A GUIDEBOOK on Household Water Supply for Rural Areas with Saline Groundwater

I Goldie
& RD Sanderson






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Water Research Commission

A GUIDEBOOK ON HOUSEHOLD WATER SUPPLY FOR RURAL AREAS WITH SALINE GROUNDWATER

Report to the Water Research Commission

by

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EXECUTIVE SUMMARY

Many small rural communities in South Africa face severe constraints in terms of the quantity and the chemical quality of their household water supply due to their geographical and climatic environment. Saline water sources, such as brackish ground water, are often available, but traditional institutional bias against the use of sophisticated technologies to improve water quality often results in desalination being regarded as too expensive or sophisticated for implementation and maintenance at such communities. It is possible, however, that specific economically feasible and community-acceptable water supply options do exist (desalination or otherwise), but that the relevant role-players do not have access to all adequate information regarding these options at the point of decision-making. This guidebook therefore aims to serve as a decision-making aid to such individuals and organisations by providing guidelines that can be used to identify relevant water supply options. The guidebook also includes a database of technical information on such water supply options. Mention is made of the typical socio-economic profile of target communities.

The content of this guidebook was developed over a two-year period through the integration of a number of inputs. These inputs included: theoretical research into relevant water supply options, consultations with researchers active in the field of desalination technology, meetings and correspondence with water authorities and field visits to typical target communities where selected water supply options are currently in use.

A number of relevant water supply options, ranging from sophisticated desalination technologies to simple household water augmentation methods, such as rainwater collection, were identified as part of the above research study. Those options that were considered of most importance in terms of actual or potential use (locally and internationally) were listed. Key technical aspects of each of these options were then identified, and then included in the database of water supply options.

The socio-economic research design used was a cross-sectional descriptive study. One-day workshops were held with experts to develop the questionnaire. Variables that were considered were: demography, housing structure, waters source, water quality, community involvement, participation and willingness to pay. A pilot study was conducted to

test and modify the questionnaire, which in the end was administered to 210 households in 7 communities including 6 farms. Communities were selected on the criteria: (1) have access to water but the quality is poor (i.e. exceeding SABS maximum allowable limits for TDS, nitrates and fluorides), and (2) have no or limited access to water but the quality is good. Accidental non-probability sampling method was applied and only those at home during study were interviewed on the basis of 1 person per household. The data was analyzed using Statistical Package for Social Scientists (SPSS).

Key findings of the socio-economic study were: (1) The main water source appears to be communal taps. 43.5% of respondents obtain household water from a communal tap of which the feeding source varies between boreholes, rainwater reservoirs, rivers and streams. Water from the boreholes requires desalination in order for it to be fit for human consumption. Only 14% of respondents have taps inside their houses. (2) Any new technology employed should be appropriate to the needs and skills of the community so that they can preferably operate and maintain it themselves. In addition to this, the technology implemented should be affordable to the community and be energized at a sustainable level. (3) It is very interesting to note that the poorer communities are more willing to pay for improved water access and quality and, further, are willing to participate in water provision projects, whereas affluent respondents regard water provision as a responsibility of government i.e. local municipal authorities. (4) Community participation and involvement in every aspect of the project may bring about social sustainability, as ownership may come automatically, be accompanied by responsibility and acceptance, which is essential for co-operation and maintenance of such projects.

It is recommended that the contents of the guidebook be revised on a regular basis to change the water supply options and to update legislative information to accommodate the changing institutional environment.

ACKNOWLEDGEMENTS

The research in this report emanated from a project funded by the Water Research Commission entitled:

"GUIDEBOOK TO ALTERNATIVE SMALL-SCALE DESALINATION TECHNOLOGIES FOR POTABLE HOUSEHOLD WATER AUGMENTATION IN SOUTH AFRICA"

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

Dr G Offringa (Chairman)	Water Research Commission
Mr JN Bhagwan	Water Research Commission
Mr MW Marler	Development Bank of Southern Africa
Mr M van Zyl	Northern Cape Provincial Government
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Mr A Wessels	Weir Envig (Pty) Ltd
Mr DR Reinecke	Kannaland District Municipality

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Mr G Hendricks	Eden DM
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R Bartlett	Peninsula Technikon
Dr MJ Hurndall	University of Stellenbosch

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APPENDICES

ABOUT THE GUIDEBOOK

ABOUT THIS GUIDEBOOK

This section covers background on the scope and applicability of this guidebook, as well as information on its layout and how to use it. The existing institutional framework is also summarised. Information in this guidebook is provided on a question & answer basis.

A. *How is the guidebook structured?*

Section 1 defines the scope and applicability of the guidebook.

