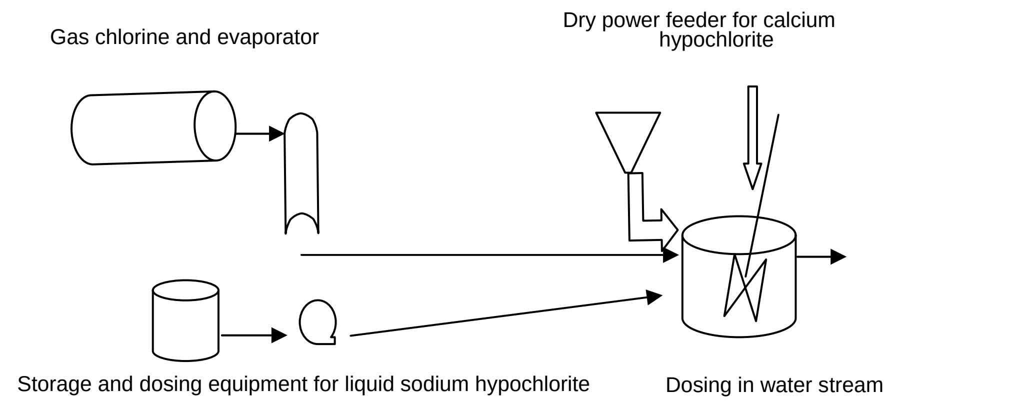
1. OXIDATION

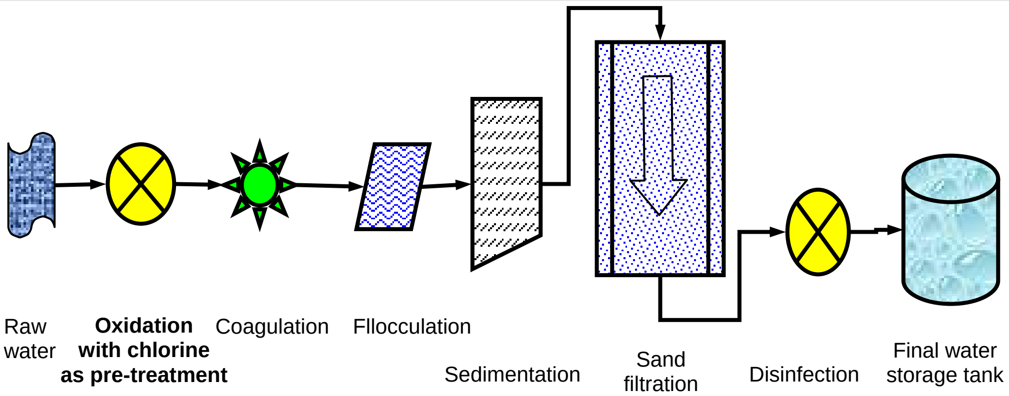
1-1 AERATION

1	**Purpose and status**	Iron removal Iron removal and stabilisation It is a proven technology
2	**Alternatives**	Chlorination Ozonation Greensand filtration
3	**Summary of key features**	Low-cost, non-chemical, simple method for oxidation of iron found in groundwater
4	**Description**	Nozzles spraying into ducts under high pressure – used effectively for iron oxidation in groundwaters Natural aeration achieved through cascading over trays or gravity flow over stone channel Raw water is aerated via fine nozzle, sprayed over filter media and limestone
5	**Technology illustration**	
6	**Performance limitations**	Aeration only effective for iron removal when pH is adjusted to 7,5 by dosage of alkali (groundwater pH normally lower than 7,5) Not effective when iron is complexed with natural organic matter (for instance in Cape coloured waters)
7	**Recommended capacity**	From household scale to 2,5 ML/day
8	**Operational requirements**	Trained operator (1 h/day) pH adjustment to pH 7,5 before aeration is important to ensure optimal oxidation of iron 8-hourly quality control is required Process can be automated
9	**Maintenance requirements**	Regular cleaning of fine openings in spray nozzles Cleaning of channels or trays
10	**Infrastructure requirements**	Power required for feed pump, dosing pump and alkali mixer Lighting required For small-scale (up to 0,25 ML/day), plastic tanks of 10 000 litre capacity can be used Only civil works required is concrete base Clean water storage required Disposal of iron precipitate required
11	**Impact of failures**	Oxidation will not take place and poor iron removal will take place, with elevated iron levels in the treated water
12	**Energy requirements**	Electricity Generator or solar power can be used
13	**Capital costs**	Capital costs are not high, and consist of provision of channels or aeration trays, or a tank, nozzles and alkali dosing equipment in the case of fine spray aeration

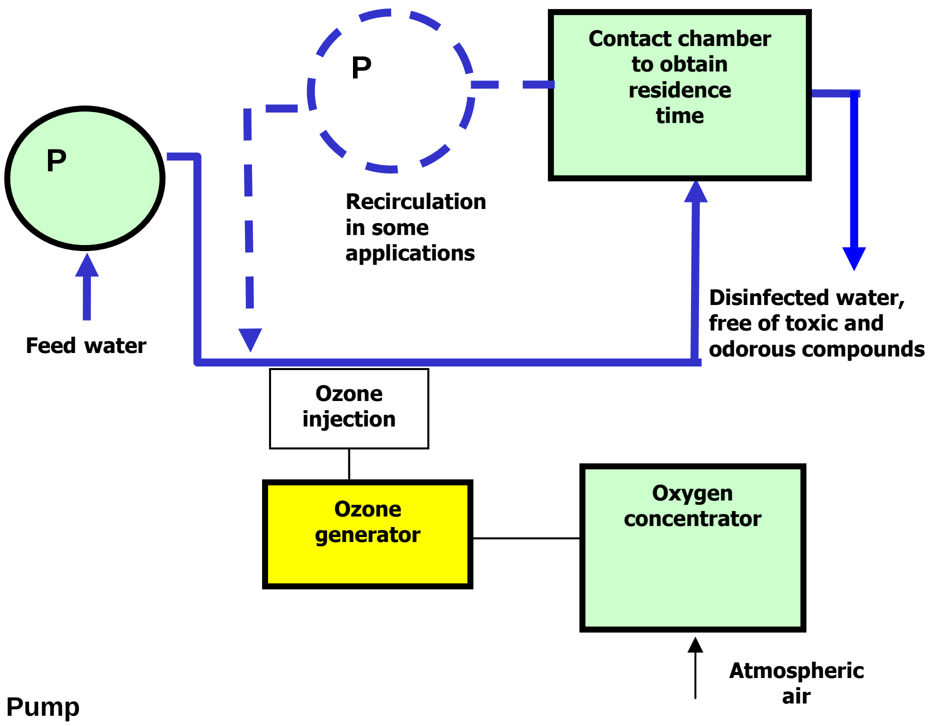
14	**Operating costs**	Operating costs are low and limited to alkali costs for pH adjustment and labour cost for daily checking of functionality of the aeration system
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Small scale plants for iron removal in the Western and Southern Cape, *e.g.* at Potberg and Buisplaas Experimental plants and a number of small-scale installations in the Western Cape
17	**Socio-economic impact**	Automated process, which requires a semi-skilled operator to visit plant once a day for an hour for cleaning and maintenance of aerating and dosing pumps Water for small-scale use must be stored hygienically and the iron precipitate disposed of effectively This low-cost plant can be effectively installed in rural communities with a water source of low iron complexity Communities to be informed of mitigating measures should the automation fail and back-up services should be accessible
18	**Research and evaluation in South Africa**	Developed and applied by CSIR Environmentek, Stellenbosch Mr Hendrik de Villiers Mr Grant Mackintosh

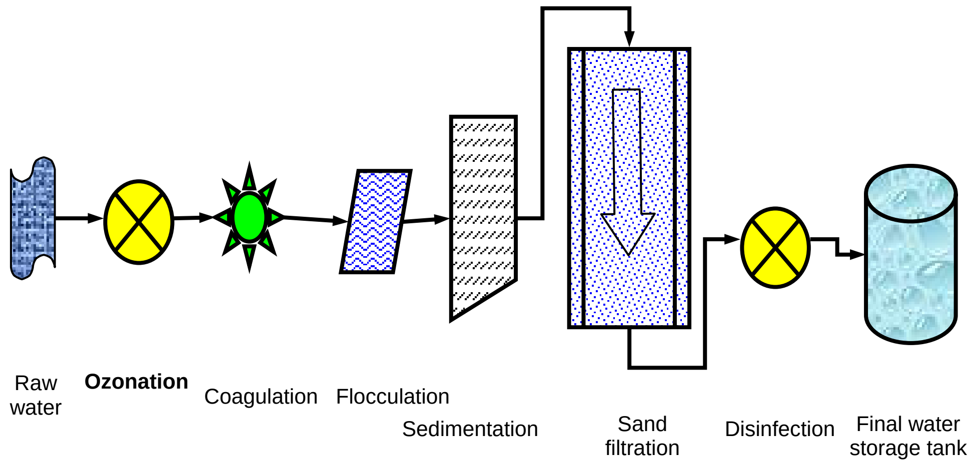
1-2 CHLORINATION FOR OXIDATION

1	**Purpose and status**	Chlorine can be used as an oxidant in eutrophic water or water contaminated with other compounds, prior to further treatment, to reduce the concentration of, or remove, undesirable algae and organic or inorganic compounds It is a proven technology: The use of chlorine as an oxidant in pre-treatment has been applied effectively for many years to inactivate problem-causing algae and remove iron and manganese through a process of oxidation, precipitation and filtration
2	**Alternatives**	Aeration Ozonation
3	**Summary of key features**	Chlorine oxidises undesirable organic compounds, algae, iron and manganese Contact time and potential trihalomethane (THM) formation are important factors
4	**Description**	The use of chlorine for oxidation will normally be the first unit process in water treatment. Its main purpose is to reduce the presence of troublesome organic compounds and algae or inorganic compounds such as iron and manganese, by oxidation. Although it is possible to apply chlorine in batch processes for the treatment of small volumes this application is more suited for continuous flow and chlorine dosage. Chlorine is available in various forms. Liquid chlorine is evaporated upon release from pressurised cylinders, in well-designed dosing equipment. The chlorine gas is then mixed with feed water to produce hypochlorous acid. Calcium hypochlorite [$Ca(HOCl)_2$] may be added as a dry powder or dissolved before addition and a sodium hypochlorite [NaHOCl] solution, with a concentration of about 11% mass per volume.
5	**Technology illustration**	
6	**Performance limitations**	The oxidation of organic-rich eutrophic water with chlorine may result in the formation of oxidation by-products such as trihalomethanes (THMs) such that the drinking water limits are exceeded. If the concentration of the contaminants, including iron and manganese, is too high be oxidised cost effectively by chlorine, or the THM concentration of the treated water exceeds the required standards or criteria, it may be advisable to use a stronger oxidant such as ozone, or combinations of ozone and other oxidants.
7	**Recommended capacity**	Can be used for all plant sizes: gas chlorination most economical in medium to larger plants Household scale < 1 m^3/d (use household bleach) Very small 1 - 10 m^3/d (use sodium or calcium hypochlorite) Small 10 - 500 m^3/d (use sodium or calcium hypochlorite) Medium 0,5 - 2,5 ML/d (use sodium or calcium hypochlorite) Large > 2,5 ML/d (use gas chlorine) Ease of expansion: easy if modular, difficult if conventional
8	**Operational requirements**	Process fully automated Trained operator required Operator input: 2 man-hours required per day/ hourly monitoring of quality control Chemical dosage required Alternative chemicals can be used Materials / chemicals for operation readily available

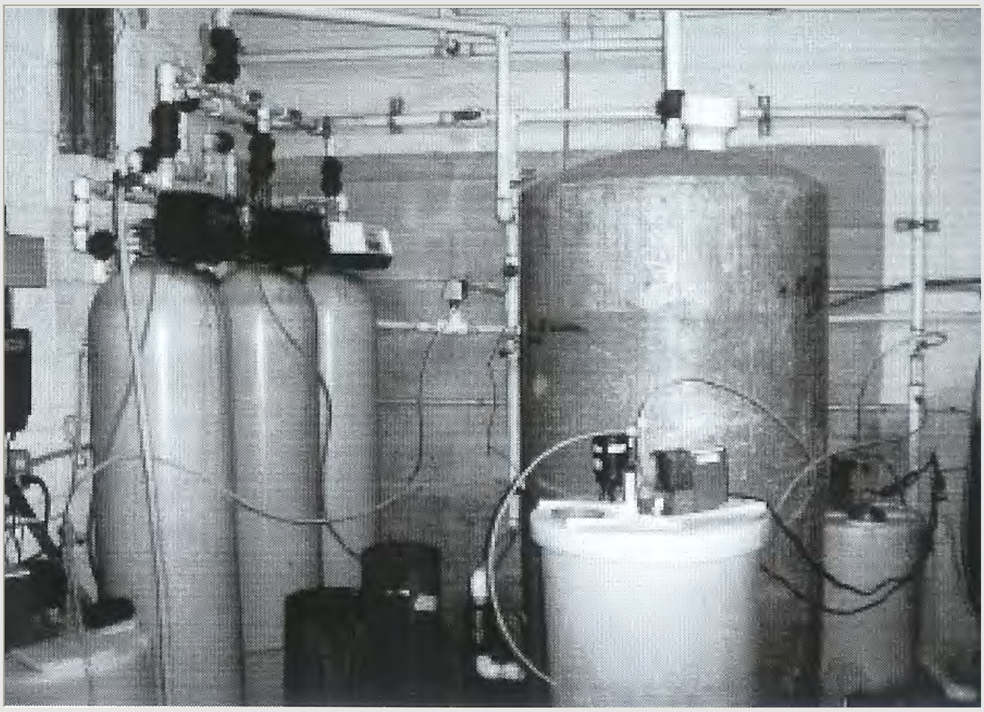
9	**Maintenance requirements**	Process fully automated Trained operator required Operator input: 2 man-hours required per day Chemical dosage required Alternative chemicals can be used Hourly monitoring of quality control required Materials / chemicals for operation readily available
10	**Infrastructure requirements**	While good ventilation is required for all chlorine dosing installations, it is essential for lgas chlorine installations Corrosive resistant materials must be used for chlorine installations
11	**Impact of failures**	When chlorination is interrupted, the water will not be disinfected and there will be a risk of infection to the user
12	**Energy requirements**	The energy requirements are a function of the chlorine compound to be used and the level of sophistication and automation of the plant. Chlorine equipment can be driven by hydraulic means that will dose the compound in proportion to the water flow, or by the pressurised chlorine in cylinders.
13	**Capital costs**	The capital cost of chlorination installations is a function of the chlorine compound to be used, dosing capacity of the plant, and the level of sophistication and automation of the plant. The cost of chlorination equipment will be similar to that of chemical dosing plant. Dosing equipment for gas chlorine is more expensive than for calcium hypochlorite (solid) or sodium hypochlorite (liquid) products.
14	**Operating costs**	Operating cost of chlorination is affected by the cost of the product and maintenance costs. In general, the direct cost of liquid chlorine is cheaper than the use of calcium or sodium hypochlorite products (per mass of chlorine used). Maintenance costs for the more sophisticated equipment are higher and such equipment requires more frequent maintenance and replacements.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Used in small water treatment plants where problems are experienced with eutrophic waters and waters containing iron and manganese
17	**Socio-economic aspects**	Community acceptance and willingness to operate and maintain oxidation by chlorination is high since it can be proved that chlorination improves water quality — it reduces taste and odour causing compounds, and enhances the removal of iron and manganese that are aesthetical unattractive. Good ventilation and corrosive resistant materials must be used.
18	**Research and evaluation in South Africa**	Rand Water Umgeni Water

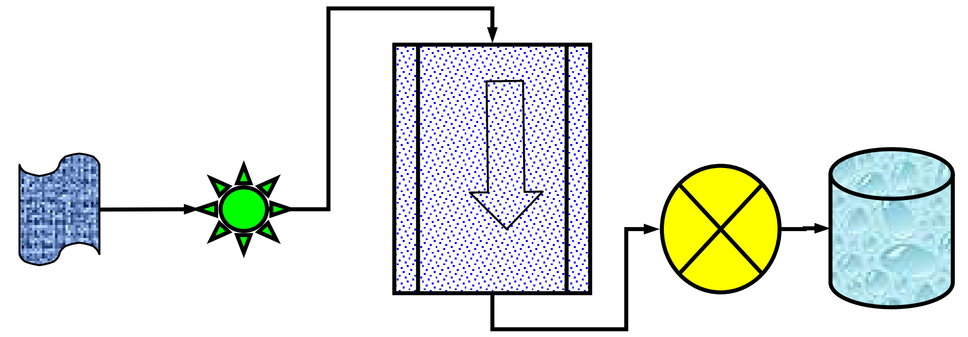
1-3 OZONATION FOR OXIDATION

1	**Purpose and status**	Application of ozone falls into two main categories: Disinfection and Oxidation. Ozone is used as highly effective disinfectant against bacteria, viruses, protozoa and fungi. Ozone destroys (oxidises) toxic organic compounds in water, a.o. pesticides, chemical waste, algal toxins (e.g.microsytine), as well as tastes and odours, iron and manganese. Ozone is a well-proven technology. Traditionally ozone was perceived as expensive, inaccessible and high technology. Current developments in South Africa can change this perception.
2	**Alternatives**	Chlorination
3	**Summary of key features**	Ozone is the most effective disinfectant agent known, disinfecting up to 1000 times more effectively than chlorine. Ozone does not leave chemical residues in water, and is environmentally friendly. Ozone removes odours, tastes and toxic compounds.
4	**Description**	The heart of the ozone system is the ozone generator, generating ozone gas from oxygen or air. Usable quantities of ozone can only be economically produced by corona discharge methods. Oxygen is supplied on site by an oxygen concentrator as part of a complete ozone system. A complete ozone system also includes an ozone injection unit to dissolve ozone in water. This may take the form of venturi injection and mixing, or bubble diffusor columns can be employed (less efficient). A contacting vessel to allow time for disinfection follows injection. Properly designed injection systems provide efficient oxidation. Ozonation systems should be designed for the specific application to ensure adequate ozone dosing. This depends on the water quality. Integral design of all components of the ozone system is essential to optimise the benefits of ozone.
5	**Technology Illustration**	 **P: Pump**
6	**Performance limitations**	Ozone is ineffective against most inorganic compounds, and organic pollutants that are not oxidisable. Ozone is unstable and does not remain in water for extended periods, therefore it does not provide longer term residual disinfection.
7	**Suitable capacity application**	10 kL/day to 5 ML/day

8	**Operation requirements**	No operator required. System starts and stops with main driving pump, and has in-built interlocks to prevent damage in case of failed operational parameters. No chemical dosing is required.
9	**Maintenance requirements**	Very low maintenance required. Only mechanical parts (seals) of pumps and compressor (oxygen concentrator) have to be replaced periodically as per manufacturer specifications (typically annually). Other unit processes used in combination with ozone e.g. sandfiltration or GAC will require backwashing.
10	**Infrastructure requirements**	Electricity supply is required, ranging from single phase 1 kW (10 kL/day) to three phase 10 kW supply. Equipment housing is required.
11	**Impact of Failures**	Ozone generators are designed in modular fashion, e.g. the ozone capacity of a system is derived from three generator modules. Failure of one leaves 66 % redundancy. Local manufacturer ensures fast replacement and inexpensive spares.
12	**Energy requirements**	Electricity supply as per section 10
13	**Capital cost**	Varies from R3-20/kL to R1-00/kL depending on size
14	**Operating cost**	Electricity cost as per 10 above Pump and compressor maintenance GAC replacement after 12 to 18 months
15	**Typical treatment process configuration (train) or example**	
16	**Examples of installations**	Magaliespark Resort (Hartbeespoort Dam)
17	**Socio-economic aspects**	Ozonation does not present some of the hazards of handling chlorination chemicals, but provision should be made for handling off-gases. Trained operators are required for monitoring and maintenance of ozone systems.
18	**Research and evaluation in South Africa**	WRC Report No. 1127/1/04 PURION Pty (Ltd) Dr Rian Strydom Umgeni Water

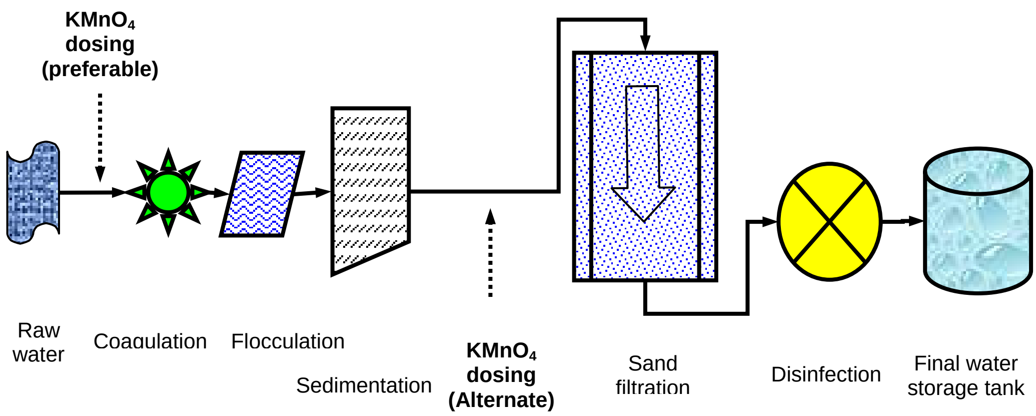
1-4 GREENSAND FILTRATION FOR OXIDATION

1	**Purpose and status**	Greensand can remove manganese and low levels of hydrogen sulphide It is a proven technology
2	**Alternatives**	Aeration and sand filtration Chlorination and sand filtration
3	**Summary of key features**	Potassium permanganate produces manganese dioxide on the surface of the medium and, once the water comes in contact with it, any iron is immediately oxidised. Synthetic greensand is a granular mineral with a manganese dioxide coating having the same ability as regular greensand. It is much lighter and requires a lower backwash rate than standard greensand.
4	**Description**	Naturally washed grains of glauconite are washed and classified to produce a filter medium with an effective size of 0,30-0,35 mm. It is then it is stabilised and coated with manganese oxide. This coating provides the glauconite with its special chemical oxidation-reduction properties for the removal of iron and manganese, and small quantities of hydrogen sulphide. The greensand is regenerated with potassium permanganate. The regeneration can be done either continuously or intermittently. Continuous regeneration is used in cases where iron in the raw water is the main problem, while intermittent regeneration is used where manganese is the main problem.
5	**Technology illustration**	
6	**Performance limitations**	Generally not feasible on very large scale. Requires the availability of potassium permanganate on site. Not effective for high manganese concentrations.
7	**Recommended capacity**	Greensand filters can be used effectively in small-scale applications, where pressure vessels are used to house them.
8	**Operational requirements**	Semi-trained operators are required to operate filtration and carry out backwashing when pre-determined head-loss is reached Regeneration with potassium permanganate must also be controlled Availability of potassium permanganate is critical for regeneration Electrical breakdowns must be minimal The system can be automated
9	**Maintenance requirements**	Spare parts for dosing pumps must be readily available No special expertise or materials are required Maintenance costs are comparable with conventional pressure filtration plants
10	**Infrastructure requirements**	A building is required to house the greensand filters, make-up tanks and dosing pumps

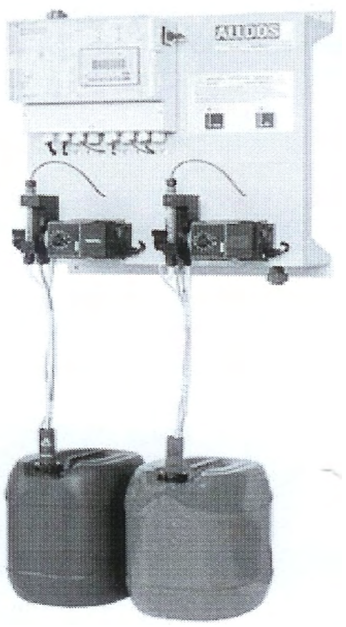
11	**Impact of failures**	Elevated iron and/or manganese levels in the filtered water can be the result of insufficient oxidation of the reduced iron or manganese, ineffective filtration through the filter media, or breakthrough as a result of too long filter runs
12	**Energy requirements**	Electricity is required for filter pumps and dosing pumps, but renewable energy may also be used
13	**Capital costs**	The capital costs are moderate, comprising pressure filtration systems and dosing pump for dosing of potassium permanganate.
14	**Operating costs**	Potassium permanganate is expensive, but at the relative low dosages required for iron removal application it is competitive with other oxidation technologies.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Graafwater
17	**Socio-economic impact**	Semi-skilled operation required Critical elements such as spare parts and potassium permanganate must always be available Electrical breakdowns must be minimal
18	**Research and evaluation in South Africa**	No specific research done on greensand filtration.

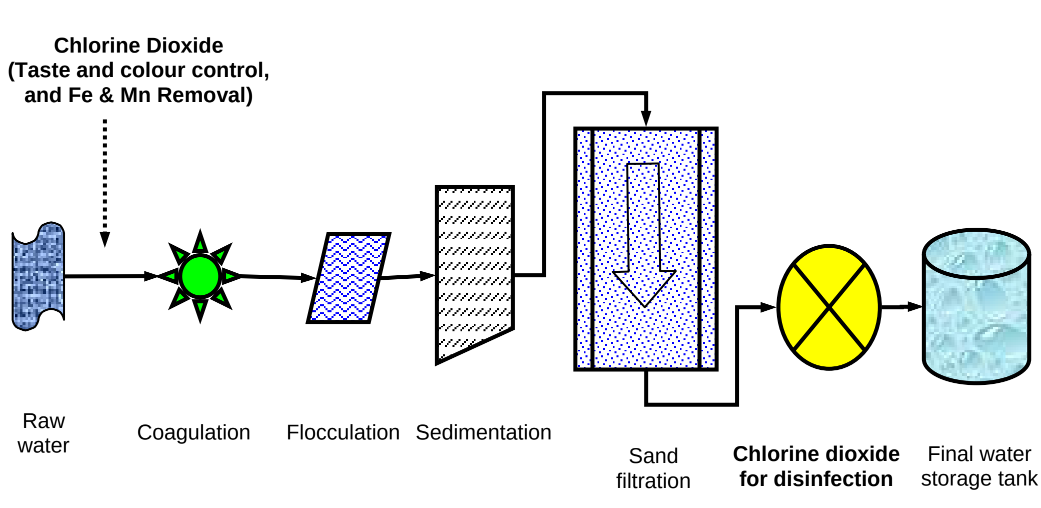
1-5 POTASSIUM PERMANGANATE OXIDATION

1	**Purpose and status**	Potassium permanganate ($KMnO_4$) is a strong oxidant, used in combination with other technologies for iron and manganese removal, control of taste and odours, and control of biological growth in treatment plants It is proven technology
2	**Alternatives**	Chlorine Ozone
3	**Summary of key features**	An aqueous solution of potassium permanganate has a characteristic purple to pink colour. It is used primarily to help control iron, manganese and sulphides in groundwater. It is also used in conjunction with manganese-treated greens and to reduce high concentrations of arsenic. Potassium permanganate is applied to surface water primarily to treat taste and odour, and manganese and trihalomethane problems.
4	**Description**	$KMnO_4$ is a strong oxidising agent that has the ability to add oxygen, remove hydrogen, or remove electrons from an element or compound. It is made up of one manganese atom surrounded by four oxygen atoms. Potassium permanganate is dosed as a liquid either before, or together with, the coagulation step, or before filtration.
5	**Technology illustration**	
6	**Performance limitations**	Although potassium permanganate has many potential uses as an oxidant, it is a poor disinfectant. Water will require chlorine addition after permanganate dosage
7	**Recommended capacity**	$KMnO_4$ can be used in capacities ranging from small plants to large treatment facilities In large treatment facilities it is mostly used for pre-treatment/pre-oxidation/organics removal, while in small water treatment plants it is mostly used for iron and manganese removal
8	**Operational requirements**	Normal dosing requirements are applicable for dosing potassium permanganate Because it is a strong oxidising agent, care must be taken when handling the product
9	**Maintenance requirements**	Normal maintenance requirements for chemical dosing systems apply

10	**Infrastructure requirements**	Proper storage of potassium permanganate is required because it is considered a 'hazardous chemical'. It can react with certain reducing agents and generate heat.
11	**Impact of failures**	Over- or under-dosing of $KMnO_4$ will have a negative effect on the quality of the final water, especially the manganese and/or iron levels, leading to customer complaints, but it will not impede the operation of the plant.
12	**Energy requirements**	Electricity is required for operation of the dosing pump
13	**Capital costs**	Similar to capital costs associated with dosing systems dosing corrosive chemicals
14	**Operating costs**	Potassium permanganate is expensive, but at the low doses required in water treatment applications it is competitive with other oxidation technologies
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	George Water treatment works, Midvaal Water (has since discontinued the use of potassium permanganate).
17	**Socio-economic impact**	Potassium permanganate has a strong oxidation potential and must be handled with care. It is preferably used as a pre-treatment method, as the sterilising ability cannot be trusted for all types of waters. Must be handled as a hazardous material, due to its reactive and heating potential.
18	**Research and evaluation in South Africa**	No specific research done on potassium permanganate.

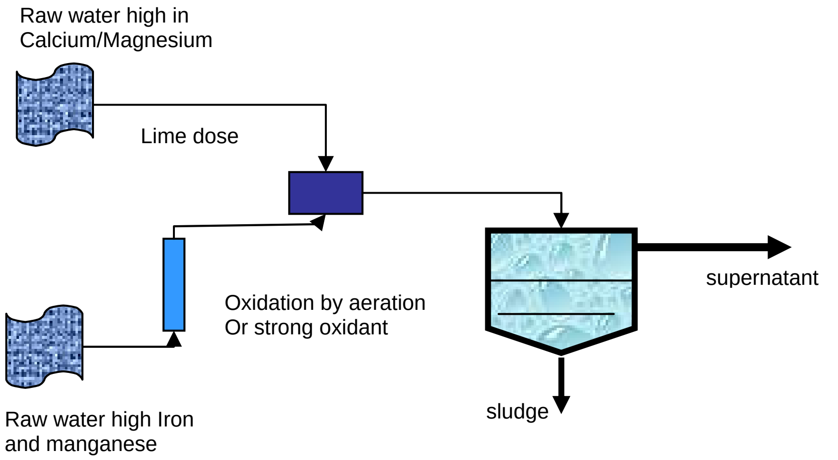
1-6 CHLORINE DIOXIDE

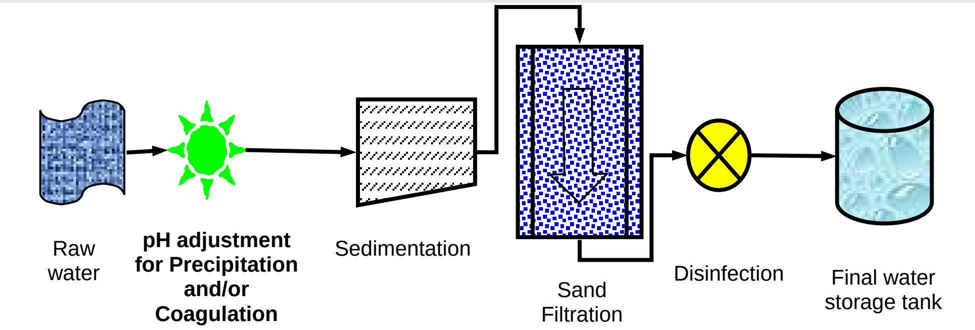
1	**Purpose and status**	Chlorine dioxide can be used as a disinfectant in water treatment, but also as an oxidant to oxidise reduced iron, manganese and sulphur compounds, and certain odour causing organic substances in water. Chlorine dioxide is a potent bactericide. It is a proven technology.
2	**Alternatives**	Chlorine Ozone
3	**Summary of key features**	Unlike chlorine, chlorine dioxide will not chlorinate organic compounds and will therefore not react with natural organic matter (NOM) in raw water to form trihalomethanes (THMs) or other chlorinated by-products. Not affected in pH range 6-10. Forms an active residual.
4	**Description**	Chlorine dioxide is produced by the following reactions: a) sodium chlorite with either chlorine gas, hydrochloric acid or molecular chlorine gas manufactured in-situ with sodium hypochlorite and dilute hydrochloric acid b) sodium chlorate with catalytic amounts of hydrogen peroxide and sulphuric acid. The yields of the above reactions vary from 80% to 100%. The chlorite or chlorate is completely converted to chlorine dioxide.
5	**Technology illustration**	
6	**Performance limitations**	The maximum concentration of chlorine dioxide that can be used will be a function of the maximum permissible concentration of chlorite in the water. In the USA the limitation is 1.4 ppm of chlorine dioxide + chlorite + chlorate. Chlorine dioxide (chlorite) can be readily measured by the DPD method (currently in use in the water treatment industry in SA).
7	**Recommended capacity**	To date, chlorine dioxide treatment installations have generally been medium-sized to large-scale but now small-scale applications are also catered for through the supply of off-site generated chlorine dioxide, available in liquid form. Capacities of chlorine dioxide generators range from 10 g/h to 2 tons/h. Hence, there are chlorine dioxide generators suitable for small water treatment systems to systems meeting the needs of Rand Water.
8	**Operational requirements**	All chlorine dioxide generators require 220 V / 15 amp electricity feed and 10 l/h to 5000 l/hr potable water quality. The footprint varies in size from 1 m x 1 m to 4 m x 4 m, depending upon the flow rate of the water plant to treat. The entire area needs to be bunded because of the handling of hazardous precursor chemicals used in the generation process.
9	**Maintenance requirements**	Annual refurbishment of pumps, replacement of seals and checking of dosing lines is required.

10	**Infrastructure requirements**	Storage requirements for feed chemicals require special attention, as sodium chlorite is explosive under certain conditions. Delivery of the precursor chemicals to plants will either be in drums (25 L to 200 L) or IBC bin (1000 L). The entire area needs to be bunded and preferably with a roof over the generator.
11	**Impact of failures**	When generated on-site, availability of sodium chlorite and chlorine or sulphuric acid is necessary. Power-breaks will result in interruption of the generation of chlorine dioxide. Explosions of generators well have an extremely low risk on shutdown. The major risk is during operation if water or one of the chemicals is missing.
12	**Energy requirements**	Normal electricity required when chlorine dioxide is generated on-site. If pre-generated, electricity only required for dosing of the chlorine dioxide.
13	**Capital costs**	Capital costs for dosing chlorine dioxide is not high when using pre-generated chemical delivered to site (for small applications). If chlorine dioxide is generated on site (larger applications), then capital costs can be moderate to high.
14	**Operating costs**	Typically the operating costs for chlorine dioxide are in the range of 10-25 cents per cubic meter, depending upon the application and flow rates. The disinfection cost is as given, whilst the cost of the reduction of Fe or Mn would be of the order of 2-5 cents per cubic meter.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	There are no current applications in SA in which chlorine dioxide is used for potable water disinfection.
17	**Socio-economic impact**	Chlorine dioxide has the potential to be used as a disinfectant and an oxidant. It must be treated as a hazardous substance; it has explosive potential under certain conditions. Caution should be exercised when making such selection. Community acceptance will be critical.
18	**Research and evaluation in South Africa**	Rand Water Midvaal

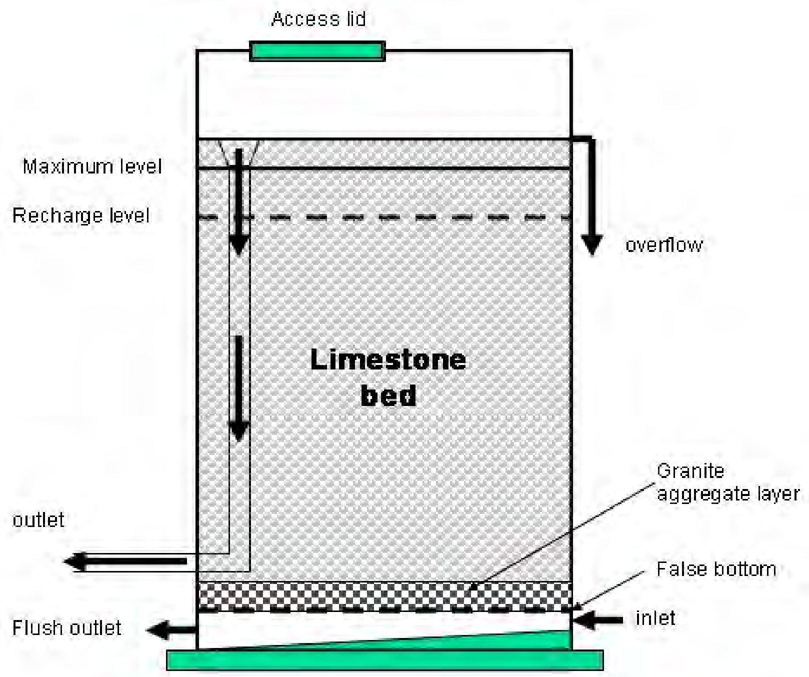
2. CHEMICAL TREATMENT

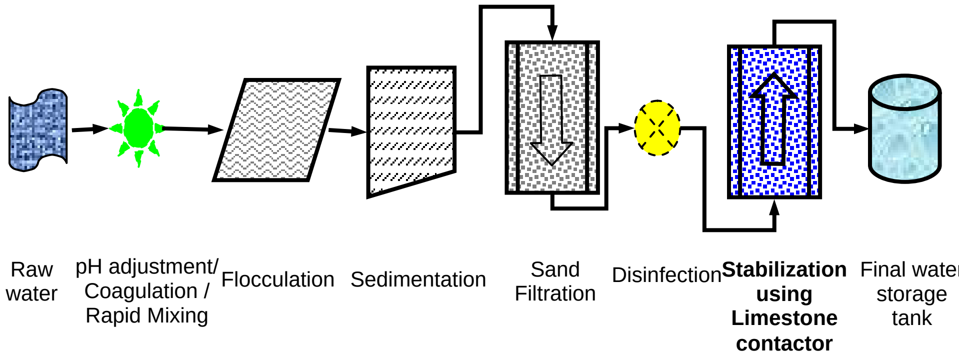
2-1 CHEMICAL PRECIPITATION

1	**Purpose and status**	Chemical precipitation in water treatment can be used to reduce the concentration of calcium and magnesium compounds to reduce hardness, heavy metals such as iron and manganese, radionuclides and organic compounds. ***<u>Proven Technology</u>***: Precipitation of contaminants is an effective process and has been used with great success for many years.
2	**Alternatives**	Ion-exchange softening; oxidation
3	**Summary of key features**	Precipitation for softening removes calcium and magnesium compounds that are responsible for water hardness as well as heavy metals. Softening improves taste and reduces scale formation and detergent consumption.
4	**Description**	Chemical precipitation is one the most commonly used processes in water treatment to reduce the concentration of undesirable inorganic and organic compounds present in the aqueous phase. No compound is totally insoluble. Therefore every compound can be made to form a saturated solution by manipulating the physical and chemical conditions of the solution. In water treatment it involves mostly chemical the conditions such as the pH or the oxidation / reduction potential of the water. The latter is changed by the addition of an oxidant such as chlorine or aeration. Once a saturated solution has been formed it is possible for the particular sparingly soluble compound to precipitate. Precipitation formation is both a physical and chemical process. The physical part comprises two phases: nucleation and crystal growth. Nucleation begins with a supersaturated solution, i.e. a solution that contains a greater concentration of ions that can exist under conditions of equilibrium. Under such conditions, condensation of ions will occur, forming very small but visible particles. Crystal growth follows as ions diffuse from the surrounding solution to the surface of the solid particles. This process continues until the condition of supersaturation has been relieved and equilibrium has been established under a specific set of chemical and physical conditions. The temperature of the solution will also influence the solubility of the compounds. Chemical precipitation by pH adjustment with lime or caustic soda is effective for the removal of **heavy metals** such as iron, manganese, cadmium, chromium, lead, and arsenic. Adjusting the pH to a specific range as applicable to each compound can remove as much as 90-95% of the contaminants as hydroxides by precipitation. **Hardness** can be reduced effectively by the removal of calcium and magnesium as respectively calcium carbonate and magnesium hydroxide by the addition of hydrated lime in the lime softening process. Removal of **nominal organic material** observed in the water as colour, total organic carbon and disinfection by-products during the softening process is not as effective as coagulation with for instance iron salts at the correct pH. **Soluble iron and manganese in water** can be removed by precipitation after oxidation by aeration or other chemicals such as chlorine as insoluble iron hydroxide and manganese oxide.
5	**Technology Illustration**	
6	**Performance limitations**	Availability and/or cost of chemicals. Trained operators to control dosing rates.