The aim of Section 2 is to assist in the process of identifying potential water supply options for new projects in the target areas. A colour-coded scheme is used to provide an overview of the potential suitability of different household water supply options:

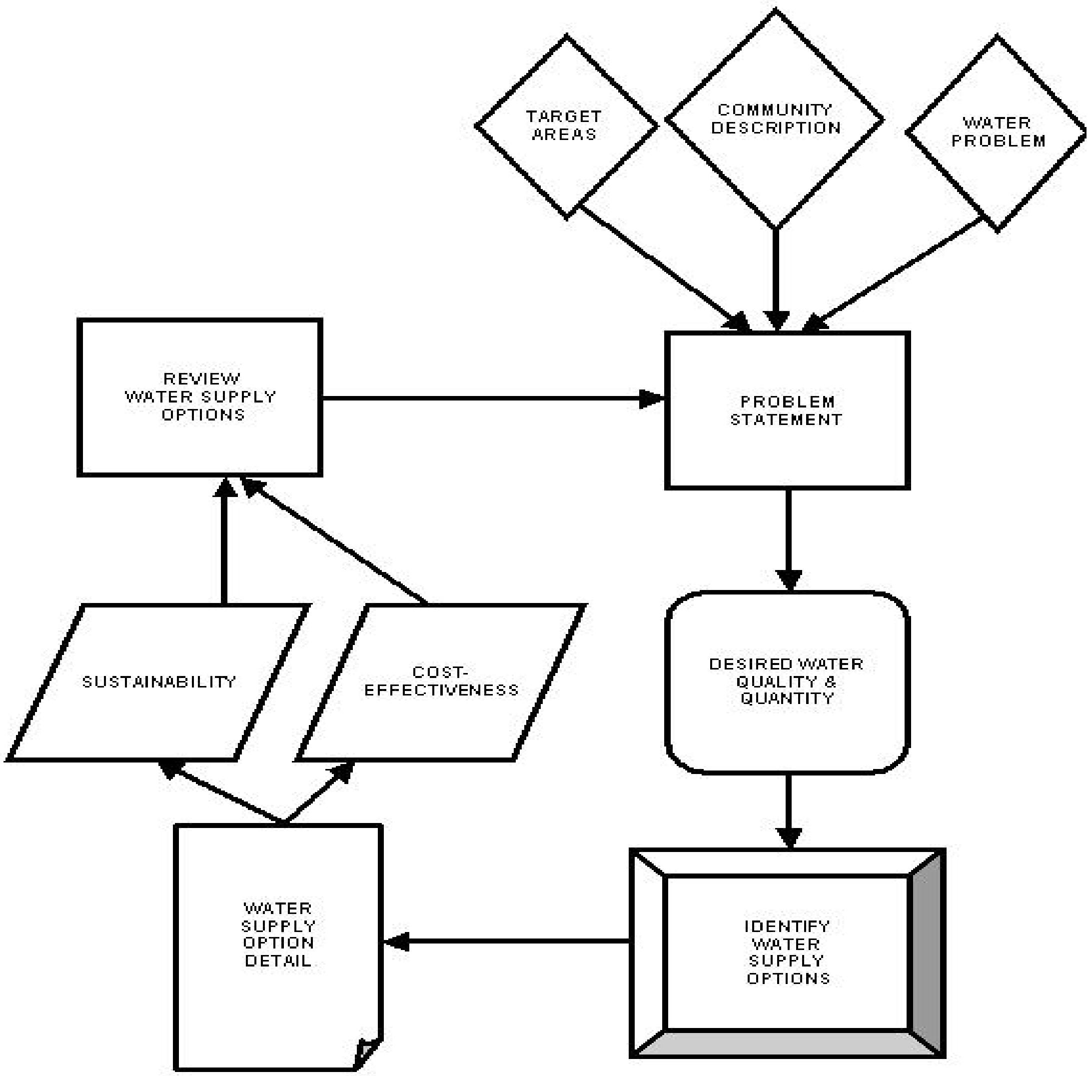
- Section 2A provides checklists for identifying potential water supply options for new household water projects according to the factors presented in figure 1.1;
- Section 2B can be used to find solutions to existing water quality problems in terms of possible treatment methods and / or alternative water supply options ;
- Section 2C can be used to identify possible solutions to water-demand problems i.e. where the existing household water supply is insufficient.
- Section 2D can be used to compare technical and socio-economical aspects of selected water supply options.

Section 3 provides more detail about the water supply options highlighted in the guidebook, and focuses on technical aspects important to potential users.

Section 4 is a report on the socio-economic study that was conducted in parallel to the technical investigation into relevant water supply options.

A glossary of terminology of this guidebook appears in Appendix A. The relevant South African legal framework is summarised in Appendix B. Important literature and internet references are given in Appendix C.

FIGURE 1.1: SCHEMATIC PRESENTATION OF THE GUIDEBOOK



B. *What is the purpose of this guidebook?*

This guidebook serves as a decision-making aid for water supply authorities and water service providers, community leaders and farming communities in defined target areas (Section 1 paragraph E) by providing relevant technical information that can enable such users to make informed choices regarding water supply systems that are appropriate to their specific circumstances and needs. The guidebook may also be useful to clinics, holiday lodges, camping sites and parks in the target areas.

C. *What information is required before making use of the guidebook?*

Information on a description of the target community, the quality and availability of existing water source(s), and knowledge of the capacity and types of nearby water supply schemes should be available to the guidebook user.

D. *Who are the potential users of this guidebook?*

This guidebook is aimed at water supply authorities and water service providers in charge of new household water supply projects, community leaders from community-based organisations and farming communities in the target areas (Section 1 paragraph E) where new household water supply projects are planned. The guidebook can also apply to clinics, schools and holiday resorts in such areas.

E. *In which target (geographical) areas in South Africa are these potential users located?*

The target areas for this guidebook can be defined in terms of rural geographical locations where community access to clean and fresh household water is problematic due to (i) too high salt content (incl. coastal communities) and / or (ii) too high fluoride content and / or (iii) too high nitrate content of the available water resource.

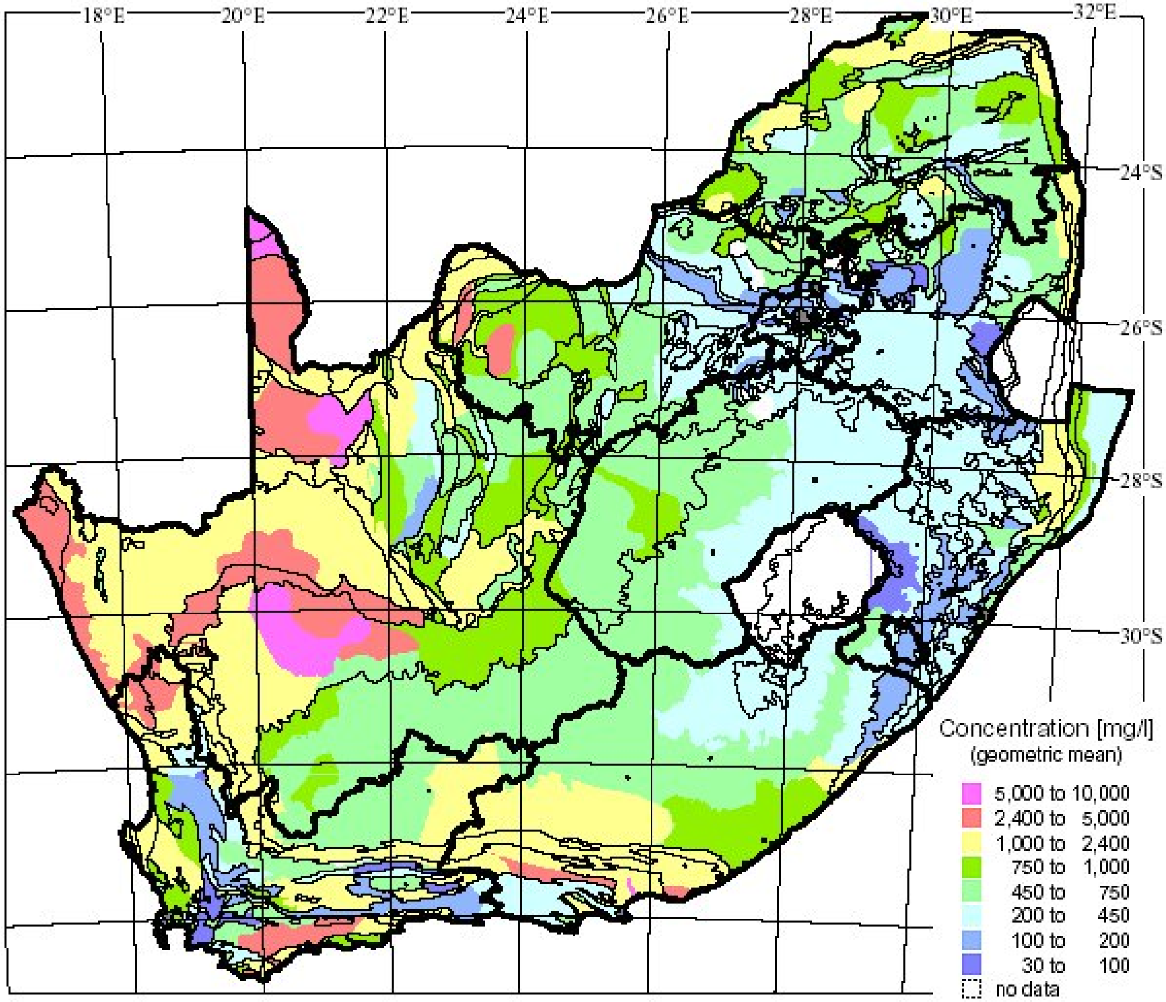
The guidelines for acceptable water quality in terms of total salinity (better known as total dissolves salts [TDS]), fluoride concentration [F^-] and nitrate concentration [NO_3^-] are best provided by the DWAF document "Quality of Domestic Water Supplies Assessment Guide (2nd ED, 1998)". According to these guidelines, analytically measurable limits are provided for each contaminant, expressed in milligrams per liter (mg/l) of contaminant dissolved in water. The following table summarises these limits for TDS, F^- and NO_3^- for different uses of household water.