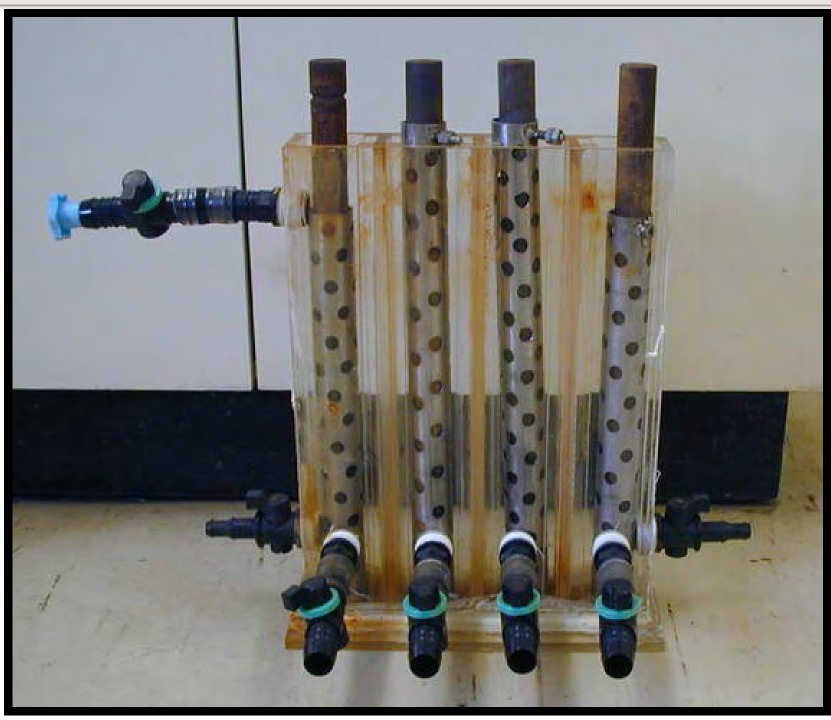
7	**Recommended capacity**	Removal of contaminants by precipitation can be applied to small and large plant as batch or continues operations. *Household scale* *< 1 m^3/d* *Very small* *1 – 10 m^3/d* *Small* *10 – 500 m^3/d* Medium 0,5 – 2,5 Ml/d *Large* *> 2,5 ML/d* *Ease of expansion:* Easy to increase capacity, normally the process will be more effective on larger plant.
8	**Operational requirements**	*Operator skills required (trained); Operator input man-hours required per day (1); Chemical dosage required (yes); Can alternative chemicals be used (yes); Degree of automation (manual to fully); Type and frequency of process and quality control monitoring tasks (hourly); Availability of materials/chemicals for operation spares (readily available)*
9	**Maintenance requirements**	*Cost of servicing/repairs/replacement (low- civil structure); (low, use of mostly lime); Frequency of servicing/repairs/replacement (monthly service); Expert or skilled maintenance inputs (skilled); Availability of recommended spares and tools (readily available)*
10	**Infrastructure requirements**	Need to have proper arrangements for the disposal of sludge produced by precipitation and will contain high concentrations of the compounds that were removed from the water. Sludge could have a high pH.
11	**Impact of Failures**	Hard waters or metals passing through to distribution networks, resulting in calcium carbonate or iron/manganese precipitation in pipes and reservoirs, or at consumers (hot water installations).
12	**Energy requirements**	For automated plant normal electricity supply is required. In the absence of electricity, the water to be treated could gravitate through sedimentation tanks where precipitation will take place. Lime could be fed by gravity as slurry or in the dry form.
13	**Capital cost**	The capital cost of a plant for the precipitation and settling of contaminants a function of the capacity of the plant and the level of sophistication and automation incorporated in the plant. The cost of such a plant would be similar to that of a conventional treatment plant.
14	**Operating cost**	Operating cost of ion-exchange plant is affected only by the cost of chemicals used and the disposal cost of sludge. Maintenance cost on the more sophisticated equipment is more expensive and would require more frequent maintenance and replacement.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of installations**	Used at treatment plants in the Western Cape where high iron and manganese concentrations occur in the raw water.
17	**Socio-economic aspects**	Community acceptance and willingness to operate and maintain plant in which contaminants are precipitated are high. Any consumer will immediately observe the effect of softening or removal of iron on the water quality. The water will be low in colour, taste pleasant and less soap and detergents will be used. Less scaling of cooking utensils will occur.
18	**Research and evaluation in South Africa**	University of Pretoria (Dr JJ Schoeman)

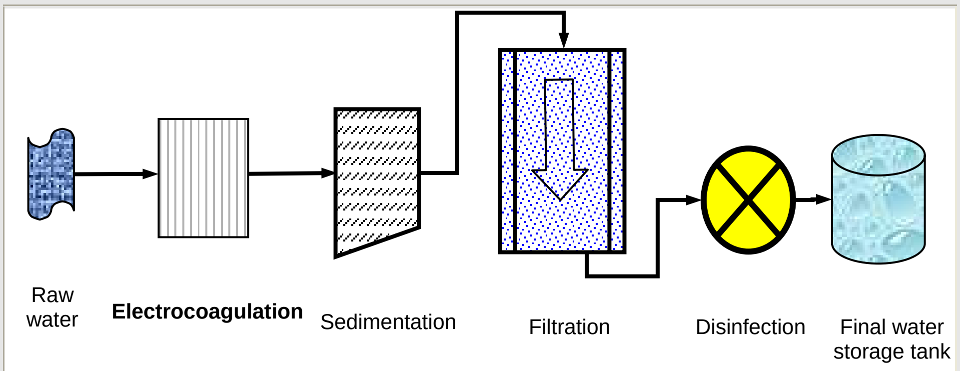
2-2 LIMESTONE CONTACT STABILISATION

1	**Purpose and status**	To stabilise soft waters by bringing the water into contact with limestone to increase alkalinity, calcium and pH, so that aggression and corrosion effects are reduced to acceptable levels for distribution systems Emerging technology, and gaining ground
2	**Alternatives**	Stabilisation using slaked lime
3	**Summary of key features**	Filtered and chlorinated water flows in an up-ward direction through a limestone contact bed.
4	**Description**	Limestone contact stabilisation uses limestone to stabilise soft waters. Water to be stabilised flows up-ward in an enclosed unit (usually cylindrical, with a limestone bed depth-to-diameter ratio of at least 1:1) containing at least a 2.0 m deep, graded fixed limestone bed (12-15 mm) supported by a graded granite aggregate layer in which gravity is used to continuously drive raw water through the filter media at filtration rates not exceeding 10 $m^3/h/m^2$ of filter-media surface. Physical and chemical mechanisms are responsible for the clarification of the raw water. It forms the final treatment stage in a water treatment plant prior to storage.
5	**Technology illustration**	
6	**Performance limitations**	Not suitable for treatment of water with > 1 NTU, > 0.10 mg/l Fe, > 0.15 mg/l Al Can stabilise water to acceptable levels for distribution networks Electricity supply is not required as long there is sufficient gravity. Operator's presence is critical because of daily monitoring of filter influent and effluent. Technical support is negligible. Impact of inflow water quality variations is critical if prolonged.
7	**Recommended capacity**	Suitable capacity ranges from medium to large. Expansion is ease by adding extra units.
8	**Operational requirements**	Untrained and semi-trained labour is required. Operator input is daily checking of flow rates. Type and frequency of process and quality control monitoring tasks: head loss and effluent quality must be checked daily.
9	**Maintenance requirements**	Low cost of servicing/repairs/replacement Cleaning frequency averages monthly

10	**Infrastructure requirements**	Conventional infrastructure plus winch/crane mechanisms to load limestone into the tanks (usually concrete)
11	**Impact of failures**	Unstable water can be supplied with possibility of increased turbidity if the filtration rates are higher than normal.
12	**Energy requirements**	Water flows by gravity through filters, but regular electricity supply is required if gravity is not available.
13	**Capital costs**	No local data yet available, but expected to vary depending on capacity of plant, site conditions and local contractors Limestone tank construction and limestone loading facilities make up the bulk of capital costs.
14	**Operating costs**	Operating costs are only due to labour used during operation and cleaning processes and replenishing of limestone, which depends on plant performance.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Rozendal (6 ML/d), Stellenbosch (Western Cape) Jonkershoek (2.5 ML/d), Stellenbosch (Western Cape) Idas Valley (18 ML/d), Stellenbosch (Western Cape) Franschhoek (2.5 ML/d) (Western Cape) Montagu (3.8 ML/d) (Western Cape)
17	**Socio-economic aspects**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	WRC Report No. 738/1/00 WRC Report No. 613/1/98 WRC Report No. 534/1/98 Council for Scientific and Industrial Research (CSIR)

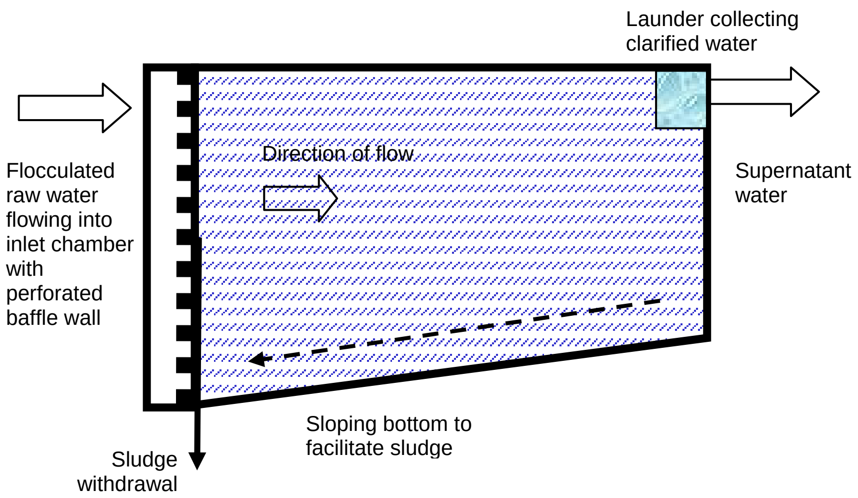
2-3 ELECTROCOAGULATION

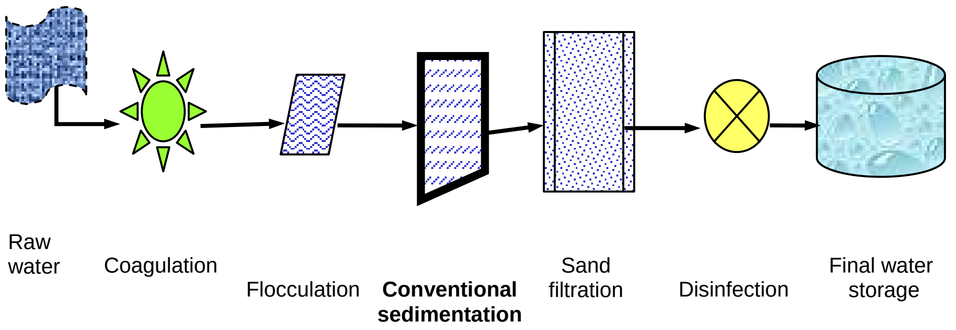
1	**Purpose and status**	Electrocoagulation produces coagulants directly into the water by the release of metal ions such as iron or aluminium by electrolysis of electrodes by applying direct electrical current. It is an experimental technology.
2	**Alternatives**	Standard metals coagulation
3	**Summary of key features**	Experimentation on Vaal Dam water with a turbidity of 60 NTU with micro-organism added. Turbidity reduced to < 3 NTU after sedimentation and sand filtration. Microbiological quality of final water acceptable for potable purposes. Dependant on the amount of chlorine added. (Also by onsite generation form salt as sodium hypochlorite).
4	**Description**	Iron or aluminium electrodes are used as sacrificial anodes together with inert cathodes to release metal ions by electrolysis that act as coagulants in water. These metal ions can act as coagulants similar to traditional metal-based coagulants such as ferric chloride or aluminium sulphate by the formation of hydrolysed metal coagulants [$Fe(OH)_3$ and $Al(OH)_3$]. The ions discharged by electrolysis are similar to those added as chemical compounds. They affect coagulation by charge neutralisation that causes flocculation and phase separation to take place. The concentration of metal ions required for effective coagulation is a function of the water quality, specifically the suspended matter concentration. The amount of metal ions released is determined by the electrical current available and surface area of the electrodes. Advantages of electrogulation are that no corrosive or aggressive compounds are handled and that the pH of the treated water is not affected. Any reliable source of direct electrical current can be used. Renewable energy resources derived from solar or wind energy are suitable to produce a direct current for electrolysis.
5	**Technology illustration**	 ***Electrocoagulation test cells***
6	**Performance limitations**	Floating debris that could interfere physically with the electrodes must be removed prior to treatment. Plant performance is highly dependant on climatic conditions; lack of wind and low solar radiation levels reduces the efficiency and output. High raw water turbidity may require a reduction in through put.

7	**Recommended capacity**	From very small to large plants Expansion is easy but costly [modular].
8	**Operational requirements**	Requires a submersible pump and semi-skilled operator with basic understanding of water quality and elementary plumbing.
9	**Maintenance requirements**	Removal of scale from the electrodes, removal and disposal of chemical sludge, and cleaning of filter.
10	**Infrastructure requirements**	Solar panel, wind generator and treatment units are factory manufactured and erected on site. Stands for wind generator, solar panel and treatment units, gravity flow required. Disposal of iron or aluminium rich sludge.
11	**Impact of failures**	Not dependant on electricity supply when using wind or solar power.
12	**Energy requirements**	Electricity is generated on site form renewable sources i.e. wind and solar power.
13	**Capital costs**	Still being determined.
14	**Operating costs**	Still being determined (but expected to be low).
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Experimental only at Rand Water.
17	**Socio-economic aspects**	Operating costs are reduced by using renewable energy sources, which can be easily maintained by the community.
18	**Research and evaluation in South Africa**	Rand Water

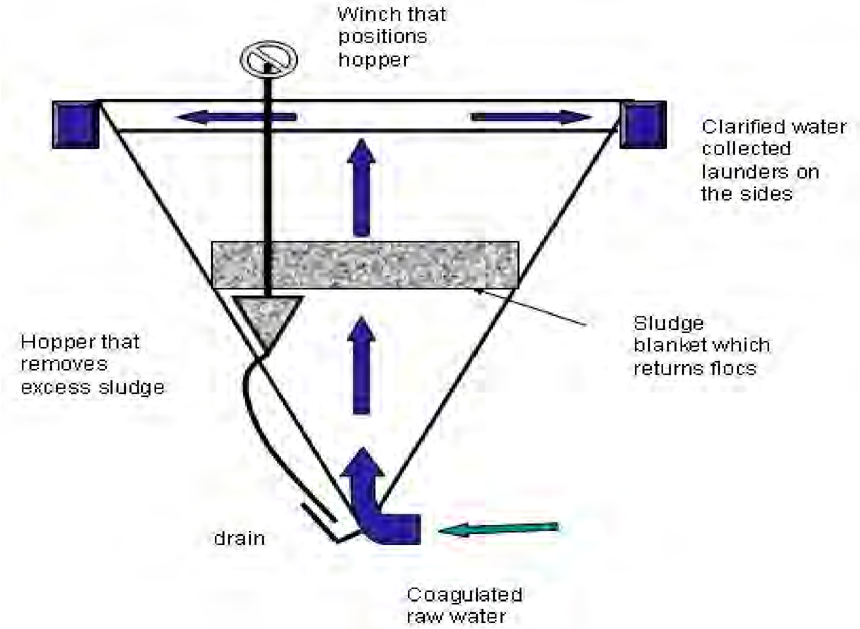
3. PHASE SEPARATION

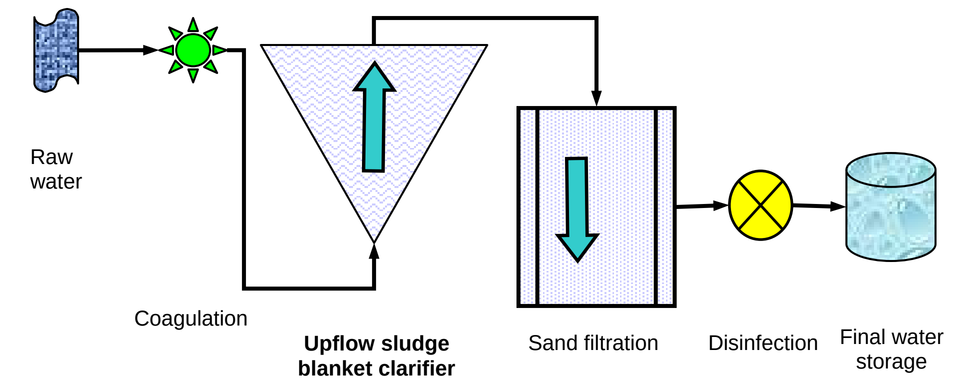
3-1 CONVENTIONAL SEDIMENTATION

1	**Purpose and status**	To continuously remove settleable flocs from coagulated raw water characterised by medium to high turbidity and suspended solids, so that it is suitable for sand filtration Proven technology: in full-scale use for a period of time in water treatment
2	**Alternatives**	Roughing filtration Up-flow sludge blanket clarifiers
3	**Summary of key features**	Conventional sedimentation is preceded by coagulation, rapid mixing and flocculation. It removes flocs by gravitation settling as the flocculated water flows in a large rectangular or circular tank.
4	**Description**	Sedimentation is a horizontal and/or radial flow settling process that takes place in an open unit in which sediments or flocs are allowed to settle by gravitational forces. Physical mechanisms are responsible for the clarification of the pre-treated raw water. It forms the pre treatment stage in a water treatment plant. In conventional sedimentation, coagulated raw water is continuously filled in a basin, with a detention time of 2-8 hours, to allow the sedimentation process to settle flocs. The clarified water is periodically withdrawn (by gravity or pumping) and directed to a filtration stage. Sedimentation basins can be circular or rectangular in shape. The rectangular shape is common. Water flows horizontally through the length of the tank at surface loading rates ranging from 500-1250 litres/h/m^2. In circular types, water flows radially. Detention time can range from 2-8 hours. Gravity drives flow through the sedimentation at a flow velocity ranging from 0.15-0.90 m/min.
5	**Technology illustration**	
6	**Performance limitations**	Can remove turbidity to less than 5 NTU. Electricity supply is critical if chemical dosing and mechanical mixing equipment is used. Operator's presence is critical because of chemical dosing, mixing and flocculation facilities. Technical support is not limiting but depends on level of sophistication. Supply of chemicals is critical as technology is ineffective without chemicals. Impact of raw water variations is critical.
7	**Recommended capacity**	Suitable capacity ranges from to small to large. Ease of expansion is generally difficult, but can be easy if package units are used in small plants.
8	**Operational**	Trained/skilled operator required.

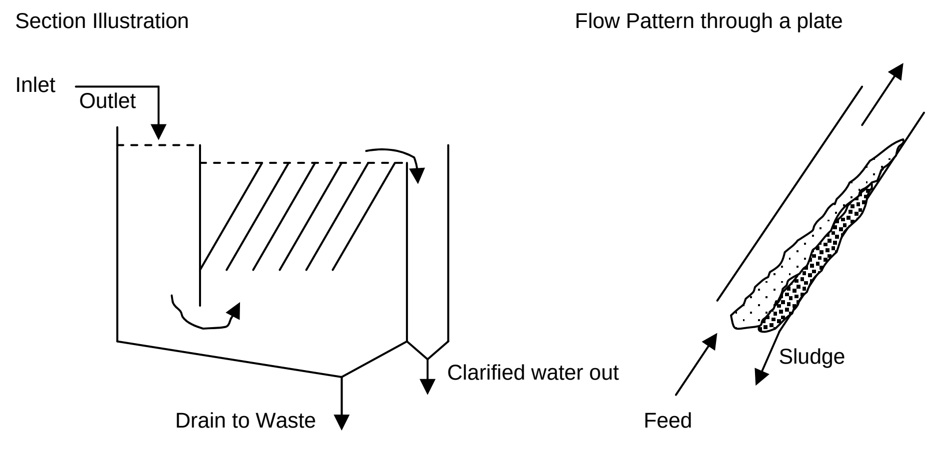
	requirements	Operator input is required 24 h/day. Chemical dosage required. Alternative chemicals can be used. Can be semi-automated or none at all. Cleaning process can be automated. Type and frequency of process and quality control monitoring tasks - daily Materials/chemicals for operation readily available Spares require a long lead-time.
9	**Maintenance requirements**	Cost of servicing/repairs/replacement is low, but high if partial automation is used. Done annually, or as required Operator can maintain but, if fully automated, expert or skilled labour is required (every 6 months). Recommended spares and tools must be readily available.
10	**Special Infrastructure requirements**	Conventional infrastructure to provide and/or support sedimentation tank
11	**Impact of failures**	High turbidity break-through can cause rapid clogging of filter media.
12	**Energy requirements**	Regular electricity supply is required if automation and mechanical equipment are used, especially for sludge removal. Gravity feed can be used.
13	**Capital costs**	No local data is yet available, but is expected to vary depending on capacity of plant, site conditions and local contractors. Sedimentation tank construction makes up the capital costs.
14	**Operating costs**	Main operating cost is as a result of the cleaning processes, energy requirements, and costs attributed to preceding coagulation and flocculation processes.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Cape Town, Ashton, Bonnievale (Western Cape) Fort Beaufort, Alice (Eastern Cape) Jozini (Kwazulu-Natal) Syferfontein (Free State) Piet Gouws (Northern Province)
17	**Socio-economic impact**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	WRC Report No. 450/1/97 Umgeni Water Cape Peninsula University of Technology

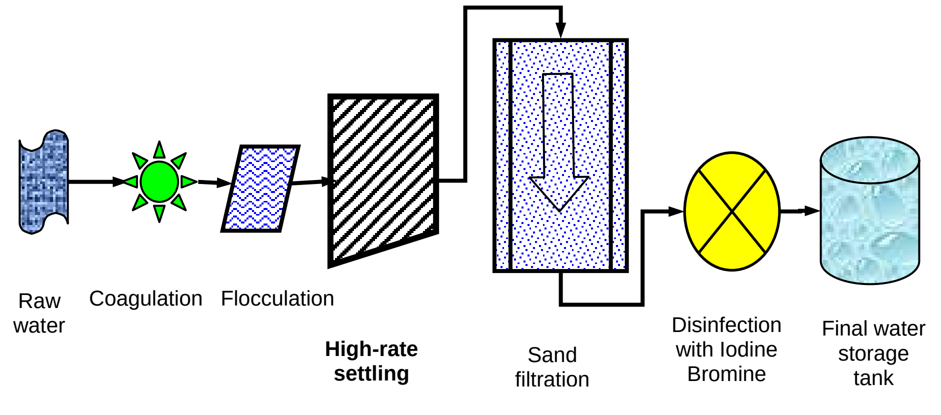
3-2 UPFLOW BLANKET SLUDGE CLARIFIER (UBSC)

1	**Purpose and status**	To clarify coagulated raw water characterised by medium to high turbidity (10-500 NTU) and colour, prior to sand filtration Proven technology that has been in application for some time now
2	**Alternatives**	Conventional sedimentation Roughing filtration combined with coagulation
3	**Summary of key features**	Coagulated raw water is flocculated and settled in a single unit in which the water flows upwards and the flocs form a floating sludge blanket, which is influential in the clarification process.
	Description	USBC units are conical in shape, with a rectangular or circular surface area, reducing conically towards the bottom. USBC must be preceded by coagulation, but flocculation and floc retention takes place in a single unit. Coagulated raw water flows in an upward direction, driven by an adequate hydraulic head. Recommended over-flow rate or velocity is 0.50-1.25 $m^3/h/m^2$, but this can go up to 2 $m^3/h/m^2$ Recommended detention time is 2-4 hours. Flocculation takes place at the lower part of the unit. A sludge blanket, made from flocs, forms, and floats within the upper section of the unit at a height determined by the flow rate or velocity of flow. Clarification is achieved by the sludge blanked and the clarified water is continuously withdrawn by suspended troughs or launders. Excess sludge is withdrawn from the blanket by a winch and hopper mechanism.
5	**Technology illustration**	
6	**Performance limitations**	Not suitable for high to very high turbidity raw water (> 500 NTU) Electricity supply is critical for the chemical dosing and mechanical mixing equipment. Operator's presence is critical because of chemical dosing and mixing facilities. Technical support is a limiting factor, but depends on level of sophistication. Supply of chemicals is critical as technology is ineffective without chemical coagulation. Impact of raw water variations is critical.
7	**Recommended capacity**	Suitable capacity ranges from to medium to large. Plant can easily be expanded by adding more units.

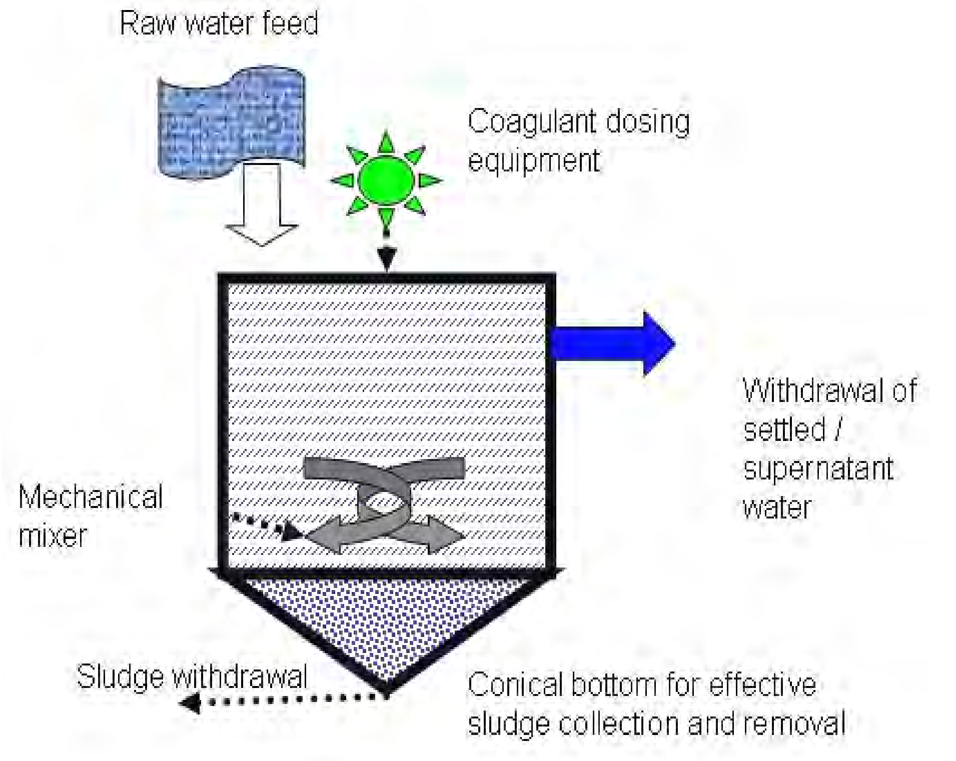
8	**Operational requirements**	Trained/skilled operator required Operator input required 8-24 h/day Chemical dosage required; alternative chemicals can be used 4-hourly monitoring of quality and flow rates Chemicals must be readily available. Spares require a long lead time.
9	**Maintenance requirements**	Cost of servicing/repairs/replacement is low. Maintenance is generally performed annually, or as required. Maintenance can be carried out by the operator, but, if fully automated, expert or skilled labour is required every 6 months. Recommended spares and tools must be readily available.
10	**Infrastructure requirements**	Conventional infrastructure plus mechanisms for removal of sludge
11	**Impact of Failures**	Floc overflows to sand filtration stage, which can lead to rapid clogging and the requirement for frequent filter maintenance.
12	**Energy requirements**	Regular electricity supply is required if coagulation equipment is mechanical. Adequate gravity must be available to drive coagulation water through unit.
13	**Capital costs**	Tank construction makes up the bulk of capital costs, but is expected to vary depending on capacity of plant, site conditions and local contractors. As at 2005, Umgeni Water estimates R600 000 for a 0.7-m-diameter unit.
14	**Operating costs**	Operating costs result from labour for cleaning processes, electricity requirements and preceding coagulation costs.
15	**Typical treatment process configuration (train) or Example**	
16	**Examples of SA installations**	Lady Frere, Eastern Cape Ashton, Western Cape Ixopo Water Works, Kwazulu-Natal
17	**Socio-economic impact**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	Umgeni Water, Durban Cape Peninsula University of Technology, Bellville Campus, Cape Town

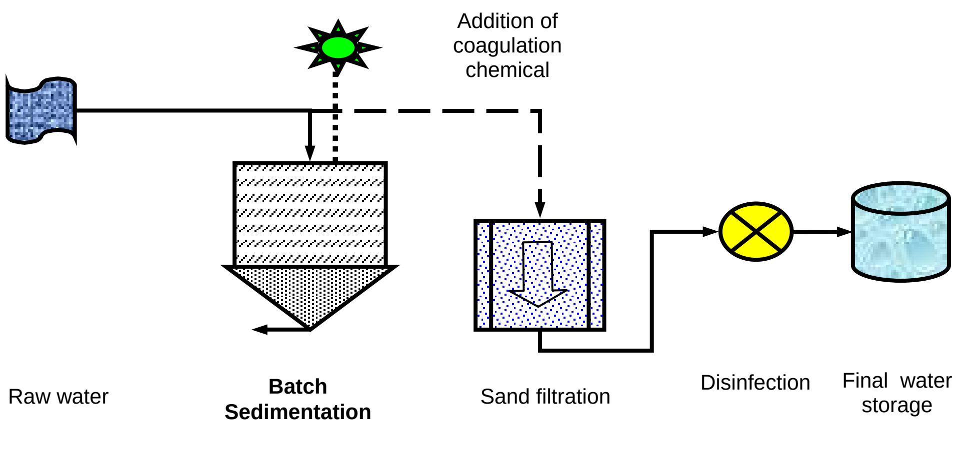
3-3 HIGH-RATE SETTLING

1	**Purpose and status**	Turbidity removal Colour removal Proven technology, but further evaluation required
2	**Alternatives**	Conventional sedimentation
3	**Summary of key features**	High up-flow velocities can be employed and hence high sedimentation rates are achieved by using inclined lamella plates or tubes in settling tanks. Considerably smaller settling tanks can therefore be used, which allows its effective application in package plants.
4	**Description**	Solids-liquid separation in a tank with inclined plates, tubes or pipes, which allow high settling rates and hence smaller settling tanks (up to 8 m/h)
5	**Technology illustration**	
6	**Performance limitations**	Less effective for light flocs (coloured water) than for more dense flocs (turbid waters) Requires frequent cleaning to prevent blockage or algal growth
7	**Recommended capacity**	From small-scale (not household) to 1 Ml/day Can be used for retrofits and for increasing the treatment capacity of existing conventional settling tanks.
8	**Operational requirements**	Unskilled operator (1 hour per day), for desludging Monthly cleaning of plates or tubes Floc carry-over requires checking during daily inspection.
9	**Maintenance requirements**	Monthly cleaning of plates or tubes required. Special material used for some installations, which may require long lead times for delivery.
10	**Infrastructure requirements**	May be either pre-fabricated tanks (package plants) or concrete tanks Inclined plates or tubes can be either commercially prefabricated or can be assembled on site. Sludge disposal facilities required.
11	**Impact of failures**	Floc carry-over to filters; rapid clogging of filters Short filter runs
12	**Energy requirements**	No electricity required
13	**Capital costs**	Reduced cost when compared to conventional settling because of the smaller footprint; however, inclined tubes or channels sometimes rather costly
14	**Operating costs**	No effect on operational cost apart from lower operation cost for cleaning. Cleaning of inside of inclined pipes or channels may prove to be quite ar rigorous task

15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Buffeljagsriver, Western Cape Brits Waterworks
17	**Socio-economic impact**	A proven technology. Preferably used in small package plants. Easy to operate, require semi-skilled operators. Must be further researched.
18	**Research and evaluation in South Africa**	None at present

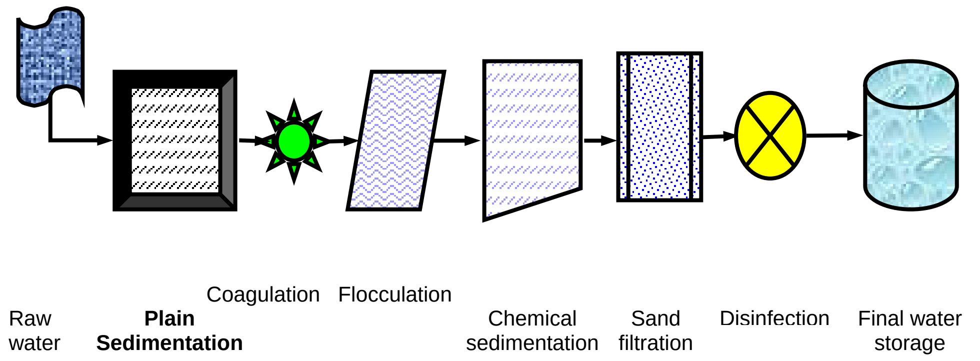
3-4 BATCH SEDIMENTATION

1	**Purpose and status**	To intermittently remove settleable flocs from coagulated raw water characterised by medium to high turbidity and suspended solids, so that it is suitable for sand filtration Proven technology: in full-scale use for a period of time in water treatment
2	**Alternatives**	Roughing filtration
3	**Summary of key features**	Raw water of high suspended solids is coagulated and detained in a tank with a conical bottom for a few hours to allow settling. The clearer supernatant is then withdrawn and sent to a filtration stage.
4	**Description**	Sedimentation is a horizontal and/or radial flow settling process that takes place in an open unit in which sediments are allowed to settle by gravitational forces. It forms the pre-treatment stage in a water treatment plant. Physical mechanisms are responsible for the clarification of the pre-treated raw water. In batch sedimentation, coagulated raw water is intermittently filled in a basin and detained for 2-8 hours to allow the sedimentation process to settle flocs. The clarified water is periodically withdrawn (by gravity or pumping) and directed to a filtration stage.
5	**Technology illustration**	
6	**Performance limitations**	Can remove turbidity to less than 5 NTU Electricity supply is critical if chemical dosing and mechanical mixing equipment is used. Operator's presence is not limiting as only required when adding chemicals and mixing. Technical support is not limiting but depends on level of sophistication. Supply of chemicals is critical as technology is ineffective without chemicals. Impact of raw water variations is negligible as process is basically manually initiated.
7	**Recommended capacity**	Suitable capacity ranges from very small, to small. Ease of expansion is generally relatively easy (modular) since technology is suitable in small communicates.

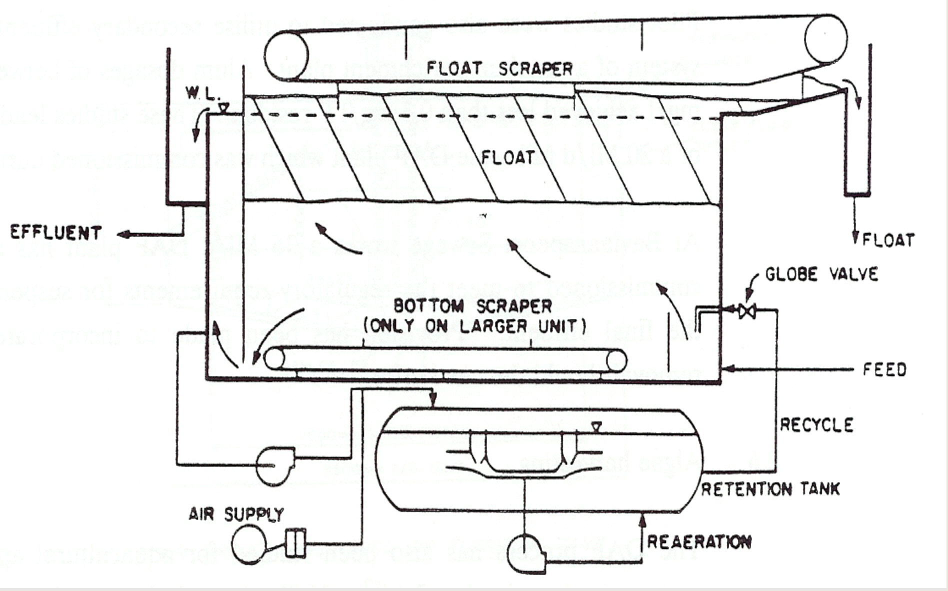
8	**Operational requirements**	Semi-skilled operators are required (trained/semi-trained/untrained). Operator input is required 8 h/day. Chemical dosage is required. Alternative chemicals can be used. Degree of automation can either be fully, semi-automated, or none. Type and frequency of process and quality control monitoring tasks - daily Materials/chemicals for operation readily available Spares require a long lead-time.
9	**Maintenance requirements**	Cost of servicing/repairs/replacement is low, but high if fully automated. Maintenance carried out annually, or as required Operator can maintain but, if fully automated, expert or skilled labour is required. Recommended spares and tools must be readily available.
10	**Infrastructure requirements**	Concrete foundation and floor base
11	**Impact of failures**	Suspended solids break-through, leading to rapid filter clogging
12	**Energy requirements**	Regular electricity supply is required if automation and electronic equipment are used, especially for chemical dosing. None when gravity feed can be used
13	**Capital costs**	No local data is yet available, but costs are expected to vary depending on capacity of plant, site conditions and local contractors. Sedimentation tanks, mechanical mixers and chemical dosing equipment make up capital costs.
14	**Operating costs**	Operating costs are due to chemicals, operator, and energy requirements.
15	**Typical treatment process configuration (train) or example**	
15	**Examples of SA installations**	Applications are reported in Package Plant installations in Gauteng.
16	**Socio-economic impact**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	WRC Report No. 450/1/97 Umgeni Water

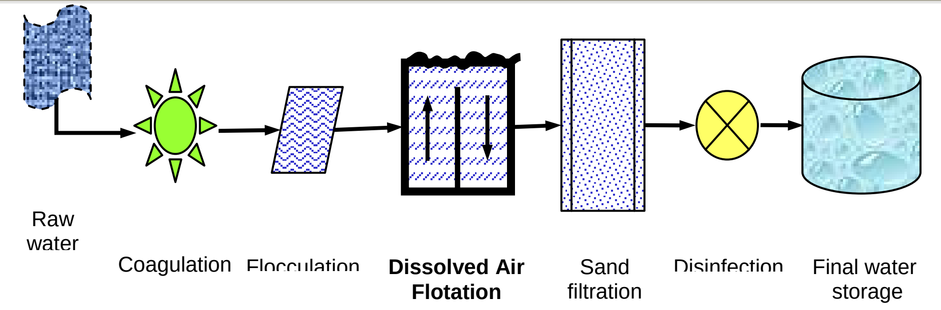
3-5 PLAIN SEDIMENTATION

1	**Purpose and status**	To continuously remove settleable solids from raw water characterised by a high content of suspended solids without the aid of chemicals so that it is suitable for further treatment Proven technology: in full-scale use for a period of time in water treatment
2	**Alternatives**	Roughing filtration
3	**Summary of key features**	Plain sedimentation is usually an intake process that removes highly settleable solids in order to protect further processes and/or ensure uninterrupted supply of raw water.
4	**Description**	Plain sedimentation is a horizontal-flow settling process that takes place in large open units in which sediments or flocs are allowed to settle by gravitational forces without the addition of coagulants. It forms the pre-treatment stage in a water treatment plant. The gravitational setting is the mechanism responsible for the clarification of the raw water. Raw water is either intermittently or continuously filled in a basin with a detention time of at least 4 hours to allow the sedimentation process to settle suspended solids. The clarified water is withdrawn by gravity or pumping for further treatment. Plain sedimentation basins can be of any shape, as long as the required detention time is provided. Sedimentation usually takes place in dams and reservoirs.
5	**Technology illustration**	
6	**Performance limitations**	Batch sedimentation can only remove settleable solids and not colloidal particles. Technical support is not limiting. Adequate detention time is critical.
7	**Recommended capacity**	Suitable capacity ranges from to small to large. Can easily be expanded.
8	**Operational requirements**	Trained/skilled operator required. Operator input required 24 h/day No chemical dosage required. No automation required. Weekly check required on effluent clarity, by visual observation,
9	**Maintenance requirements**	Maintenance carried out as required

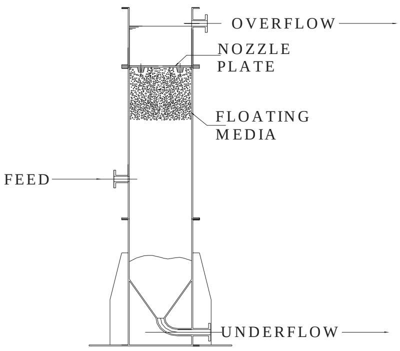
10	**Infrastructure requirements**	Conventional infrastructure to provide and/or support sedimentation tank
11	**Impact of failures**	High suspended solids breakthrough can cause rapid clogging of subsequent treatment processes.
12	**Energy requirements**	Gravity feed is usually employed when feeding plain sedimentation basins/tanks.
13	**Capital costs**	No local data is yet available, but is expected to vary depending on capacity of plant, site conditions and local contractors. Sedimentation tank construction makes up most of the capital costs
14	**Operating costs**	Main operating cost is as a result of the energy requirements in cases where there is no gravity feed and those attributed to operator involvement.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Cape Town, Ashton, Bonnieville (Western Cape) Fort Beaufort, Alice (Eastern Cape)
17	**Socio-economic impact**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	No particular research reported as technology is simple

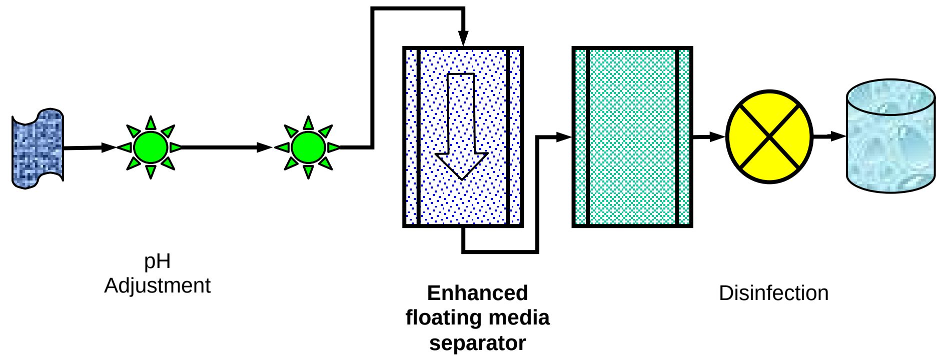
3-6 DISSOLVED AIR FLOTATION

1	**Purpose and status**	Removal of suspended solids, which could be either chemical flocs or untreated material (such as algae) in reverse gravity mode through the aid of finely dispersed micro-bubbles, and in which the scum is removed from the supernatant. It is a proven technology.
2	**Alternatives**	Sedimentation (which is not effective for low density particles)
3	**Summary of key features**	Requires saturators for saturation of a recycle stream with air at elevated pressures. Clarification takes place in a clarification zone. Formation of high-concentration of micro-bubbles largely dictates the efficiency of the process.
4	**Description**	Solids-liquid separation in which light flocculated material rises with microscopic bubbles formed by reducing pressure of pressurised water oversaturated with air to atmospheric pressure.
5	**Technology Illustration**	
6	**Performance limitations**	Type of suspended matter, coagulant used, success of flocculation determines the rise and settling rate of the flocculated material. Rise rate of the water is determined by this factor, bubbles size of the air, efficiency of the air saturation system.
7	**Suitable capacity application**	From medium-sized to large plants. DAF have been used in small-scale containerised plants, mostly overseas.
8	**Operation requirements**	As with conventional treatment, the effective chemical treatment for floc conditioning is essential to ensure efficient solids removal in the DAF process. Additional operational requirements consist of checking saturator pressures and trouble-free operation of the scum-removal mechanism.
9	**Maintenance requirements**	Regular cleaning of the nozzles through which the micro-bubbles are formed is essential to prevent blockages. Mechanical equipment for scum removal requires additional maintenance inputs.
10	**Infrastructure requirements**	Purpose designed tank with scum removal system and clarified water withdrawal points.
11	**Impact of Failures**	Flocs will be carried to the filters together with the sub-natant and will result in rapid filter blockages and short filter runs. Process will fail during electricity interruptions because supersaturation of water with air will not be possible. Requires additional operator attention without which the quality of the clarified water may be compromised.
12	**Energy requirements**	Bulk of energy is required for the air saturation system and lesser amount for scum removal.

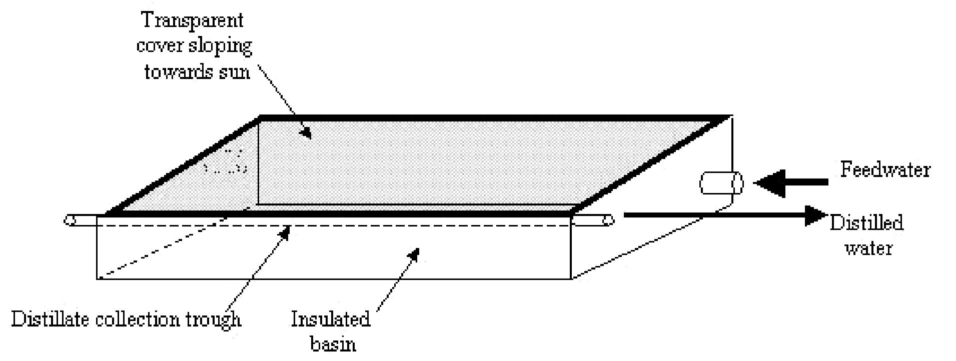
13	**Capital cost**	Cost related to plant size. Civil costs of DAF plants are generally lower than for sedimentation due to higher upwards velocities that are attained; however, mechanical, electrical and control equipment will increase the capital cost.
14	**Operating cost**	Additional operating cost as a result of higher electricity cost required for saturation and sludge (scum) removal. Labour costs will also be higher.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of installations**	Rietvlei, Pretoria Schoemansville, Hartbeespoort Dam, Pretoria
17	**Socio-economic aspects**	Relating to more operation input required and higher sophistication of the treatment system.
18	**Research and evaluation in South Africa**	CSIR Division of Water Technology RAU Dr L van Vuuren Dr G Offringa Prof J Haarhoff

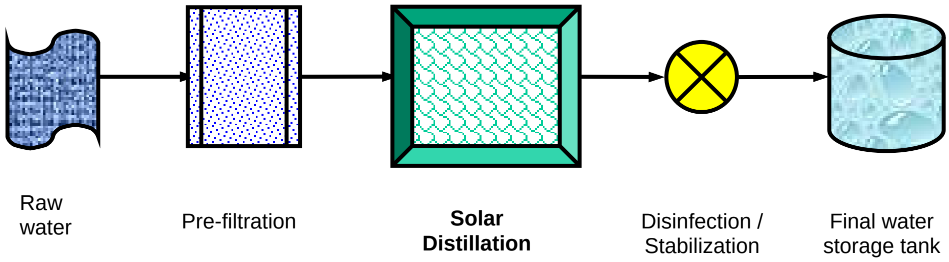
3-7 ENHANCED FLOATING MEDIA SEPARATOR (EFMS)

1	**Purpose and status**	Pre-treatment of surface waters having very high or fluctuating turbidity In original form used since 1986 in mining and industry, now the subject of WRC Research Project K5/1527, led by Prof. Ed Jacobs of Stellenbosch University
2	**Alternatives**	Conventional coagulation, clarification and sand filtration
3	**Summary of key features**	Combines settling, with or without the use of polyelectrolytes, physical filtration and the adsorbance of hydrophobic species onto olefinic floating media Used as pre-treatment before membrane processes, produces microflocs, which significantly increase flow rates and reduce membrane fouling Reduced backwash water requirements
4	**Description**	The separator is normally in the form of a deep cylinder with an inverted-cone bottom section. The EFMS is a combined settler and up-flow filter in which the filter medium may be in the form of beads of compounded polyolefins (polypropylene or low-density polyethylene). The processes involved in EFMS include: 1. Flocculation 2. Settling 3. Pre-coat filtration 4. Granular medium filtration 5. Surface adsorption. The EFMS may be used in conventional potable water treatment or as pre-treatment before a membrane process.
5	**Technology illustration**	 **Simplified cross-section through an EFMS pilot plant**
6	**Performance limitations**	The performance of a FMS is constrained by limitations in the size, density, shape and physical properties of compounded polyolefins particles available on the South African market. In many industrial and mining applications, perfectly clear filtrates are obtained using highly charged, fine media particles, but backwashing this media is very difficult. Coarse media is easier to clean, but filtrate quality is often unacceptable. R & D under this contract is therefore concentrated on developing uniformly-sized media, which has either a fixed negative or positive charge, on enhancing media adsorption capacity and on improving backwash systems.
7	**Recommended capacity**	There are no limitations on capacity.
8	**Operational requirements**	Since the EFMS vessels are generally tall circular tanks with cone bottom sections, pumps are normally required for feed and backwash circuits, but not for the transfer of the filtered water to the chlorination and storage tanks.

9	**Maintenance requirements**	Maintenance requirements are minimal in a well-designed system. Replacement of media lost during backwashing should not exceed 10% per year of the initial charge.
10	**Infrastructure requirements**	There are no special requirements in respect of the infrastructure.
11	**Impact of failures**	Failures can be categorised into: 1. Premature blocking of the media – requiring more frequent backwashing 2. Premature breakthrough – again requiring more frequent backwashing. Poor filtration - may require a reduction in the feed flowrate, or a change in the media.
12	**Energy requirements**	The energy requirements have not yet been determined for a full-scale potable water plant, but should be less than for a conventional potable water clarification and sand filtration plant.
13	**Capital costs**	The media costs are not known at this stage. Other capital costs should be lower than for a conventional potable water plant. The footprint is also much lower than for a conventional plant.
14	**Operating costs**	Unknown at this stage, but should be less than for a conventional plant
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	There are no full-scale installations at this stage.
17	**Socio-economic impact**	The EFMS has the potential to be developed into a simple, reliable and robust process for drinking water production in rural and peri-urban areas, especially in 'problematic' regions that experience very high or fluctuating raw water turbidities.
18	**Research and evaluation in South Africa**	The EFMS is the subject of WRC Research Project K5/1527, led by Prof. Ed Jacobs of Stellenbosch University. R & D under this contract is concentrated on developing uniformly sized media, with either a fixed negative or positive charge, on enhancing adsorption capacity and on improving backwash systems.