TABLE 1.1: Household water quality guidelines

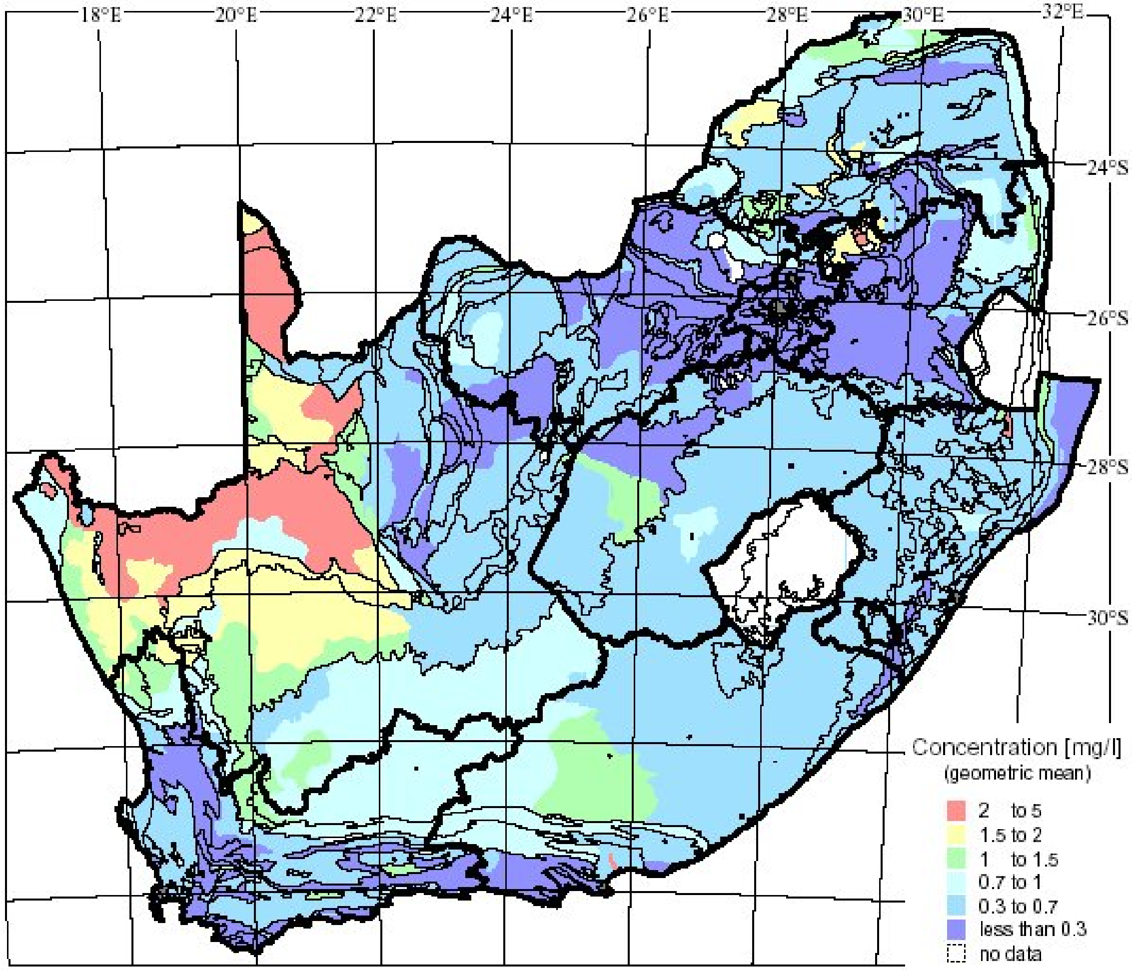
DISSOLVED ION mg/l		Drinking water	Food preparation	Bathing	Laundry
	TDS	< 1000	< 1000	< 3400	< 2400
	Fluoride	< 1,0	< 1,0	-	-
	Nitrate (as N)	< 10	< 10	< 20	-

The following maps from the WRC's Groundwater Atlas can be used to identify geographical areas where the guidebook may be applicable.

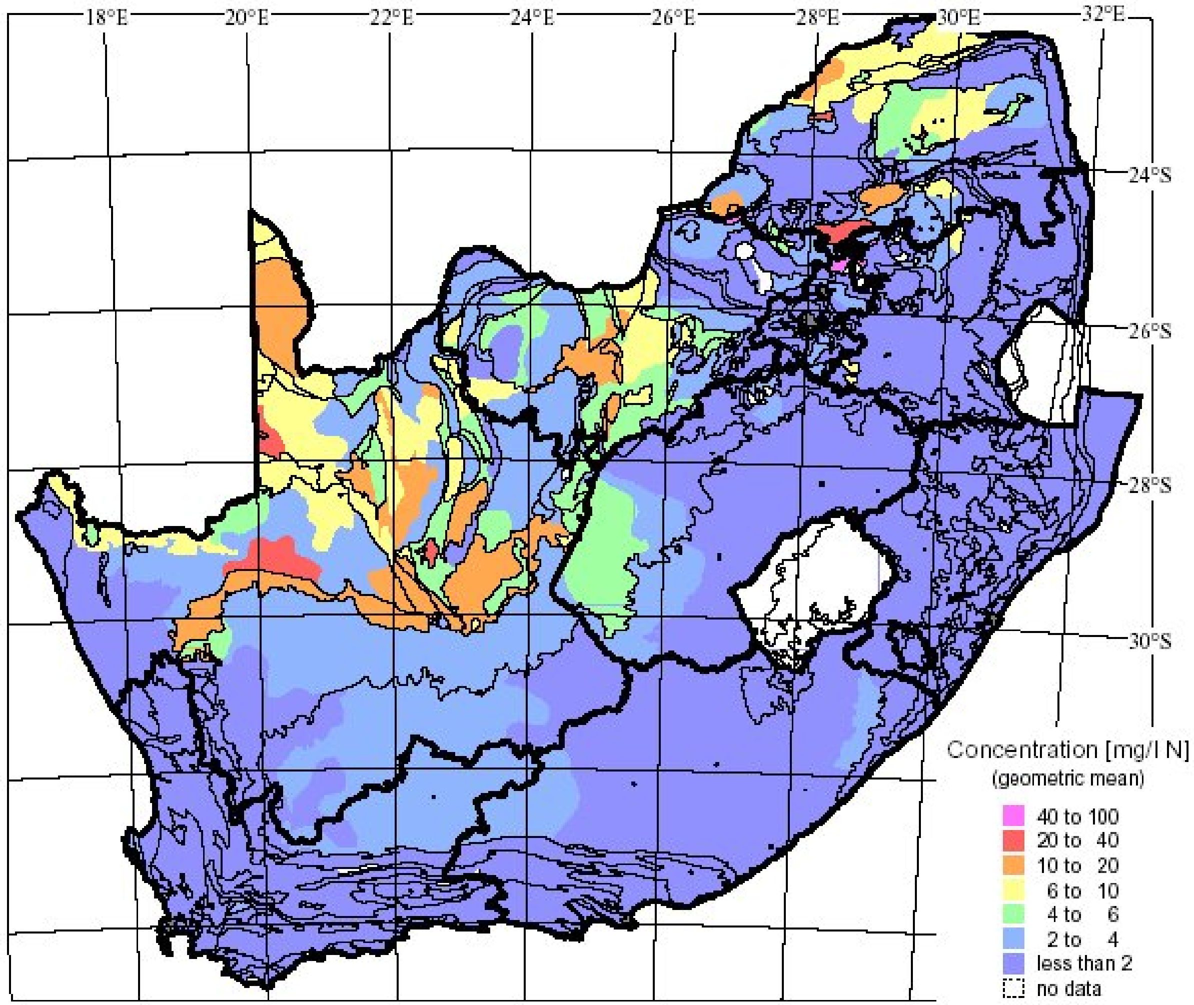
Map 1.1: TDS map of South Africa



<u>Map 1.2:</u> Fluoride map of South Africa:



Map 1.3: Nitrate map of South Africa:



F. *What is the scope of 'small-scale household water supply options' applicable to this guidebook?*

Small-scale household water supply options refer to water supply systems that can provide for the basic water supply to single households and small communities in the rural areas defined in par. C above. Desalination technologies as well as other water augmentation systems are included. Not all these systems can necessarily be regarded as small water systems. It is assumed that groundwater can be made available above ground; drilling for water is not included as a water supply option.