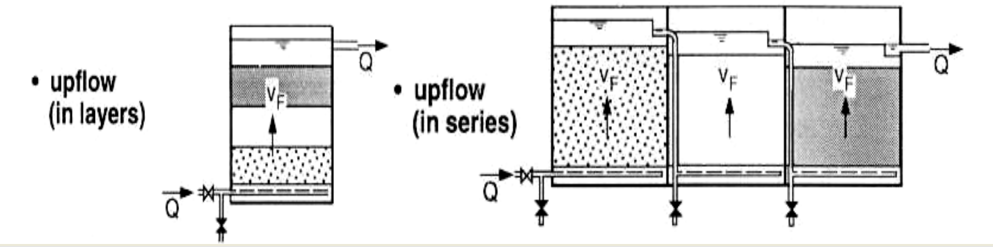
3-8 SOLAR DISTILLATION

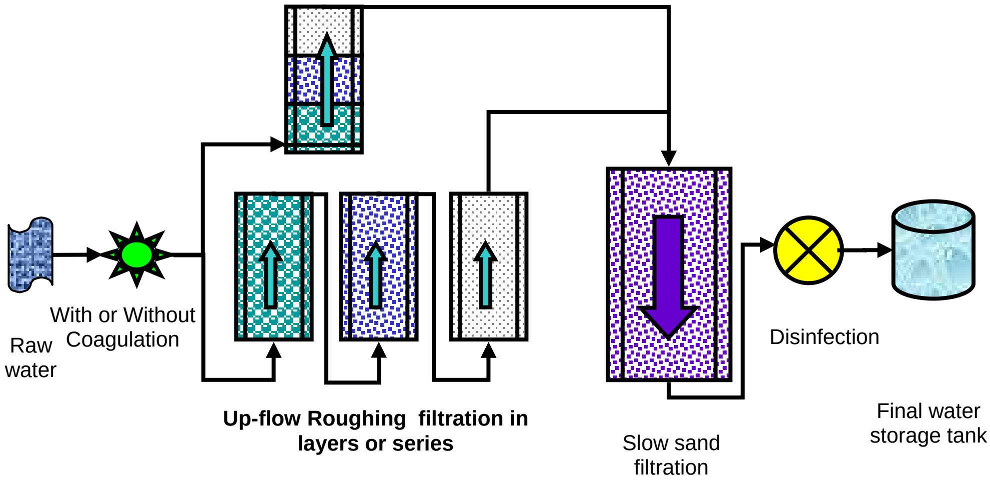
1	**Purpose and status**	Desalination (to less than 8 mg/L) Suitable for brackish water or seawater (TDS independent) Product water may be blended with raw water to add mineral content (e.g. taste). Solar distillation is an emerging technology in South Africa.
2	**Alternatives**	Reverse osmosis Electrodialysis
3	**Summary of key features**	Solar distillation is a low running cost desalination technology suitable for use on very small (household to small community) scale
4	**Description**	Solar desalination is a complete, small-scale desalination technology that utilises solar energy for the production of drinking water. Distillation takes place inside an insulated solar distillation unit (called as solar still). Brackish water is pumped or gravitated into a black-lined solar still basin, where it is heated and evaporated by the sun. Water vapour condenses against the transparent glass cover, and the distillate is collected and stored / treated further for household use. The remainder of the brine is routinely (e.g. daily) flushed out of the basin to prevent salt precipitation. Water production varies according to the amount of solar radiation received. Any number of such modular units can be integrated into a low-flow-rate solar distillation plant. Product water may be blended with raw water to add mineral content (e.g. taste) and increase production capacity.
5	**Technology illustration**	
6	**Performance limitations**	Suitability for disinfection not proven Not suitable for removal of volatile organics Limited to very small-scale operations
7	**Recommended capacity**	Household to very small plants Capacity expansion is modular
8	**Operational requirements**	Untrained operators (30 min/day), no chemical dosage, manual to automated options exist, monthly quality control required, readily available spares
9	**Maintenance requirements**	Annual servicing (low cost), skilled maintenance input required, most spares readily available
10	**Infrastructure requirements**	The following are required: access roads, raw and clean-water storage, civil construction, waste disposal, reticulation system. The following are not required: power, lighting, chemical storage. All infrastructure components can be site constructed.
11	**Impact of failures**	No product water flow (solar still units broken), breakthrough of saline feed water into product water (pump or feed valve failure)
12	**Energy requirements**	Renewable (solar)
13	**Capital costs**	The capital cost of a household or very small solar distillation system is higher than for a RO unit.
14	**Operating costs**	The running cost of a household or very small solar distillation system is much lower than for a RO unit.

15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Kerkplaas (Klein Karoo): 0,2 m^3 /day Algerynskraal (Klein Karoo): 0,4 m^3 /day
17	**Socio-economic impact**	Solar distillation technology is easily understood and maintained by untrained community members, although electronic controls may require specialised maintenance.
18	**Research and evaluation in South Africa**	WRC Report 1032/1/03 WRC Report 1392 Polymer Institute, University of Stellenbosch Department of Chemical Engineering, Cape Technikon

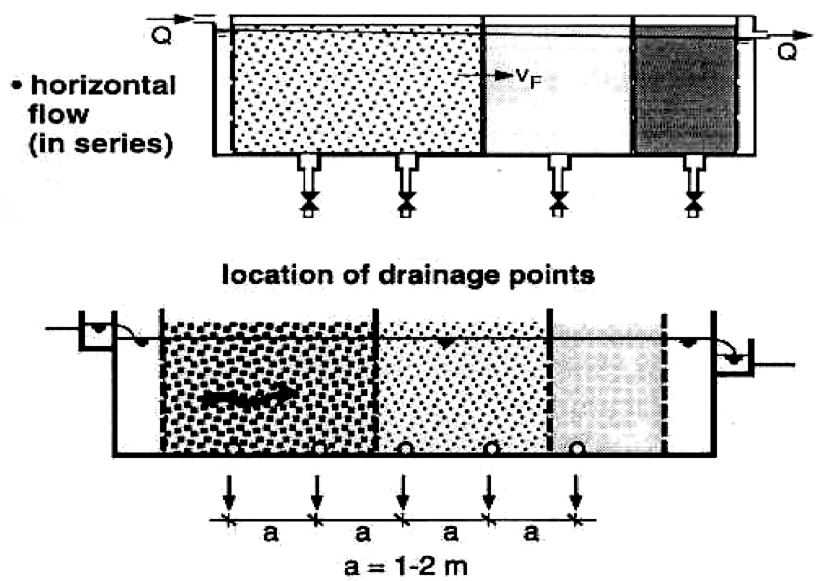
4. COARSE FILTRATION

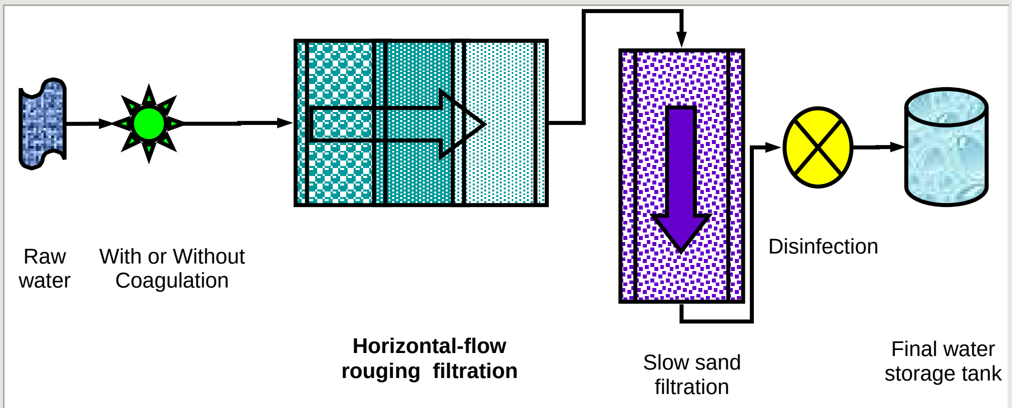
4-1 UP-FLOW ROUGHING FILTRATION (URF)

1	**Purpose and status**	Up-flow roughing filtration (URF) is used to reduce turbidity and suspended solids from raw water that is characterised by medium to high turbidity (10-500 NTU) and suspended solids greater than > 5 mg/L, to levels acceptable for effective slow sand filtration. URF is a proven technology but emerging in application.
2	**Alternatives**	Conventional sedimentation, horizontal-flow roughing filtration
3	**Summary of key features**	Raw water flows in an upward direction through several graded gravel media layers (increasing in size in the direction of flow) placed either in a single unit or in three separate units, which are in series. Sedimentation mechanisms retain the suspended particles within the gravity pores and the filter unit is cleaned by fast drainage.
4	**Description**	URF is a gravel (d_e = 2-20 mm) filtration process in which the gravel is arranged in layers within one compartment or in series in separate compartments to continuously drive raw water through the filter media at filtration rates ranging from 0.30-5.0 $m^3/h/m^2$ of filter media surface. The depth of the filter unit usually ranges from 1.2 to 1.5 m. Physical mechanisms are responsible for the clarification of the raw water, although to some extent biological mechanisms are also active. URF is usually applied as a pre-treatment stage prior to slow sand filtration — a combination widely known as multi-stage filtration. Coagulation can be included as a pre-treatment to enhance the URF process, especially for handling high-turbidity raw water.
5	**Technology illustration**	
6	**Performance limitations**	Not suitable for treatment of water with very high turbidity (> 500 NTU) and high colour without the aid of chemical coagulation URF can remove turbidity to less than 5 NTU and colour to less than 5 Colour units. Electricity supply is not critical unless electronic chemical dosing equipment and pumping are used. Operator's presence is required daily. Regular technical support is necessary. Supply of chemicals is not critical, but necessary where there is high-turbidity raw water. Impact of raw water variations for short periods is not very critical.
7	**Recommended capacity**	Suitable capacity ranges from to small to medium. Capacity can be expanded by adding more units.
8	**Operational requirements**	Semi-trained and trained labour is required. Operator input is required 8 h/day. No chemical dosage required, but can be required if coagulation is incorporated. No automation is required. Head loss and effluent quality must be checked daily.
9	**Maintenance requirements**	No moving parts, hence cost of servicing/repairs/replacement is low. Filter cleaning frequency is usually monthly, or more often. Recommended spare valves and tools for cleaning must be readily available.
10	**Infrastructure requirements**	Conventional infrastructure
11	**Impact of failure**	Can lead to effluent turbidity not suitable for slow sand filtration (SSF), hence rapid clogging o f SSF can be expected if the URF fails.

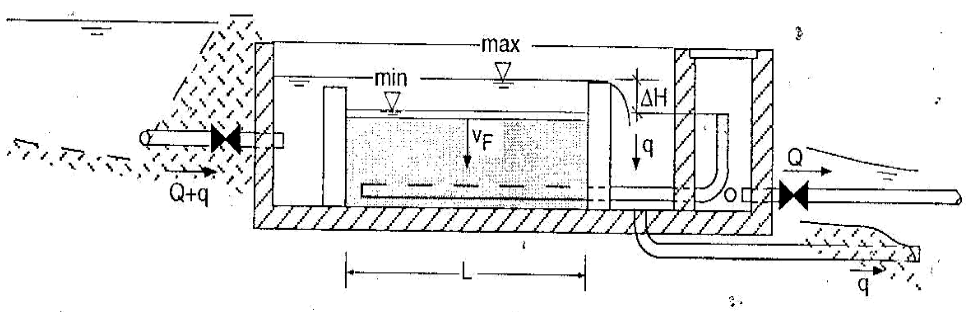
12	**Energy requirements**	Water flows by gravity through filters, but a regular electricity supply is required if raw water is supplied by pumping and if electronic chemical dosing is employed.
13	**Capital costs**	No local data is yet available, but cost is expected to vary depending on capacity of plant, site conditions and local contractors. Filter tank construction and chemical dosing facilities make up the bulk of capital costs.
14	**Operating costs**	Operating costs are only due to labour used during operation and cleaning processes.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Stormsvlei, Western Cape Some applications are reported in Kwazulu-Natal.
17	**Socio-economic aspects**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	Cape Peninsula University of Technology

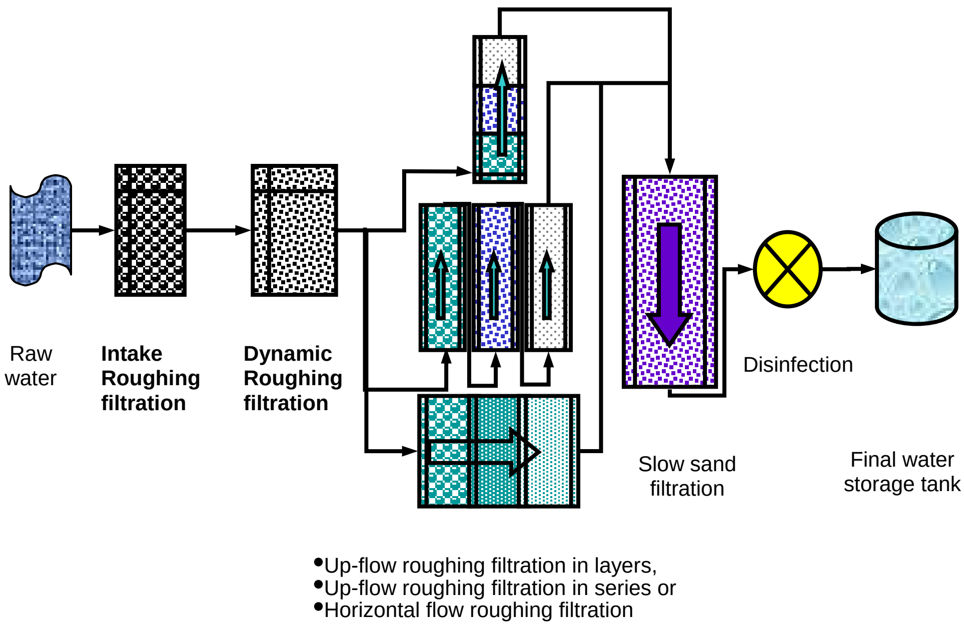
4-2 HORIZONTAL-FLOW ROUGHING FILTRATION (HRF)

1	**Purpose and status**	Horizontal-flow roughing filtration (HRF) is used to reduce turbidity and suspended solids in raw water that is characterised by medium to high turbidity (10-500 NTU) and suspended solids > 5 mg/L, to levels acceptable for effective slow sand filtration. HRF is a proven technology but emerging in application.
2	**Alternatives**	Conventional sedimentation, up-flow roughing filtration
3	**Summary of key features**	Raw water flows in a horizontal direction through several graded gravel media (increasing in size in the direction of flow) placed in separate units arranged in series. Sedimentation mechanisms retain the suspended particles within the gravel pores and the filter unit is cleaned by fast drainage.
4	**Description**	HRF is a gravel (d_e = 2-20 mm) filtration process in which several graded gravel layers are placed in separate compartments, arranged in series and gravity continuously drives raw water through the filter media at filtration rates ranging from 0.50-2.0 $m^3/h/m^2$ of filter media surface. The depth of the filter media is usually less than 1.0 m and the total length usually greater than 5.0 m. Physical mechanisms are responsible for the clarification of the raw water, although to some extent biological mechanisms are also active. URF is usually applied as a pre-treatment stage prior to slow sand filtration — a combination widely known as multi-stage filtration. Coagulation can be included as a pre-treatment to enhance the HRF process, especially for handling high-turbidity raw water.
5	**Technology illustration**	
6	**Performance limitations**	Not suitable for treatment of raw water with very high turbidity (> 500 NTU) and high colour without the aid of chemical coagulation Can remove turbidity to less than 5 NTU and colour to less than 5 Colour units. Electricity supply is not critical unless electronic chemical dosing equipment and pumping are used. Operator's presence is required daily. Regular technical support is necessary. Supply of chemicals is not critical, but necessary where there is high-turbidity raw water. Impact of raw water variations for short periods is not very critical.
7	**Recommended capacity**	Suitable capacity ranges from small to medium. Capacity can be expanded by adding more units.

8	**Operational requirements**	Semi-trained and trained labour is required. Operator input is required 8 h/day. No chemical dosage required unless coagulation is incorporated. No automation is required. Head loss and effluent quality must be checked daily.
9	**Maintenance requirements**	No moving parts, hence cost of servicing/repairs/replacement is low. Frequency of filter cleaning is usually monthly, or more often. Recommended spare valves and tools for cleaning must be readily available.
10	**Infrastructure requirements**	Conventional infrastructure
11	**Impact of failure**	Can lead to effluent turbidity unsuitable for slow sand filtration, hence rapid clogging of filter media can be expected if the HRF fails.
12	**Energy requirements**	Water flows by gravity through filters, but a regular electricity supply is required if raw water is supplied by pumping and if electronic chemical dosing is employed.
13	**Capital costs**	No local data is yet available, but costs are expected to vary depending on capacity of plant, site conditions and local contractors. Filter tank construction and chemical dosing facilities make up the bulk of capital costs.
14	**Operating costs**	Operating costs are only due to labour used during operation and cleaning processes.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Exact locations are unknown, but HRF reported to be in use in KwaZulu-Natal and Eastern Cape Provinces.
17	**Socio-economic aspects**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	Umgeni Water

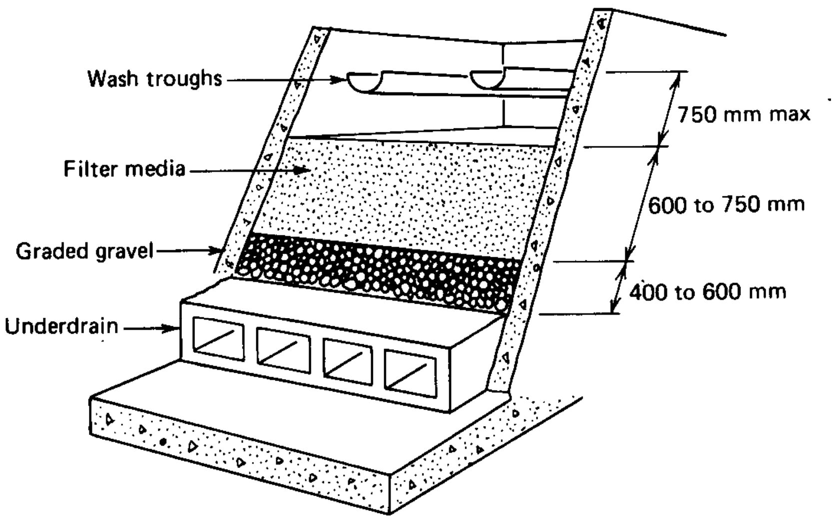
4-3 INTAKE AND DYNAMIC ROUGHING FILTRATION

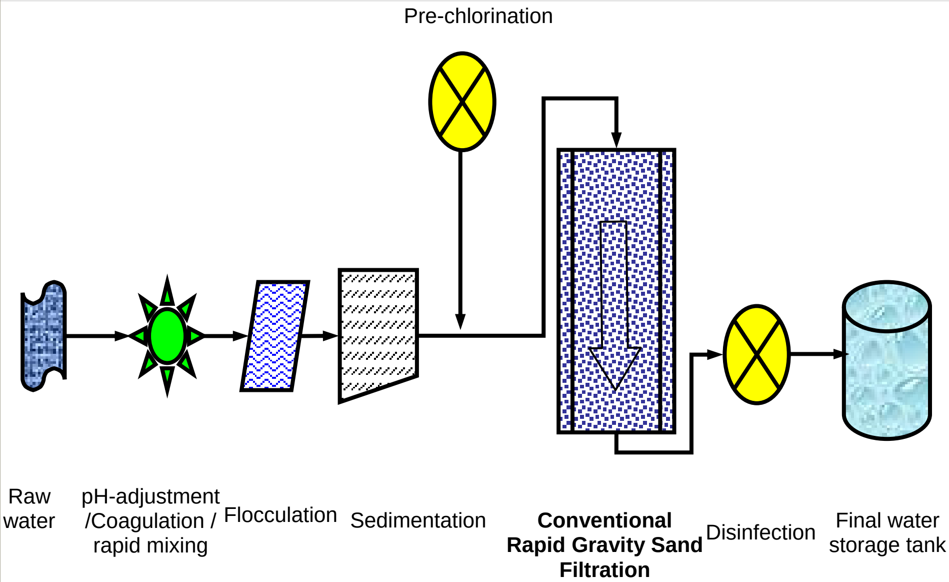
1	**Purpose and status**	Intake and dynamic roughing filtration (IDyRF) are applied as first pre-treatment unit processes in a water treatment scheme to reduce suspended solids and turbidity from raw water that is characterised by medium to very high turbidity (>10-500 NTU). Suspended solids are reduced to levels acceptable in water to be treated by other filtration processes. It is a proven technology, but emerging in application in SA.
2	**Alternatives**	Plain sedimentation
3	**Summary of key features**	Raw water flows downwards through several graded gravel media layers (decreasing in size in the direction of flow) placed in a single unit. Surplus water flows in a horizontal direction, leading to an overflow chamber. Sedimentation and straining mechanisms retain the suspended particles within the gravel pores. The filter unit is cleaned by fast drainage.
4	**Description**	IDyRF are gravel filtration processes in which the gravel is arranged in layers within one compartment gravity continuously drives raw water through and above the filter media at filtration rates ranging from 0.30-1.0 and 2-3 m^3/h per m^2 of filter media surface, respectively. (See Field No. 5 for design details.) Intake roughing filtration is usually applied at the intake to remove suspended solids while dynamic roughing filters are applied within the treatment plant to protect the plant against sudden peak turbidity and suspended solids. Physical mechanisms are responsible for the clarification of the raw water, although to some extent biological mechanisms are also active. IDyRF are applied as a pre-treatment stage prior to up-flow or horizontal flow roughing filtration–slow sand filtration system, a combination widely known as multi-stage filtration.
5	**Technology illustration**	 **list of symbols** d_g (mm) gravel size L (m) filter length W (m) filter width A (m^2) filter area ΔH (cm) headloss Q (m^3/h) flow rate v_F (m/h) filtration rate q (m^3/h) surplus flow rate **design guidelines** — intake filter / dynamic filter filtration rate $v_F = \frac{Q}{L \cdot W} = \frac{Q}{A}$ — 0.3 - 1 m/h / 2 - 3 m/h max. headloss (operation) ΔH — ~20 - 40 cm / ~20 - 40 cm gravel size — gravel layer height d_g = 2 - 4 mm — – / 20 - 30 cm d_g = 4 - 8 mm — 30 - 40 cm / 10 cm d_g = 8 - 12 mm — (10 - 20 cm) / 10 cm
6	**Performance limitations**	Not suitable for treatment of coloured raw water Can remove turbidity to less than 5 NTU and colour to less than 5 Colour units. Electricity supply is not critical unless pumps are required to abstract raw water. Operator's presence is required weekly. Regular technical support is necessary. Supply of chemicals is not critical. Impact of raw water variations for short periods is not very critical.

7	**Recommended capacity**	Suitable capacity ranges from to small to medium. Capacity can be expanded by adding more units.
8	**Operational requirements**	Semi-trained and trained labour is required. Operator input required is 2 h per week No chemical dosage is required. No automation is required. Head loss and effluent quality must be checked weekly.
9	**Maintenance requirements**	No moving parts, hence cost of servicing/repairs/replacement is low. Filter cleaning frequency is usually weekly, or more often. Recommended spare valves and tools for cleaning must be readily available.
10	**Infrastructure requirements**	Conventional infrastructure
11	**Impact of failure**	Can lead to effluent turbidity and suspended solids not suitable for up-flow or horizontal flow roughing filtration–slow sand filtration systems, hence rapid clogging
12	**Energy requirements**	Water flows by gravity through filters, but a regular electricity supply is required if raw water is supplied by pumping.
13	**Capital costs**	No local data is yet available, but is expected to vary depending on capacity of plant, site conditions and local contractors. Filter tank construction and filter media make up the bulk of capital costs.
14	**Operating costs**	Operating costs are only due to labour used during monitoring and cleaning tasks.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	No local applications documented as yet.
17	**Socio-economic aspects**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	Cape Peninsula University of Technology

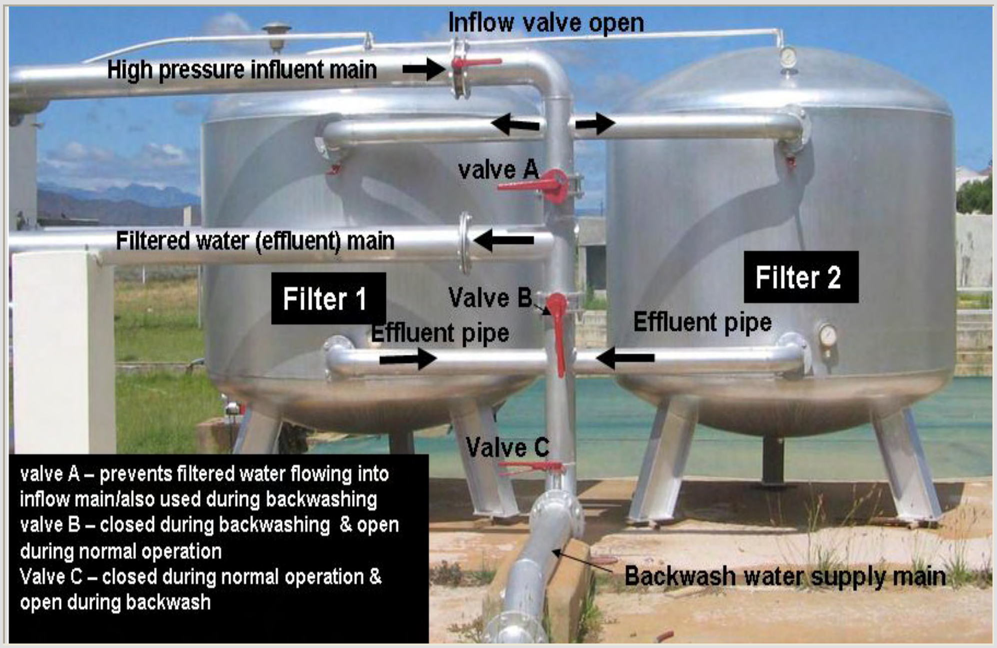
5. FINE FILTRATION

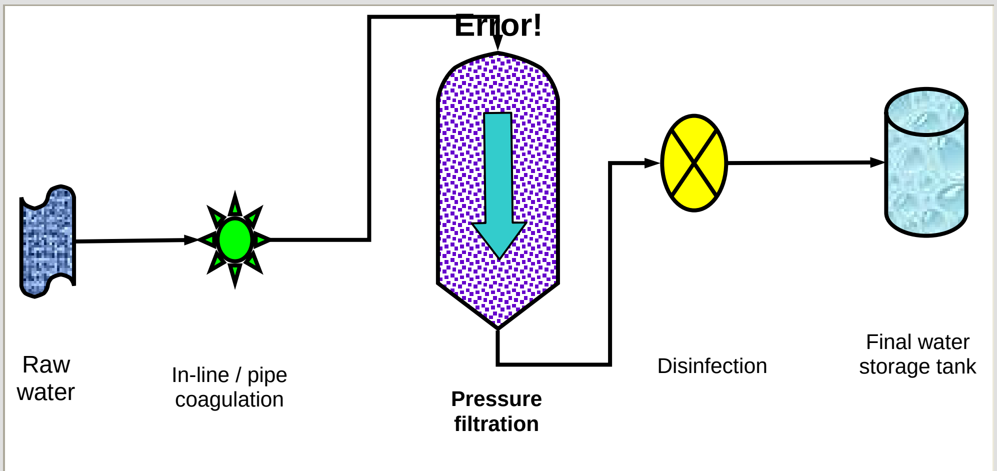
5.1 CONVENTIONAL RAPID GRAVITY SAND FILTRATION

NO	FIELD	INFORMATION
1	**Purpose and status**	To reduce turbidity, and other water quality such as colour and algae from raw water that is characterised by medium to very high levels to levels acceptable for effective disinfection It is a proven technology in application over several years now
2	**Alternatives**	Slow sand filtration, pressure filtration,
3	**Summary of key features**	Filter media cleaning by backwashing mechanisms and control of filtration rates
4	**Description**	▪ CRGSF is a down-flow sand filtration process that takes place in an open unit containing filter media (sand d_e ~ 0.5 – 0.7 mm) in which gravity is used to continuously drive pre-treated raw water through the filter media at filtration rates ranging from 5 – 15 $m^3/h/m^2$ of filter media surface. ▪ Physical mechanisms are responsible for the clarification of the pre-treated raw water. ▪ It forms the main treatment stage in a water treatment plant. ▪ The pre-treatment processes applied to raw water are pre-chlorination (if required), pH-adjustment (if required), coagulation/rapid mixing, flocculation and sedimentation. ▪ When the filter media is clogged, it is cleaned by backwashing
5	**Technology Illustration**	
6	**Performance limitations**	Not suitable for treatment of saline raw water Can remove turbidity to less than 1 NTU and colour to less than 5 Colour units, Electricity supply is critical for filter washing and pre-treatment processes Operator's *presence is critical* Regular technical support is very critical, coupled with periodic maintenance Supply of chemicals is critical for the pre-treatment stage Impact of raw water variations is critical
7	**Suitable capacity application**	*Suitable capacity ranges from to small to large* *Expansion is not easy*
8	**Operation requirements**	*Semi-trained and skilled labour is required* *Operator input required daily as required* *chemical dosage required - YES, for pre-treatment needs;* *Full and partial- autonomy* *Type and Frequency of process and quality control monitoring tasks - ; effluent quality can be checked daily;*
9	**Maintenance requirements**	*High cost of servicing/repairs/replacement, because of moving parts* *Filter media cleaning frequency is at least daily or as required* *Recommended spares for chemical dosing equipment must be readily available;*

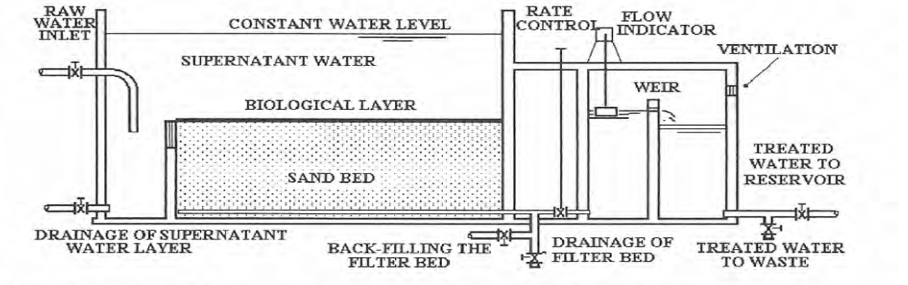
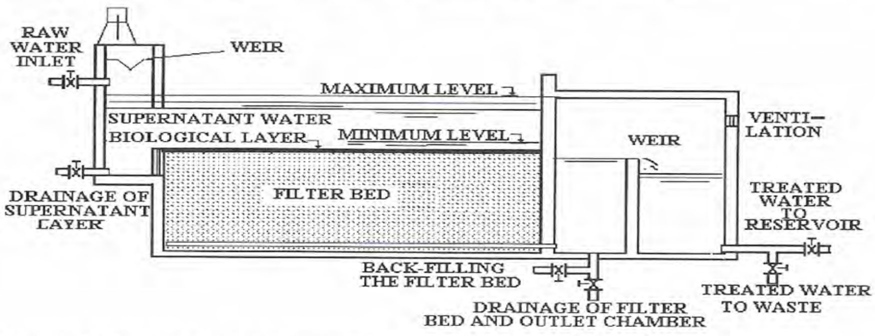
10	**Infrastructure requirements**	*Conventional infrastructure*
11	**Impact of Failures**	Turbidity break-through can take place leading to ineffective disinfection
12	**Energy requirements**	*Regular electricity supply is required for pre-treatment processes*
13	**Capital cost**	Mainly comprise of filter unit construction (usually made of reinforced concrete), under drain and backwashing facilities electrification and automation (if selected) also make up capital costs
14	**Operating cost**	Operating costs are high due to chemical and skilled labour used during operation and maintenance
15	**Typical treatment process configuration (train) or example**	 NOTE: pre-chlorination is applied if raw water has algae to prevent algae growth in the filters
16	**Examples of installations**	*Ashton WTW , 1 Ml/d, Western Cape* Dordrecht, 1.6 *Ml/d*, Eastern Cape *Bredasdorp,.5 Ml/d, Western Cape* *Henkries WTW, Nababeep, Northern Cape* *Clocolan, 2 Ml/d, Free State*
17	**Socio-economic aspects**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of and manage this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	*Umgeni Water* *Chris Swartz Water Utilisation Engineers* *Cape Peninsula University of Technology* *University of Johannesburg* *Water Research Commission*

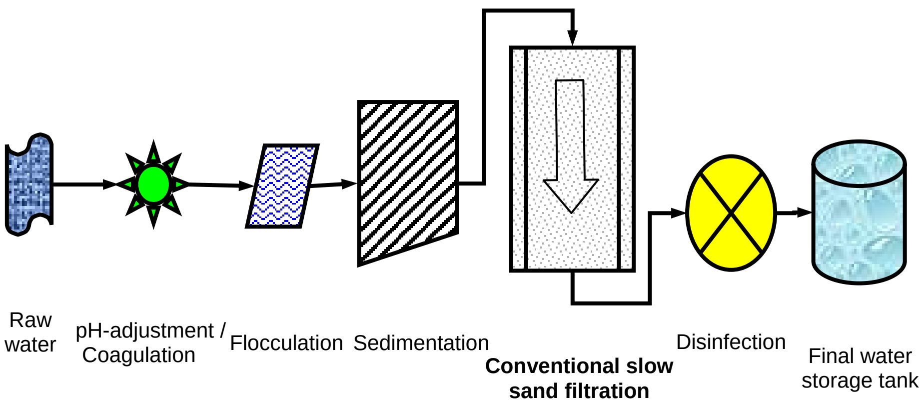
5-2 DIRECT PRESSURE SAND FILTRATION

1	**Purpose and status**	To reduce turbidity and colour from raw water that is characterised by low to medium turbidity (<10-50 NTU) and colour (< 25-100 mg/l as Pt), to levels acceptable for effective disinfection It is a proven technology, in application over several years now.
2	**Alternatives**	Direct up-flow rapid sand filtration Slow sand filtration
3	**Summary of key features**	Direct pressure filtration is only preceded by coagulation without any separate structures for rapid mixing and flocculation/sedimentation. Rapid mixing takes place in the raw water pipe where the coagulant is added. Flocculation and sedimentation take place inside the filter unit. The filter medium is cleaned by backwashing mechanisms.
4	**Description**	Pressure filtration is a down-flow sand filtration process that takes place in an enclosed unit containing filter media (sand d_e ~ 0.5 mm) in which high pressure is used to continuously drive pre-treated raw water through the filter media at filtration rates ranging from 5-20 $m^3/h/m^2$ of filter media surface. Physical mechanisms are responsible for the clarification of the pre-treated raw water. It forms the main treatment stage in a water treatment plant. In conventional pressure filtration, the pre-treatment processes applied to raw water are pH-adjustment (if required), coagulation/rapid mixing, flocculation and sedimentation.
5	**Technology illustration**	
6	**Performance limitations**	Not suitable for treatment of high-turbidity raw water Can remove turbidity to less than 1 NTU and colour to less than 5 Colour units. Electricity supply is critical for the requirement of high pressure through filter. Operator's presence is not critical as process can also be automated. Technical support is negligible, but required for annual maintenance. Supply of chemicals is critical for the coagulation stage. Impact of raw water variations is not limiting as pre-treatment can be adjusted to handle this.
7	**Recommended capacity**	Suitable capacity ranges from to small to medium. Ease of expansion is simple as units are usually made in modular format.
8	**Operational requirements**	Semi-trained and trained labour is required. Operator input is required 8 h/day. Chemical dosage is required, for pre-treatment needs. Full and partial automation Head loss and effluent quality must be checked daily.

9	**Maintenance requirements**	Cost of servicing/repairs/replacement is high, because of mechanical operation and chemical pre-treatment. Daily filter media cleaning is required. Recommended spares for chemical dosing equipment and tools for cleaning must be readily available.
10	**Infrastructure requirements**	Conventional infrastructure
11	**Impact of failures**	Turbidity break-through can take place, leading to ineffective disinfection.
12	**Energy requirements**	Regular electricity supply is required for pressure.
13	**Capital costs**	Costs vary depending on capacity of plant, site conditions and local contractors. Filter tank construction and chemical dosing facilities make up the bulk of capital costs.
14	**Operating costs**	Operating costs are mainly due to chemicals and labour used during chemical preparations
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Hogsback (< 0.3 Ml/d), Nkokobe Municipality (Eastern Cape) Monguzi Hospital (0.55 Ml/d) (Kwa-Zulu Natal) Upper Mnyameni (0.26 Ml/d) (Eastern Cape) Silverstroom WTP (unknown capacity) (Western Cape) Wellington WTP (unknown capacity), Wellington Municipality (tel. 021-8731121) Porterville WTP (7.5 Ml/d), Porterville Municipality (tel. 026-232100)
17	**Socio-economic aspects**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	WRC Report No. 450/1/97 Umgeni Water WRC Report No. 738/1/00 Chris Swartz Water Utilisation Engineers

5-3 CONVENTIONAL SLOW SAND FILTRATION

1	**Purpose and status**	To reduce turbidity, suspended solids, colour and pathogenic micro-organisms from raw water that is characterised by medium to high turbidity (10-500 NTU), suspended solids greater than > 5 mg/l, high colour and pathogenic contamination, to levels acceptable for effective disinfection, with the help of pre-treatment It is a proven technology, in full-scale use for a period of time in water treatment.
2	**Alternatives**	Conventional rapid sand filtration Pressure filtration
3	**Summary of key features**	Conventional slow sand filtration (CSSF) treats medium- to high-turbidity raw water, with the aid of conventional chemical pre-treatment (coagulation, flocculation and sedimentation).
4	**Description**	Slow sand filtration is a down-flow sand filtration process that takes place in an open unit containing fine filter sand (de ~ 0.15-0.35 mm) in which gravity is used to continuously drive raw water through the filter media at filtration rates ranging from 0.10-0.30 $m^3/h/m^2$ of filter media surface Physical and biological mechanisms are responsible for the clarification of the raw water. CSSF forms the main treatment stage in a water treatment plant. The filtration rate can either be controlled from the inlet or outlet side of the filter unit, either option having its own pros and cons, depending on designer preference. In CSF, pre-treatment is applied to raw water; using conventional coagulation, flocculation and sedimentation.
5	**Technology illustration**	 Scheme of a slow sand filter with constant rate and constant supernatant water layer  Scheme of a slow sand filter with constant rate and variable supernatant water layer
6	**Performance limitations**	Not suitable for treatment of floc overflows from sedimentation stage Can remove turbidity to less than 1 NTU and colour to less than 5 Colour units, and less than 1 FC/100 ml. Electricity supply is not critical for the chemical dosing equipment and pumping (if required). Operator's presence is critical because of the chemical pre-treatment stage. Requirement for Technical support is negligible. Supply of chemicals is critical for the pre-treatment process as chemicals are not required for this application. Impact of raw water variations is critical.

7	**Recommended capacity**	Suitable capacity ranges from to small to large. Ease of expansion is generally difficult, but can be easy if package units are used in small plants.
8	**Operational requirements**	Semi-trained and trained labour is required. Operator input is required 24 h/day. No chemical dosage required but chemicals required for pre-treatment. No automation Head loss and effluent quality can be checked daily.
9	**Maintenance requirements**	Cost of servicing/repairs/replacement is high, because of chemical pre-treatment. Filter cleaning frequency can range from 1 to 6 months. Recommended spares for chemical dosing equipment and tools for cleaning must be readily available.
10	**Infrastructure requirements**	Conventional infrastructure
11	**Impact of failures**	Effluent quality not affected but production is reduced.
12	**Energy requirements**	Water flows by gravity through filters, but regular electricity supply is required if raw water is supplied by pumping, and because of chemical dosing.
13	**Capital costs**	No local data is yet available, but is expected to vary depending on capacity of plant, site conditions and local contractors. Filter tank construction and chemical dosing facilities make up the bulk of capital costs.
14	**Operating costs**	Operating costs are only due to chemicals and labour used during operation and cleaning processes.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Ashton (~2 ML/d), Swellendam (_5 MlLd) (Western Cape) Seymour water treatment plant (< 2 ML/d), Nkokobe Municipality (Eastern Cape) Moganyaka town plant (0.8 ML/d) (Northern Province) Mosvold hospital (0.3 ML/d), Frischgewaagd (0.68 ML/d) (Kwa-Zulu Natal)
17	**Socio-economic aspects**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	WRC Report No. 450/1/97 Umgeni Water WRC Report No. 738/1/00 Cape Peninsula University of Technology

5-4 DIRECT SLOW SAND FILTRATION

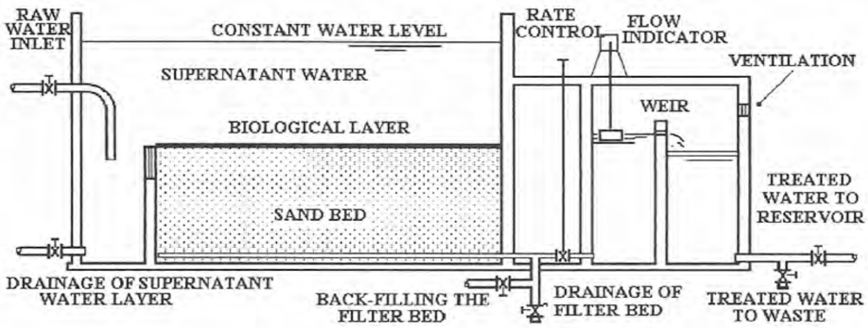
<table>
<tr><td>1</td><td>Purpose and status</td><td>To reduce turbidity, colour, suspended solids and pathogenic micro-organisms from raw water that is characterised by low turbidity (< 10 NTU), low colour (< 15 colour units), suspended solids (< 5 mg/L) and pathogenic contamination, to levels acceptable for effective disinfection, without the requirement for any pre-treatment

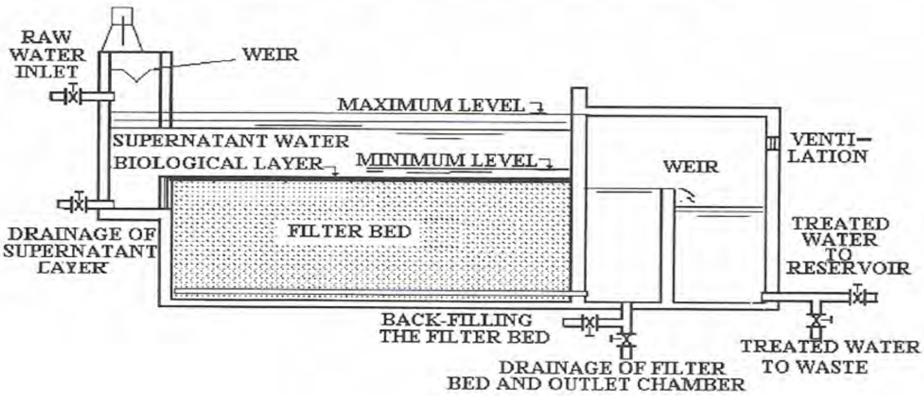
Proven technology: in full-scale use in water treatment</td></tr>
<tr><td>2</td><td>Alternatives</td><td>Dynamic-cross flow sand filtration</td></tr>
<tr><td>3</td><td>Summary of key features</td><td>Low turbidity raw water is filtered by slow sand filtration with any pre-treatment</td></tr>
<tr><td>4</td><td>Description</td><td>No pre-treatment of the raw water is required, but the water must be characterised by low turbidity (< 10 NTU).

Slow sand filtration is a down-flow sand filtration process that takes place in an open unit containing fine filter sand (d_e ~ 0.15-0.35 mm) in which gravity is used to continuously drive raw water through the filter medium at filtration rates ranging from 0.10-0.30 $m^3/h/m^2$ of filter medium surface.

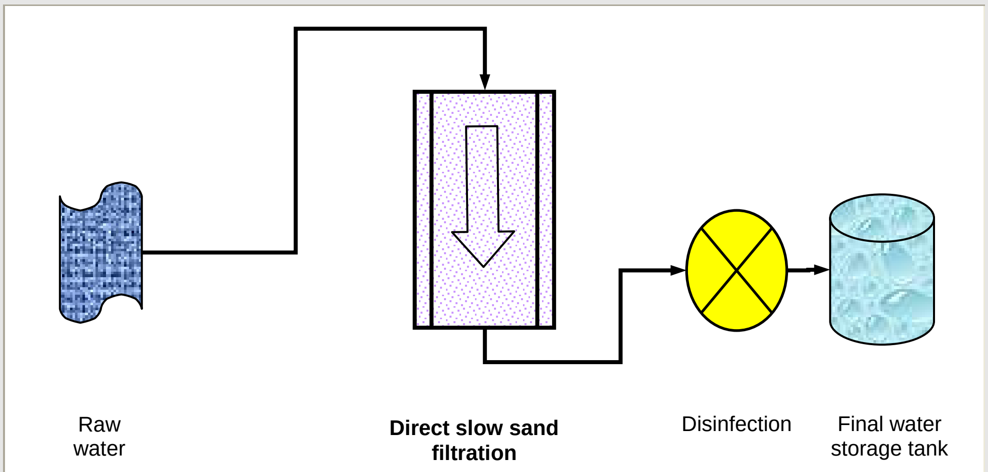
The filtration rate can either be controlled from the inlet or outlet side of the filter unit. Both options have their pros and cons, depending on designer preference.

Physical and biological mechanisms are responsible for clarification of the raw water.

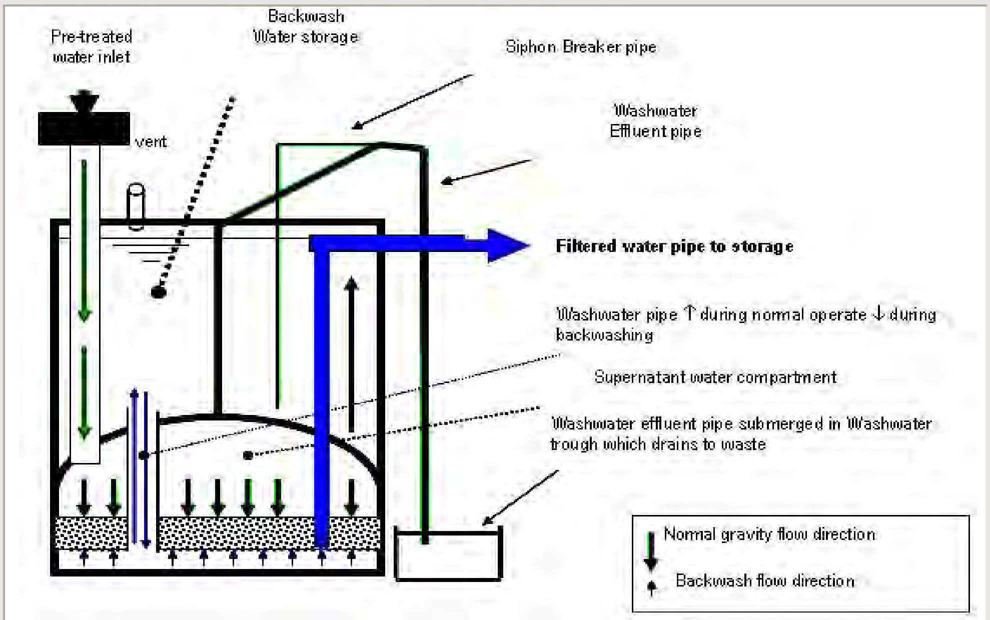
It forms the main treatment stage in a water treatment plant.</td></tr>
<tr><td>5</td><td>Technology illustration</td><td>


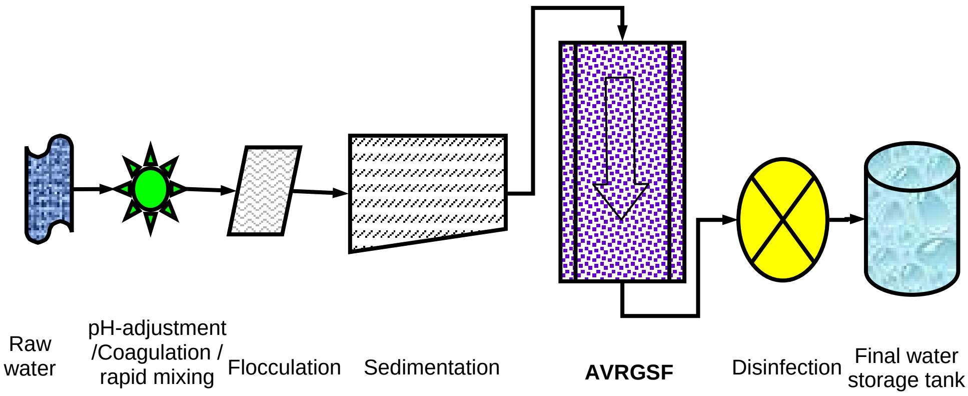
Scheme of a slow sand filter with constant rate and constant supernatant water layer


Scheme of a slow sand filter with constant rate and variable supernatant water layer
</td></tr>
<tr><td>6</td><td>Performance limitations</td><td>Process is unsuitable for treatment of raw water with high turbidity and colour.
It can remove turbidity to less than 1 NTU and colour to less than 5 colour units, and less than 1 FC/100 mL.
Electricity supply is not critical unless gravity supply is not available and electronic equipment is used to dose chemicals.
Operator’s presence is not critical, although it is required at the disinfection stage.
Technical support is negligible.</td></tr>
</table>

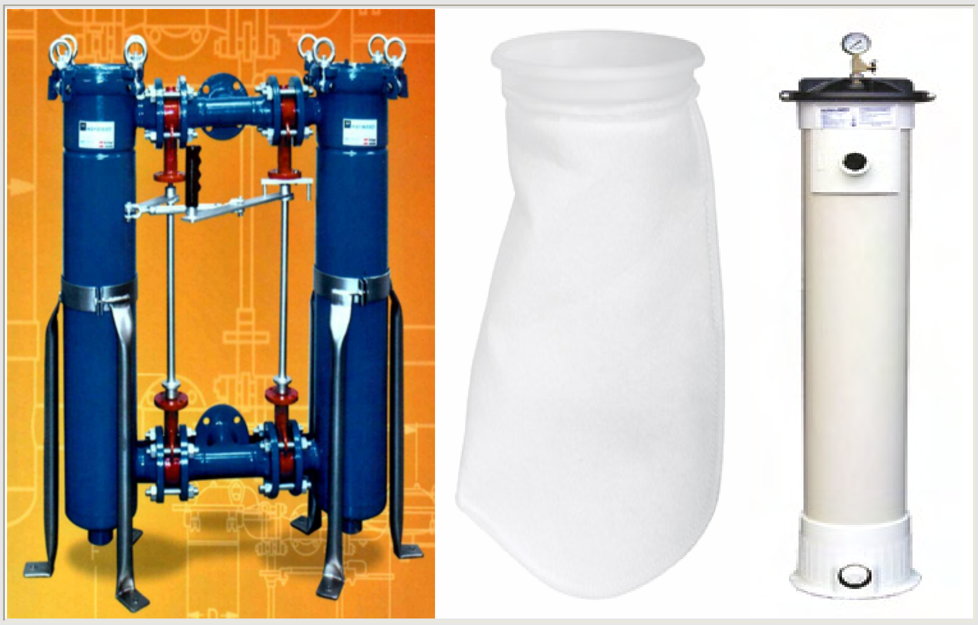
		Impact of raw water variations is critical.
7	**Recommended capacity**	Suitable capacity ranges from small to large. Ease of expansion is generally difficult, but can be easy if package units are used in small plants.
8	**Operational requirements**	Semi-trained and untrained labour is required. Operator input is required 24 h/day. No chemical dosage is required. No automation is required. Head loss and effluent quality can be checked daily.
9	**Maintenance requirements**	Servicing/repairs/replacement costs are low, due to absence of pre-treatment. Frequency of filter cleaning can range from 1 to 6 months. Recommended tools for cleaning must be readily available.
10	**Infrastructure requirements**	Conventional infrastructure
11	**Impact of failures**	Turbidity breakthrough and deterioration of microbiological quality of the filtrate
12	**Energy requirements**	Water flows through filters by gravity, but a regular electricity supply is required if raw water is to be supplied by pumping.
13	**Capital costs**	No local data is available. Costs will vary depending on capacity of plant, site conditions and local contractors. Filter tank construction makes up the bulk of the capital costs
14	**Operating costs**	Operating costs are only due to labour used during cleaning processes.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Tulbagh (< 5 ML/d), Ceres Municipality (Western Cape) Vredendal WTP (7.5 ML/d), Vredendal Municipality (Western Cape) (tel. 0271-31045)
17	**Socio-economic aspects**	Community acceptance and participation tested / known. Willingness to accept ownership and manage the technology needs community involvement and training from the start of the project. Operating cost will have an effect on willingness to pay.
18	**Research and evaluation in South Africa**	Cape Peninsula University of Technology (CPUT)

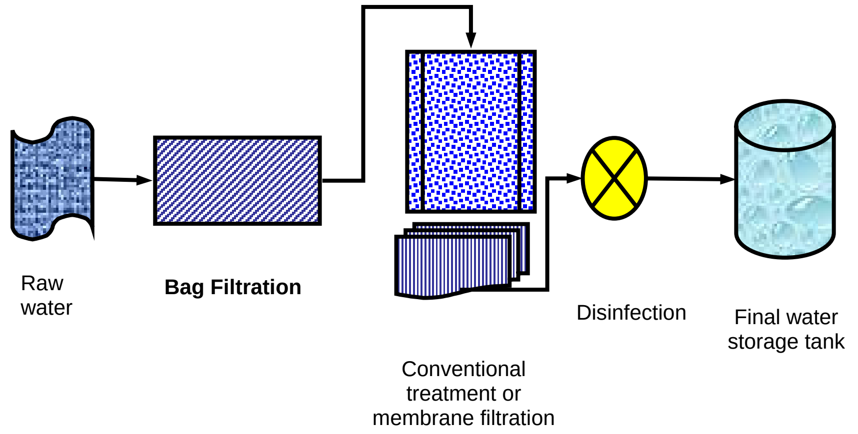
5-5 AUTOMATIC BACKWASH FILTRATION

1	**Purpose and status**	To reduce turbidity and colour from raw water that is characterised by medium to high turbidity (50-500 NTU) and colour (15-300 Colour units), to levels acceptable for effective disinfection It is a proven technology, however its application is scanty but gaining ground.
2	**Alternatives**	Rapid sand filtration Slow sand filtration Pressure filtration
3	**Summary of key features**	Automatic backwashing (filter media cleaning) mechanisms
4	**Description**	Autonomous backwashing filtration (ABF) s a down-flow sand filtration process that takes place in an enclosed unit containing filter media (sand d_e ~ 0.5 mm), in which gravity is used to continuously drive pre-treated raw water through the filter media at filtration rates averaging 5 $m^3/h/m^2$ of filter- media surface. Physical mechanisms are responsible for the clarification of the pre-treated raw water. The pre-treatment processes applied to raw water are pH-adjustment (if required), coagulation/rapid mixing, flocculation and sedimentation. Both the normal filter operation and filter-media cleaning is autonomous, without the need to operate any valves, hence the name autonomous-valveless. Under normal operation, the filter unit stores the filtered water until the backwash storage is full, then the filtered water starts to flow to the storage reservoir. As the filter media gets clogged, the supernatant water rises up the washwater effluent pipe, driving out all the air. It forms the main treatment stage in a water treatment plant.
5	**Technology illustration**	
6	**Performance limitations**	Not suitable for direct filtration of high-turbidity raw water, with or without coagulation. Not suitable for treatment of excessive floc overflows from sedimentation stage. Can remove turbidity to less than 1 NTU and colour to less than 5 Colour units. Electricity supply is critical for coagulation. Operator's presence is not critical. Regular technical support is not very critical, but required for periodic maintenance. Supply of chemicals is critical for the coagulation stage. Impact of raw water variations is critical if sedimentation is absent.
7	**Recommended capacity**	Suitable capacity ranges from small to medium. Expansion is easy as units are usually made in modular format.

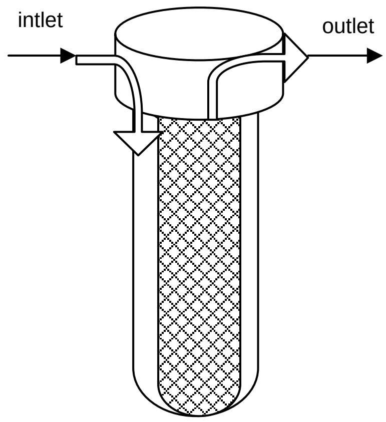
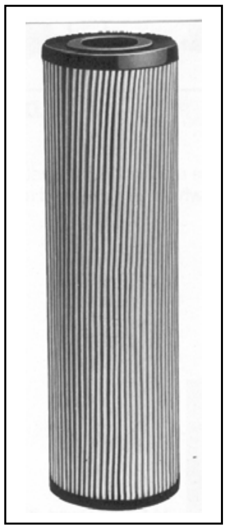
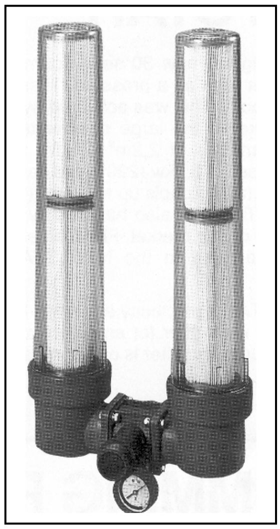
8	**Operational requirements**	Semi-trained and trained labour is required. Operator input is required daily. Chemical dosage is required, for pre-treatment needs. Full and partial autonomy Effluent quality can be checked daily
9	**Maintenance requirements**	Cost of servicing/repairs/replacement is low, because of absence of moving parts. Daily cleaning of filter media is required, or as required. Recommended spares for chemical dosing equipment must be readily available.
10	**Infrastructure requirements**	Conventional infrastructure
11	**Impact of failures**	Ineffective backwashing and poor effluent quality
12	**Energy requirements**	Regular electricity supply is required for pre-treatment processes.
13	**Capital costs**	No local data available, but is expected to vary depending on capacity of plant, site conditions and local contractors. Filter tank construction and chemical dosing facilities make up the bulk of capital costs.
14	**Operating costs**	Operating costs are only due to chemicals and labour used during monitoring pre-treatment processes.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Riviersonderend (1 ML/d) (Western Cape) Alice (3 ML/d), Chofimvaba (0.5 ML/d) (Eastern Cape)
17	**Socio-economic aspects**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	WRC Report No. 919/1/03 Umgeni Water Cape Peninsula University of Technology

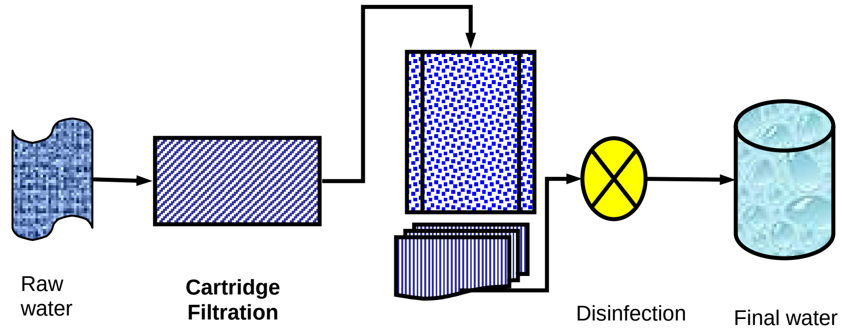
5-6 BAG FILTERS

1	**Purpose and status**	To remove fine suspended material from the feed stream. It is a proven technology
2	**Alternatives**	Cartridge filtration; Sand filtration
3	**Summary of key features**	Normally used as fine filtration method in industrial applications or as pre-treatment in drinking water treatment.
4	**Description**	A bag filter works by the principle of micro filtration. The liquid is purified in bags by passing small permeable pores. Bag filters can be used for large amounts of water. The sizes of these pores are between the 1 – 200 micron. The capacity depends on the surface area from the bags. Bigger systems can clean up to more than 500 m^3/h (multi bag filters).There are special bag filters for various chemicals. The liquid flows from the top of the filter house and is distributed equally amongst the bags. The liquid comes out at the bottom leaving the dirt behind. Since the bag is locked in at the top of the vessel all the dirt is trapped inside the bag, the filter vessel never requires cleaning after use.
5	**Technology Illustration**	
6	**Performance limitations**	Too high flow rates applied; too high solids loadings applied.
7	**Suitable capacity application**	Small-scale to medium size drinking water treatment plants.
8	**Operation requirements**	Monitor the head-loss over the system and hence the degree of fouling of the bags; clean or replace the bags when required.
9	**Maintenance requirements**	Check values and housing; check pressure meters
10	**Infrastructure requirements**	Can be used in-line in the feed water stream; minimal infrastructure is required.
11	**Impact of Failures**	Low throughputs when severe fouling of the bags takes place.
12	**Energy requirements**	Electricity required for feed pumps.
13	**Capital cost**	Moderate capital costs may be expected when stainless steel vessels are used as housing.
14	**Operating cost**	Minimal operating costs for relatively clean waters; can be high when frequent bag change-outs are required.

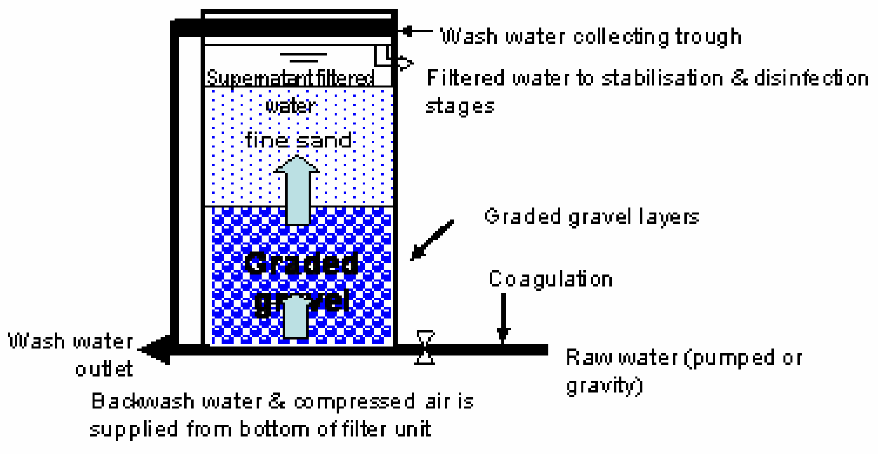
15	**Typical treatment process configuration (train) or example**	
16	**Examples of installations**	Saron (Drakenstein Municipality)
17	**Socio-economic aspects**	Only requirement for the treatment plant operator (or community) is to change the filter bags when it becomes fouled.
18	**Research and evaluation in South Africa**	Bag filter suppliers

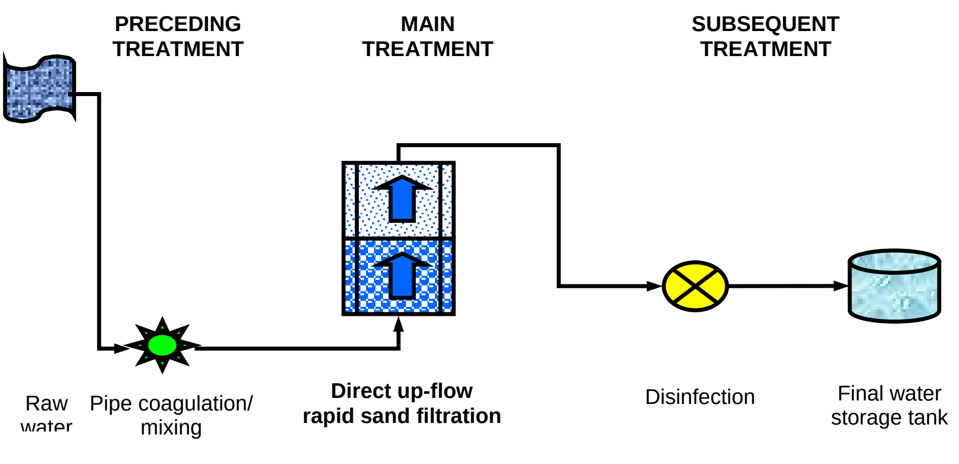
5-7 CARTRIDGE FILTRATION

1	**Purpose and status**	Suspended solids removal Proven technology
2	**Alternatives**	Sand filtration; bag filtration
3	**Summary of key features**	Cartridge filters are installed in-line in the process stream, either as main treatment or as pre-treatment for subsequent processes. Removes suspended material and small particles from 1 micron to 50 micron. Can be used as pre-treatment for subsequent finer filtration processes such as Microfiltration or ultrafiltration.
4	**Description**	Pleated paper or fibre wound cartridge filters The cartridges are sized to screen particles ranging in size from 1 micron to 50 micron. Used as pre-treatment for particle removal.
5	**Technology Illustration**	  
6	**Performance limitations**	Cannot remove fine colloidal material or organics. Need to be cleaned regularly to ensure effective performance.
7	**Suitable capacity application**	Effective on household scale to small treatment plants and package plants. Not suitable for large installations.
8	**Operation requirements**	Only operational input required is checking of differential pressure over the cartridge filters and cleaning the filter by removing it and flushing and rinsing thereof, or replacement if required. No backwashing on these filters. Semi-skilled operator. Half hour per day.
9	**Maintenance requirements**	Cleaning of cartridges and filter housings. Checking of pressure meters. Equipment and cartridges readily available from commercial suppliers.
10	**Infrastructure requirements**	No specific requirements. Feed pump must provide sufficient pressure.
11	**Impact of Failures**	Reduced flow when excessive fouling takes place. No feed to the cartridge filters during electricity supply interruptions. If labour not available for required change-out of cartridges, excessive fouling may occur.
12	**Energy requirements**	No additional requirements apart from electricity for feed pump.
13	**Capital cost**	Relatively low, comprising only filter housing and fixtures.
14	**Operating cost**	The operating costs may be substantial, depending on the solids loading on the cartridge filters, which governs the frequency of replacement of the filters. Lower if the filters are used as pre-treatment for relatively clean water.

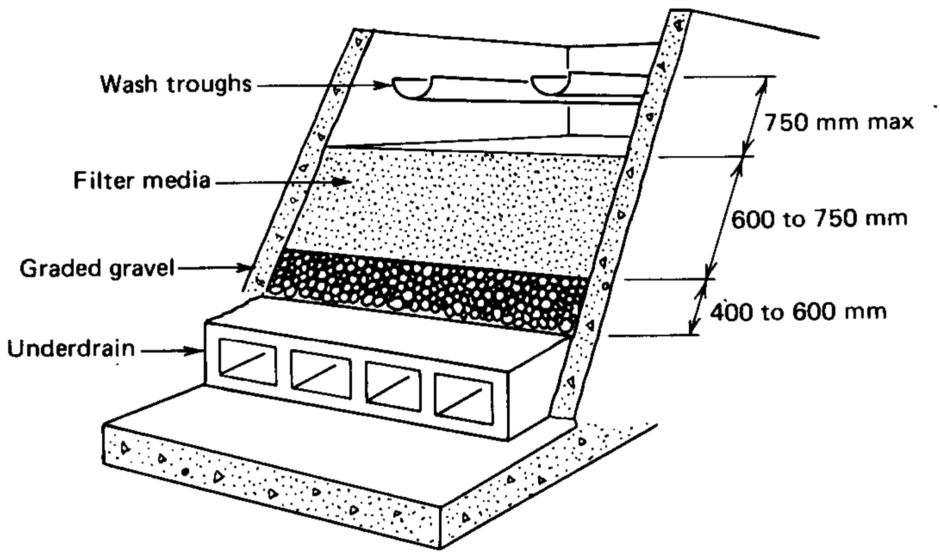
15	**Typical treatment process configuration (train) or example**	
16	**Examples of installations**	Used in industrial process streams, household systems and for in-line pre-treatment. Used widely in industry. Use in small scale drinking water treatment systems is limited.
17	**Socio-economic aspects**	Proven technology. Must be used in tandem with micro or ultra filtration. Needs a full time operator to clean regularly. Effective on a household scale. Cost-effectiveness to be compared with other small-scale pre-treatment systems. Community acceptance and participation to be encouraged.
18	**Research and evaluation in South Africa**	University of Stellenbosch

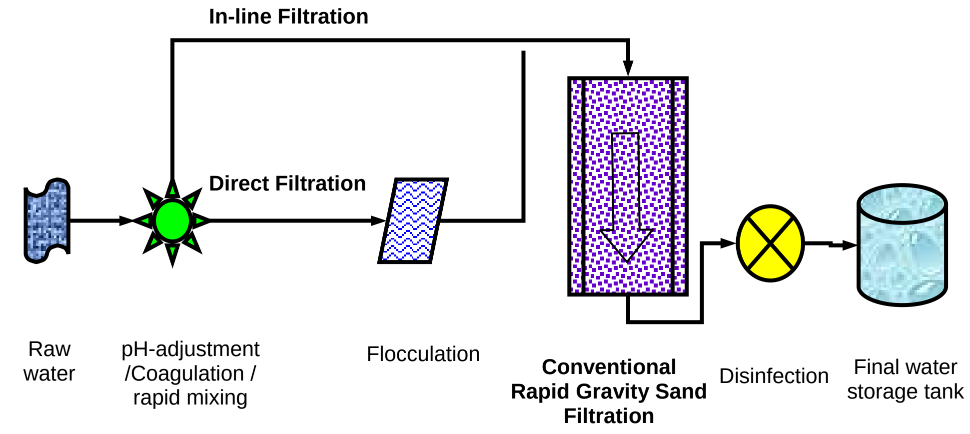
5-8 DIRECT UP- FLOW RAPID SAND FILTRATION

1	**Purpose and status**	To reduce turbidity, colour and algae from raw water that is characterised by low turbidity (< 10 NTU), colour and entropic, to levels acceptable for effective disinfection Emerging technology, that is gaining ground
2	**Alternatives**	Direct pressure filtration Direct slow sand filtration
3	**Summary of key features**	Direct up-flow rapid sand filtration is characterised by upward flow and preceded by coagulation without separate flocculation and sedimentation stages. The flocculation, sedimentation and filtration take place in one unit. The bottom part contains the gravel and the top half is filter sand. Flocculation and sedimentation take place in the gravel layer. Filter media is cleaned by backwashing
4	**Description**	DURSF is an up-flow sand and gravel filtration process that takes place in an open unit, which contains both graded layers of gravel (d_e ~ 1.5-40 mm) placed at the bottom and fine filter sand (d_e ~ 0.50-0.70 mm) on top of the gravel, in which gravity or pump(s) is used to continuously drive coagulated raw water through the filter medium at filtration rates ranging from 5-10 $m^3/h/m^2$ of the filter media surface. DURSF comes from conventional rapid sand filtration (CRSF). It is characterised by downward flow and preceded by conventional pre-treatment processes (coagulation/rapid mixing, flocculation and sedimentation) that take place in separate units. Coagulation and flush/rapid mixing take place in the raw water mains while flocculation and sedimentation processes take place within the graded gravel layers. Physical and chemical mechanisms are responsible for the clarification of the raw water. It forms the main treatment stage in a water treatment plant.
5	**Technology illustration**	
6	**Performance limitations**	Not suitable for treatment of medium to high turbidity (> 20-50 NTU), high algae and high colour raw water. Can remove turbidity to less than 1 NTU and colour to less 10 mg/L - Pt. Electricity supply is critical if electronic equipment is used. Operator's presence is critical because of the chemical dosing. Technical support is not limiting but depends on level of sophistication. Supply of chemicals is critical as technology is ineffective without chemicals. Impact of raw water variations depends on range and period of variation; small and large variations over a few hours can be sustained and may not be limiting while large variations exceeding 6 hours can be critical, requiring changes in chemical dosages and filtration rates.

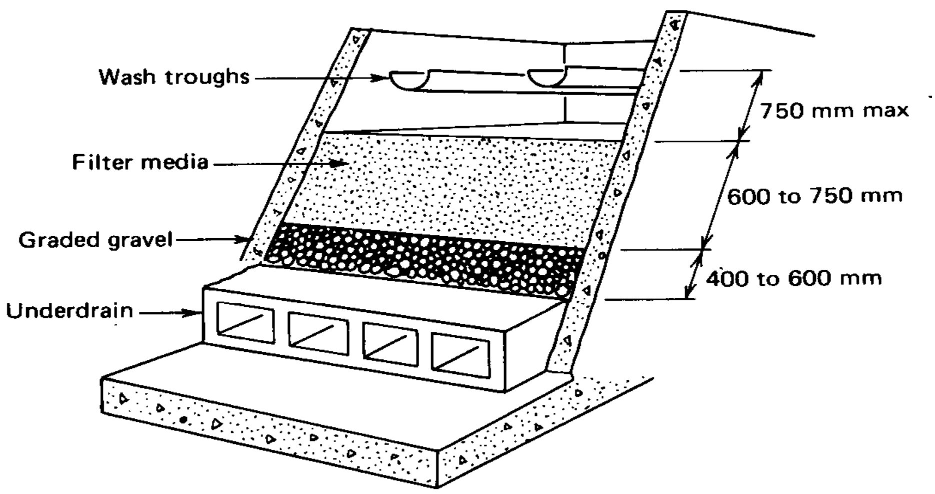
7	**Recommended capacity**	Suitable capacity ranges from small to large. Ease of expansion is generally 'easy' [modular] since technology is suitable in small communities, but can also be 'difficult' [conventional] when capacity is large (>2.5 Ml/d).
8	**Operational requirements**	Semi-skilled operator is required (trained/semi-trained/ untrained). Operator input can either be 8 or 24 man-hours/ day, depending on level of sophistication. Chemical dosage is required. Alternative chemicals can be used. Degree of automation can either be fully, semi-automated, or none. Type and frequency of process and quality control monitoring tasks: daily Availability of materials/chemicals for operation spares: readily available and long lead time
9	**Maintenance requirements**	Cost of servicing/repairs/replacement is low, but high if fully automated. Maintenance done annually, or as may be necessary. Operator can carry out maintenance but if process is fully automated, expert or skilled labour is required. Recommended spares and tools must be readily available.
10	**Infrastructure requirements**	Conventional infrastructure
11	**Impact of failures**	Turbidity, colour and algae break-through lead to undesirable odours, colour and turbidity.
12	**Energy requirements**	Regular electricity supply is required if automation and electronic equipment are used. None is required where gravity feed can be used.
13	**Capital costs**	Capital cost is 30% less than that of a conventional water treatment plant since the sedimentation and flocculation stages are omitted. Capital costs vary according to capacity of plant, site conditions and local contractors. Construction of filter units and pumping/piping contribute substantially to these costs.
14	**Operating costs**	Operating cost is due to chemicals, operator, and energy requirements.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Montagu Water Works (~4 ML/ld); Breederivier municipality; Local Authority; Montagu; Stoffberg, Malelane
17	**Socio-economic aspects**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	WRC Report No. 534/1/98 WRC Report No. 738/1/00 Cape Peninsula University of Technology

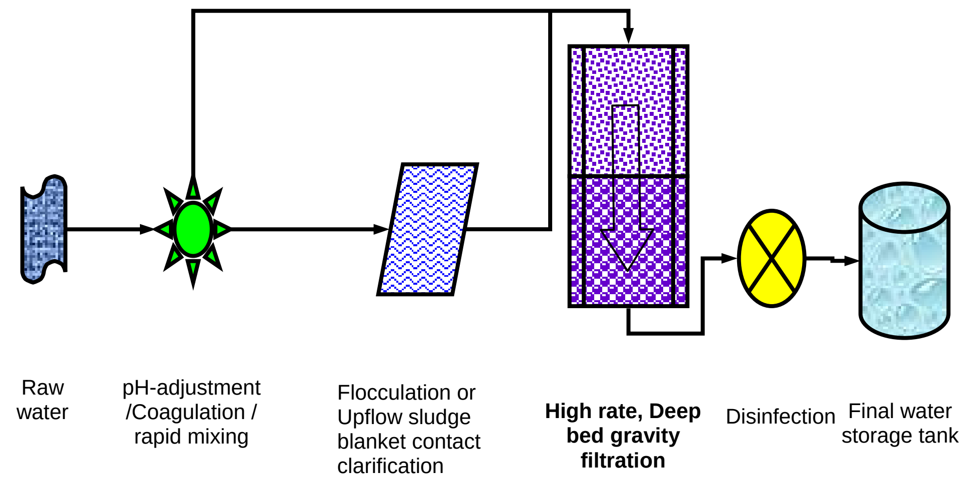
5-9 DIRECT AND IN-LINE FILTRATION

1	**Purpose and status**	To reduce turbidity, colour and algae from raw water that is characterised by low turbidity (< 10 NTU), colour and algae, to levels acceptable for effective disinfection Emerging technology, that is gaining ground
2	**Alternatives**	Direct pressure filtration Direct slow sand filtration Direct up-flow filtration
3	**Summary of key features**	Direct and in-line filtration processes are conventional rapid sand filtration minus the sedimentation unit process and minus the flocculation/sedimentation processes, respectively. The filtration flow is downward by gravity and filter media is cleaned by conventional backwashing
4	**Description**	Direct and in-line filtration processes are both gravity-flow, sand-filtration processes that take place in an open unit, which contains fine filter sand (d_e ~ 0.50- 0.70 mm) supported by graded gravel, in which gravity is used to continuously drive coagulated raw water through the filter medium at filtration rates not exceeding 5 $m^3/h/m^2$ of filter media surface. In direct filtration, rapid mixing/coagulation and flocculation precede the filtration process, without the sedimentation process. In in-line filtration, only mixing/coagulation precedes the filtration processes Physical and chemical mechanisms are responsible for the clarification of the raw water. It forms the main treatment stage in a water treatment plant.
5	**Technology illustration**	
6	**Performance limitations**	Not suitable for treatment of medium to high turbidity (> 10 NTU) and high colour raw water. Can remove turbidity to less than 1 NTU. Electricity supply is critical if electronic equipment is in use. Operator's presence is critical because of the presence of chemical dosing. Technical support is not limiting but depends on level of sophistication. Supply of chemicals is critical as technology is ineffective without chemicals. Impact of raw water quality variations depends on range and period of variation; small and large variations over few hours can be sustained and may not be limiting, while large variations (exceeding 6 hours) can be critical, requiring changes in chemical dosages and filtration rates.
7	**Recommended capacity**	Suitable capacity ranges from small to medium. Ease of expansion is generally 'easy' [modular] since technology is suitable in small communities, but can also be 'difficult' [conventional] when capacity is large (>2.5 Ml/d).

8	**Operation requirements**	Skilled operator is required. Operator input can either be 8 or 24 man-hours per day, depending on level of sophistication and capacity. Chemical dosage is required. Alternative chemicals can be used. Degree of automation can either be fully, semi-automated, or none. Type and frequency of process and quality control monitoring tasks: daily. Availability of materials/chemicals for operation/spares: readily available and long lead time
9	**Maintenance requirements**	Cost of servicing/repairs/replacement is low due to the absence of some unit processes, but high if fully automated. Maintenance carried out annually, or as may be necessary. Operator can maintain but, if fully automated, expert or skilled labour is required. Recommended spares and tools must be readily available.
10	**Infrastructure requirements**	Conventional infrastructure
11	**Impact of failures**	Turbidity break-throughs can occur, leading to undesirable turbidity levels in filtered water.
12	**Energy requirements**	Regular electricity supply is required if automation and electronic equipment are used.
13	**Capital costs**	Capital cost is 30% less than that of a conventional water treatment plant since sedimentation and flocculation stages are omitted. Cost can vary according to capacity of plant, site conditions and local contractors. Construction of filter units and pumping/piping contribute substantially to these costs.
14	**Operating costs**	Operating cost is due to chemicals, operator, and energy requirements.
15	**Typical treatment process configuration (train) or example]**	
16	**Examples of SA installations**	No documentation found to-date
17	**Socio-economic aspects**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	No documentation found to-date

5–10 HIGH-RATE GRAVITY SAND FILTRATION

1	**Purpose and status**	To reduce turbidity from raw water that is characterised by low turbidity (< 10 NTU), to levels acceptable for effective disinfection Proven technology
2	**Alternatives**	Direct pressure filtration Direct slow sand filtration Direct up-flow filtration Direct and in-line filtration
3	**Summary of key features**	Similar to conventional rapid gravity sand filtration and pressure filtration but filter medium is deeper and smaller in surface cross-sectional flow area. The filtration flow is downward by gravity and the filter medium is cleaned by conventional backwashing.
4	**Description**	High-rate gravity filtration is similar to conventional gravity rapid sand filtration and pressure filtration except that the filter bed is deeper and smaller in cross-sectional flow area, allowing for higher filtration rates. Flow is by gravity, and takes place in an open dual-media filter unit, which contains sand and anthracite as filter media, supported by graded gravel. Gravity continuously drives coagulated raw water through the filter media at filtration rates not exceeding 5 $m^3/h/m^2$ of filter media surface. Pre-treatment processes may include coagulation, coagulation with flocculation, or up-flow contact clarification or sedimentation. Physical and chemical mechanisms are responsible for the clarification of the raw water. It forms the main treatment stage in a water treatment plant.
5	**Technology illustration**	
6	**Performance limitations**	Not suitable for treatment of medium to high turbidity (> 10 NTU) and high colour raw water Can remove turbidity to less than 1 NTU. Electricity supply is critical if electronic equipment is used. Operator's presence is critical because of the presence of chemical dosing. Technical support is not limiting but depends on level of sophistication. Supply of chemicals is critical as technology is ineffective without chemicals. Impact of raw water quality variations depends on range and period of variation; small and large variations over a few hours can be sustained and may not be limiting, while large variations (exceeding 6 hours) can be critical, requiring changes in chemical dosages and filtration rates.
7	**Recommended capacity**	Suitable capacity ranges from small to medium. Ease of expansion is generally 'easy' [modular] since technology is suitable in small communities, but can also be 'difficult' [conventional] if capacity is large (>2.5 Ml/d).

8	**Operational requirements**	Skilled operator is required. Operator input is required either 8 or 24 man-hours per day, depending on level of sophistication and capacity. Chemical dosage is required. Alternative chemicals can be used. Degree of automation can either be fully, semi-automated, or none. Type and frequency of process and quality control monitoring tasks: daily Availability of materials/chemicals for operation/spares: readily available and long lead time
9	**Maintenance requirements**	Cost of servicing/repairs/replacement is low due to the absence of some unit processes, but is high if fully automated. Maintenance should be carried out annually, or as may be necessary. Operator can carry out maintenance but, if process fully automated, expert or skilled labour is required. Recommended spares and tools must be readily available.
10	**Infrastructure requirements**	Conventional infrastructure
11	**Impact of failures**	Turbidity break-throughs can occur, leading to undesirable turbidity levels in filtered water.
12	**Energy requirements**	Regular electricity supply is required if automation and electronic equipment are used.
13	**Capital costs**	Costs can vary according to capacity of plant, site conditions and local contractors. Construction of filter units and pumping/piping contribute significantly to these costs.
14	**Operating costs**	Operating cost is due to chemicals, operator, and energy requirements.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	No documentation found to-date
17	**Socio-economic aspects**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	No documentation found to-date

5–11 DIRECT SERIES FILTRATION

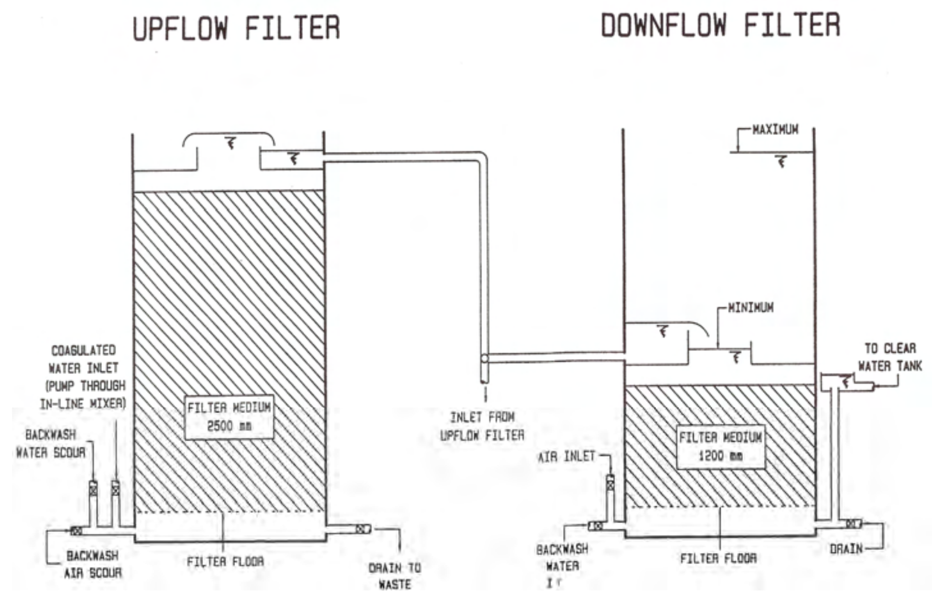
<table>
<tr><td>1</td><td>Purpose and status</td><td>Direct series filtration (DSF) is a two-stage filtration system (up-flow contact clarifier followed by rapid gravity down-flow filter), which is not preceded by a separate flocculation or sedimentation stage. It is used mainly for turbidity removal.

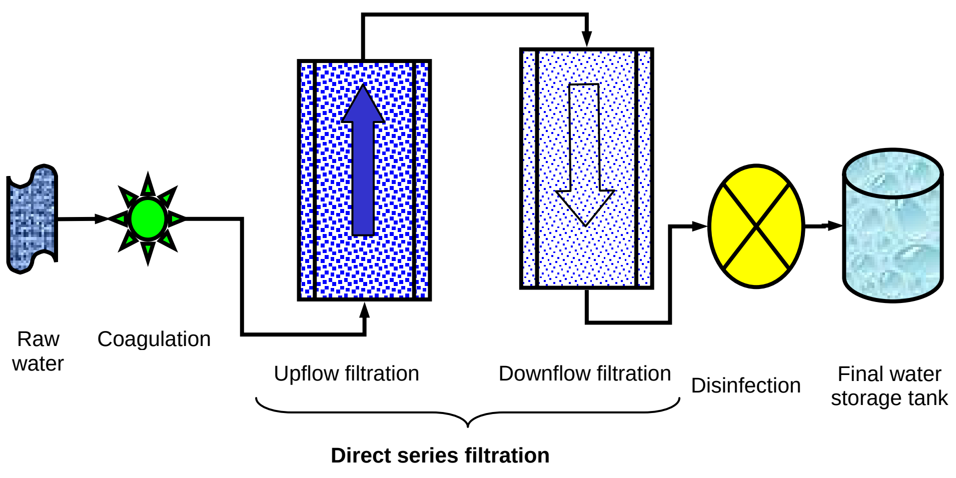
It is a proven technology.</td></tr>
<tr><td>2</td><td>Alternatives</td><td>Conventional treatment
(Coagulation + flocculation + sedimentation + sand filtration)</td></tr>
<tr><td>3</td><td>Summary of key features</td><td>DSF presents an economical alternative to conventional treatment because it does not employ the processes of flocculation and sedimentation. It is flexible because modular sections can be used. High filtration rates (up to 15 m/h) can be achieved. Lower coagulant doses are normally required.

It presents an easy and economical way for the upgrading of existing treatment systems.</td></tr>
<tr><td>4</td><td>Description</td><td>DSF is a two-stage filtration system that is not preceded by a separate flocculation or sedimentation stage. It consists of either an up-flow or down-flow filter as contact clarifier in the first stage, followed by a rapid gravity down-flow as the second stage.

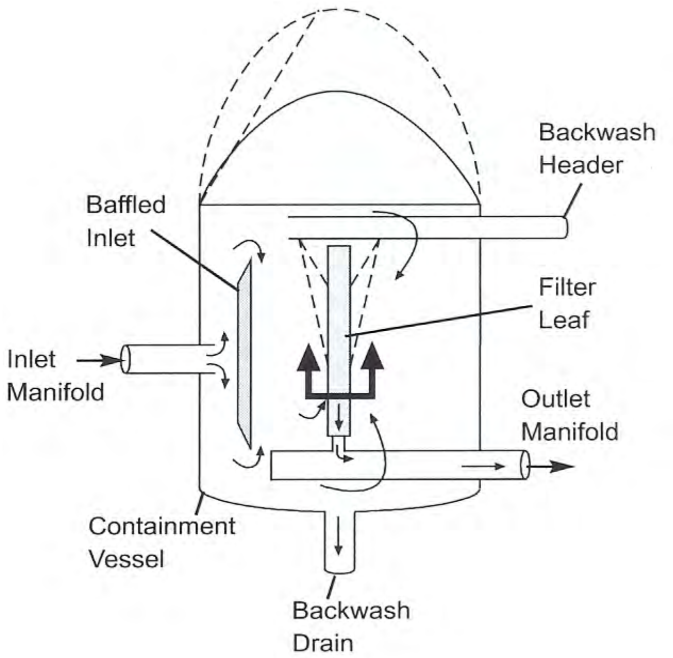
Most of the filters installed to date in South Africa consist of prefabricated concrete pipe sections. The primary clarification stage entails coagulated water inflow at the bottom of the battery of upflow filter (or contact clarifiers) operating in parallel. The filter medium ranges from graded gravel (6-12 mm) to coarse sand (0,9-1,5 mm), with a total depth of 2,5 m.

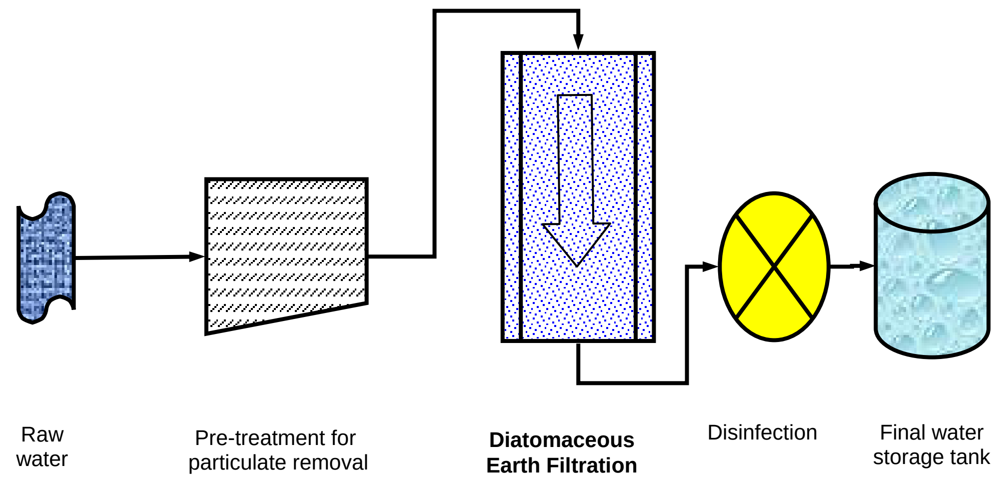
A common header connects the overflows with the inlet of the down-flow filters, of which the operating mode is typically declining rate filtration.