G. *Which types of water quality problems are addressed in this guidebook?*

This guidebook is aimed at addressing chemical water-quality problems, and specifically water with a too high dissolved solids content and/or fluoride and/or nitrate content. The acceptability limits of these contaminants are given in par. C.

- *Why is the TDS content of household water important?*

  Too high TDS may cause infants to experience a disturbance in their salt and water balance, heart patients may experience problems with high blood pressure, and individuals with renal disease may be at risk. Too high salt content also has a negative aesthetic effect on drinking water (bad taste).

- *Why is the fluoride concentration of household water important?*

  Fluorosis is the condition of mottling of the tooth enamel caused by excess fluoride exposure. It produces a chalky, cloudy, or opaque appearance of the tooth enamel. In severe fluorosis, the enamel becomes soft, crumbly, and darkly stained. Chronic intake of high fluoride levels may damage the skeleton, causing bones to become hard and brittle, which can lead to the breaking of skeletal bones.

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  The use of nitrate-contaminated drinking water to prepare infant formula is a well-known risk factor for infant methemoglobinemia (’blue baby’ syndrome). Affected infants develop a peculiar blue- grey skin colour and may become irritable or lethargic, depending on the severity of their condition. The condition can progress rapidly to cause coma and death if it is not recognised and treated appropriately. Excess nitrate can also cause tiredness and failure to thrive (chronic effects).

H. *What is the difference between a ‘Water quality problem’ and a ‘Water supply problem’ in the context of providing a basic water supply?*

A water quality problem refers to the unsuitability of a water source for household use due to chemical contamination. This does not imply that the water supply capacity is insufficient.

A water supply problem refers to the capacity of a water source to meet the household water demand. This means that the particular water source is not sustainable, although the water quality may be acceptable for household use (i.e. there is not ‘enough’ water). A daily minimum of 25 liters of household water per capita has been defined for the target communities (WRC Report 480/1/96).

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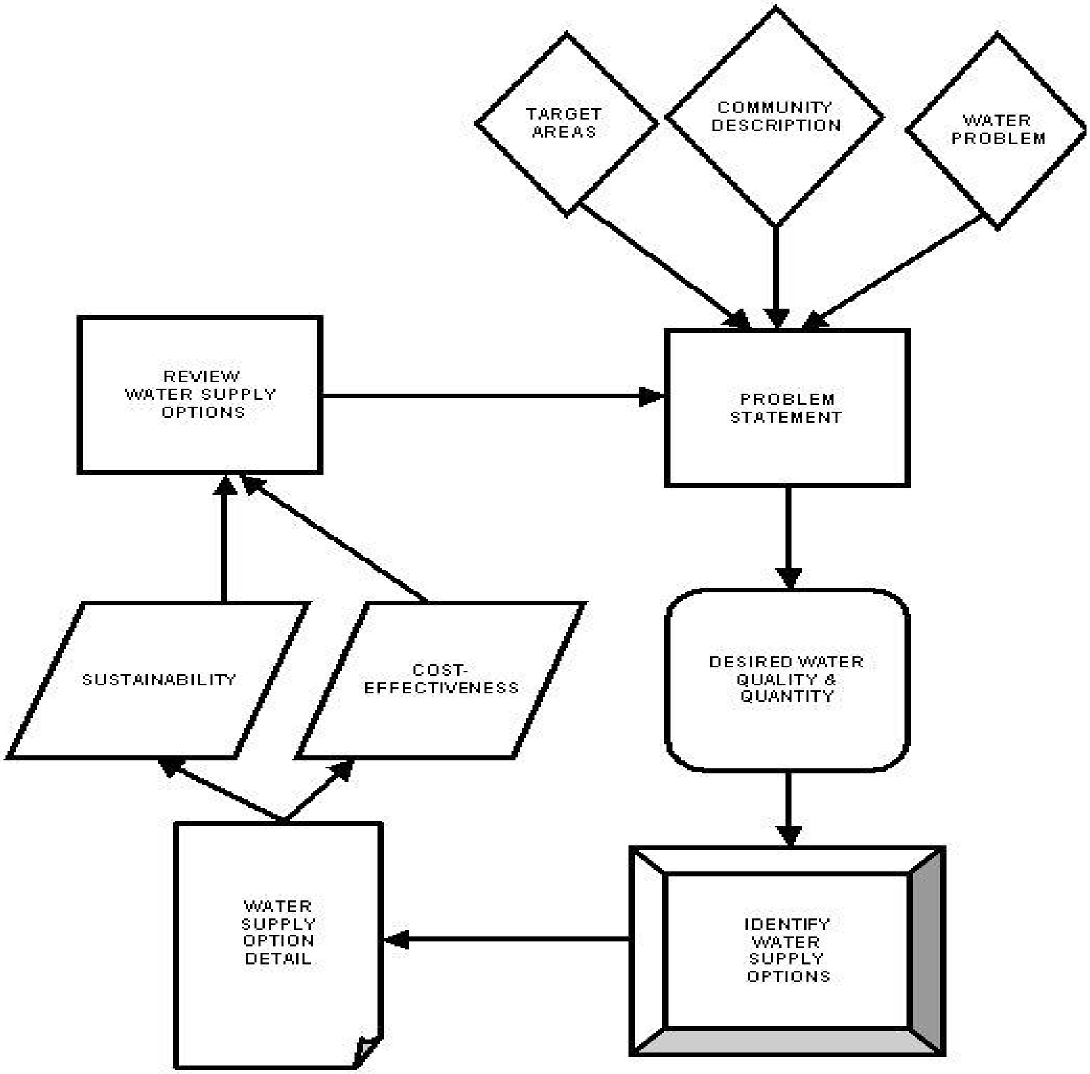