The up-flow filter is backwashed with raw water in six steps, while the down-flow filters are backwashed conventionally with air. The backwashing is semi-automated for ease of operation.</td></tr>
<tr><td>5</td><td>Technology illustration</td><td>
</td></tr>
<tr><td>6</td><td>Performance limitations</td><td>The most important limiting factor is the filter run time, which is limited by the clogging head available for the down-flow filter.
It is not effective for the removal of algal cells.
It is not effective for the treatment of coloured waters, mainly as a result of the fragile nature of the flocs that are formed.</td></tr>
<tr><td>7</td><td>Recommended capacity</td><td>Direct series filtration plants can be constructed for small- to medium-sized applications.
Full-scale plants in South Africa that are operating successfully are in the range of 0,5-2,0 Ml/d.</td></tr>
</table>

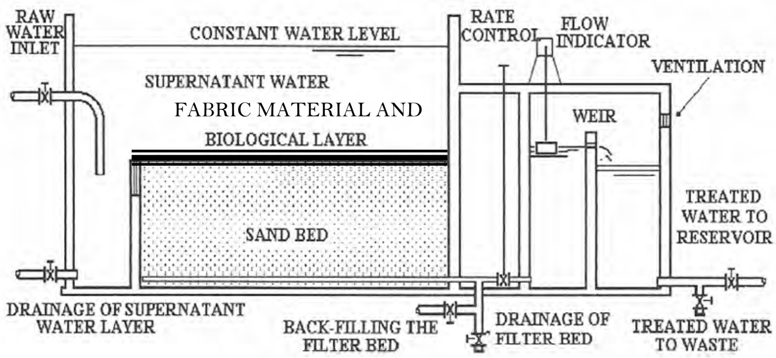
8	**Operational requirements**	Considerable effort has gone into the development of a simple, robust electro-pneumatic sequencing and control system that will complete the entire backwashing operation once initiated by the operator. Chemical dosage is required (mostly polyelectrolytes). Filter runs can vary between 12 and 50 hours.
9	**Maintenance requirements**	Maintenance requirements are generally low, with no special skills or materials required. Regular inspection of the automated backwashing system by a suitably qualified technician is recommended.
10	**Infrastructure requirements**	Plants are site-constructed (using prefabricated concrete pipe sections). Electricity is required for the feed, dosing and backwash pumps. Clean water storage is required for backwashing of the down-flow filters.
11	**Impact of failures**	If the semi-automated backwashing system fails, the process will have to be shut down after reaching maximum headloss. The same applies for operator absence or electricity supply interruptions.
12	**Energy requirements**	Electricity is required for the feed, coagulant dosage, backwash and clean water pumps. Solar power can be used in remote locations.
13	**Capital costs**	Capital costs savings of 20-50% can be attained, compared to conventional treatment, because no flocculation and sedimentation stages are required.
14	**Operating costs**	Coagulant stages of up to 20% can be realised.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Magaliesberg (0,5 ML/d) Hectorspruit (1,5 ML/d) Marloth Park (0,8 ML/d) Burgersfort (2,0 ML/d)
17	**Socio-economic impact**	A proven technology Economically feasible for small communities
18	**Research and evaluation in South Africa**	Mr Piet van der Merwe WRC Report No. 354/1/97 “Evaluation of Direct Series Filtration for the Treatment of South Africa Surface Waters”. CSIR Environmentek

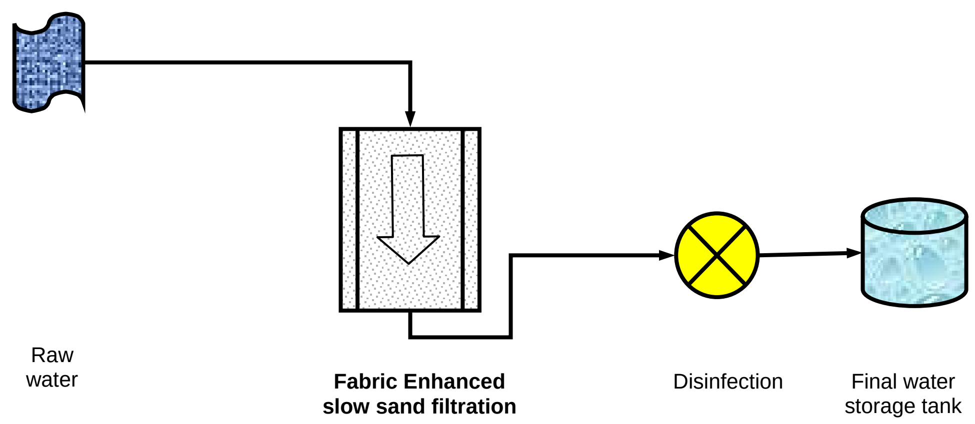
5-12 DIATOMACEOUS EARTH (DE) FILTRATION

1	**Purpose and status**	Diatomaceous earth (DE) filtration is a form of pre-cost filtration used to produce high-quality drinking water from feed waters with turbidities of less than 10 NTU. It is also effective in removing cysts, algae and asbestos from water. It does not remove colour. It is a proven technology.
2	**Alternatives**	Pressure sand filtration Slow sand filtration Microfiltration
3	**Summary of key features**	DE filtration strains particulate matter from water. It normally does not require upstream coagulant dosing. Its use is limited to treating source water with an upper limit of turbidity of 10 NTU. It does not remove dissolved material, and therefore does not remove colour.
4	**Description**	DE filtration is a process that uses diatoms or diatomaceous earth (the skeletal remains of small, single-celled organisms) as the filter medium. DE filtration relies upon a layer of diatomaceous earth placed on a filter element or septum (a permeable cover over interior collection channels). Recirculation of DE slurry through the filter septum establishes this layer. After the pre-cost forms on the filter leaves, raw water containing a low dose of DE is fed through the filter. Particulate solids are separated on the pre-cast surface. When maximum head-loss is reached, the flow of water into the filter is stopped and the filter cake is cleaned with high-pressure sprays to detach the cake. Once cleaned, the filtration operation is repeated, beginning with the pre-coat cycle. The DE removed from the filter leaves is normally discarded.
5	**Technology illustration**	
6	**Performance limitations**	Not suitable for treating feed water with turbidities in excess of 10 NTU. Not suitable for treating coagulated water. Not suitable for colour removal (removal of NOM). The particle size that DE filtration removes relies on the size distribution of the DE particles used for the pre-coat and body feed.
7	**Recommended capacity**	DE filters may be used from small scale to medium-sized applications. It is also often used in swimming pool filtration.
8	**Operational requirements**	Operators must continuously monitor raw and filtered water turbidity. They require mechanical skills to operate the body feed pumps, pre-coat pumps, mixers, pipes and valves. They must also be skilled in preposing the body feed and pre-coat slurries, and keeping the filter leaves properly cleaned. Filters can be semi-automated. Spare filter leaves must be readily available.

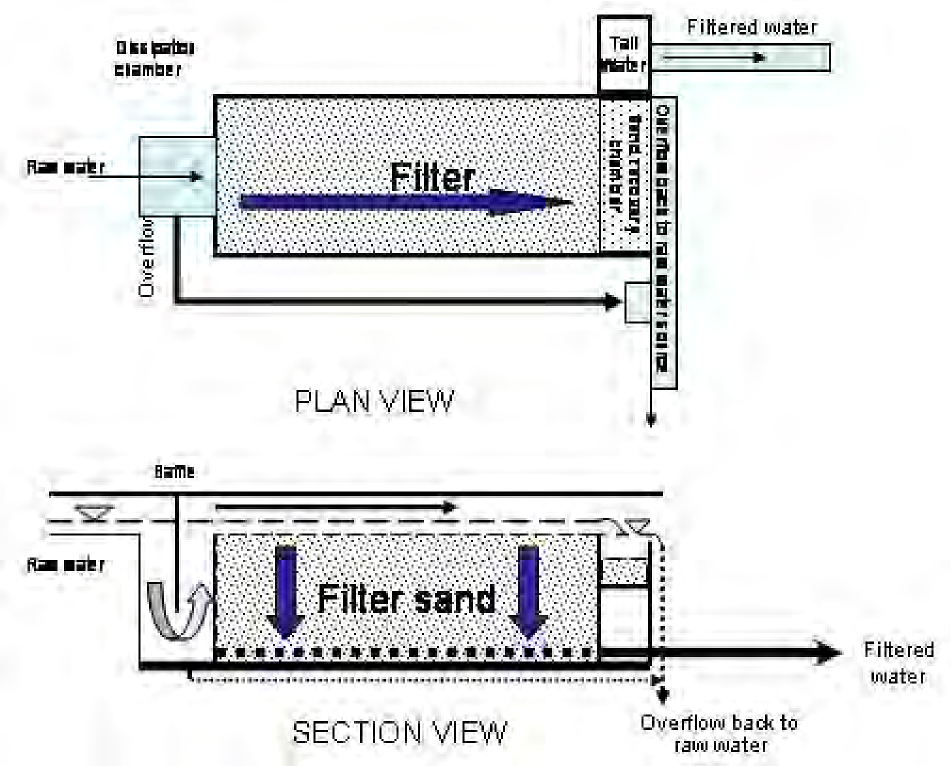
9	**Maintenance requirements**	DE filter maintenance requires frequent servicing to ensure that the filters work effectively. Technical back-up must be readily available.
10	**Infrastructure requirements**	A building is required to house the DE filters.
11	**Impact of failures**	Incorrect operation (preparation of pre-coat, cleaning of filter leaves) can result in poor performance and reduced water quality. Supply of DE material is critical to the operation of the filter; without it the DE filter cannot operate.
12	**Energy requirements**	Electricity supply is required for the pumps. Renewable energy (solar) may be used. A generator may also be used.
13	**Capital costs**	The capital cost is higher than for a pressure sand filter.
14	**Operating costs**	The operation cost largely comprises the DE material cost and filter leaves replacement.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Most applications are in swimming pool treatment.
17	**Socio-economic impact**	Cost is high. Semi-skilled/skilled operator required. Operation requires electricity or standby generator. Community acceptance and willingness to pay must be considered.
18	**Research and evaluation in South Africa**	Atlas Filters in East London carried out research with the CSIR for process optimisation.

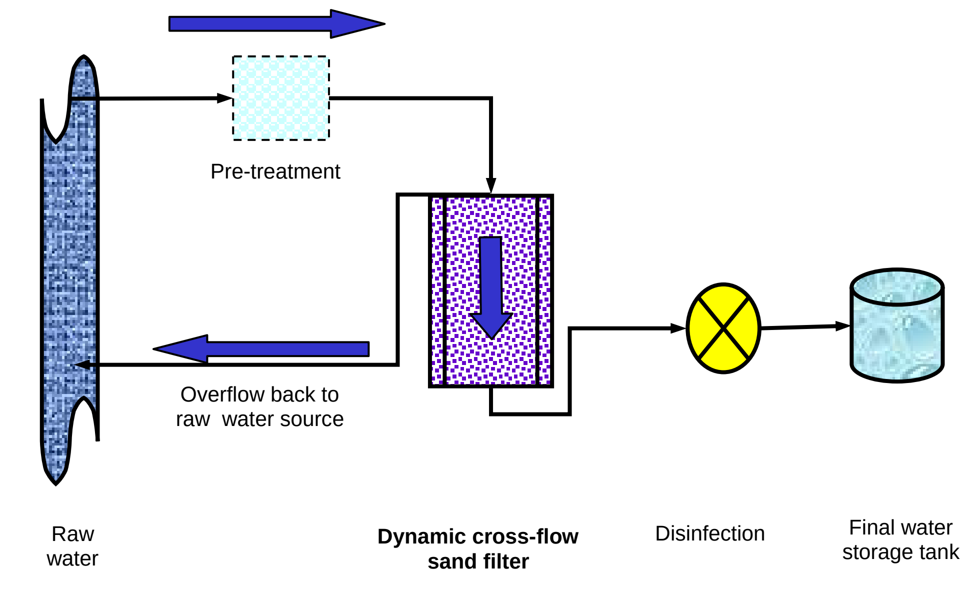
5-13 FABRIC-ENHANCED SLOW SAND FILTRATION

1	**Purpose and status**	To reduce turbidity, colour, suspended solids and pathogenic micro-organisms from raw water that is characterised by low turbidity (< 10 NTU), low colour (< 15 colour units) and suspended solids (< 5 mg/L), and pathogenic contamination, to levels acceptable for effective disinfection, without the help of coagulation It is an emerging technology, with very scarce application in water treatment.
2	**Alternatives**	Dynamic cross-flow sand filtration Direct slow sand filtration Direct rapid sand filtration Direct pressure filtration
3	**Summary of key features**	Fabric-enhanced slow sand filtration (FESSF) treats low-turbidity raw water with only the aid of fabric material laid on the top of the filter bed to provide additional protection against rapid clogging.
4	**Description**	FESSF is a down-flow sand filtration process that takes place in an open unit containing a 0.5-0.8-m deep fine filter sand bed (d_e ~ 0.35-0.60 mm) overlaid with fabric material and supported by graded gravel, in which gravity is used to continuously drive untreated raw water through the filter sand at filtration rates not greater than 0.30 $m^3/h/m^2$ of filter media surface. Physical and biological mechanisms are responsible for the clarification of the raw water. The filtration rate can either be controlled from the inlet or outlet side of the filter unit, either option having its own pros and cons depending on designer preference. In FESSF there is no pre-treatment process, except for the fabric material, the purpose of which is to protect SSF from instantaneous high turbidity and also allow easier cleaning. It forms the main treatment stage in a water treatment plant.
5	**Technology illustration**	  Picture of a FESSF in Tulbagh, Western Cape

6	**Performance limitations**	Not suitable for treatment of high-turbidity raw water Can remove turbidity to less than 1 NTU and colour to less than 5 Colour units, and less than 1 FC/100mL. Electricity supply is not critical for the chemical dosing equipment and pumping (if required). Operator's presence is not critical because of the absence of the chemical pre-treatment stage. Technical support is negligible. Impact of raw water variations is critical.
7	**Recommended capacity**	Suitable capacity ranges from small to medium. Capacity can easily be expanded, especially in small plants.
8	**Operational requirements**	Semi-trained labour is required. Operator input required is less than 24 h/day. No chemical dosage is required, but pre-treatment needs chemicals. No automation Head-loss and effluent quality can be checked daily.
10	**Maintenance requirements**	Low cost of servicing/repairs/replacement Filter cleaning frequency can range from 1 to 6 months. Tools for cleaning must be readily available.
11	**Infrastructure requirements**	Conventional infrastructure
11	**Impact of failures**	Effluent quality is not affected but production is reduced continuously.
12	**Energy requirements**	Water flows by gravity through filters, but a regular electricity supply is required if raw water is supplied by pumping.
13	**Capital costs**	Filter tank construction makes up the bulk of capital costs.
14	**Operating costs**	Operating costs are only due to labour used during operation and cleaning processes.
15	**Typical treatment process configuration (train) or example]**	
16	**Examples of SA installations**	Tulbagh (< 1 Ml/d) (Western Cape) Plant known to exist in Kwa-Zulu Natal (< 1 Ml/d)
17	**Socio-economic aspects**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	Cape Peninsula University of Technology

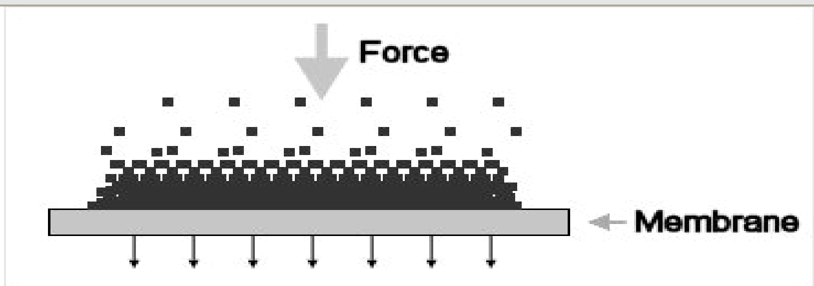
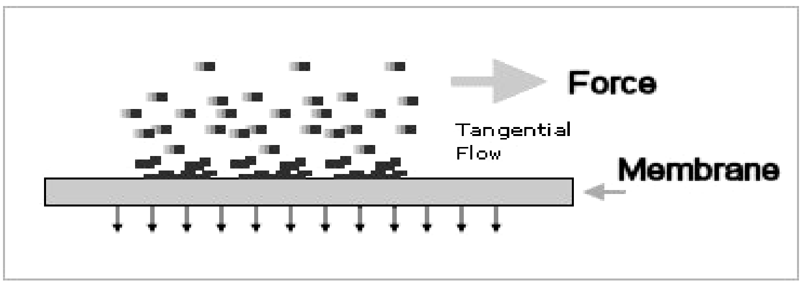
5-14 DYNAMIC CROSS-FLOW SAND FILTRATION

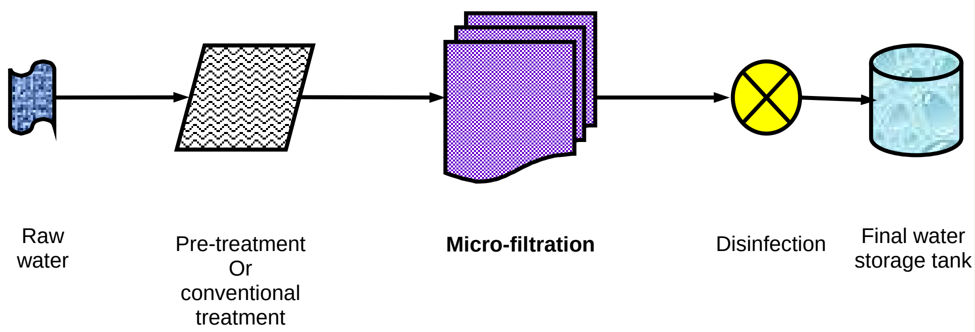
1	**Purpose and status**	To reduce turbidity and suspended solids from raw water that is characterised by medium to high turbidity (10-500 NTU) and suspended solids > 5 mg/L, to levels acceptable for effective disinfection, with or without the help of pre-treatment It is an emerging technology, with little application, but has great potential in remote/rural communities.
2	**Alternatives**	Multistage filtration (combination of roughing filtration and slow sand filtration)
3	**Summary of key features**	Flow through the unit is in two directions (horizontal and downward). The horizontal flow effects the self-cleaning of the suspended solids retained on top of the filter bed by the downward flow through the filter bed. It is the downward flow that is responsible for the purification process.
4	**Description**	Dynamic cross-flow sand filtration is a down-flow sand filtration process that takes place in an open unit containing a 0.5-m-deep fine filter sand bed (d_e ~ 0.15-0.35 mm) supported by a graded gravel layer, in which gravity is used to continuously drive raw water through the filter media at filtration rates ranging from 0.10-0.20 $m^3/h/m^2$ of filter media surface. Physical and biological mechanisms are responsible for the clarification of the raw water. The filtration rate is controlled from the inlet side of the filter unit. It forms the main treatment stage in a water treatment plant.
5	**Technology illustration**	
6	**Performance limitations**	Not suitable for treatment of highly coloured water Can remove turbidity to less than 1 NTU and colour to less than 5 Colour units, and less than 1 FC/100mL. Electricity supply is not required as long as there is sufficient gravity. Operator's presence is critical because of daily maintenance of the filter bed. Technical support is negligible. Supply of chemicals is not required for this application. Impact of raw water variations is critical if prolonged.
7	**Recommended capacity**	Suitable capacity ranges from very small to small (10-500 m^3/d). Expansion is easy, by adding extra units.

8	**Operational requirements**	Untrained and semi-trained labour is required. Operator input is required daily. No chemical dosage is required, but pre-treatment requires chemicals. No automation Head-loss and effluent quality can be checked daily.
9	**Maintenance requirements**	Low cost of servicing/repairs/replacement, because of chemical pre-treatment Daily filter cleaning, by raking top of sand Tools for cleaning must be readily available.
10	**Infrastructure requirements**	Conventional infrastructure
11	**Impact of failures**	Loss of production and possible turbidity breakthrough
12	**Energy requirements**	Water flows by gravity through filters, but a regular electricity supply is required if raw water is supplied by pumping.
13	**Capital costs**	No local data is yet available, but is expected to vary depending on capacity of plant, site conditions and local contractors. Filter tank construction and chemical dosing facilities for disinfection make up the bulk of the capital costs.
14	**Operating costs**	Operating costs are only due to labour used during operation and cleaning processes.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of installations**	Emmaus (55m^3/d) (Kwa-Zulu Natal)
17	**Socio-economic aspects**	Conditions/demands for community acceptance and participation: ability and willingness to accept ownership of, and manage, this type of technology; ability and willingness to operate and maintain this type of system
18	**Research and evaluation in South Africa**	WRC Report No. 539/1/97 Council for Scientific and Industrial Research

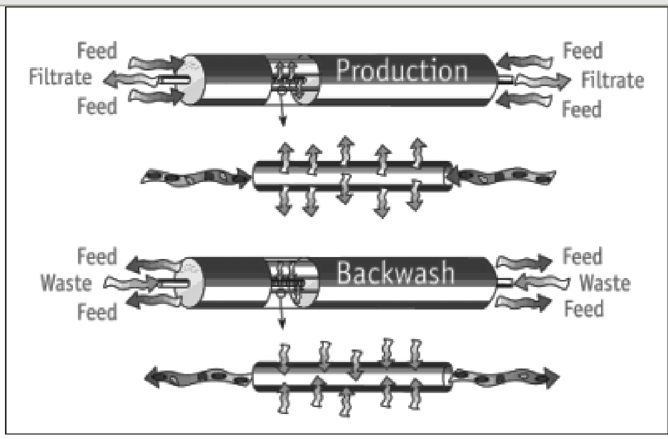
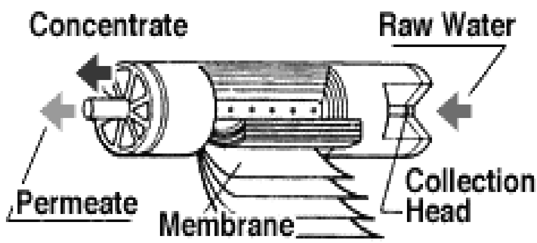
6. MEMBRANE FILTRATION

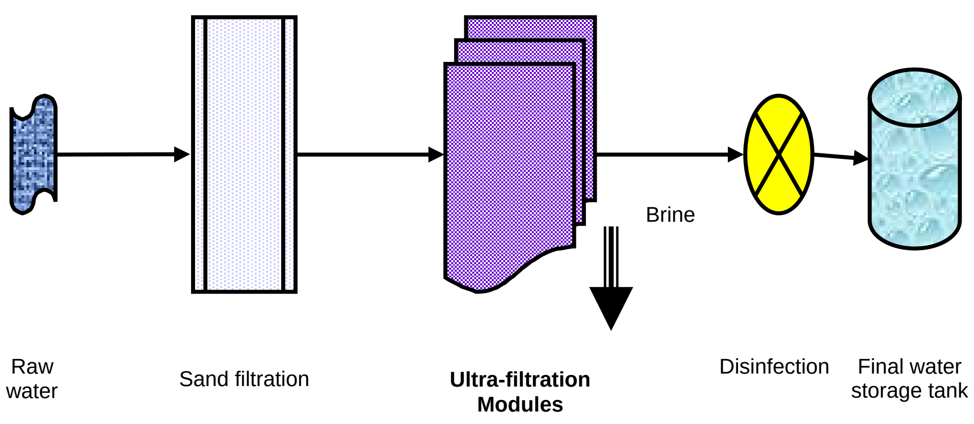
6-1 MICROFILTRATION (MF)

1	**Purpose and status**	MF is used for the removal of suspended solids and turbidity, as well as particulate matter such as precipitated forms of Fe, Al and Mn. It also provides a degree of disinfection through physical retention of bacteria and protozoan cysts. When combined with coagulation, MF has the ability to remove colour and organic carbon. MF is a proven technology.
2	**Alternatives**	Immersed microfiltration
3	**Summary of key features**	MF is a membrane process used for the removal of suspended solids and turbidity, as well as particulate matter such as precipitated forms of Fe, Al and Mn. MF membranes can be used for direct filtration or coupled with conventional processes such as oxidation, coagulation or biological treatment. MF is not suitable for the removal of organics, macromolecules, hardness or salts. It does not remove viruses smaller sized bacteria.
4	**Description**	Most MF water treatment plants use direct or dead-end flow since it leads to considerable energy savings, by not requiring recirculation. Another form of MF uses crossflow, which is the continuous removal of contaminants through the pressurised flow of feed water across the membrane. Operating pressures typically vary between 0.07 and 1.7 bar. There is 100% recovery of water, except for the small fraction of the water that is used to periodically backwash the system. MF plants typically rely on either liquid or pneumatic backwashing systems. MF membranes have a nominal pore size of 0.1-10.0 microns. Membrane materials are similar to the materials used for RO and UF membranes (e.g. polycarbonate, polypropylene, polyethylene, polyamide and even PTFE, and the membranes can therefore have quite rugged physical and chemical characteristics. The properties of the membrane materials are directly reflected in their end application (e.g. strength, chemical compatibility and cost). MF membranes can be used for direct filtration or coupled with conventional processes such as oxidation, coagulation or biological treatment:
5	**Technology illustration**	 **Dead- end MF**  **Crossflow MF**
6	**Performance limitations**	MF is not suitable for the removal of organics, macromolecules, hardness or salts. It does not remove viruses and smaller sized bacteria. It is necessary to complement microfiltration with a post-membrane disinfection process such as chlorination.

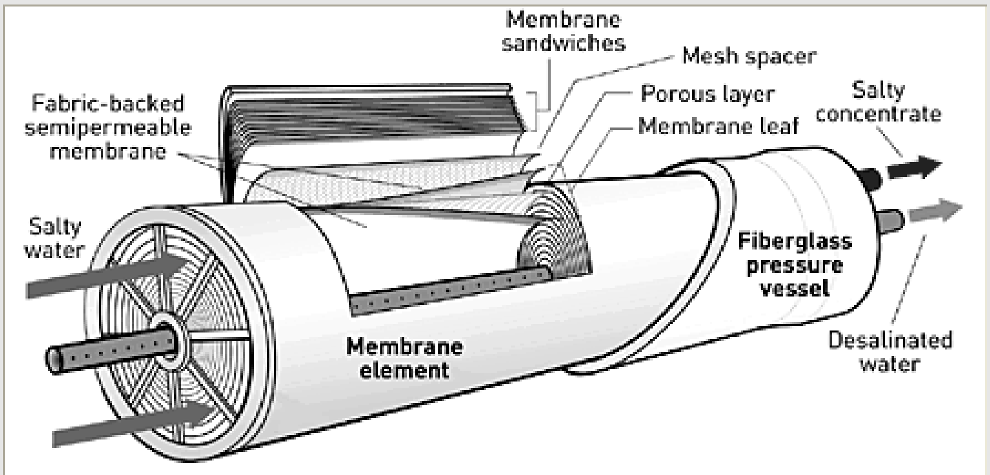
7	**Recommended capacity**	Very small to large (world's largest MF plant in Victoria, Australia (124 m^3/day)) Typical design parameters for low turbidity water (i.e. < 2.0 NTU) are as follows: microfilter pore size of 0.1-1.0 µm, permeate production of 1.9 l/min/m^2, system recovery of 80-95+ percent of plant capacity, feed pressure of 1-5 bar, backwash volume of five percent of plant capacity.
8	**Operational requirements**	A full-time, trained operator is required. Microfiltration uses a relatively low feed pressure, which makes it cost-effective. Air or water backwashing is required every 10-60 minutes.
9	**Maintenance requirements**	Membrane integrity needs to be monitored. Membranes should be chemically cleaned with a 2% caustic and detergent solution for two to three hours at a two to six week frequency. Microfiltration membranes can last several years. Maintenance should be carried out by trained personnel.
10	**Infrastructure requirements**	Facility to handle backwash streams with concentrated contaminants
11	**Impact of failures**	Loss of product water stream or membrane failure will allow contaminants into the product water stream.
12	**Energy requirements**	Electricity
13	**Capital costs**	Similar to conventional plants
14	**Operating costs**	Higher than conventional plants
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Dwarsrivier Prison, near Wolseley in the Western Cape (20 m^3/h)
17	**Socio-economic impact**	Trained operators are required to meet appropriate operational and maintenance requirements.
18	**Research and evaluation in South Africa**	WRC report 531/1/96 Chris Swartz Engineers Dr JJ Schoeman, UP

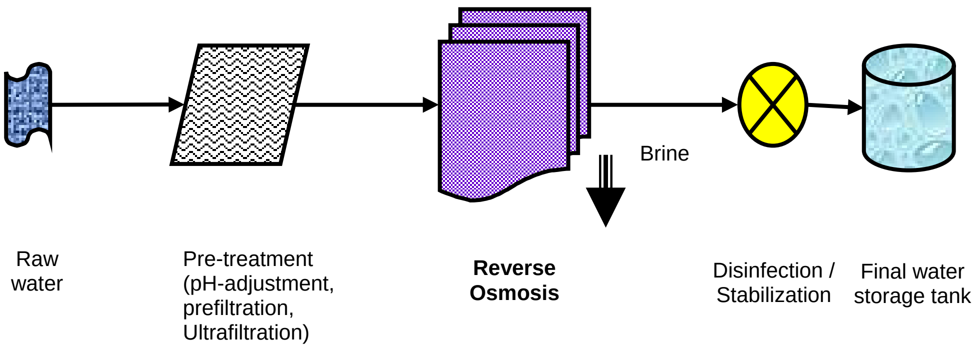
6-2 ULTRAFILTRATION (UF)

1	**Purpose and status**	UF is used for the removal of NOM, turbidity, bacteria, protozoan cysts and viruses from water. It is a proven technology.
2	**Alternatives**	Conventional treatment
3	**Summary of key features**	A UF system is a membrane filtration process, generally used for the removal of macromolecules from raw water.
4	**Description**	UF is a process employing membrane modules with pore sizes of 0,001-0.1 mm, operated under pressure in the range of 3-10 bar. UF removes matter, the size of which depends on the molecular weight cut-off (MWC) of the membrane. UF technology employs tubular (hollow fibre) or spiral-wound membranes to separate dissolved solids or macromolecules from water. Hollow-fibre membrane systems have two modes of operation: a production mode, where feed is forced through the membranes, and a backwash mode, where some of the filtrate is forced back through the membranes, to remove any debris. Commercially used membranes are mostly made of cellulose acetate, polysulphonates and polyamides. The flow rate through a membrane is dependent on a number of factors, including the pump pressure, the type of flow over the membrane, the degree of fouling and the physical condition of the membrane. Suppliers quote membrane module flow rates of up to 50 kl/h. A complete system normally consists of pre-treatment, pressurisation, physical membrane separation and post-treatment:
5	**Technology illustration**	 **Hollow fibre UF membrane elements (from:** *http://www.esemag.com/0903/edr1.gif*)  **Spiral wrap UF membrane element (from:** *http://www.asahi-kasei.co.jp/membrane/microza/en/kiso/images/spiral.gif)*
6	**Performance limitations**	UF is not suitable for the removal of hardness or salts from water, and it can only achieve partial disinfection (post-membrane disinfection is required).
7	**Recommended capacity**	From household to large plants
8	**Operational requirements**	Trained operator (1 h/day), pre-treatment may require chemical dosage, operation normally automated, 8-hourly quality control required, long lead time for spares.

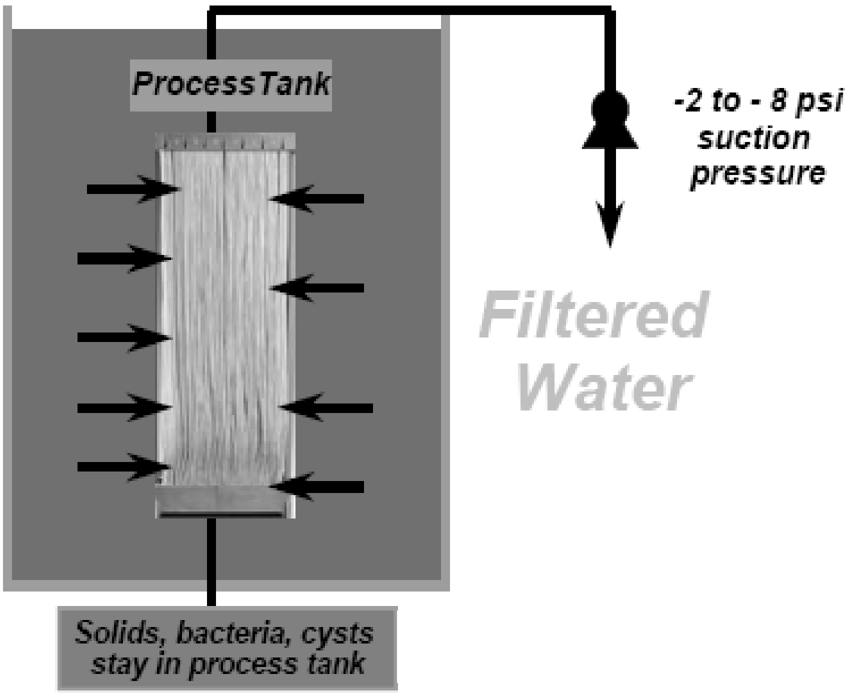
9	**Maintenance requirements**	Maintenance costs are high, monthly servicing required, membrane replacement required every 3-5 years, expert input required, long lead time for spares.
10	**Infrastructure requirements**	The following are required: access roads, power, lighting, prefabricated components, raw and clean water storage, civil construction, brine disposal. No reticulation system is required.
11	**Impact of failures**	No product water flow (membrane fouling), contaminant breakthrough into product water (membrane failure)
12	**Energy requirements**	Electricity
13	**Capital cost**	The capital cost of a complete UF plant is normally of the same order as that of a conventional plant
14	**Operating cost**	The running cost of a complete UF plant is normally significantly higher than that of a conventional plant.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Experimental sites: Suurbraak, Wiggins Water Works, Amatola Water, Zingqutu (12 m^3/d)
17	**Socio-economic impact**	Trained operators are required to meet appropriate operational and maintenance requirements.
18	**Research and evaluation in South Africa**	WRC reports (e.g. WRC reports 1070/1/04 and 445/1/94) Dr EP Jacobs, University of Stellenbosch Dr VL Pillay, Durban Institute of Technology

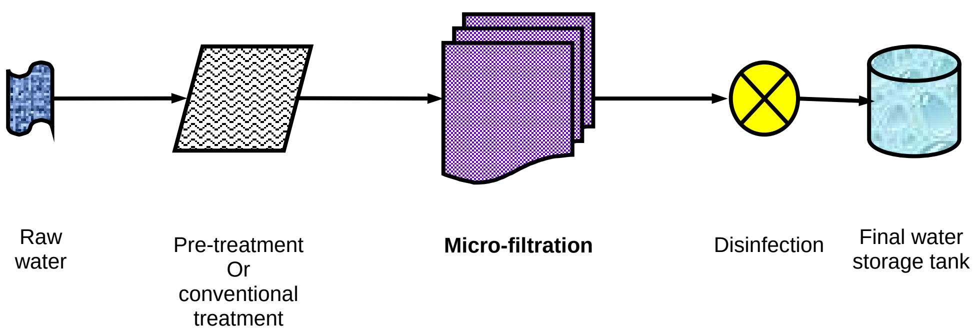
6-3 REVERSE OSMOSIS (RO)

1	**Purpose and status**	Desalination / TDS reduction of brackish or sea water, nominal rejection ratio between 85% and 98% RO can be more than 90% effective in nitrate and fluoride removal. RO is a proven technology.
2	**Alternatives**	Electrodialysis (brackish water), solar distillation (household scale), activated alumina (defluoridation), ion exchange (nitrate removal)
3	**Summary of key features**	RO is a membrane desalination process operated under high to very high pressures. The flow rate through a membrane is dependent on a number of factors, including the pump pressure, the type of flow over the membrane, the degree of fouling and the physical condition of the membrane.
4	**Description**	RO is a membrane process operated under high to very high pressures (10 to 70 bar, depending on raw water salinity). Several kinds of RO membranes are available, but spiral-wrap membranes of cellulose acetate, polysulphonates and polyamides are the types most widely used commercially. Commercial RO elements are generally available in 2-, 5-, 4-, 8- and 16-inch diameter modules. Flow rates per membrane module of up to 45 kL/day (for seawater) and 60 kl/day (for brackish water) are quoted by suppliers. A RO system normally comprises four major components, namely chemical pre-treatment, pressurisation, physical membrane separation and chemical post-treatment stabilisation.
5	**Technology illustration**	 **From:** *http://membrane.ces.utexas.edu/Home/Articles/WaterWorks_Files/7915scit4.ce.gif*
6	**Performance limitations**	RO may not be appropriate for treating water contaminated with micro-organisms, or with particulate matter that will cause membrane fouling.
7	**Recommended capacity**	From very small to large plants
8	**Operational requirements**	Trained operator (1 h/day), pre-treatment may require chemical dosage, operation normally automated, 8-hourly quality control required, long lead time for spares
9	**Maintenance requirements**	Maintenance costs are high, monthly servicing of membrane required, membrane replacement every 3-7 years, expert input required, long lead time for spares
10	**Infrastructure requirements**	The following are required: access roads, power, lighting, prefabricated components, raw and clean water storage, civil construction, brine disposal. No reticulation system is required.
11	**Impact of failures**	No product water flow (membrane fouling), or breakthrough of contaminants (membrane failure)
12	**Energy requirements**	Electricity (single or three-phase) Solar (emerging)

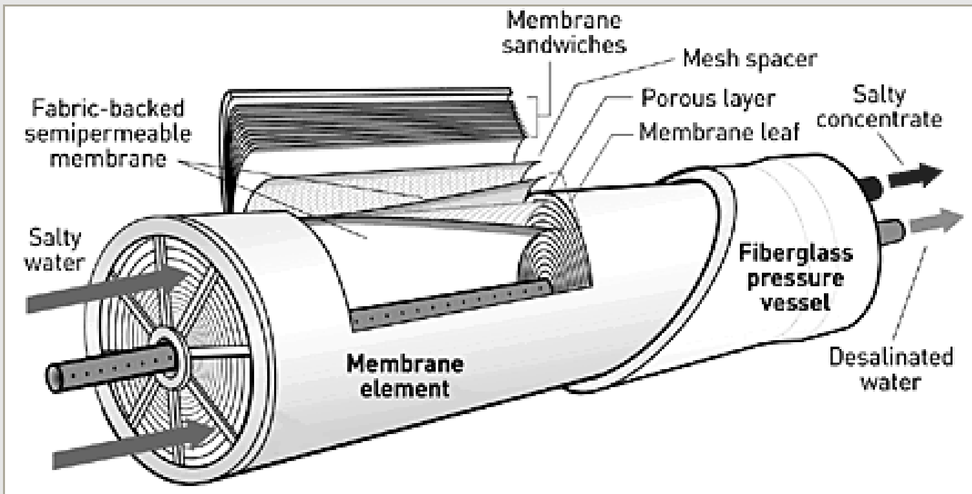
13	**Capital cost**	The capital cost of a RO plant is normally lower than that of a conventional treatment plant
14	**Operating cost**	The running cost of a RO plant is normally lower than that of a conventional treatment plant
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Bitterfontein / Nuwerus / Kheis (ground water) Robben Island / Boesmansriviermond (seawater)
17	**Socio-economic impact**	Community plants can be operated successfully if suitably trained personnel operate the plant, with effective communication channels to the next service level available, when required.
18	**Research and evaluation in South Africa**	WRC reports TT/124/00 Polymer Institute, US Dr JJ Schoeman, UP

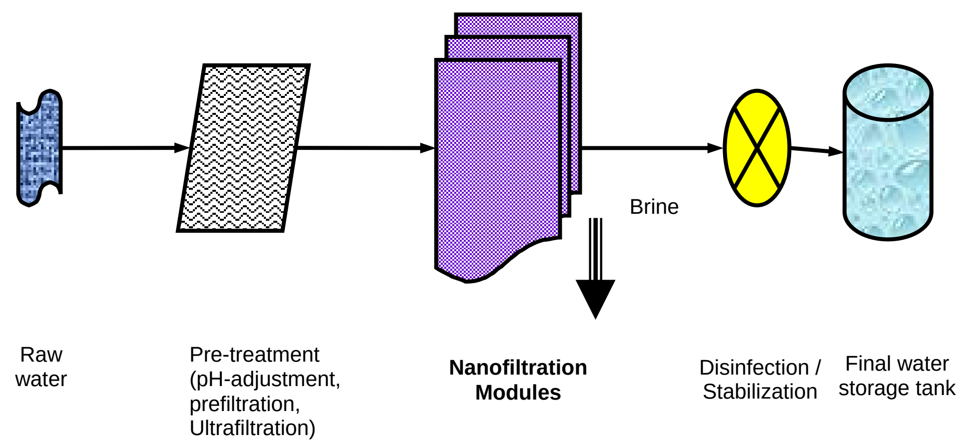
6-4 IMMERSED MICROFILTRATION (IMM MF)

1	**Purpose and status**	Immersed MF (Imm MF) is used for the removal of suspended solids and turbidity, as well as particulate matter such as precipitated forms of Fe, Al and Mn. It also provides a degree of disinfection through physical retention of bacteria and protozoan cysts (also see *Microfiltration*). Emerging technology (currently mostly pilot plant testing)
2	**Alternatives**	Microfiltration
3	**Summary of key features**	Immersed MF is an emerging water treatment technology used for the removal of suspended solids and turbidity, as well as particulate matter (similar to microfiltration). It is necessary to complement microfiltration with a post-treatment disinfection process.
4	**Description**	Immersed MF is a recent development in terms of membrane process configurations. Hollow-fiber membranes are installed (immersed) in a vessel and a small vacuum is applied to their downstream side. As filtered water permeates through the membranes and is continuously removed from the system, the solids are rejected and accumulate in the vessel. Air can be introduced at the bottom of the membrane feed vessel, creating turbulence in the tank, effectively scrubbing the solids from the membrane surface. A typical membrane material is PVDF. The membrane itself is a non-woven, flat-sheet membrane with many small pores (ca. 0.2 µm) of a small diameter distribution, thus ensuring good flux with low clogging potential (good performance on a small plant area. Commercial immersed MF membranes are available. Immersed MF membranes can be used for direct filtration or coupled with conventional processes such as oxidation, coagulation or biological treatment: *Raw water feed - [conventional treatment] -* ***ImmMF*** *- disinfection*
5	**Technology illustration**	
6	**Performance limitations**	Immersed MF is not suitable for the removal of organics, macromolecules, hardness or salts. It does not remove viruses and smaller bacteria, therefore, it is necessary to complement microfiltration with a post-treatment disinfection process.
7	**Recommended capacity**	From small to large (Largest immersed membrane filtration plant for potable water is at Choa Chu Kang Waterworks (CCK) in Singapore — treatment capacity 364 Ml/d (96 mgd).)

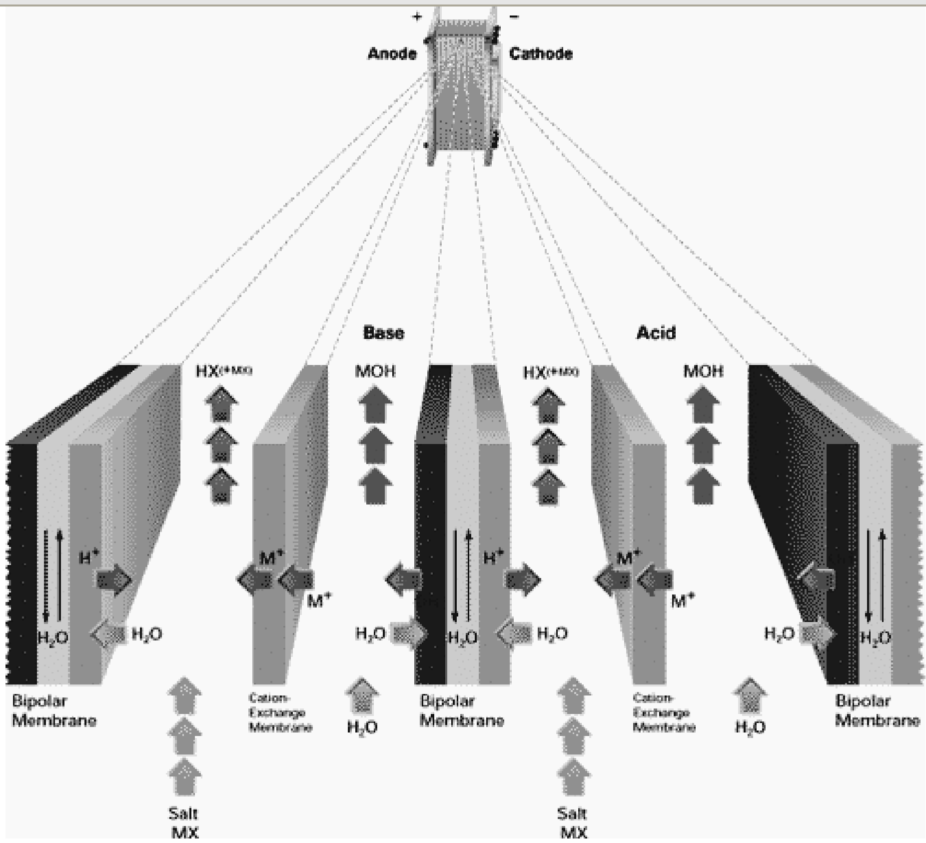
8	**Operational requirements**	Filtration is typically done continuously at relatively low fluxes, ranging between 40 and 70 l/m²/h, under a low transmembrane pressure of 0.1 to 0.5 bar (no feed pressure drop). Special care must be given to controlling the concentration of solids in the process tank, and the routine cleaning of the membranes. This is a key feature as chemical cleaning procedures are more difficult than in the case of conventional pressure vessels. The most frequently used methods of physical cleaning are backwashing and aeration. These methods are typically performed frequently and thus may influence the filtering process. In backwashing, permeation through the membranes is stopped momentarily. Air or water then flows through the membranes in a reverse direction to physically remove solids off of the membranes. In aeration, bubbles are produced in the water in the tank, below the membranes. As the bubbles rise, they agitate or scrub the membranes and thereby remove some solids. Simultaneously, an air-lift effect is created and the tank water is circulated, causing the solids to be carried away from the membranes. These two methods may also be combined.
9	**Maintenance requirements**	Fouling control requires special attention.
10	**Infrastructure requirements**	A facility to handle backwash streams with concentrated contaminants is required.
11	**Impact of failures**	Membrane fouling can lead to reduced or even no product water flow. Membrane failure can lead to breakthrough of contaminants into product water stream.
12	**Energy requirements**	Electricity for feed pumps
13	**Capital cost**	High (higher than MF)
14	**Operating cost**	Medium (similar to other membrane processes)
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Main application is in wastewater treatment.
17	**Socio-economic impact**	Unknown, but sophisticated control and maintenance procedures may require specialised training.
18	**Research and evaluation in South Africa**	WRC research project K5/1598 (until 03/2007) WRC research project K5/1369

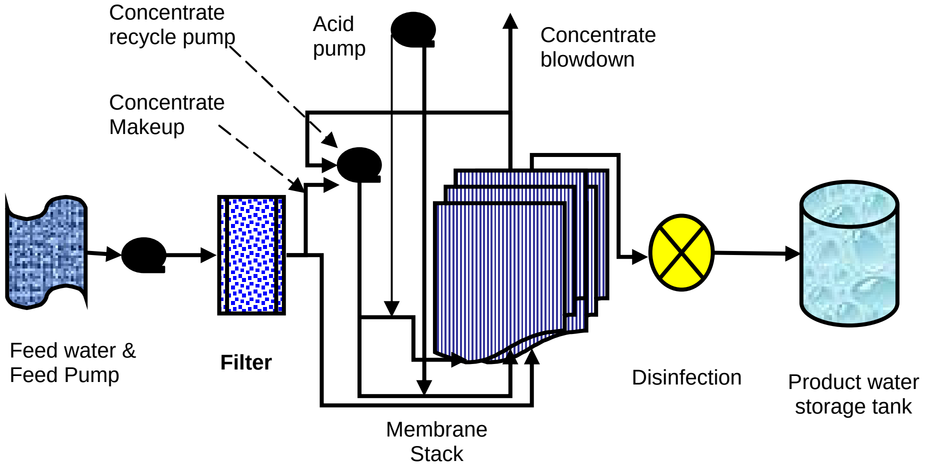
6-5 NANOFILTRATION

1	**Purpose and status**	Removal of hardness, i.e. multivalent ions such as Ca and Mg, especially where TDS < 2000 mg/L; removal of 80-95% of NOM; removal of bacteria and viruses NF is an emerging technology in the South African drinking water context.
2	**Alternatives**	Ion exchange (water softening), reverse osmosis (desalination)
3	**Summary of key features**	NF is an emerging membrane technology, similar to but slightly cheaper than RO, and can be used for water softening.
4	**Description**	NF is a membrane process typically operated at pressures ranging from 6-10 bar. Spiral wrap membranes of cellulose acetate, polysulphonates and polyamides are the types mostly in use. The flow rate through a membrane is dependent on a number of factors, including the pump pressure, the type of flow over the membrane, the degree of fouling and the physical condition of the membrane. Flow rates per membrane module of up to 40 kl/day (for high salt rejection rates) and 60 kl/day (for low pressure NF) are quoted by suppliers. A NF system normally consists of four major components, namely chemical pre-treatment, pressurisation, physical membrane separation and chemical post-treatment stabilisation (also see RO).
5	**Technology illustration**	 **From:** *http://membrane.ces.utexas.edu/Home/Articles/WaterWorks_Files/7915scit4.ce.gif*
6	**Performance limitations**	NF is not a general desalination technology. It cannot be used for TDS reduction or removal of specific ions such as Na or F, or low molecular weight organic compounds (e.g. methanol).
7	**Recommended capacity**	From very small to large plants Capacity expansion is easy (modular).
8	**Operational requirements**	Trained operator (1h/day), pre-treatment may require chemical dosage, operation normally automated, 8-hourly quality control required, long lead time for spares
9	**Maintenance requirements**	Maintenance costs are high, monthly servicing required, membrane replacement required every 3-5 years, expert input required, long lead time for spares.
10	**Infrastructure requirements**	The following are required: access roads, power, lighting, prefabricated components, raw and clean water storage, civil construction, brine disposal. No reticulation system is required.
11	**Impact of failures**	No product water flow (fouling of membranes), or contaminated product water flow (membrane failure)

12	**Energy requirements**	Electricity
13	**Capital cost**	The capital cost of a NF plant is normally high (similar to brackish water RO). Competing water softening technologies may be cheaper for water softening purposes.
14	**Operating cost**	Operating cost of a NF plant is higher than for a conventional plant.
15	**Typical treatment process configuration (train) or example [overall process flow diagram indicating required preceding and subsequent treatment]**	
16	**Examples of SA installations**	Heimat Estate (Berg river)
17	**Socio-economic impact**	Unknown, but will probably be similar to Reverse Osmosis
18	**Research and evaluation in South Africa**	WRC reports (TT/124/00) Dr JJ Schoeman, UP

6-6 ELECTRODIALYSIS (ED) / ELECTRODIALYSIS REVERSAL (EDR)

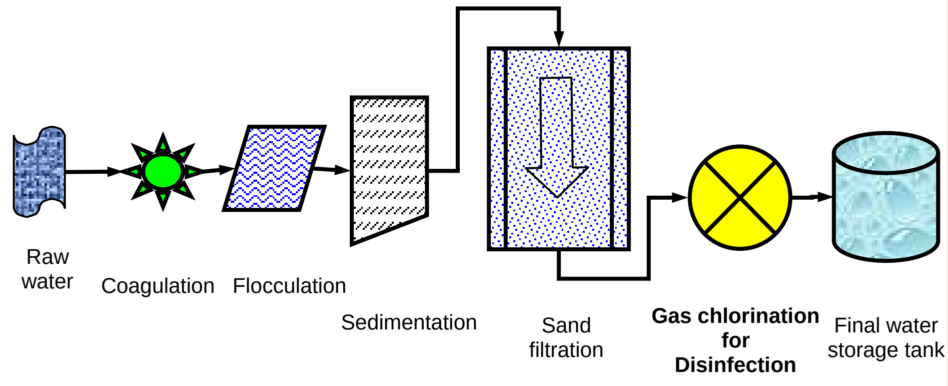
1	**Purpose and status**	Electrodialysis (ED) or Electrodialysis Reversal (EDR) [ED(R)] can be used for desalination and removal of fluorides and nitrates. ED(R) plants can remove up to 80% of the salts in brackish water, particularly when the TDS is less than 3000 mg/l. ED(R) may also be used for brackish feed water where the TDS is slightly higher. ED(R) is a proven technology (internationally).
2	**Alternatives**	Reverse osmosis
3	**Summary of key features**	ED or EDR is an efficient desalination technology for low to medium TDS raw waters. Due to its complexity, it is normally not appropriate for rural communities.
4	**Description**	ED(R) is a continuous desalination process based on the separation of ions through membranes as a result of the application of a direct electric current and the consequent removal of the charged ions from the water. An ED unit is made up of a pre-treatment arrangement, a membrane stack, a low-pressure circulating pump, a power supply for direct current (a rectifier) and post-treatment infrastructure. EDR is an ED process in which the polarity of the electrodes is reversed on a prescribed time cycle, thus continuously reversing the direction of ion movement in a membrane stack to prevent scaling. Different anion- and cation-exchange membranes are used in the stack. Feed is continuous and stack capacities can be to 50 kl/h of treated water.
5	**Technology illustration**	 **From:** *http://www.ameridia.com/img/gr5.gif*
6	**Performance limitations**	ED(R) is not economically viable for the desalination of seawater or highly brackish water. ED(R) cannot be used for disinfection.
7	**Recommended capacity**	From small to large plants Expansion is easy (modular)
8	**Operational requirements**	Trained operator (8 h/day), pre-treatment may require chemical dosage, operation normally automated, hourly quality control required, long lead time for spares. ED(R) units are operated at pressures of less than 0.4 bar.
9	**Maintenance requirements**	Maintenance costs are high, monthly frequency of servicing with membrane replacement every 5-7 years, expert input required, long lead time for spares

10	**Infrastructure requirements**	The following are required: access roads, power, lighting, prefabricated components, raw and clean water storage, civil construction, brine disposal. No reticulation system is required.
11	**Impact of failures**	No desalination will take place
12	**Energy requirements**	Electricity (units require a reliable source of electrical power for the direct current used to separate the ionic substances in the membrane stack)
13	**Capital cost**	High (may vary between R2000 and R10000/m^3/day capacity)
14	**Operating cost**	High (may vary between R5-00 to R20-00/m^3)
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	None – limited to mining operations Of the large-scale desalination plants that exist internationally, ED(R) comprises about 5% of the world's installed desalination capacity.
17	**Socio-economic aspects**	Normally not suitable for (smaller) rural application due to the sophisticated O&M involved (RO is preferred)
18	**Research and evaluation in South Africa**	Dr JJ Schoeman, UP

7. DISINFECTION

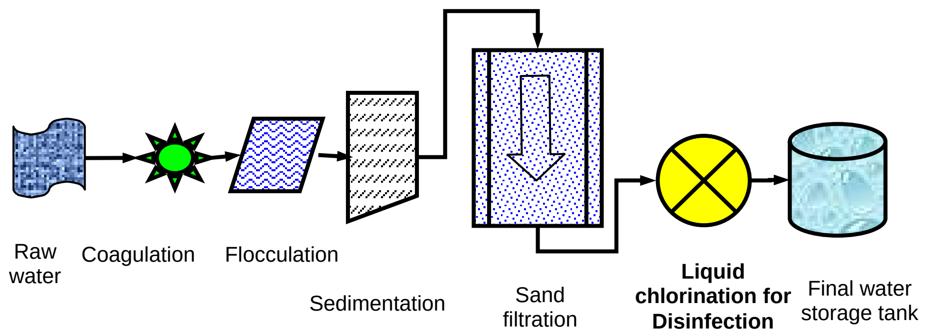
7-1 GAS CHLORINE

1	**Purpose and status**	Chlorination is the most widely used method to disinfect clarified water to eliminate pathogenic micro-organisms and to reduce the number of heterotrophic bacteria in order to maintain water quality up to the consumer. It is a proven technology
2	**Alternatives**	Liquid chlorine or gas chlorine Ozonation
3	**Summary of key features**	Effective means for disinfection of water to be used for household purposes. Lowest cost method of chlorination, but safety concerns when handling gas bottles.
4	**Description**	Chlorine as disinfectant is a chemical process and normally the last process in water treatment. It is essential that chlorine be added without interruption in a continuous process such that all the water comes in contact with the chlorine at the desired concentration. The same applies for batch treatment. A minimum contact time, depending on water quality, turbidity, natural chlorine demand of the water and temperature is required to ensure that the water is effectively disinfected. Contact time can be provided for in purposely designed contact chambers or in the distribution system provided that consumers are not close to the point of chlorination. The amount of chlorine to be added to the water is a function of the concentration and type of suspended matter, number and type of micro-organisms present and the residual chlorine concentration required after the process. Liquid chlorine which is evaporated as it is released from pressurised cylinders in well designed dosing equipment. The chlorine gas is then mixed with carriage water form to produce hypochlorous acid.
5	**Technology illustration**	
6	**Performance limitations**	The water to be chlorinated should have a low as possible suspended solid concentration (*preferably* NTU <1) to ensure that all micro-organisms all are exposed to the chlorine. Chlorination of water that contains high concentrations of organic matter may lead to the formation of disinfection by-products, commonly known as trihalomethanes (THM).
7	**Recommended capacity**	From household to large, provided that the correct chlorine compound is selected. It is easy to increase the chlorine dosing capacity.

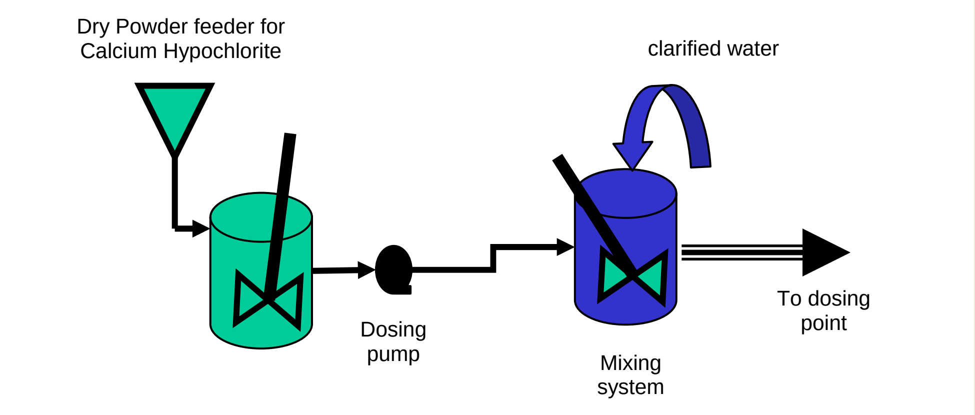
8	**Operational requirements**	*Operator skills required (trained); Operator input man-hours required per day (2); Chemical dosage required (yes); Can alternative chemicals be used (yes); Degree of automation (fully); Type and frequency of process and quality control monitoring tasks (hourly); Availability of materials/chemicals for operation spares (readily available)*
9	**Maintenance Requirements**	*Cost of servicing/repairs/replacement (high (liquid chlorine); medium (other chlorine compounds); Frequency of servicing/repairs/replacement (monthly service); Expert or skilled maintenance inputs (skilled); Availability of recommended spares and tools (readily available)*
10	**Infrastructure requirements**	While good ventilation is required for all chlorine dosing installations; it is essential for liquid chlorine installations. Corrosive resistant materials must be used for chlorine installations.
11	**Impact of Failures**	May led to poorly disinfected water, with associated health risks. Gas leaks may be hazardous for treatment plant personnel.
12	**Energy requirements**	The energy requirements are a function of the chlorine compound to be used and the level of sophistication and automation. Chlorine dosing equipment can be driven by hydraulic means that will dose the compound in proportion to the water flow or by the pressurized chlorine in cylinders.
13	**Capital costs**	Higher than for liquid or granular chlorine dosing, and comprising vacuum regulator, injector, scale, automatic switch-over, safety equipment and warning systems.
14	**Operating costs**	Relatively low when compared to liquid or granular chlorine; lower than other means of disinfection
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	4ML/d,Thulamahashe plant, Bushbuckridge, Mpumalanga, One ton liquid chlorine cylinder. 0,8 ML/d, Oranjeville, Free State, Calcium hypochlorite in powder form
17	**Socio-economic aspects**	Ignorance exists on dosing and residual chlorine. Education on impacts appearance health and treatment systems is often lacking. Ability and willingness to accept, operate and maintain needs training, preferably community members.
18	**Research and evaluation in South Africa**	Rand Water; CSIR

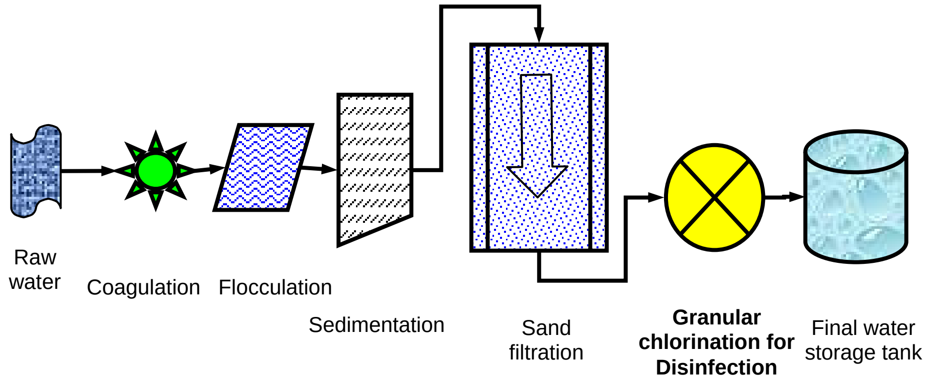
7-2 LIQUID CHLORINE (HYPOCHLORITE)

1	**Purpose and status**	Chlorination is the most widely used method to disinfect clarified water to eliminate pathogenic microorganisms and to reduce the number of heterotrophic bacteria in order to maintain water quality up to the consumer. It is a proven technology.
2	**Alternatives**	Gas chlorination; granular chlorine; UV disinfection
3	**Summary of key features**	Correct chlorine concentration required for disinfection Contact time Low water turbidity THM formation possible with organic compounds
4	**Description**	Chlorine as disinfectant is a chemical process and normally the last process in water treatment. It is essential that chlorine be added without interruption in a continuous process such that all the water comes in contact with the chlorine at the desired concentration. The same applies for batch treatment. A minimum contact time, depending on water quality, turbidity, natural chlorine demand of the water, and temperature are required to ensure that the water is effectively disinfected. Contact time can be provided for in purposely-designed contact chambers or in the distribution system, provided that consumers are not close to the point of chlorination. The use of pure liquid chlorine is most practical for continuous application from small- to large-scale operations but is not well suited for batch processes. Dosages required are site-specific, depending on water quality. The amount of chlorine to be added to the water is a function of the concentration and type of suspended matter, number and type of microorganisms present, and the residual chlorine concentration required after the process.
5	**Technology illustration**	
6	**Performance limitations**	The water to be chlorinated should have a suspended solid concentration that is as low as possible (preferably NTU <1) to ensure that all microorganisms are exposed to the chlorine. Chlorination of water that contains high concentrations of organic matter may lead to the formation of disinfection by-products, commonly known as trihalomethanes (THMs).
7	**Recommended capacity**	From small to large plants It is easy to increase the chlorine dosing capacity.
8	**Operational requirements**	Operator skills required (trained); operator input / man-hours required per day (2); chemical dosage required (yes); can alternative chemicals be used (yes); degree of automation (manual to fully automated); type and frequency of process and quality control monitoring tasks (hourly); availability of materials/chemicals for operation spares (readily available)

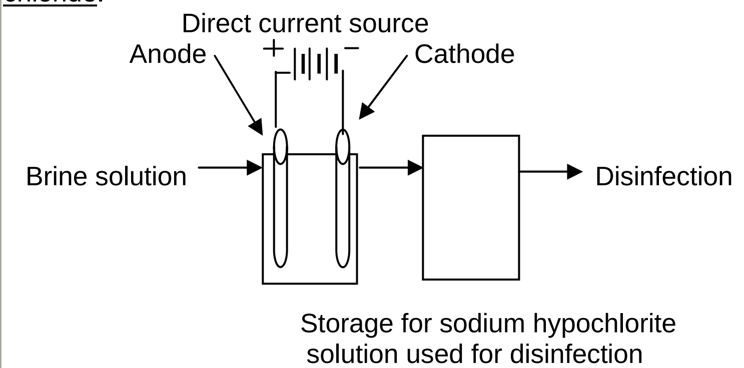
9	**Maintenance Requirements**	Cost of servicing/repairs/replacement (medium); frequency of servicing/repairs/replacement (monthly service); expert or skilled maintenance inputs (skilled); availability of recommended spares and tools (readily available)
10	**Infrastructure requirements**	Good ventilation is required for calcium and sodium hypochlorite dosing installations. Corrosive resistant materials must be used for chlorine installations.
11	**Impact of Failures**	Non-delivery of the chemical or malfunctioning of the dosing pump may lead to compromised final water quality and health risks.
12	**Energy requirements**	Electricity is not essential. Chlorine dosing equipment can be driven by hydraulic means that will dose the compound in proportion to the water flow. In-line dissolution of calcium hypochlorite is possible for the addition of chlorine on a continuous basis.
13	**Capital costs**	The capital cost of a hypochlorite dosing installation is less than that of a pure liquid chlorine installation but is also affected by the level of sophistication and automation built into the equipment. The cost of providing storage and handling for hypochlorite compounds compared to pure liquid chlorine is low.
14	**Operating costs**	The cost of hypochlorite compounds is relatively high compared to pure liquid chlorine - per equivalent mass of available chlorine. Due to the relatively low level of sophistication, maintenance on hypochlorite installations is lower than on pure liquid chlorine installations.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Oranjeville, Free State (1,0 ML/d) - calcium hypochlorite in powder form Edenburg, Bushbuckridge (1,0 ML/d) - calcium hypochlorite in powder form
17	**Socio-economic aspects**	Community acceptance and willingness to operate and maintain is high since it has been proven that chlorination as disinfectant improves water quality.
18	**Research and evaluation in South Africa**	Relevant to this technology: WRC reports; other R&D reports from research institutions/suppliers of equipment/chemicals; other references; names of researchers/consultants working in this field

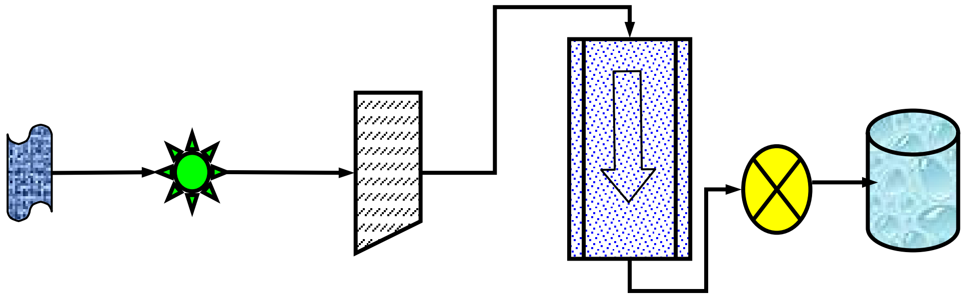
7-3 GRANULAR CHLORINE

1	**Purpose and status**	Chlorination is the most widely used method to disinfect clarified water to kill pathogenic micro-organisms and to reduce the number of heterotrophic bacteria in order to maintain water quality up to the consumer. Proven Technology: Has been used with great success for many years.
2	**Alternatives**	Gas chlorination; liquid chlorine; UV disinfection
3	**Summary of key features**	Correct chlorine concentration required for disinfection. Contact time. Low water NTU. THM formation possible with organics.
4	**Description**	Chlorine as disinfectant is the last process in water treatment to eliminate pathogenic micro-organisms to render water safe for human consumption. Water that is treated should have a low turbidity, < 1 NTU. Chlorine must be added continuously such that all the water comes in contact with the chlorine at the desired concentration for a long enough period. The same principles apply for batch treatment. Calcium hypochlorite [$Ca(HOCl)_2$] that contains 60 % active chlorine may be added as a dry powder to dissolve in the water while it is mixed and agitated. Alternatively it can be dissolved before addition. The chlorine dosage is adjusted according to the concentration and type of suspended matter, number and type of microorganisms present and the residual chlorine concentration required after the process.
5	**Technology Illustration**	
6	**Performance limitations**	The water to be chlorinated must have low turbidity to ensure contact with micro-organisms Minimum contact time required. Disinfection by Products [trihalomethanes (THM)] may form between chlorine and organic matter
7	**Recommended capacity**	Chlorination with granular calcium hypochlorite can be used from the smallest to very large applications provide that correct chlorine compound is selected. *Household scale* *< 1 m^3/d* *Very small* *1 – 10 m^3/d* *Small* *10 – 500 m^3/d* *Medium* *0,5 – 2,5 ML/d* *Large* *> 2,5 ML/d* *Ease of expansion:* The chlorine dosing capacity can easily be increased.
8	**Operational requirements**	*Operator skills required (trained); Operator input man-hours required per day (2); Chemical dosage required (yes); Can alternative chemicals be used (yes); Degree of automation (fully); Type and frequency of process and quality control monitoring tasks (hourly); Availability of materials/chemicals for operation spares (readily available)*
9	**Maintenance requirements**	*Cost of servicing/repairs/replacement medium: Frequency of servicing/repairs/replacement (monthly service); Expert or skilled maintenance inputs (skilled); Availability of recommended spares and tools (readily available)*
10	**Infrastructure requirements**	Good ventilation is required for sodium hypochlorite dosing installations. Corrosive resistant materials must be used for chlorine installations.
11	**Impact of Failures**	Non-delivery of the chemical or malfunctioning of the dosing pump may lead to compromised final water quality and health risks.

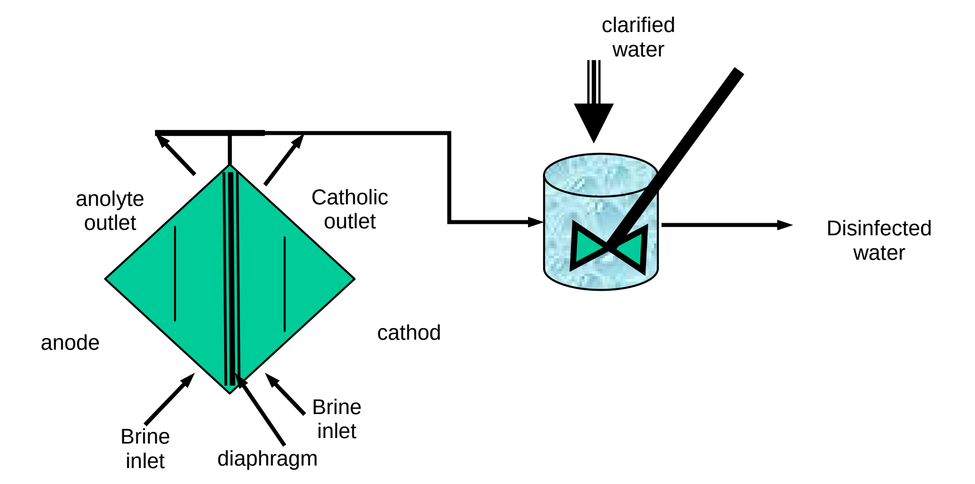
12	**Energy requirements**	Normal electricity supply required, in absence of electricity, chlorine equipment can be driven by hydraulic means that will dose the compound in proportion to the water flow.
13	**Capital cost**	The capital cost of chlorination installations is a function of the chlorine compound to be used, dosing capacity of the plant and the level of sophistication and automation incorporated in the plant. The cost of chlorination equipment would be in line with that of chemical dosing plant. *Dosing equipment for liquid chlorine is more expensive than for calcium hypochlorite products.*
14	**Operating cost**	The cost of sodium hypochlorite compounds are relative expensive compared to pure liquid chlorine per equivalent mass of available chlorine. Due to the relative low level of sophistication maintenance on sodium hypochlorite installations is lower than that of pure liquid chlorine installations.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of installations**	0,8 ML/d, Oranjeville, Free State, Calcium hypochlorite in powder form.
17	**Socio-economic aspects**	Community acceptance and willingness to operate and maintain is high since that it can be proven that chlorination improves water quality.
18	**Research and evaluation in South Africa**	Rand Water; CSIR

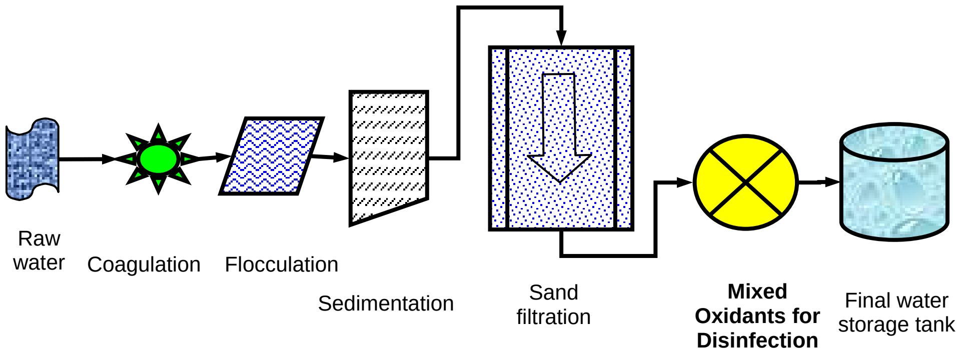
7-4 ON-SITE CHLORINE GENERATION

1	**Purpose and status**	Chlorination is the most widely used method to disinfect clarified water to kill pathogenic microorganisms and to reduce the number of heterotrophic bacteria in order to maintain water quality up to the consumer. *Proven Technology*: Onsite chlorine generation has been used with great success for many years on small scale and by its use saved many lives as pathogens in drinking water were destroyed.
2	**Alternatives**	Gas chlorination Liquid chlorination Granular chlorination Ozonation
3	**Summary of key features**	Chlorine concentration required for disinfection. Contact time. Water turbidity. Formation of THM compounds. Reliable source of electricity.
4	**Description**	It is possible to produce chlorine on-site by the electrolyses from sodium chloride that forms a weak sodium hypochlorite solution with a chlorine content of about 2 % mass by volume. This process is particularly suitable for small treatment plants that have access to a reliable power source. The advantage of the on-site production of chlorine by electrolyses is that the source material, sodium chloride, is cheap and easily available and the process is safe because of the low concentration of chlorine in the sodium hypochlorite solution. The amount of chlorine to be added to the water is a function of the concentration and type of suspended matter, number and type of microorganisms present and the residual chlorine concentration required after the process. Suitable commercial equipment is available to produce sodium hypochlorite by electrolyses.
5	**Technology Illustration**	Electrolytic cell used for on-site production of sodium hypochlorite from sodium chloride. 
6	**Performance limitations**	The water to be chlorinated should preferably have a low as possible suspended solid concentration (<1 NTU turbidity) to ensure that all microorganisms all are exposed to the chlorine. A minimum contact time, depending on water quality, turbidity, natural chlorine demand of the water and temperature is required to ensure that the water is effectively disinfected. Contact time can be provided for in purposely-designed contact chambers or in the distribution system provided that consumers are not close to the point of chlorination. Chlorination of water that contains high concentrations of organic matter may lead to the formation of Disinfection By-Products notably trihalomethanes (THM). Chlorine as disinfectant in any form is not effective against pathogenic protozoa such as giardia and cryptosporidium.
7	**Recommended capacity**	Chlorine produced by onsite electrolyses can be used from the smallest to relatively large applications provided that a suitable and reliable electrical supply is available. Household scale < 1 m^3/d Very small 1 – 10 m^3/d Small 10 – 500 m^3/d Medium 0,5 – 2,5 ML/d Large > 2,5 ML/d Ease of expansion: The onsite chlorine production and dosing capacity can easily be increased as the units are modular.

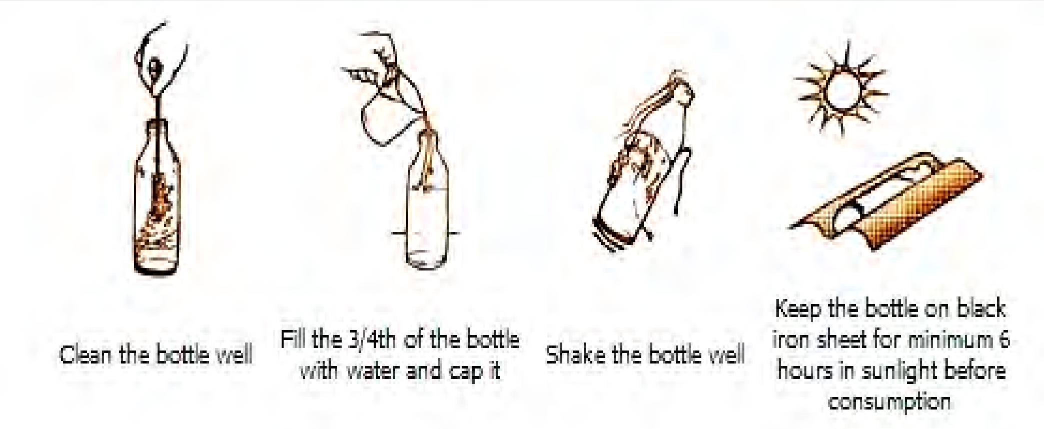
8	**Operational requirements**	Operator skills required (trained); Operator input man-hours required per day (1); Chemical dosage required (yes); Can alternative chemicals be used (yes); Degree of automation (fully); Type and frequency of process and quality control monitoring tasks (daily); Availability of materials/chemicals for operation spares (readily available)
9	**Maintenance requirements**	Cost of servicing/repairs/replacement; low (replacement of electrodes); Frequency of servicing/repairs/replacement (monthly service); Expert or skilled maintenance inputs (skilled); Availability of recommended spares and tools (readily available)
10	**Infrastructure requirements**	Good ventilation is required for all chlorine dosing installations. Corrosive resistant materials must be used for chlorine installations or where chlorine vapours are present.
11	**Impact of Failures**	Reduced efficiency in production of chlorine, resulting in ineffective disinfection of the water and potential health implications. Control systems and alarms are therefore important.
12	**Energy requirements**	A suitable reliable source of electricity is essential to produce chlorine on site. Electricity from regular supplies, or generated onsite by engine driven generator or from renewable sources, dependant on the electricity demand, is suitable. Sodium hypochlorite produced on site can be dosed with electrical or hydraulically driven equipment that will dose the compound in proportion to the water flow to obtain a specific minimum chlorine concentration.
13	**Capital cost**	The capital cost of hypochlorite dosing installations are less than that of pure liquid chlorine installations but is also affected by the level of sophistication and automisation built into the equipment. The cost to provide storage and handling for hypochlorite compounds compared to pure liquid chlorine is low. The main cost element would be the provision of a reliable electrical supply. Suitable supplies are from the standard electrify supply or generated on site by engine driven generator or from renewable sources.
14	**Operating cost**	Operation costs are limited to the cost of sodium chloride (table salt), electricity and occasional replacement of electrodes.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of installations**	Rand Water Barrage water purification plant. 10 m^3/h.
17	**Socio-economic aspects**	Community acceptance and willingness to operate and maintain is high since that it can be proven that chlorination improves water quality and reduces water borne bacterial diseases such as cholera or typhoid fever.
18	**Research and evaluation in South Africa**	The Development Of Appropriate Brine Electrolysers For The Disinfection Of Rural Water Supplies WRC project K5/1442

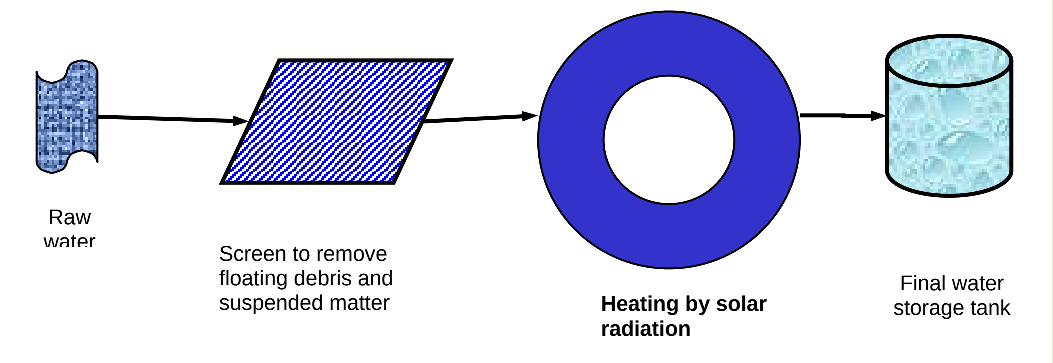
7-5 MIXED OXIDANTS (MIOX)

1	**Purpose and status**	Mixed Oxidants may present an alternative method to disinfect clarified water to kill pathogenic microorganisms and to reduce the number of heterotrophic bacteria in order to maintain water quality up to the consumer. New Technology: Although it is reported that MIOX has been used in the Eastern Block countries for some time very little is known about it or its application in the Western world. Research done in South Africa could show no difference in the efficiency of MIOX and chlorine compounds as disinfectant.
2	**Alternatives**	Chlorination (gas; liquid; granular); UV disinfection
3	**Summary of key features**	Possible to produce MIOX on site using water or brine provided electricity is available.
4	**Description**	Mixed oxidants are produced by a process of Electrochemical Activation (ECA) which is defined as: “decomposing of water with electricity by physical-chemical modification such that H^+, OH ions, metal oxides and hydrates , acids, peroxide compounds and radicals , free chlorine, oxone, hydrogen peroxide, hypochlorite anion, etc. appearing in the water.” The reactions take place in the Flow Electrolytic Module (FEM) and either slightly mineralised water or sodium chloride brine can be used as electrolyte. An anolyte with low pH and positive redox potential and a catholyte with high pH and negative redox potential are produced. These solutions that contain the oxidants listed above are purported to have higher disinfection efficiency per mass than that of chlorine. Mixed oxidants could also be applied as pre-oxidant.
5	**Technology Illustration**	
6	**Performance limitations**	The water to be treated with MIOX must have low turbidity to ensure optimum contact with microorganisms. A specific minimum contact time with the oxidant is required to be effective. Dosages required would be site specific depending on water quality. Little is known about the possible side reactions between MIOX and chemical constituents present in the water.
7	**Recommended capacity**	Much research is required before MIOX can be applied in potable water purification.
8	**Operational requirements**	Not known.
9	**Maintenance requirements**	Not known
10	**Infrastructure requirements**	As very strong oxidants are produced good ventilation is essential where MIOX is produced or applied. Similar precautions as for chlorine or ozone installations would apply. Corrosive resistant materials must be used for MIOX installations.
11	**Impact of Failures**	Non-delivery of the chemical or malfunctioning of the dosing pump may lead to compromised final water quality and health risks.
12	**Energy requirements**	Regular electricity is required.

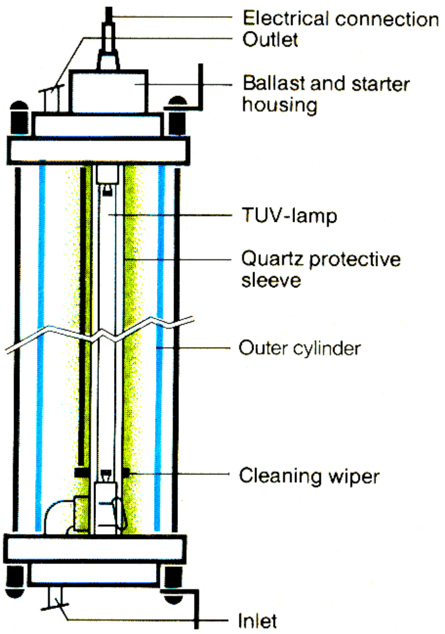
13	**Capital cost**	Higher than using chlorination on its own.
14	**Operating cost**	Depends on the chemicals used and the ratios between the different chemicals.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of installations**	No installation in South Africa on a potable water plant.
17	**Socio-economic aspects**	If it can be proven that MIOX is efficient community acceptance and willingness to operate and maintain installations would be high as this form of disinfection could improve water quality.
18	**Research and evaluation in South Africa**	The application and efficiency of "Mixed Oxidants" for treatment of drinking water. WRC report 832/1/00

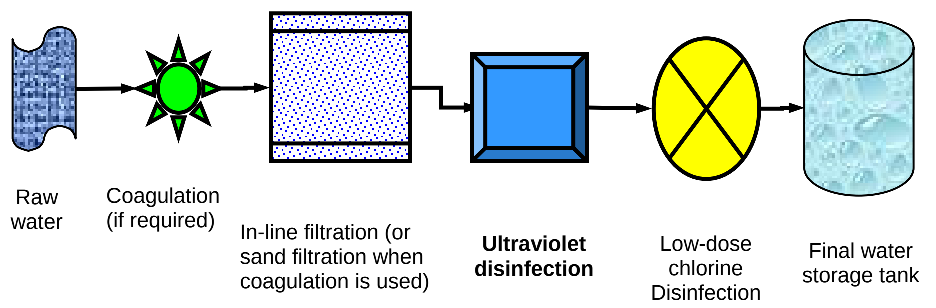
7-6 SOLAR PASTEURISATION

1	**Purpose and status**	Solar pasteurisation is used to disinfect water. It is an emerging technology.
2	**Alternatives**	Boiling
3	**Summary of key features**	Solar energy may be used as an alternative to render water safe for consumption.
4	**Description**	The exposure of water in sealed transparent containers to absorb sunlight energy has proven to be successful to eliminate bacterial indicators of faecal pollution as well as some pathogenic micro-organisms. A simplified process flow is: *Raw water - screen - **exposure to solar energy***
5	**Technology illustration**	
6	**Performance limitations**	Heating by exposure to solar energy is not suitable for grossly polluted water. Many thermo-tolerant micro-organism species that could be present will not be killed at temperatures that can be reached by exposure to the sun. This treatment is only suitable for the treatment of small volumes of water. Another disadvantage of this treatment is that there is no easy control mechanism that can be applied to determine the water safety.
7	**Suitable capacity application**	Household scale Expansion to larger volumes is difficult.
8	**Operational requirements**	Operator skills required: no special training required, normal household skills will suffice
9	**Maintenance requirements**	Cost of servicing/repairs/replacement: low Frequency of servicing/repairs/replacement: daily Expert or skilled maintenance inputs: operator Availability of recommended spares and tools: readily
10	**Infrastructure requirements**	No special infrastructure requirements except household utensils and a source of energy to boil water or recoverable transparent bottles
11	**Impact of failures**	Potential failures are minimal, but if it occurs, will lead to deterioration of microbiological quality of the water.
12	**Energy requirements**	Fossil or renewable energy sources required / solar energy
13	**Capital costs**	Capital outlay is very low compared the conventional treatment; cost is usually within the reach of households. Recycled material can be used as containers.
14	**Operating costs**	Operating cost is not a factor as process is dependent purely on the number of available sun hours per day, and the availably of suitable transparent containers.

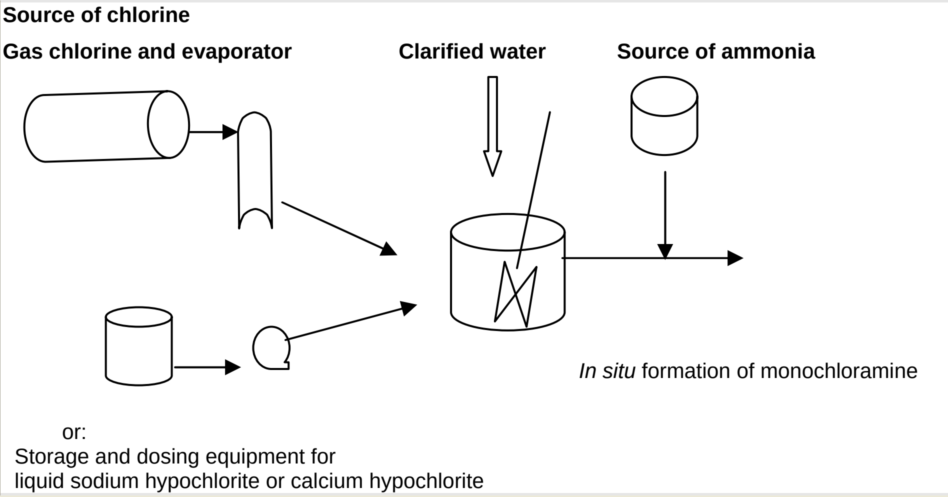
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Used by households and individuals, as required, normally in emergencies
17	**Socio-economic aspects**	The use of solar energy to heat water in bottles may be applied on an ongoing basis once a system has been established.
18	**Research and evaluation in South Africa**	Solar energy: Verena Meyer of TUT

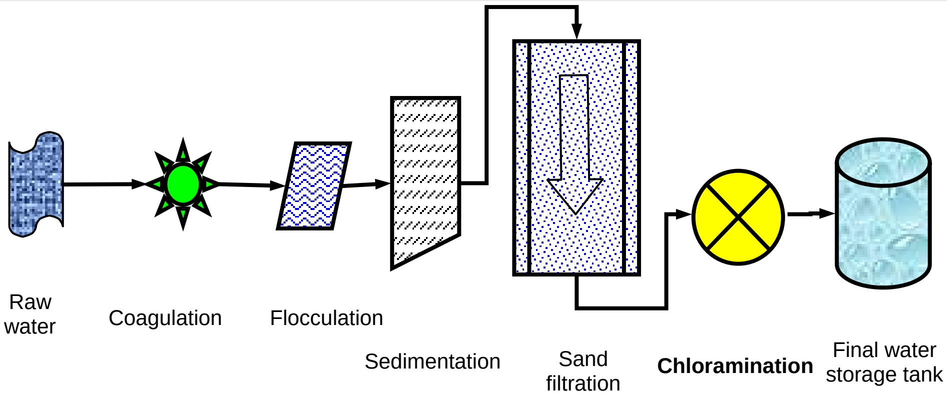
7-7 ULTRAVIOLET (UV) DISINFECTION

1	**Purpose and status**	Mainly for disinfection of pre-treated high-quality waters Also for oxidation in certain instances It is an emerging technology.
2	**Alternatives**	Solar pasteurisation, boiling, chlorine, etc
3	**Summary of key features**	Promising non-chemical method of disinfection of water, but requires effective pre-treatment to produce high clarity water before treatment by UV Low-dosage chlorination still required after UV disinfection to ensure safe drinking water in tanks, reservoirs and distribution networks
4	**Description**	Low- or medium-pressure UV lamps produce ultraviolet irradiation (energy). When microorganisms present in a water source are exposed to a sufficient dose of UV energy, the genetic material (DNA) in the cells of the microorganisms is disrupted, thereby inhibiting replication.
5	**Technology illustration**	
6	**Performance limitations**	Cannot be used to treat polluted water without sufficient pre-treatment Turbidity, colour, algae and metals (iron/manganese) interfere with efficiency of radiation to ‘reach’ microorganisms. Effective pre-treatment is therefore crucial. Lamp replacement is required after 4000-5000 hours of continuous operation. Infrequent cleaning of lamp and sleeve is required. Does not have a residual effect.
7	**Recommended capacity**	Can be used for all sizes of small water treatment systems.
8	**Operational requirements**	A flow meter is required to ensure that flow through UV system does not exceed the design flow thereby resulting in reduced irradiation and inefficient disinfection. Ideally a spectrophometer is required to measure transmissivity on-site, but it is too expensive for small rural plants. A turbidimeter and colour meter can be used as alternatives. If raw water quality deteriorates or flow rate exceeds design flow rate, chlorine should be dosed at rates that will ensure efficient disinfection. Trained operator is required 1 h/day.
9	**Maintenance requirements**	Preferably serviced by a supplier as part of a maintenance service contract Maintenance requirements not high Lamps require cleaning
10	**Infrastructure requirements**	Safe enclosure (building/security fencing) required No specific requirement for road access Sludge disposal facilities not required

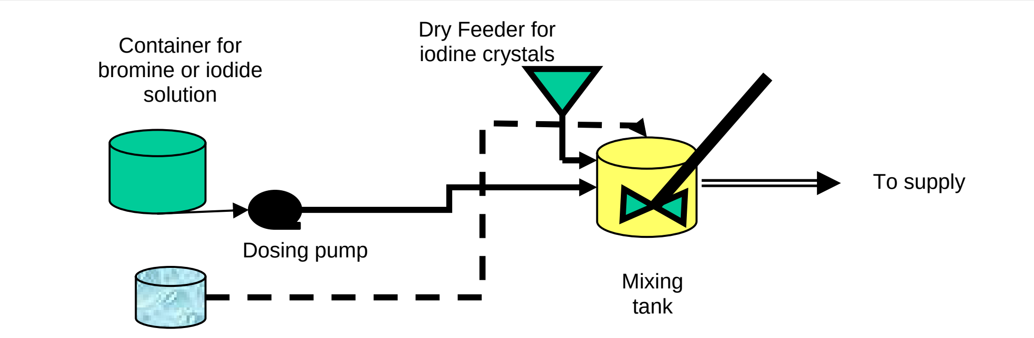
11	**Impact of failures**	Power interruptions, dirty lamps/sleeves or low radiation may lead to deterioration in microbiological quality of the final water, and health risks.
12	**Energy requirements**	Electrical power required
13	**Capital costs**	The capital costs are moderate and typical values are R 6 900.00 for a 1 m^3/h unit and R 50 000.00 for 10 m^3/h.
14	**Operating costs**	The operating costs are low and depends on the size of the installations, but typical per annum consumable costs are R750.00/annum for 1 m^3/h, R5900.00/annum for 10 m^3/h and R12000.00/annum for 100 m^3/h.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Saron (community of about 6000 people, near Porterville in the Western Cape) is currently the only example of UV disinfection for small-scale potable water supply in South Africa. The UV system is a Model TL-63/70 and consists of a single 7 kW UV lamp mounted centrally and on the longitudinal axis of the stainless steel chamber.
17	**Socio-economic aspects**	A survey was performed in the community by the Health Sciences Department of the Peninsula Technikon in May 2003 (refer to report).
18	**Research and evaluation in South Africa**	CSIR Environmentek, Pretoria