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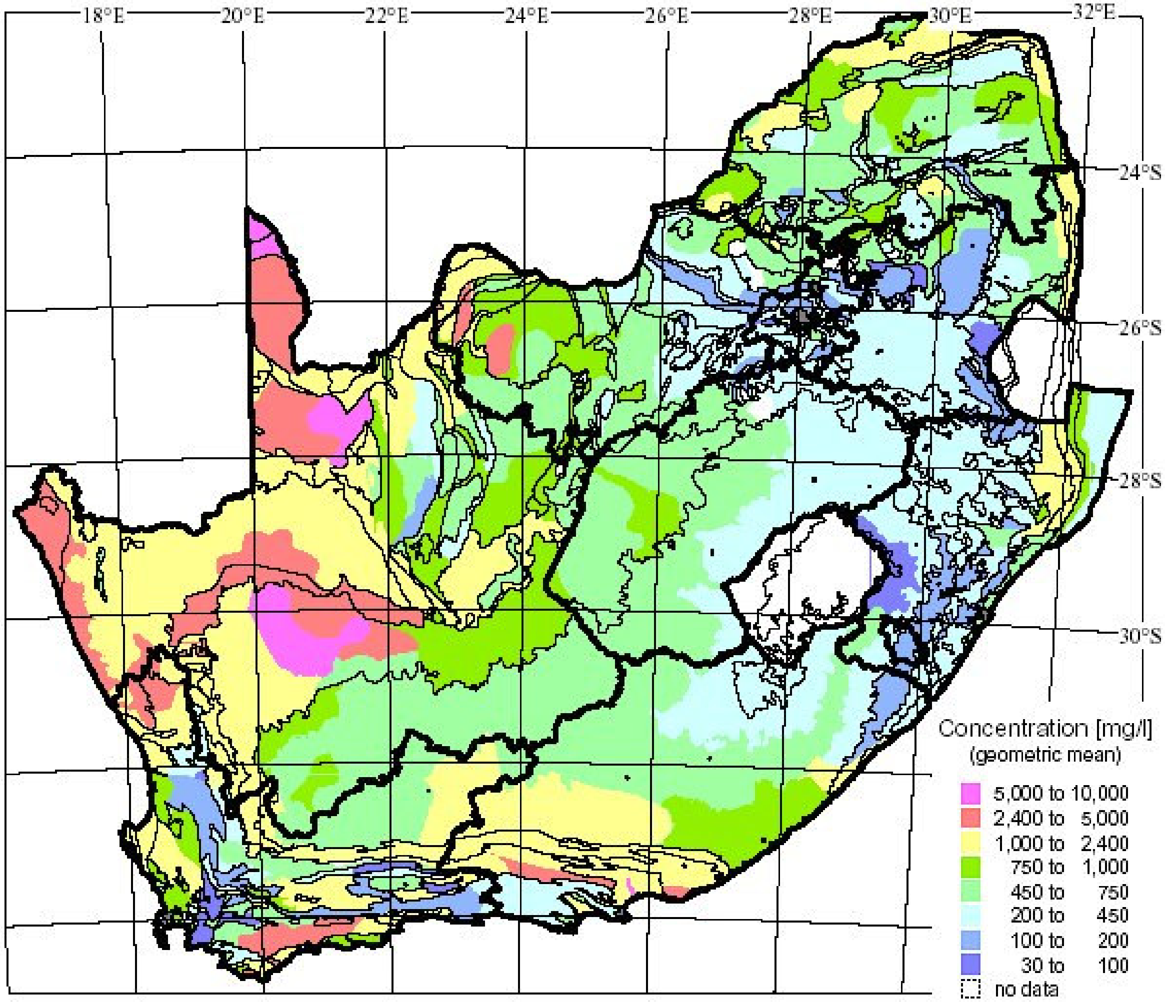