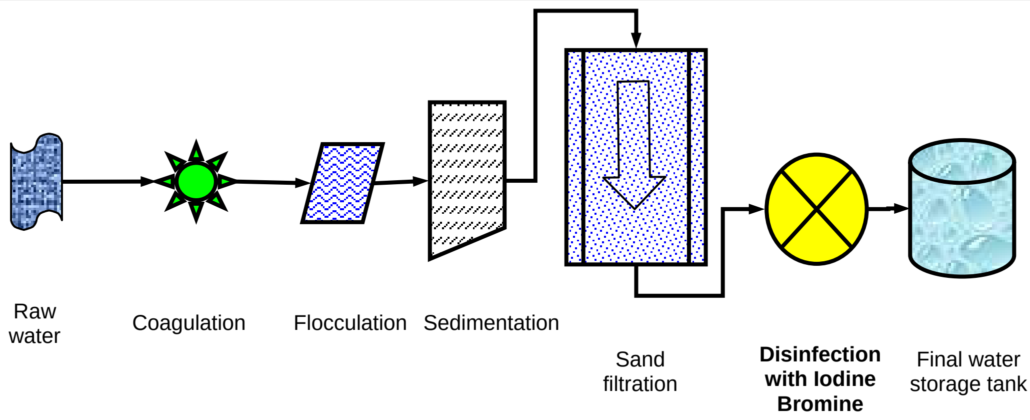
7-10 CHLORAMINATION

1	**Purpose and status**	Chloramination is normally used as a secondary disinfectant that is formed *in situ* to maintain microbiological quality in long distribution systems. It can also be used as a primary disinfectant if very long contact times are available. It is a proven technology.
2	**Alternatives**	Chlorination; chlorine dioxide; UV disinfection.
3	**Summary of key features**	Correct monochloramine concentration required for disinfection Contact time Requires low water NTU to be effective Forms a measurable residual
4	**Description**	Chloramination refers to the formation of monochloramine (NH_2Cl) in water by mixing chlorine and ammonia, measured as N, in a ratio of 5:1 in water. Any chlorine compound may be used for chloramination. Ammonia may be obtained from ammonium hydroxide solution or from ammonium sulphate. The chlorine to ammonia, as N, must be carefully controlled to prevent the overdosage of chlorine that could lead to the formation of di- and tri-chloramines that may produce taste and odour. Monochloramine is normally used as a secondary disinfectant because it is considered to be a bacteristatic compound and not a strong bactericide. It has the capacity to maintain the microbiological quality of water by preventing the increase of microorganisms after primary disinfection. Monochloramine is effective against microorganisms in biofilms. When used as a primary disinfectant a very long contact time is required to compensate for the lower microbicidal activity. Monochloramine does not react with ammonium compounds in water and does not form typical disinfection by-products such as trihalomethanes (THMs) with organic compounds. The activity of monochloramine is not affected by pH. Monochlormine is formed in the pipeline and cannot be produced prior to use.
5	**Technology illustration**	
6	**Performance limitations**	The water to be disinfected with monochloramine must have low turbidity to ensure contact with microorganisms, and requires adequate contact time to react. Dosages required are site-specific, depending on water quality.
7	**Recommended capacity**	From small to large plants (preferable)
8	**Operational requirements**	Operator skills required (trained); operator input / man-hours required per day (2); chemical dosage required (yes); can alternative chemicals be used (yes); degree of automation (manual to fully automated); type and frequency of process and quality control monitoring tasks (hourly); availability of materials/chemicals for operation / spares (readily available)
9	**Maintenance requirements**	Cost of servicing/repairs/replacement (high); frequency of servicing/repairs/replacement (monthly service); expert or skilled maintenance inputs (expert); availability of recommended spares and tools (readily available)

10	**Infrastructure requirements**	Good ventilation is essential for chloramination installations. Corrosive resistant materials must be used for chloramine installations. It is essential to mix the chlorine and ammonia compounds in the correct proportions, therefore accurate measuring instrumentation is required.
11	**Impact of failures**	Non-delivery of the chemical or malfunctioning of the dosing pump may lead to compromised final water quality and health risks.
12	**Energy requirements**	Normal electricity requirements Continuous chlorine monitors require electrical supply.
13	**Capital costs**	The capital cost of a chloramination installation is of the same order as for a chlorine dosing installation. In the design and operation strict health and safety requirements must be considered. The use of pure liquid chlorine in pressurised cylinders requires extra precautions. Good ventilation and the use of corrosive resistant materials are essential. The level of sophistication of the chloramination will affect the capital cost.
14	**Operating costs**	The operating cost of a chloramination installation is of the same order as for a chlorine dosing installation.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Rand Water applies chloramination as a secondary disinfectant.
17	**Socio-economic aspects**	Community acceptance and willingness to operate and maintain will be high since it can be proven that chloramination improves water quality.
18	**Research and evaluation in South Africa**	Rand Water

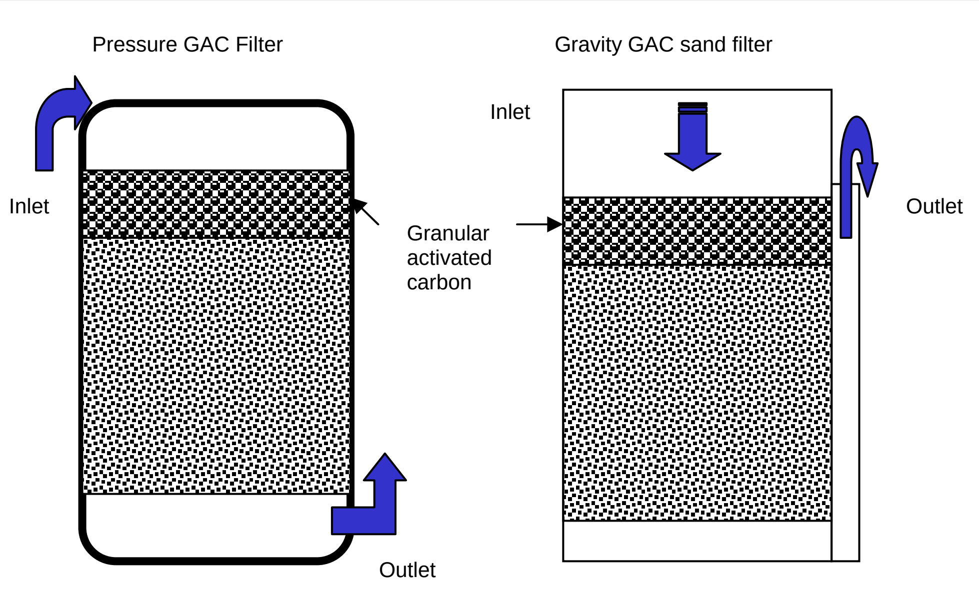
7-11 BROMINE AND IODINE DISINFECTION

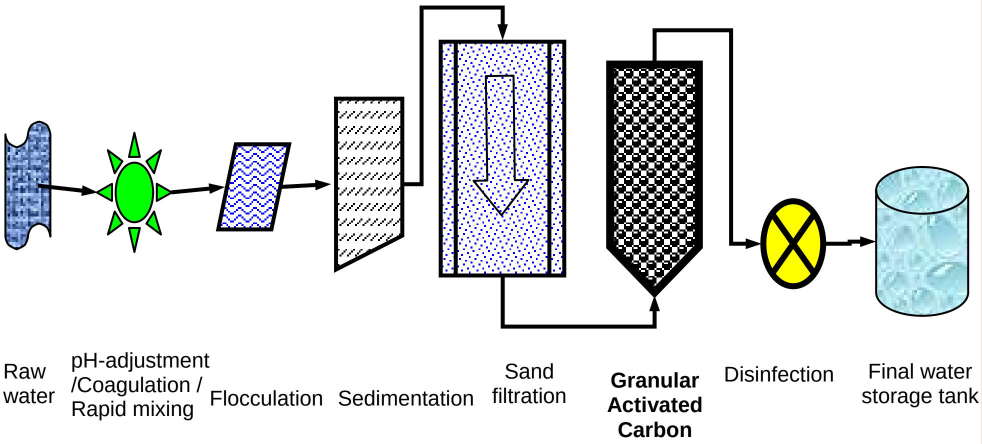
1	**Purpose and status**	Bromine or iodine disinfection is used to eliminate pathogenic microorganisms and to reduce the number of heterotrophic bacteria in potable water in order to maintain water quality up to the consumer. It is proven technology, but it has not gained much ground as alternative disinfectants to chlorine because of the difficulty in dosing the compounds, associated negative health effects, and cost.
2	**Alternatives**	Chlorination; ozonation; UV disinfection
3	**Summary of key features**	Bromine and iodine can be used as disinfectants. They are more applicable on small scale, more expensive than chlorine, and require chlorine to oxidise the bromide to bromine. Bromine and iodine compounds are imported.
4	**Description**	Both bromine and iodine may be used as replacement disinfectants to chlorine under very specific conditions. Iodine can be dosed in the neat form as iodine crystals that are dissolved in water, while the release of bromine from bromides requires oxidation by chlorine at pH <2. Solutions of bromine that contain chlorine are commercially available. One of the advantages that bromine and iodine have over chlorine is that neither reacts with ammonia that may be present. Bromine is also less affected less by high pH, conditions under which chlorite ions will be formed when chlorine is used. A disadvantage of both bromine and iodine is the high reactivity towards organic matter, including biofilms, present in water. These reactions will consume a large proportion of the added halogens. Some concern has been raised about the prolonged use of iodine because of possible undesirable physiological effects requiring for dosages to be kept within the 1-2 mg/l range. The use of bromine results in bromides that, upon oxidation, form bromates, which is a human carcinogen. A typical process flow is: *Raw water - coagulation / flocculation - sedimentation - filtration -* ***disinfection***
5	**Technology illustration**	
6	**Performance limitations**	Neither bromine nor iodine is suitable for the treatment of water with high concentrations of organic matter, as the latter will consume the oxidants (due to high reactivity with the organic material). Therefore it is important that organic matter should be reduced before adding bromine or iodine. This high reactivity also makes it difficult to form and maintain an oxidant residual in distribution systems.
7	**Recommended capacity**	From household scale (iodine solution only) to large plants (bromine or bromide/chlorine solution)
8	**Operational requirements**	Operator skills required (trained); operator input / man-hours required per day (2); chemical dosage required (yes); can alternative chemicals be used (yes); degree of automation (manual); type and frequency of process and quality control monitoring tasks (hourly); availability of materials/chemicals for operation and spares (long lead time)
9	**Maintenance requirements**	Cost of servicing/repairs/replacement (high); frequency of servicing/repairs/replacement (annually); expert or skilled maintenance inputs (skilled); availability of recommended spares and tools (long lead time)

10	**Infrastructure requirements**	While good ventilation is required for bromine and iodine dosing installations, it is essential for bromine dosing installations. Corrosive resistant materials must be used for installations.
11	**Impact of failures**	Problems with the dosing of the disinfectants will result in poor microbiological quality of the water and constitute a health risk.
12	**Energy requirements**	The energy requirements are a function of the bromine or iodine compounds used and the level of sophistication and automation. Bromine and iodine dosing equipment can be driven by hydraulic means that will dose the compound in proportion to the water flow.
13	**Capital costs**	The capital cost of dosing equipment for bromine and iodine is relatively low compared to that used for liquid chlorine. Corrosion resistant materials must be used in the construction of equipment. The level of sophistication and automation of the dosing equipment will affect the cost of the dosing installation.
14	**Operating costs**	The cost of the bromine or iodine compounds used as disinfectant is a function of the type of compound used and the availability. All bromine and iodine compounds that can be used for disinfection are imported, and generally the cost is higher than that of chlorine compounds.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Iodine applied in water purifying kits used by campers and hikers Bromide used in combination with chlorine to disinfect underground mine water high in ammonia that would consume chlorine
17	**Socio-economic aspects**	Community acceptance and willingness to operate and maintain is high since it can be proven that chlorination improves water quality and reduces water-borne diseases such as cholera. Technology requires specific conditions. High corrosiveness may impact on cost effectiveness and willingness to pay. Possibility of undesirable physiological effects Carcinogenic effects cannot be excluded.
18	**Research and evaluation in South Africa**	WRC Reports (report no.); current WRC projects (project no); other R&D reports from research institutions/suppliers of equipment/chemicals; other references; names of researchers/consultants working in this field

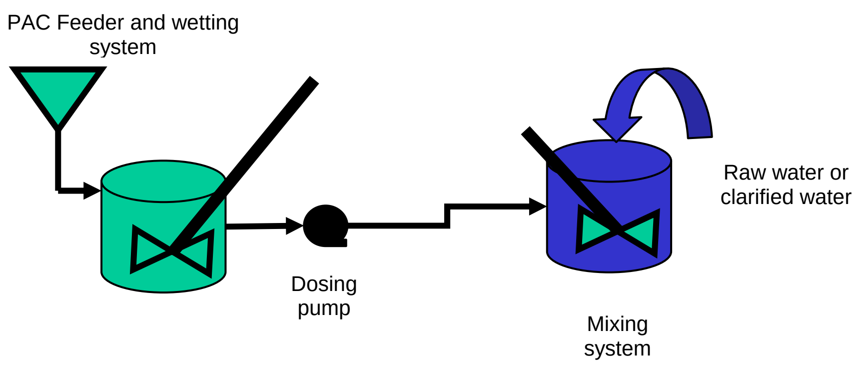
8. ADSORPTION

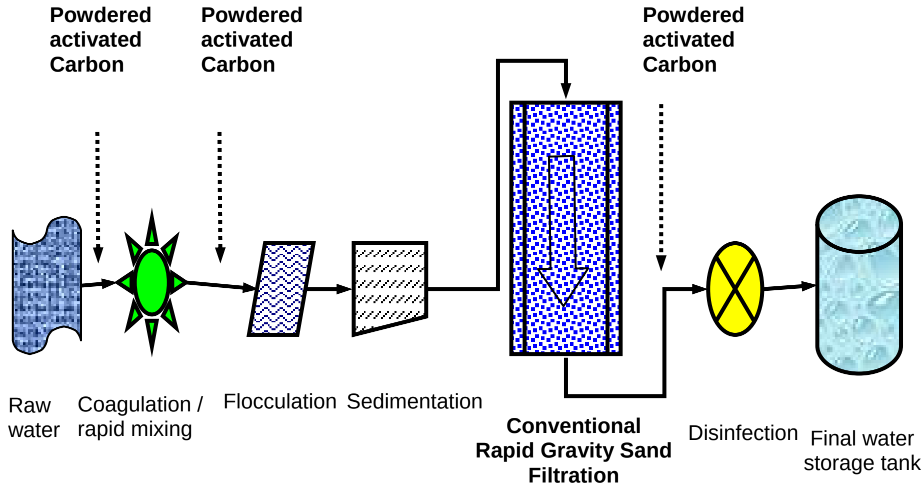
8-1 GRANULAR ACTIVATED CARBON (GAC)

1	**Purpose and status**	Granular activated carbon (GAC) is used for the removal of taste and odour-causing compounds, as well as precursors to the formation of THM compounds. It can produce a filtrate that contains 2 mg/l or less of taste and odour causing compounds while the THM precursors are reduced to within the required limits after disinfection. It is a proven technology.
2	**Alternatives**	Powder activated carbon
3	**Summary of key features**	GAC is used for the removal of taste and odour causing compounds as well as precursors to the formation of THM compounds.
4	**Description**	GAC is normally applied after all suspended matter has been removed from raw water by coagulation, flocculation, sedimentation and filtration, but it may also be used in filtration to remove suspended matter and act as an adsorber to remove organic compounds. The selection of the correct GAC material is critical and is dependent on the type of organic compounds to be removed and the general properties of the water. The particle size of the material also plays an important role in determining the efficiency. GAC adsorption is a continuous process and the feed water is normally gravitated or pumped through the GAC bed (approximately 1000 to 1500 mm deep) at a linear velocity of between 7 and 10 m/h. Up-flow GAC contactors are also used. Provision for backwashing must be made to remove suspended matter that is collected. When the GAC is used as a filter/absorber, the frequency between cleanings will be comparable to that of a sand filter. The up-flow velocity of the wash water should not exceed 10-15 m/h to prevent excessive bed expansion and loss of adsorptive material.
5	**Technology illustration**	
6	**Performance limitations**	GAC treatment is not suitable for the treatment of highly turbid waters. GAC will generally not remove dissolved inorganic compounds but water that is oversaturated with calcium carbonate may cause blinding of the GAC particles, whereby adsorption of the organic target compounds could be impeded. After the adsorptive capacity of the GAC has been reached, breakthrough of the targeted or other organic compounds may take place.
7	**Recommended capacity**	From very small to large Expansion of capacity is easy (modular).

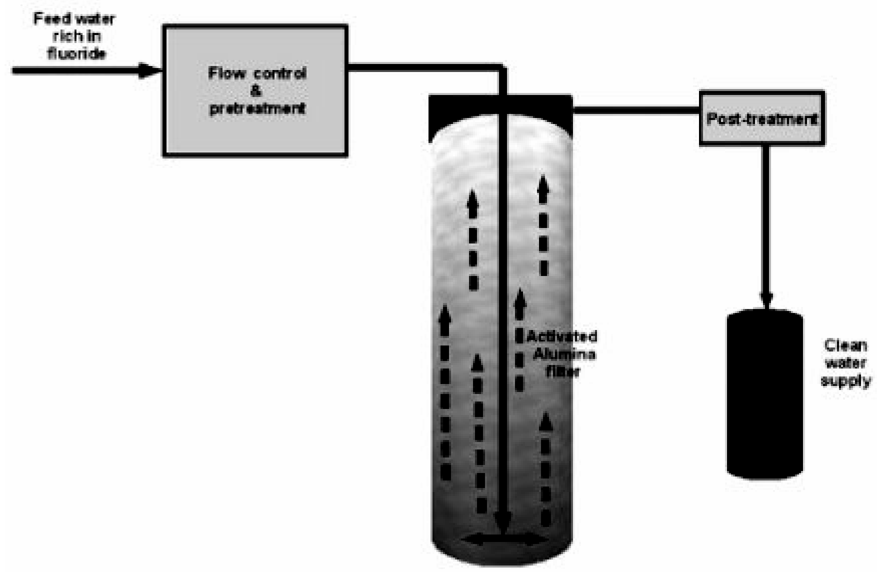
8	**Operational requirements**	Operator skills required (trained); operator input: man-hours required per day (1); chemical dosage required (no); can alternative chemicals be used (yes); degree of automation (semi-automated); type and frequency of process and quality control monitoring tasks (twice weekly); availability of materials/chemicals for operation/ spares (readily available)
9	**Maintenance requirements**	Cost of servicing/repairs/replacement (high); frequency of servicing/repairs/replacement (annually); expert or skilled maintenance inputs (operator); availability of recommended spares and tools (readily available)
10	**Infrastructure requirements**	GAC contactors have a similar construction to conventional treatment facilities, i.e. rapid gravity sand filter or pressure sand filter.
11	**Impact of failures**	Breakthrough may lead to elevated organics concentrations and/or taste and odour problems in the product water.
12	**Energy requirements**	None (e.g. gravity feed can be used)
13	**Capital costs**	The capital cost for the installation of GAC filters is high, and similar to the cost of conventional rapid gravity sand filters. It involves most civil construction. On small-scale plants steel pressure vessels could be used. The GAC material to charge the filters is expensive and must be included in the capital cost.
14	**Operating costs**	The operation cost of GAC contactors is high as regular cleaning is required, similar to rapid gravity sand filters. When the GAC has lost its effectiveness it must be replaced by unused GAC or regenerated GAC. The cost of removing the GAC increases the maintenance cost. During normal use and each regeneration cycle some efficiency is lost, which means that fresh GAC must be added and the periods between recycling becomes shorter.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Rand Water, Barrage water treatment plant (1 Ml/d) Rietvlei Dam, Tshwane.
17	**Socio-economic impact**	Acceptance from the community will be high, as the aesthetical water quality will be noticeably improved without having to perform sophisticated procedures.
18	**Research and evaluation in South Africa**	CSIR

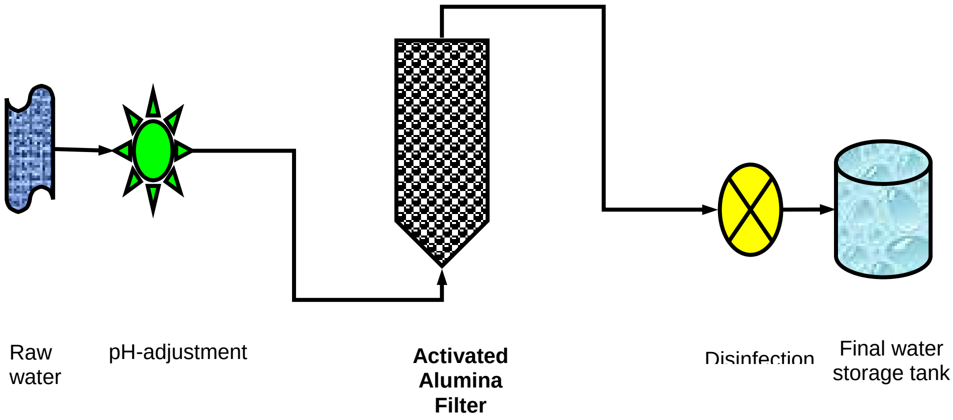
8-2 POWDER ACTIVATED CARBON (PAC)

1	**Purpose and status**	Powder activated carbon (PAC) is used to adsorb soluble organic compounds from water that are responsible for taste and odours, mostly geosmin and 2-MIB, or those that may act as precursors to the formation of trihalomethanes (THMs) when chlorine is added. It is a proven technology.
2	**Alternatives**	Granular activated carbon
3	**Summary of key features**	PAC is used as required to remove specific nuisance compounds such geosmin and 2-MIB. Unit treatment cost is high and precautions must be taken to prevent the penetration of PAC through sand filters.
4	**Description**	PAC is preferably added at a point in the water purification process that will ensure maximum water contact to enhance the adsorption of the targeted compounds. The advantage of adding PAC just prior to filtration is that the contact time with the water is long and all the water that passes through the filter comes into contact with the PAC. In this case care must be exercised to avoid the penetration of PAC through the filter, as that will introduce particles that may contain micro-organisms into the water and also interfere with the chlorine used for disinfection (as it will be neutralised). The primary characteristic that differentiates PAC from GAC is the particle size. The efficiency of adsorption onto PAC is a function of PAC particle size; the smaller particles are more effective. The advantage of PAC dosage is that it can be added as required when troublesome compounds are present and must be added continuously. In practice the maximum dosing rate is dosing is about 15 mg/l.
5	**Technology illustration**	
6	**Performance limitations**	PAC is not effective where the feed water is high in organic matter concentrations or has high turbidity (when simultaneous addition of chlorine and PAC must be avoided, as the PAC will neutralise the chlorine).
7	**Recommended capacity**	From very small to large plants Expansion of capacity is easy.
8	**Operational requirements**	Operator skills required (trained); operator input man-hours required per day (1); chemical dosage required (yes); can alternative chemicals be used (yes); degree of automation (manual); type and frequency of process and quality control monitoring tasks (4-hourly); availability of materials/chemicals for operation spares (readily available)
9	**Maintenance requirements**	Cost of servicing/repairs/replacement (medium); frequency of servicing/repairs/replacement (weekly); expert or skilled maintenance inputs (skilled); availability of recommended spares and tools (readily available)
10	**Infrastructure requirements**	PAC material is difficult to wet and must be mixed with carriage water and then dosed in the slurry form. It is important to manage the nuisance, and possible dangerous, effects that can be caused by the dust generated when PAC is handled.

11	**Impact of failures**	Power interruptions or malfunctioning of dosing pumps may lead to elevated levels of organics in the product water, and/or taste and odour problems.
12	**Energy requirements**	Electricity supply not essential; gravity feed and hand mixing can be used.
13	**Capital costs**	The capital cost of installations is a function of capacity and level of sophistication. Providing secure storage could add to the capital cost.
14	**Operating costs**	The correct grade of PAC is not always readily commercially available, and therefore it is essential that adequate stock must be kept. This could add to the operating cost as the PAC may be stocked for a long time. PAC dosing rates are dependant on the type and concentration of undesirable organic compound, but could vary from 10 to 20 mg/L.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Rand Water - very large capacity (1800 ML/d) Zuikerbosch Voelvleidam, Cape Town Metro
17	**Socio-economic aspects**	Acceptance from the community will be high, as the aesthetical water quality will be noticeably improved, without having to perform sophisticated procedures.
18	**Research and evaluation in South Africa**	CSIR

8-3 ACTIVATED ALUMINA

1	**Purpose and status**	Defluoridation, where the total raw water TDS <1500 mg/l. The process can reduce fluoride in feed water from 20 mg/L to less than 1.5 mg/L. Proven technology
2	**Alternatives**	Reverse osmosis
3	**Summary of key features**	Defluoridation using activated alumina is an efficient adsorption process for the removal of fluoride in low-TDS feed waters. Small communities can successfully use this treatment process.
4	**Description**	It is a complete process of chemical defluoridation of drinking water by a slow down-flow adsorption process of fluoride-contaminated water through a column with activated alumina (aluminium oxide). A vessel/column packed with the adsorbent is required. Equipment and chemicals for activation and regeneration of the adsorbent are necessary (periodic cleaning with a mild alkali, e.g. NaOH, and acid, e.g. H_2SO_4). Effluent disposal facilities may be required. The product water output can be connected to hand pumps or stand pipes (community systems), or taps (household systems). It is often used in conjunction with other filtration systems.
5	**Technology illustration**	
6	**Performance limitations**	Effective defluoridation will not occur in feed water with TDS >1500 mg/l. Regeneration yields effluent rich in accumulated fluoride, causing disposal problems.
7	**Recommended capacity**	From household to < 50 m^3/day Ease of expansion - difficult
8	**Operational requirements**	Semi-trained operator (4 h/day), pre-treatment may require chemical dosage, semi-automated, 4-hourly quality control required, spares readily available.
9	**Maintenance requirements**	Maintenance costs are low, weekly servicing required, operator input required, spares readily available.
10	**Infrastructure requirements**	The following are required: access roads, raw and clean water storage, civil construction, brine disposal. Components are site-constructed.
11	**Impact of failures**	Breakthrough of fluorides may occur unnoticed. Process is adversely affected by high alkalinity associated with high silicate and bicarbonate concentrations.
12	**Energy requirements**	None (gravity can be used)
13	**Capital costs**	Activated alumina is suitable for household to small plant sizes, and the capital costs are lower than for reverse osmosis.

14	**Operating costs**	The running cost for small plants is similar to that of a reverse osmosis plant.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Manke, Moretele and Taung districts in the Northern Province)
17	**Socio-economic impact**	Activated alumina process can be effectively operated by semi-trained or untrained community members as long as they are skilled in chemical handling procedures, and a fault reporting structure exists and functions.
18	**Research and evaluation in South Africa**	Dr JJ Schoeman, UP WRC Report TT 124/00

9. ION EXCHANGE

9-1 ION-EXCHANGE SOFTENING

<table>
<tr><td>1</td><td>Purpose and status</td><td>Ion-exchange softening is used for the reduction of hardness in water, caused by high concentrations of polyvalent metallic ions. The concentration of these compounds, specifically calcium and magnesium, must be reduced if it causes an offensive taste, excessive precipitation and scaling of pipelines and high consumption of detergents.

It is a proven technology.</td></tr>
<tr><td>2</td><td>Alternatives</td><td>Lime softening</td></tr>
<tr><td>3</td><td>Summary of key features</td><td>The ion exchange water softening process removes calcium and magnesium from source water. Softening may also remove as much as 5-10 mg/L of iron and manganese.</td></tr>
<tr><td>4</td><td>Description</td><td>Ion-exchange resins in drinking water are used for softening and demineralisation by typically removing some or all of the following: calcium, magnesium, sodium, chloride, sulphate and nitrate.

In water treatment applications ion-exchange involves the exchange of an ion present in the aqueous phase with an ion present in the solid phase. The solid phase is insoluble and can be of natural origin such as kaolinite or made from a synthetic material such as a polymeric resin.

The reactions in which the anions or cations are removed from the aqueous phase onto the solid phase are normally reversible. The spent solid phase is regenerated by the application of a strong solution that contains counter-ions of the same kind as those that were replaced when the solid phase was exposed to the aqueous phase. During the regeneration process, brine that contains high concentrations of the removed counter-ions is generated. Special care must be taken with the disposal of the brine as it could lead to pollution.

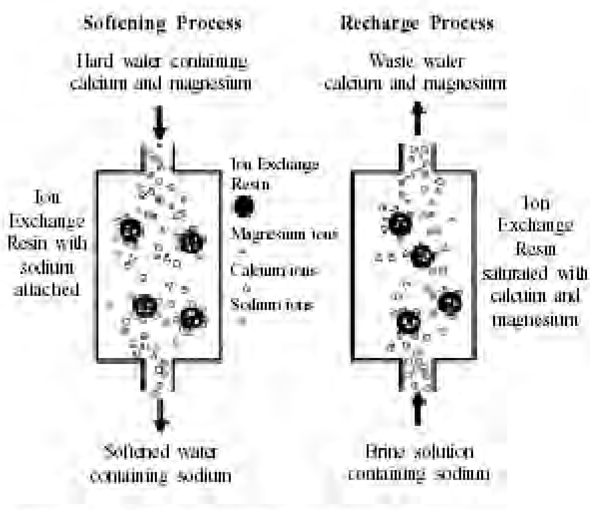
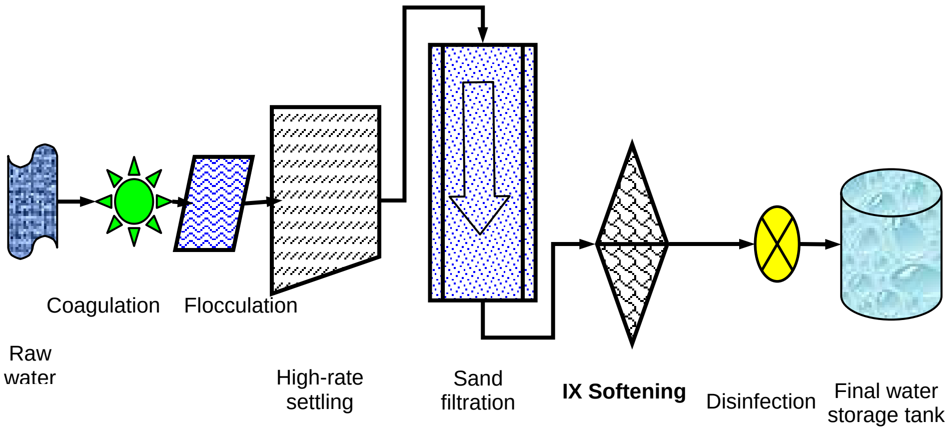
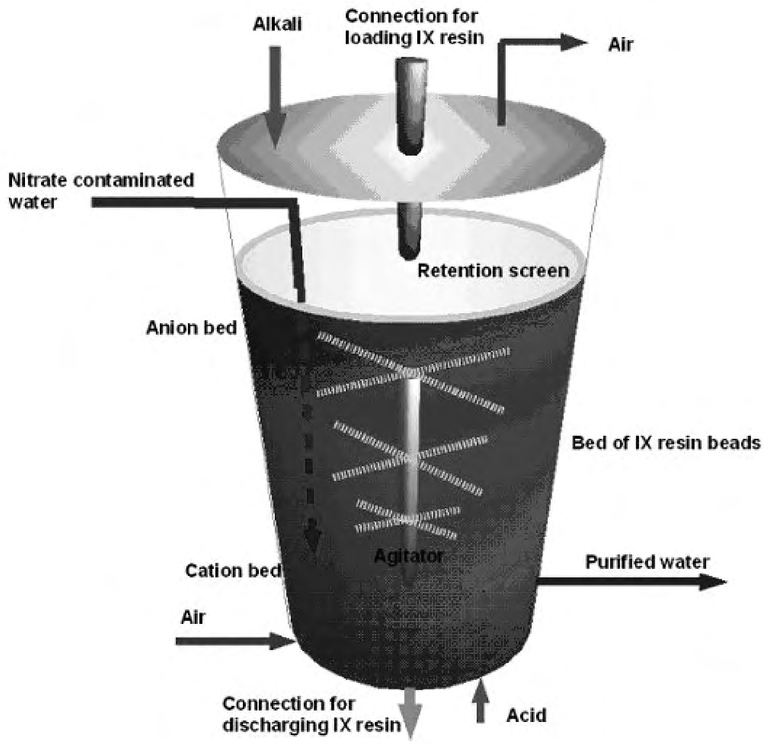
Demineralised water can be produced by passing water through ion-exchange resins in series so that anions and cations can be removed in succession, or through a mixed ion-exchange resin, where the cations and anions are removed simultaneously.</td></tr>
<tr><td>5</td><td>Technology illustration</td><td>

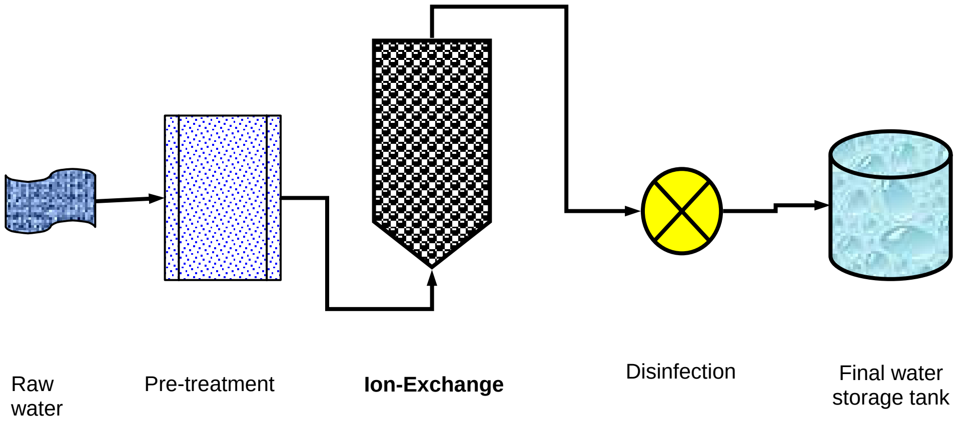
Figure 1. The water softening and recharge process.

Ion Exchange System</td></tr>
<tr><td>6</td><td>Performance limitations</td><td>While ground water with low turbidity can be treated directly, suspended matter must first be removed from surface water by conventional means. The concentration of hardness-causing compounds and the level of hardness required will be determined by the capacity of the ion-exchange plant.</td></tr>
<tr><td>7</td><td>Recommended capacity</td><td>From household to large plants
The capacity of an ion-exchange plant can easily be increased due to the modular design.</td></tr>
</table>

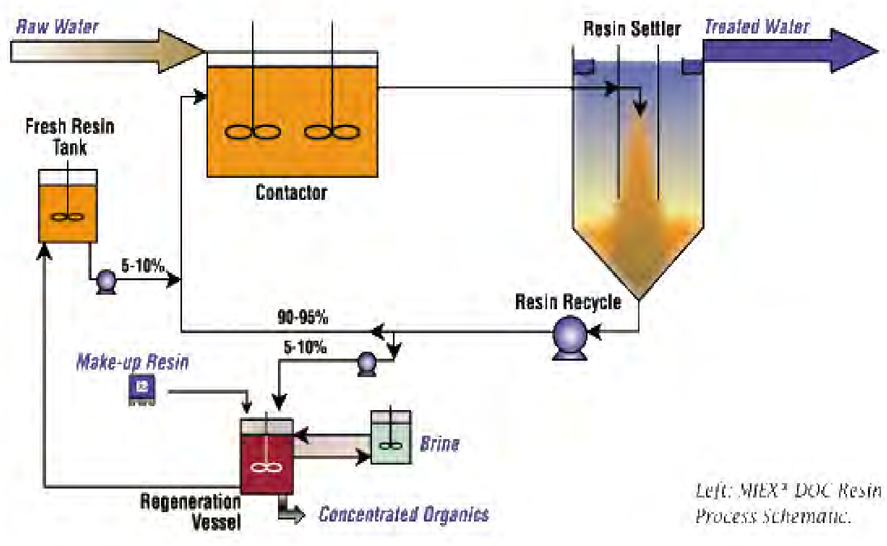
8	**Operational requirements**	Adequate backwashing of the bed is important to ensure efficient regeneration of the unit. If backwashing is to be done manually or is semiautomatic, the backwash should be continued until the water runs clear. If the unit is fully automatic and backwash time is adjustable the time should be adjusted so the backwash is long enough to produce clear water in the drain.
9	**Maintenance requirements**	Maintenance of water softening equipment is dependent on the type of softener. Some degree of monitoring or managing the regeneration process is generally required. The softener must be kept regenerated to avoid hard water flowing into pipes and appliances.
10	**Infrastructure requirements**	Power supply, housing (recommended).
11	**Impact of failures**	Calcium and magnesium ions in water react with heat, metallic plumbing, and chemical agents such as detergents to decrease the effectiveness of nearly any cleaning task. Cleaning agents used with hard water are not able to completely remove dirt and grime. Clothes may become dingy and gray with time and feel harsh or scratchy, and glassware may become spotted when dry.
12	**Energy requirements**	Energy requirements comprise pumping of regenerant (salt)
13	**Capital costs**	Capital costs are moderate, comprising the treatment vessel, exchange resin, pumps and regerant tank.
14	**Operating costs**	The operating costs are low, consisting of energy for pumping regenerant and the salt used for regeneration.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	A large number of household-sized ion-exchange softeners are found in areas with hard source water, e.g. De Aar, Stilbaai.
17	**Socio-economic aspects**	Operation and maintenance of ion-exchange softeners is normally less cumbersome than using chemical (lime) softening.
18	**Research and evaluation in South Africa**	CSIR

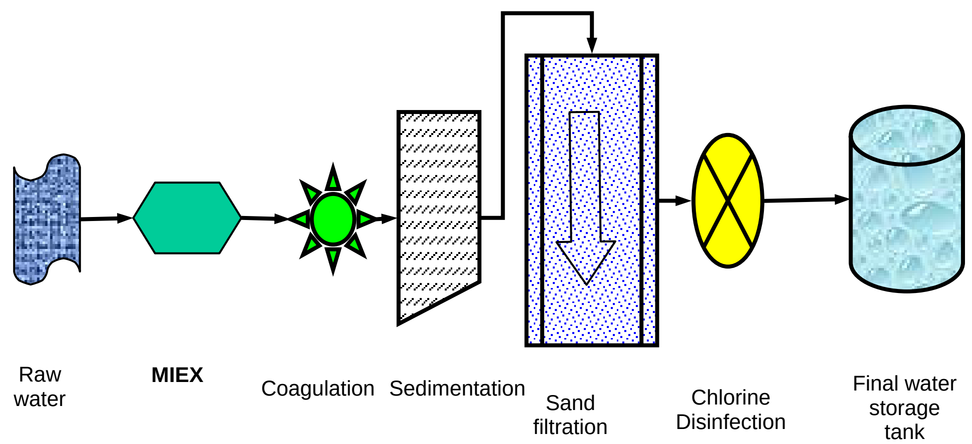
9-2 ION EXCHANGE (IX) FOR NITRATE REMOVAL

1	**Purpose and status**	Removal of nitrates from raw water (nitrate reduction of 80-99% can be achieved) It is a proven technology.
2	**Alternatives**	Biological nitrate removal Reverse osmosis
3	**Summary of key features**	Ion-exchange for nitrate removal is a specific process for the removal of nitrates and sulphates, i.e. it is not a general desalination process. Regeneration of the IX resin is an integral part of the technology.
4	**Description**	It is a complete process of nitrate removal through ion exchange. An IX column and an IX resin are required (an anion exchange resin consists of positively charged sites that are bonded to negatively charged ions; sodium chloride is generally used to charge the column). Nitrate-specific resins are available. Regeneration procedures are critical in order to ensure that the system is operating efficiently. A flow system low in suspended solids is needed to avoid clogging of the IX medium. IX is a continuous process.
5	**Technology illustration**	
6	**Performance limitations**	Only nitrates and sulphates are removed, i.e. it is not a general desalination process. IX is suitable where the TDS of the feed water is < 3000 mg/L, preferably <1500 mg/L (in water with high TDS an increase in chloride concentration may occur). High sulphate concentrations can reduce the efficiency of conventional IX resins. Suspended solids must be low.
7	**Recommended capacity**	Household to large installations Expansion is difficult and expensive.
8	**Operational requirements**	The type of resin and the regeneration conditions impact on the overall process performance. Plant operation is normally automatic.
9	**Maintenance requirements**	Regeneration procedures are critical, otherwise the resin may become saturated with nitrate and start releasing it into the product water.
10	**Infrastructure requirements**	Brine treatment facility – mainly spent sodium chloride solution (total volume of brine can be up to 4% of water treated)
11	**Impact of failures**	Nitrates may be released into the product water and causes “blue baby problems” (methaemoglobinemia).

12	**Energy requirements**	Electricity for low pressure pumps
13	**Capital costs**	Between R3 and R10/kL (economy of scale exists)
14	**Operating costs**	Between R2 and R4/kL (mainly chemicals)
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Moretele, Kudumane Springbok flats (Namaqualand)
17	**Socio-economic impact**	Brine disposal may be problematic – the recommended disposal technique into lined, fenced evaporation ponds may be too expensive.
18	**Research and evaluation in South Africa**	Dr JJ Schoeman, UP WRC report TT 124/00

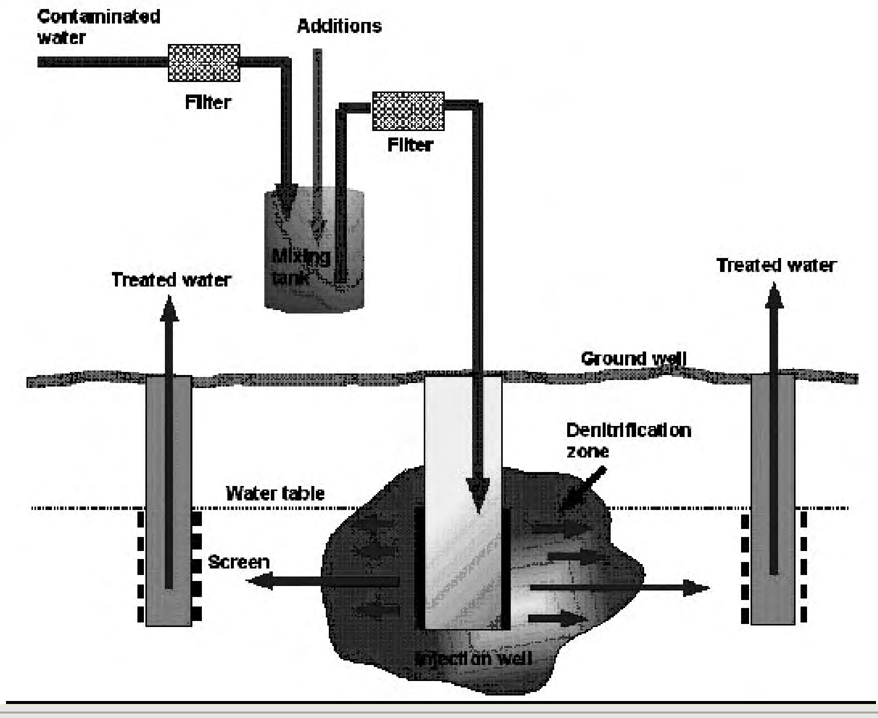
9-3 MAGNETIC ION EXCHANGE (MIEX^{TM})

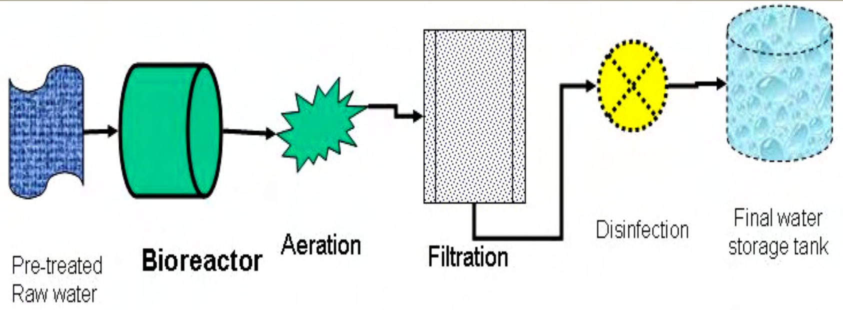
1	**Purpose and status**	MIEX^{TM} has the potential to remove mostly dissolved organic compounds (DOC) such as humic and fulvic acids and THM precursors from water and also reduce the amount of water treatment chemicals that would be required to effectively coagulate the water. Technology in development stage : MIEX^{TM} is still a relatively new process and only a few full scale plants around the world exist.
2	**Alternatives**	Activated carbon adsorption; oxidation
3	**Summary of key features**	Removal of dissolved organic compounds
4	**Description**	The MIEX^{TM} resin is a patented high capacity ion exchange resin which includes a magnetised compound. The combination of this magnetic resin with a unique continuous ion exchange process offers a process capable of reducing the organic content of the final water by: • Reducing coagulant demand • Improved floc formation • Reduction in production of water treatment sludge • Reduction in formation of DBPs. MIEX^{TM} resin is mixed with the raw water in a contactor after which it goes to a separator in which the resin is recovered. Only a small concentration of resin is required of because of the small particle size, 180 µm which improves rapid DOC exchange to the resin in the contactor. About 99,9% of the resin is recovered in the settler and remaining MIEX^{TM} particles are removed by filtration. Between 5 and 10% of the recovered resin is regenerated by washing in a sodium chloride solution. In contrast to ion exchange in columns in which break through of contaminants is possible when resins are exhausted this process ensures the continuous removal of organic compound and a product of consistent quality. The MIEX^{TM} does not require any pre-treatment of the raw water and can also be applied as a polishing step at the end of the process.
5	**Technology Illustration**	 Left: MIEX® DOC Resin Process Schematic.
6	**Performance limitations**	Efficient performance requires the application of correct dosage regimes of magnetic resin.
7	**Suitable capacity application**	Removal of contaminants by MIEX^{TM} can be applied to small and large plant as batch or continues operations. *Household scale* *< 1 m^3/d* *Very small* *1 – 10 m^3/d* *Small* *10 – 500 m^3/d* *Medium* *0,5 – 2,5 ML/d* *Large* *> 2,5 ML/d* Ease of expansion: Not easy to expand as process units will be designed to handle specific flows, modular expansion would be advisable.

8	**Operational requirements**	Operator skills required (trained); Operator input man-hours required per day (1); Chemical dosage required (yes); Can alternative chemicals be used (no); Degree of automation (manual to fully); Type and frequency of process and quality control monitoring tasks (/daily); Availability of materials/chemicals for operation spares (resin imported, sodium chloride locally available)
9	**Maintenance requirements**	Operator skills required (trained); Operator input man-hours required per day (1); Chemical dosage required (yes); Can alternative chemicals be used (no); Degree of automation (manual to fully); Type and frequency of process and quality control monitoring tasks (/daily); Availability of materials/chemicals for operation spares (resin imported, sodium chloride locally available)
10	**Infrastructure requirements**	Need to have proper arrangements for the disposal of brine used to regenerate the resin, it will contain high concentrations of the organic mater compounds that were removed from the water and sodium chloride. Resin recovery system must be efficient to minimise losses.
11	**Impact of Failures**	Power interruptions or malfunction of pumps would lead to process failure and compromised organics removal.
12	**Energy requirements**	For automated plant normal electricity supply is required. Small batch process could be manual.
13	**Capital cost**	The capital cost of a plant for the removal of contaminants by MIEX^{TM} is a function of the capacity of the plant and the level of sophistication and automation incorporated in the plant. The cost of such a plant would be similar to that of a conventional treatment plant.
14	**Operating cost**	Operating cost of ion-exchange plant is affected only by the cost of chemicals used and the disposal cost of brine . Maintenance cost on the more sophisticated equipment is more expensive and would require more frequent maintenance and replacement.
15	**Typical treatment process configuration (train) or example**	
16	**Examples of installations**	*No plant in South Africa*
17	**Socio-economic aspects**	Community acceptance and willingness to operate and maintain plant in which contaminants are precipitated are high. Any consumer will immediately observe the effect of removal of colour on the water quality. .
18	**Research and evaluation in South Africa**	*Preformed by the suppliers of MIEX^{TM} resin*

10. BIOLOGICAL TREATMENT

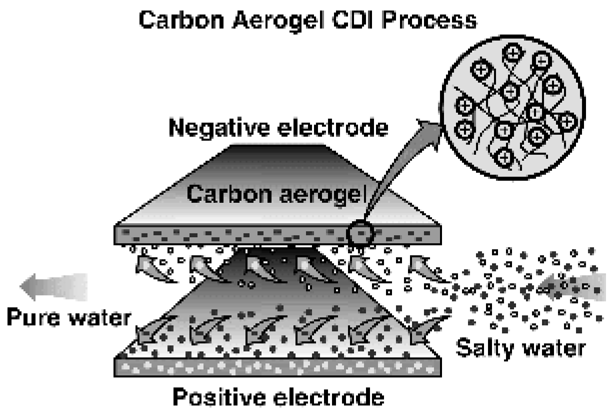
10-1 BIOLOGICAL NITRATE REMOVAL (DENITRIFICATION)

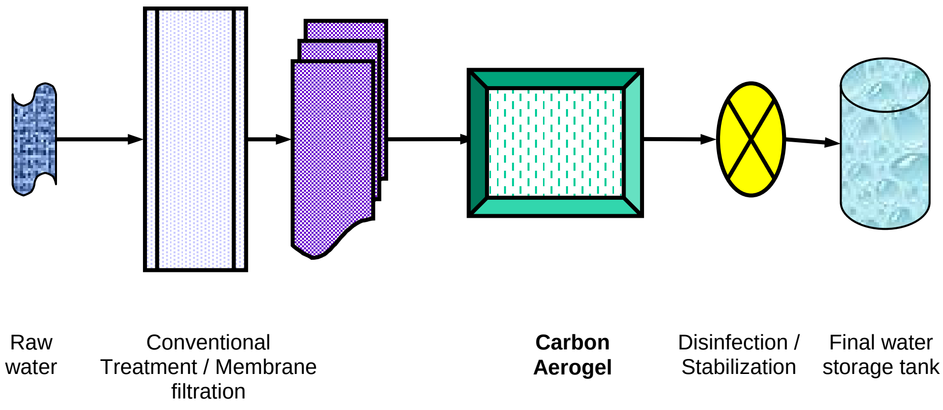
1	**Purpose and status**	Nitrate removal; efficiency between 70% and 90%, to below 10 mg/l as nitrate-nitrogen Nitrate is reduced to gaseous nitrogen species. Emerging technology with limited use in potable water applications
2	**Alternatives**	Reverse osmosis Ion-exchange nitrate removal
3	**Summary of key features**	Biological nitrate removal is used to remove nitrates in water, with efficiencies of up to 90%. It is a complex technology, with a specialised process – normally not suitable for rural communities.
4	**Description**	Biological nitrate removal involves the bacteriological degradation of nitrate ions in contaminated water. Heterotrophic nitrate removal is most widely applied. A biological nitrate removal plant basically comprises an injection well for adding nutrients, a biological reactor, and a pumping well for the abstraction of treated water. The process requires a sufficient supply of nitrate, which serves as the oxygen source for the organic (heterotrophic) reaction, plus an energy source (often organic matter such as methanol or ethanol), plus anaerobic conditions (dissolved oxygen below 0.5 mg/l). Post-treatment (aeration / filtration / disinfection) of product water is generally required. Advantages include the small amount of wastewater and nitrate not returned to the water.
5	**Technology illustration**	
6	**Performance limitations**	The process is slow, difficult to control, and it produces organic residues. Fluctuations in product water quality can be expected.
7	**Recommended capacity**	From small to large plants Expansion is difficult and expensive.
8	**Operational requirements**	Plant start-up time of up to six weeks is required. Full-time well-trained operator required – high degree of monitoring and control. Chemicals need to be added to product water. Metabolites, microbial debris and biomass (dead bacteria) must be removed once the nitrate is gone. In addition, microbes must be fed, and the food source also must be removed from the water.
9	**Maintenance requirements**	Periodic and thorough cleaning of plant components
10	**Infrastructure requirements**	Large land area for construction

11	**Impact of failures**	Nitrites can be formed if insufficient carbon or energy is available and substrate is in excess. Residual microbes may be present in the treated water, which must then be post-treated.
12	**Energy requirements**	Low electrical energy may be required in order to keep the bacterial floc in suspension, by stirring.
13	**Capital costs**	Very high (double IX nitrate removal)
14	**Operating costs**	High (similar to IX)
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	No plants in RSA Mainly used for treatment of wastewater
17	**Socio-economic impact**	Underground wells require specialised maintenance. Generally unacceptable for rural application
18	**Research and evaluation in South Africa**	WRC (wastewater treatment)

11. DEMINERALISATION

11-3 CARBON AEROGEL DESALINATION (CDI)

1	**Purpose and status**	Desalination (lowering of TDS) The carbon aerogel desalination (CDI) process purifies brackish water with a salt content of 800-10 000 mg/L using 10-20 times less energy than conventional electrolysis. Experimental technology
2	**Alternatives**	Reverse osmosis Electrodialysis (reversal)
3	**Summary of key features**	This experimental technology is largely unproven in the field of desalination, and its application is currently limited to a few evaluation projects in the USA.
4	**Description**	CDI technology involves the removal of dissolved ions from saline water through the use of carbon aerogel (CA) electrodes that are maintained at a potential difference of about one volt. Salts are removed by the imposed electrostatic field and retained on the electrode surface until the polarity is reversed. Modular, plate-and-frame low-pressure construction allows for a very wide capacity range, as carbon aerogel electrodes have excellent chemical stability and a very high surface area.
5	**Technology illustration**	 **From:** *http://www.llnl.gov/ipac/technology/profile/aerogel/CarbonAerogelCapacitiveDeionizationOfWater/index.php*
6	**Performance limitations**	Unknown (It is known that natural organic matter (NOM) can potentially foul the carbon aerogel surface). Seawater desalination potential is unknown.
7	**Recommended capacity**	Household to 50 m^3/day (unproven) Ease of expansion: easy [modular]
8	**Operational requirements**	Trained operator (8 h/day), no chemical dosage, semi-automated, hourly quality control required, long lead-time for spares
9	**Maintenance requirements**	Unknown
10	**Infrastructure requirements**	Unknown
11	**Impact of failures**	Unknown (loss of desalination capability)
12	**Energy requirements**	Electricity supply capable of reversible voltage range of up to 12 V and current range up to 60 A Projected energy requirement for brackish water: 0.594 kWh/kl
13	**Capital costs**	At this stage CDI will be more expensive than RO for smaller plants.
14	**Operating costs**	At this stage the running cost of a small CDI plant is projected to be significantly higher than for a RO plant.

15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	None in RSA, experimental in USA
17	**Socio-economic impact**	Unknown
18	**Research and evaluation in South Africa**	Licensing is done by Lawrence Livermore National Laboratory, California, USA (LLNL) - developed intellectual property (see http://www.llnl.gov/IPandC/) University of Pretoria (Engineering Faculty), Prof CF Schutte

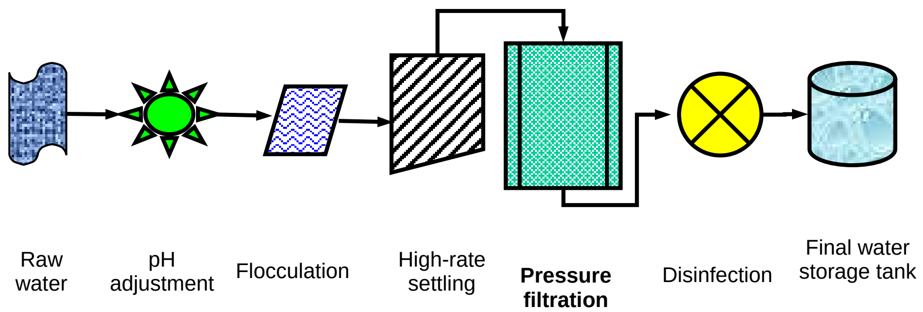
12. RADIATION

13. ELECTRICAL AND MAGNETIC TREATMENT

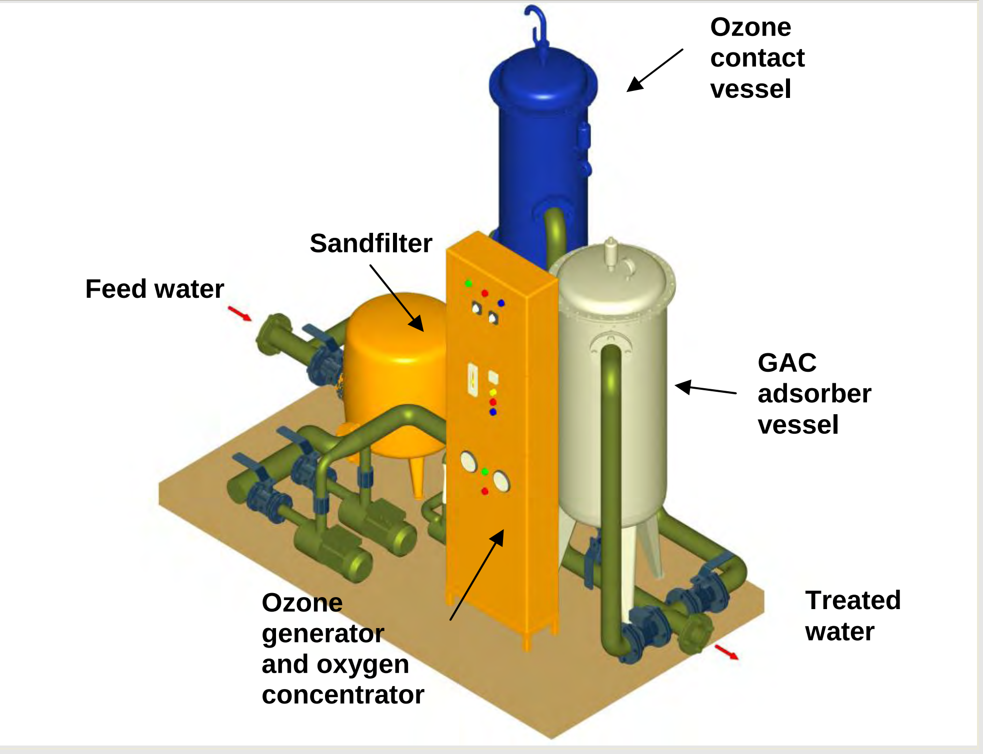
14. PACKAGE PLANTS

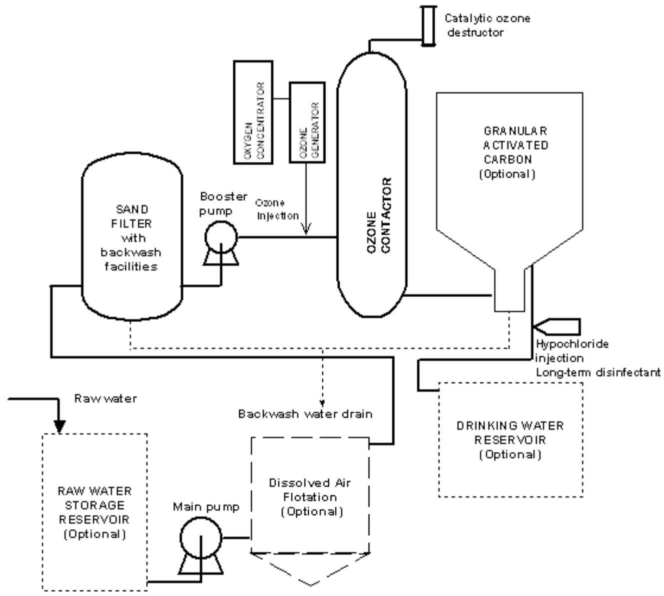
14-1 CONVENTIONAL FILTRATION PACKAGE PLANTS

1	**Purpose and status**	WPCP D/W 50 – DW 250 Modular/Package treatment plant options. This type of plant can supply Class I quality drinking water from a wide range of raw water conditions i.e. from turbidities of less than 50 up to a 5000 NTU The plant consists of mainly free standing components and is easily constructed and being modular, is easily expandable! It can also be moved to another location should the need arise. Capacity in modules of 50 m^3/hr
2	**Alternatives**	Civil/conventional plants which are expensive and hugely time consuming to construct, and not easily expandable(or movable)
3	**Summary of key features**	Flocculation using our liquid Aluminium Chlorhydrate (ACH)/Polymer blends, Inclined tube settling; Dual Media Filtration and finally disinfection using Bromine/Chlorine tablets or some other form of chlorine
4	**Description**	The plant elements include a) In-line mixing and slow mixing for flocc conditioning b) Sedimentation using a uniquely designed Inclined tube (lamella) settler that is the same size as 6m shipping container c) 2 x DW 25 Steel Dual Media pressure filters.d) Tablet disinfection All sections are usually piped up using uPVC piping
5	**Technology Illustration**	The plant is designed around the latest technology wrt flocculation – ACH based liquid blends; Sedimentation – inclined tube settling; Filtration – Dual media (Silica Sand and Hydranthrazit) and Tablet Bromination Bromine Chlorine Hydantoin tablets 
6	**Performance limitations**	In terms of capacity the plants modular design limits the capacity to about 5 modules or 5 ML/d In terms of raw water quality the plant would not handle turbities in excess of 5000 NTU
7	**Suitable capacity application**	From 1,0 - 5,0 ML/d

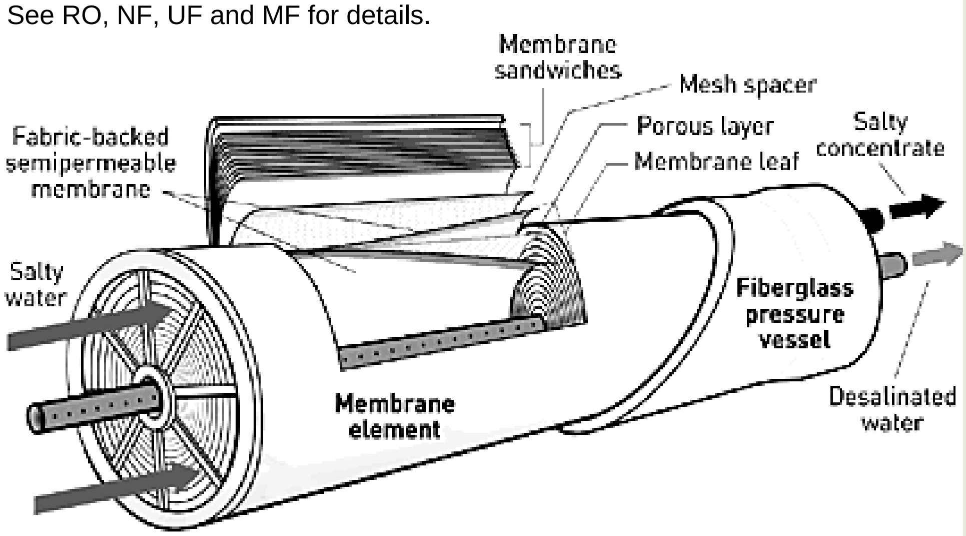
8	**Operation requirements**	The plant is normally designed to operate automatically with auto desludge of the settlers and push button start for filter backwash using actuated butterfly valves, so operation personnel requirements are limited, probably 1 hour per day.
9	**Maintenance requirements**	Very little maintenance required. Chemical stocks need to be replenished approximately once per week. The flocculant dosing pump will need a monthly service the filter and raw water pumps will need an annual maintenance service. The plant does however have fairly sophisticated instrumentation and electrical equipment, e.g. timers and level relays, so suitably trained personnel need to be available to maintain this equipment as the need arises
10	**Infrastructure requirements**	The package plants (either pre-fabricated or assembled on site) requires power supply (normally three-phase), concrete slab, facilities for chemical storage, sludge / backwash-water disposal facilities, and security fencing.
11	**Impact of failures**	As pressure filtration normally forms the main treatment process, power interruptions and pump failure will lead to process failure and no treated water being produced. The availability of standby is therefore of high importance.
12	**Energy requirements**	380 V approx 100 AMPS
13	**Capital cost**	Budget estimate – R1.5 million per ml For a 1 – 2 ml/d plant, tapering down to about R1.0 million per ml for a 5.0 ml/d plant
14	**Operating cost**	Estimated at about R0.38 per kl
15	**Typical treatment process configuration (train) or example [overall process flow diagram indication required preceding and subsequent treatment]**	
16	**Examples of installations**	New Treatment plant at Mankayane for Swazi Water Services corporation Capacity 50 m^3/ hr, easily expandable to 100 m^3/hr Piggs peak plant 250 m^3/hr also for Swazi Water Services corporation
17	**Socio-economic aspects**	The plant is fairly sophisticated and needs a fairly high level of trained operator so one may argue that it is not “appropriate Technology” for rural areas
18	**Research and evaluation in South Africa**	The processes (e.g. inclined tube settlers and dual media filters) are not new and have been well researched and operating effectively for some years now. Some 30 similar plants are working well in SA and the surrounding states

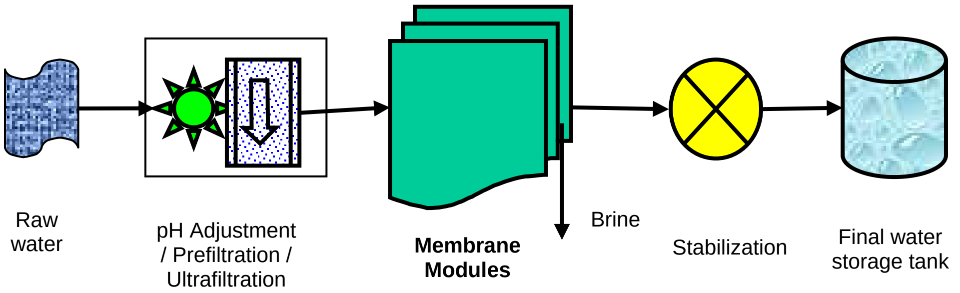
14-2 ALTERNATIVE OXIDATION PACKAGE PLANTS

1	**Purpose and status**	Safewater ™ is a package water treatment plant using ozone as base technology, in combination with granular activated charcoal (GAC). A Safewater™ plant provides highly effective disinfection against bacteria, viruses, fungi and protozoan species, as well as removal of toxic compounds, odours and tastes, and iron and manganese. Safewater™ reproduces the benefits demonstrated by state-of-the-art large scale ozonation/GAC plants on a small scale. Ozone technology, and its combination with GAC are well proven.
2	**Alternatives**	Separate O_3 and GAC plants
3	**Summary of key features**	Safewater™ provides a complete water treatment solution, integrating ozone technology and GAC with other pre-filtration unit processes.
4	**Description**	Feed water to a Safewater™ plant is obtained from surface or ground water. Depending on surface water quality, the first unit process comprises Dissolved Air Flotation (DAF). This is followed by sand filtration with optional automatic backwashing facilities. Ozone is injected into the water flow by venturi and static mixing to facilitate oxidation of pollutants (ozone dosage is modelled and calculated per application on the basis of expected water quality and pollutants). Residual ozone levels are allowed into a contact vessel for residence times adequate to ensure removal of all bacteria, viruses, *giardia* and *cryptosporidium* oo-cysts to US EPA limits. Disinfected water flows through a pressurised GAC vessel operating in adsorption and BAC mode to remove residual ozone and polish water quality. Considerable (up to three times) lifetime of the GAC is attainable in the combination with ozone.
5	**Technology Illustration**	
6	**Performance limitations**	Safewater™ is ineffective against most inorganic compounds except iron and manganese. Safewater™ does not provide long-term residual disinfection, but low-dose chlorine or hypochlorite can be included.
7	**Suitable capacity application**	10 kL/d to 3 ML/d current capacity. Safewater™ is designed to treat average to peak flow variations of 1 to 4.
8	**Operation requirements**	Safewater™ can be fully automated, including sandfilter and GAC backwashing sequences, depending on budget. In this case, not operator is required since the ozone system is interlocked with the electricity supply, and is protected against damage that may occur through component or other system failure. No chemical dosing is required except when residual chlorine disinfectant is supplied. Trained operators are not required.

9	**Maintenance requirements**	Routine maintenance includes the normal required attention to pumps (e.g. seals) and compressors. Typically, annual replacement is required. GAC lifetime is extended significantly by ozone, depending on water quality, at least 18 months lifetime is foreseen before replacement. No other replacements or maintenance are required.
10	**Infrastructure requirements**	Equipment must be housed, or alternatively can be supplied in a container. Electricity supply is required, from 1 kW single phase at lower range to 30 kW three phase at high range. Raw and clean water reservoirs are optional, but are not requirements for use of Safewater™.
11	**Impact of Failures**	Ozone systems are modular, and Safewater ™ provides a typical worst case 66 % availability.
12	**Energy requirements**	Electricity is required as specified in section 10.
13	**Capital cost**	Varies from R3-20/kL to R1-00/kL depending on size
14	**Operating cost**	Electricity cost as per 10 above Pump and compressor maintenance GAC replacement after 12 to 18 months
15	**Typical treatment process configuration (train) or example [overall process flow diagram indication required preceding and subsequent treatment]**	
16	**Examples of installations**	Magalies Park Resort, Hartbeespoort Dam
17	**Socio-economic aspects**	Trained operators required for operation and maintenance of these package plants.
18	**Research and evaluation in South Africa**	PURION Pty (Ltd) WRC Report No. 1127/1/04

14-3 MEMBRANE PACKAGE PLANTS

1	**Purpose and status**	*(See Technology Information Sheets for specific membrane technologies.)* All categories of membrane separation technologies, inclusive of combinations thereof (RO / NF / UF / MF), can be incorporated into package plants. While all types of membranes work well under suitable conditions, choosing the most appropriate membrane for a given application still remains crucial. In many cases, selection is complicated by the availability of new types of membranes, applications, and site-specific conditions. Proven technology
2	**Alternatives**	*(See Technology Information Sheets for specific membrane technologies.)*
3	**Summary of key features**	All categories of membrane separation technologies, inclusive of combinations thereof (RO / NF / UF / MF), can be incorporated into package plants.
4	**Description**	A membrane package plant is typically a skid-mounted, self-reliable unit with all required controls, instrumentation, blowers, compressors and pumps needed for a fully functional system included. Package plants arrive on site virtually ready to operate and are designed to minimise the daily attention required to operate the equipment. Typically, membrane package plants offer the following advantages: • A proven and reliable membrane technology • Easy access to membranes for cleaning replacement purposes • Automated, with PLC control • Designed to operate in harsh environments • Modular system with expandable building block design • A compact footprint and minimal ceiling clearance above the system. Different technologies (membrane and/or other) can be incorporated into a package plant to provide comprehensive water treatment.
5	**Technology illustration**	See RO, NF, UF and MF for details. 
6	**Performance limitations**	Variable feed-water quality requires higher levels of operational skill and attention, and that tends to impact negatively on the package plant advantages of low cost and automation. Also, package plants may not have the ability to treat multiple types of contaminants.
7	**Recommended capacity**	Very small to large Capacity can be increased by adding modules.
8	**Operational requirements**	Operation and monitoring of membrane package plants normally requires trained staff. Staffing levels can vary by up to three persons per shift per day, depending on the capacity and the complexity of the plant. Package plant operation is simplified by including automated features and other operating parameters, such as backwashing. Chemical feed controls are especially important for plants without full-time operators or with variable feed water characteristics. When the automation fails, the operator needs to turn off the automatic controls/instrumentation and operate the plant manually.

9	**Maintenance requirements**	Maintenance normally requires trained staff. Maintenance requirements are well documented in manuals. An extensive spare parts inventory must be maintained. Operational support by the manufacturer, to make adjustments to the plant and inspect the equipment's operation and performance, is recommended.
10	**Infrastructure requirements**	Serviced location (electricity / provision for feed / brine / product water in- or outflows)
11	**Impact of failures**	No product water flow or contaminated product water flow (see unit processes)
12	**Energy requirements**	Normally a reliable electricity source (single or three phase)
13	**Capital costs**	The most significant associated costs, aside from the capital cost, are the costs of electricity, membrane replacement and labour. All desalination techniques are energy-intensive relative to conventional technologies.
14	**Operating costs**	See unit processes. For example (RO plant in 2004): **Feedwater Type** / **Capital cost per unit of daily capacity ($/m³/day)** / **Operation and maintenance per unit of production ($/m³)** Brackish water / 380 - 562 / 0.28 - 0.41 Seawater / 1341 - 2379 / 1.02 - 1.54
15	**Typical treatment process configuration (train) or example**	
16	**Examples of SA installations**	Desalination package plants near Garies (Kamiesberg Municipality) on the West-Coast (Kheis, Lepelfontein, Klipfontein, Spoegrivier, Soebatsfontein).
17	**Socio-economic impact**	Membrane package plants are perceived to be expensive and complex, which restricts their application to high-value areas and limits their use in areas with saline groundwater where access to more conventional technologies is not possible.
18	**Research and evaluation in South Africa**	*(See Technology Information Sheets for specific membrane technologies.)*

ANNEXURE C

REPORTS ON WATER TREATMENT SYSTEMS, CONFIGURATIONS AND TECHNOLOGIES

WRC Report KV 134/01
A pilot environmental and social baseline study for rural water supply and sanitation projects
Motaung N
2001

WRC Report TT 133/00
The level of communication between communities and engineers in the provision of engineering services
Pybus P; Schoeman G; Hart T
2000

WRC Report TT 150/01
Assessment of the attended coupon-operated access-point cost recovery system for community water supply schemes
Lima Rural Development Foundation
2001

WRC Report 1032/1/03
Economically viable solar still units for use in remote, rural areas of South Africa
Goldie I; Theunissen A; Bonthuys J; Cloete V
2003

WRC Report 1077/1/02
The use of life cycle assessment in the selection of water treatment processes
Friederich E; Buckley CA
2002

WRC Report 1271/1/03
Investigation of water supply issues in typical rural communities: case studies from Limpopo Province
Maselaganye PM
2003

WRC Report 386/1/98
Development of a crossflow microfilter for rural water supply
Pillay VL
1998

WRC Report 450/1/97
Package Water Treatment Plant Selection
Voortman WJ; Reddy CD
2001

WRC Report 520/1/01
Guidelines on appropriate technologies for water supply and sanitation in developing communities
Pearson IA; Bhagwan J; Kariuki W; Banda W
2001

WRC Report 539/1/97
Part 1: A dynamic cross-flow sand filter for rural water treatment. Part 2: A technical guide for a dynamic cross-flow sand filter
Environmentek CSIR; Kariuki AW (Part 1); Solsona F
1997

WRC Report 649/1/98
An assessment of common problems associated with drinking water disinfection in the developing areas
Pearson G; Idema G
1998

WRC Report 677/1/98
Guidelines for the evaluation of water resources for rural development with an emphasis on groundwater
Sami K; Murray EC
1998

WRC Report 738/1/00
Guidelines for the upgrading of existing small water treatment plants
Swartz CD
2000

WRC Report 764/1/00
Water supply to rural and peri-urban communities using membrane technologies
Jacobs EP; Pillay VL; Pryor M; Swart P
2000

WRC Report 817/1/00
Strategies for empowerment of women in water supply and sanitation projects
Duncker L
2000

WRC Report 828/1/01
Field evaluation of alternative disinfection technologies for rural water supply projects
2001

WRC Report 837/1/01
Decision support system for the development of rural water supply schemes
Carmichael SS; Forsyth D; Hughes DA
2001

WRC Report TT 124/00
Defluoridation, denitrification and desalination of water using ion-exchange and reverse osmosis
Schoeman JJ; Steyn A
2000

WRC Report 1042/1/01
Development of a solar-powered reverse osmosis plant for the treatment of borehole water
Louw GJ
2001

WRC Report 1071/1/02
Electrochemical generation of high-concentration ozone in compact integrated membrane systems
Bessarabov DG
2002

WRC Report 662/1/03
Evaluation and optimisation of a crossflow microfilter for the production of potable water in rural and peri-urban areas
Pillay VL; Buckley CA
2003

WRC Report 965/1/03
Ultrafiltration capillary ultrafiltration membrane process development for drinking water
Jacobs EP; Pillay VL; Botes JP; Bradshaw SM; Pryor M; Swart P
2003

WRC Report TT 101/98
Quality of domestic water supplies. Vol 1: Assessment guide.
DWAF; Dept of Health; WRC
1998

WRC Report TT 92/97
Water purification works design.
Van Duuren FA
1997

WRC Report 1026/1/02
Consolidation and transfer of limestone mediated stabilisation technology for small to medium scale water users.
Mackintosh GS; Du Plessis GJ; De Souza PF; De Villiers HA
2002

ANNEXURE D

CONTACT INFORMATION FOR A SELECTION OF LOCAL TECHNOLOGY SUPPLIERS

The information below comprises a selection of local technology suppliers, and is not necessarily all-inclusive. The mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Technology Supplier	Technology Type(s)	Contact details	e-mail	Web Site
African Pegmatite (Pty) Ltd	Maddox iron and manganese removal systems	Tel: (016) 362 0600 Fax: (016) 362 1239	pegmatite@ cyberserv.co.za	
Alldos (Pty) Ltd	Dosing pumps	Tel: (012) 346 1271 Fax: (012) 346 1547	alldos@ alldos.co.za	www. alldos.co.za
Aquamat cc South Africa	Filtration systems Exfetron	Tel: (011) 472 1311 Fax: (011) 672 7592	aquamat@ cyberhost.co.za	
ASW Engineering	Filtration equipment	Tel: (011) 793 1330 Fax: (011) 793 4829	ken@ asw.co.za	www. asw.co.za
Atlas Filter Co	Pre-coat filtration Diatomaceous earth (DE) filtration	Tel: (043) 722 5421 Fax: (043) 743 0181	atlasfil@ iafrica.com	www. atlas-filters.co.za
Bateman Africa (Pty) Ltd	Water treatment technologies	Tel: (011) 201 2300 Fax: (011) 201 2500	enquiries@ batemanafrica.co.za	www.bateman engineering.com
Biwater	Water treatment systems Membrane systems	Tel: (011) 549 7600 Fax: (011) 463 8404	hardus@ biwater.co.za	www. biwater.com
BTC Products and Services	Chlorine Dioxide systems and technologies	Tel: (011) 794 9239 Fax: (011) 794 9027	btc001@ btcproducts.co.za	www. btcproducts.co.za
CH Chemicals	Membrane technologies	Tel: (011) 876 6738 Fax: (011) 255 2938	hschade@ chcgroup.co.za	www. chcgroup.co.za
Chemfreeaqua	Ozone systems	Tel: (031) 309 4177 Fax: (031) 309 4005	info@ chemfreeaqua.com	www. chemfreeaqua.com
CWC Consolidated Water Conditioning	Filtration Ion-exchange Membrane systems	Tel: (011) 828 0103 Fax: (011) 828 9699	colin@ cwc.co.za	www. cwc.co.za

Degremont (Pty) Ltd	Membrane systems	Tel: (011) 807 1983 Fax: (011) 807 4118	george.van.der.merwe@degremont.co.za	www.degremont.co.za
DoseTech (Pty) Ltd	Liquid dosing technology	Tel: (011) 397 5120 Fax: (011) 397 5502	liquiddosing@dosetech.co.za	
Explochem Water Treatment (Pty) Ltd	Membrane systems Water treatment systems	Tel: (011) 888 3926 Fax: (011) 888 3942	maniec@explochem.co.za	www.explochem.co.za
FiltRSA	Membrane technologies Filtration systems	Tel: (021) 808 3178 Fax: (021) 808 3913	epj@sun.ac.za	
GE Water Technology	Membrane technologies	Tel: (011) 237 0025 Fax: (011) 314 0121	james.dark@ge.com	www.ge.com
Grahamtek Systems (Pty) Ltd	Membrane technologies	Tel: (021) 853 0699 Fax: (021) 853 0692	neil@grahamtek.com	www.grahamtek.co.za
Hemcro Africa	Package water treatment plants	Tel: 083 629 5128 Fax: (012) 653 7341	hennie@hemcro.co.za	www.hemcro.co.za
HydroPhil (Pty) Ltd	Water technology suppliers, incl membrane systems	Tel: (021) 883 2116 Fax: (021) 883 9427	info@hydrophil.co.za	www.hydrpohil.co.za
Improchem	Chemicals and Water Technology Suppliers	Tel: (011) 971 0400 Fax: (011) 394 3436	improchem@improchem.co.za	www.improchem.co.za
Keyplan	Membrane technologies Filtration Activated carbon	Tel: (011) 444 8120 Fax: (011) 444 8014	info@keyplan.co.za	www.keyplan.edx.co.za
Klomac Engineering	Chemical dosing Filtration	Tel: (031) 579 1041 Fax: (031) 579 1043	cp@klomaceng.co.za	www.klomaceng.co.za
Lektratek Water Technology	Water treatment equipment	Tel: (018) 293 0487 Fax: (018) 293 0489	general@lwt.co.za	www.lwt.co.za
Metsi Chem (Pty) Ltd	Water treatment chemicals	Tel: (011) 813 1100 Fax: (011) 813 1341	mosesm@icon.co.za	
Montan Chemicals	Water treatment chemicals	Tel: (011) 824 2582 Fax: (011) 827 8414	bharvey@prochem.co.za	www.prochem.co.za
NCP Chlorchem (Pty) Ltd	Water treatment chemicals	Tel: (011) 921 3111 Fax: (011) 976 4736	willieBi@ncp.co.za	www.ncp.co.za

Ozone Services Industries	Ozone generators and equipment	Tel: (011) 791 4403 Fax: (011) 791 4465	office@ ozonize.co.za	www. ozonize.co.za
Ozonic	Ozone systems	Tel: (012) 651 4721 Fax: (012) 651 4925	cobus@ ozonic.co.za	www. ozonic.co.za
Overberg Water	Package water treatment plants	Tel: (028) 722 8000 Fax: (028) 722 8006		www. overbergwater. co.za
PALL South Africa	Filtration systems Membrane technologies	Tel: (011) 266 2300 Fax: (011) 315 3243	jakes_jacobs@ africa.pall.com	www. pall.com
PCISA (Paterson Candy)	Filtration package plants	Tel: (011) 704 5372 Fax: (011) 704 5373	azihc@ bv.co.za	
Prominent Fluid Controls (SA) (Pty) Ltd	Dosing pumps Water treatment systems	Tel: (011) 825 4142 Fax: (011) 825 4132	promsa@ mweb.co.za	
Proxa (Pty) Ltd	Membrane systems Desalination systems	Tel: (021) 872 0089 Fax: (021) 872 7299	wimpie@ proxa.co.za	www. proxa.co.za
Purion	Ozone systems	Tel: (012) 253 0464 Fax: (012) 253 0469	parc@ icon.co.za	
Quality Filtration Systems	Filtration systems Membrane technologies	Tel: (021) 883 3534 Fax: (021) 883 3469	qfs@ iafrica.com	
Rand Water	Water treatment process development and evaluation	Tel: (011) 682 0481 Fax: (011) 682 0444	slushaba@ randwater.co.za	www. randwater.co.za
S.A.M.E. SA Mechanical Erection (Pty) Ltd	Package water treatment plants	Tel: (011) 902 4900 Fax: (011) 902 8854	same@ netactive.co.za	
SA Water Cycle Group	Advanced oxidation Advanced water treatment	Tel: (012) 665 4113 Fax: (012) 665 4117	info@ sawater.co.za	www. sawater.co.za
Separations	In-line filters Membrane technologies	Tel: (011) 792 3428 Fax: (011) 792 1043	water@ separations.co.za	www. separations.co.za
Sud-Chemie Water and Process Technologies (Pty) Ltd	Water treatment chemicals Package plants	Tel: (011) 929 5800 Fax: (011) 976 3170	scsa@ sc-world.co.za	www. sud-chemie.com
Swan's Water Treatment (Pty) Ltd	Water treatment systemss Filtration package plants	Tel: (011) 662 1800 Fax: (011) 662 1940	peter@ swanswater treatment.co.za	www. swanswater treatment.co.za

Umgeni Water	Water treatment technology development and evaluation	Tel: (033) 341 1111 Tel: (033) 341 1167	info@ umgeni.co.za	www. umgeni.co.za
UV Water Systems	UV disinfection and oxidation technologies	Tel: (012) 346 4242 Fax: (012) 346 4269	sales@ uvwater.co.za	www. uvwater.co.za
Valve and Allied cc	Water filtration systems Automatic backwash filters	Tel: (011) 789 4110 Tel: (011) 886 4398	info@ vacc.co.za	www. vvacc.co.za
VWS Envig	Desalination systems Membrane technologies	Tel: (011) 663 3600 Fax: (011) 608 4772	info.vwsenvig@ veoliawater.com	www. veoliawater.com
WPCP Water Purification Chemical and Plant cc	Package water treatment plants Water treatment chemicals	Tel: (031) 502 3310 Fax: (031) 502 3025	lpmdbn@ iafrica.com	
Zetachem (Pty) Ltd	Water treatment chemicals	Tel: (031) 469 0165 Fax: (031) 469 0408	zetachem@ zetachem.co.za	www. zetachem.co.za

ANNEXURE E

GLOSSARY OF TERMS

Activated Carbon	The process of passing water through a filter material containing activated carbon, whereby organic substances dissolved in the water are retained on the activated carbon filter by a process known as adsorption
Adsorbent	A solid material which adsorbs, such as clay, carbon, and activated alumina
Aeration	A process whereby intimate contact of a liquid with air is facilitated, e.g. by bubbling air through the liquid, by passing the liquid over a waterfall, or by spraying the liquid through the air
Alkaline	The condition of water or soil which contains a sufficient amount of alkaline substances to raise the pH above 7,0
Alkalinity	The capacity of water to neutralise acids, imparted mainly by carbonates, bicarbonates and hydroxides, occasionally by borates, silicates and phosphates
Anaerobic biological reduction	Biologically mediated decrease in the oxidation state in the absence of oxygen
Anion	A negatively charged ion, which moves under the influence of an electric field towards the anode
Backwash	To reverse flow of fluid (air, liquid) through the filter element to effect deposited solids removal
Baffle	A plate to deviate flow entering a vessel
Basin	The surface area within a given drainage system
Bridging	Particles being removed
Carbonate alkalinity	Alkalinity caused by carbonate ions
Carbonate hardness	Hardness caused by the presence of carbonates and bicarbonates of calcium and magnesium
Cation	A negatively charged ion, which moves under the influence of an electric field towards the cathode
Coagulant	A substance added to destabilise colloids in a stable suspension
Coagulation	The clumping together of suspended particles in water so as to form larger clumps, which may be settled out by the action of gravity
Colloid	Finely divided solids, less than 0,001 mm in size; intermediate between a suspension and a true solution
Corrosive	Having a tendency to corrode a material. In terms of human skin, that which burns and destroys tissue. In terms of metals, rusting.

Deionisation	The process of removing dissolved ions from water, usually through use of ion-exchange resins
Demineralisation	A process whereby dissolved salts (=minerals) are removed from water
Denitrification	The process whereby dissolved nitrates in water are removed from the water by biologically mediated chemical reduction to nitrogen gas
Depth filtration	The use of a deep bed of a medium to remove particulate matter by filtration
Diatomaceous earth	Diatom skeletons of silica in the form of fine particles; used in cake form as a filter medium
Disinfection	The process of counteracting infection through the use of a disinfectant, which is a chemical substance that destroys micro-organisms such as bacteria
Dissolved air flotation	A process whereby suspended particles are floated to the surface as scum which can be skimmed off, by passing air through the water in water treatment
Distillation	The process whereby water is turned into steam through the application of heat, and then recondensed into water. The salts remain behind and the recondensed water (= the distillate) is free of dissolved salts.
Electrodialysis	The movement of ions across a semi-permeable membrane assisted by an electrical potential difference
Evaporation	The process by which water becomes a vapour at a temperature below its boiling point
Ferric salts	Salts of the element iron in the +3 valence state of the ion
Filter	A filtration device or a structure consisting of a supported filter medium and equipment for the subsequent removal of the deposited solids
Filtration	The process whereby suspended solid particles are removed by passing a liquid through a porous material (= the filter) so that the liquid portion passes through the filter, and the solid particles are retained on the filter
Flocculant	Substances added to a destabilised suspension to accelerate flocculation, densify or strengthen flocs
Flocculation	The process by which a settlable floc is made through coagulation of suspended particles into larger sized settlable particles of flocs
Groundwater	Subsurface water occupying the saturation zone from which wells and springs are fed
Head	The height of the free surface of fluid above any point in a hydraulic system; a measure of the pressure or force exerted by the fluid
Hydroxide	The compound resulting when the oxide of a metal reacts with water to form a substance with –OH (hydroxide) groups
Inactivation	The process of rendering inactive or harmless
Inorganic	Not of an organic nature, i.e. chemical compounds of any element/s other than carbon

Ion	A charged atom, molecule, or radical, the migration of which affects the transport of electricity through an electrolyte or, to some extent through a gas
Ion-exchange	The process whereby a semi-porous material, known as the ion-exchange resin exchanges charged solute particles with other solute particles of like charge in solution, but differing electronic affinity for the resin. Ion exchange is a process whereby charged salt particles or ions, may be removed from solution.
Microbes	Microscopic organisms, especially disease-causing organisms
Micron	The unit of length equivalent to 10^{-6}m
Micro-organisms	Biological organisms, some of which have a disease-causing nature, of microscopic size, such as bacteria, viruses, protozoa, etc.
Milligrams per litre	A mass/volume unit of concentration of constituents of water or wastewater
Mineral	Any substance that is neither animal nor vegetable; obtained by mining
Organic	Chemical substances of animal or vegetable origin, basically carbonaceous
Oxidation	The process whereby a molecule loses electrons in a chemical reaction, so as to increase its oxidation state. This may occur through reaction with oxygen or any other oxidant material, which has an affinity for electrons.
Pathogens	Disease-causing organisms; word derived from the Greek Pathos = disease and gen = giving rise to
pH	The reciprocal of the logarithm of the hydrogen ion concentration
Powdered activated carbon	Powdered carbon which has been activated, usually by heat treatment, so that chemical absorption sites on the surface of the carbon particles have been activated to serve as sites for absorbing especially organic compounds. Used in water treatment to remove organic poisons.
Precipitation	The process whereby substances in clear solution appear as a solid phase, as suspended particles, which may then settle to the bottom of the container through gravitational action. The substance which settles out of solution is known as the precipitate. When a precipitate forms, a previously clear liquid becomes cloudy as a consequence of the formation of a solid precipitate.
Preoxidation	Use of an oxidant prior to use of another reagent
Purification	The removal of undesirable or objectionable matter from water by natural or contrived means – an extractive process
Reagents	Chemical substances used to cause a chemical reaction
Recarbonation	Re-adding carbon dioxide to water, when this has been lost in the water treatment process as a consequence of pH modification; done so as to restabilise the water with respect to the pH and buffering capacity
Reverse osmosis	The technological process whereby water is forced under pressure against an osmotic gradient, i.e. from a more saline solution to a less saline solution on the low pressure side of a semi-permeable membrane, which is a membrane permeable to water molecules, but relatively impermeable to dissolved salts present in solution in the water

Saturation	A condition reached by a material holding another material in an amount such that no more can be held within it in the same state
Sediment	Solids, settled from suspension in a liquid
Sedimentation	The process whereby suspended particles in a liquid settle to the bottom of the container containing the liquid if allowed to stand, over time, as a result of the action of gravity on the suspended particles
Substance/variable/ property/constituent	Those things which are present in water and which may be analysed to determine the quality of the water with respect to fitness for use
Supernatant	Liquid above settled solids
Turbidity	A measure of the scattering and absorption of light rays, caused by the presence of fine suspended matter
Unit process	In which chemical changes take place
Water purification	The removal of undesirable substances from water
Water supply	In general, the sources of water for public or private uses
Water treatment	The addition of substances to water in order to render it more suitable for any particular purpose.