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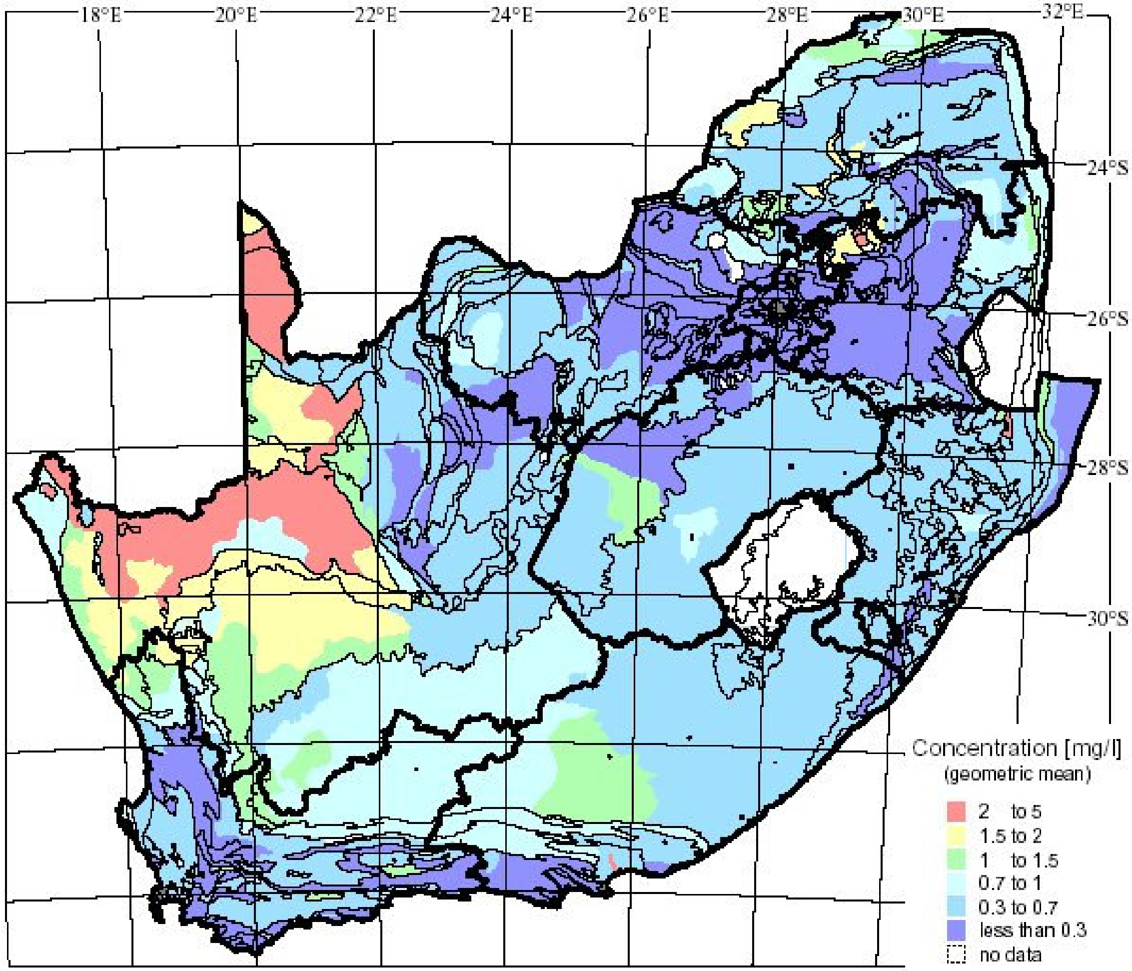

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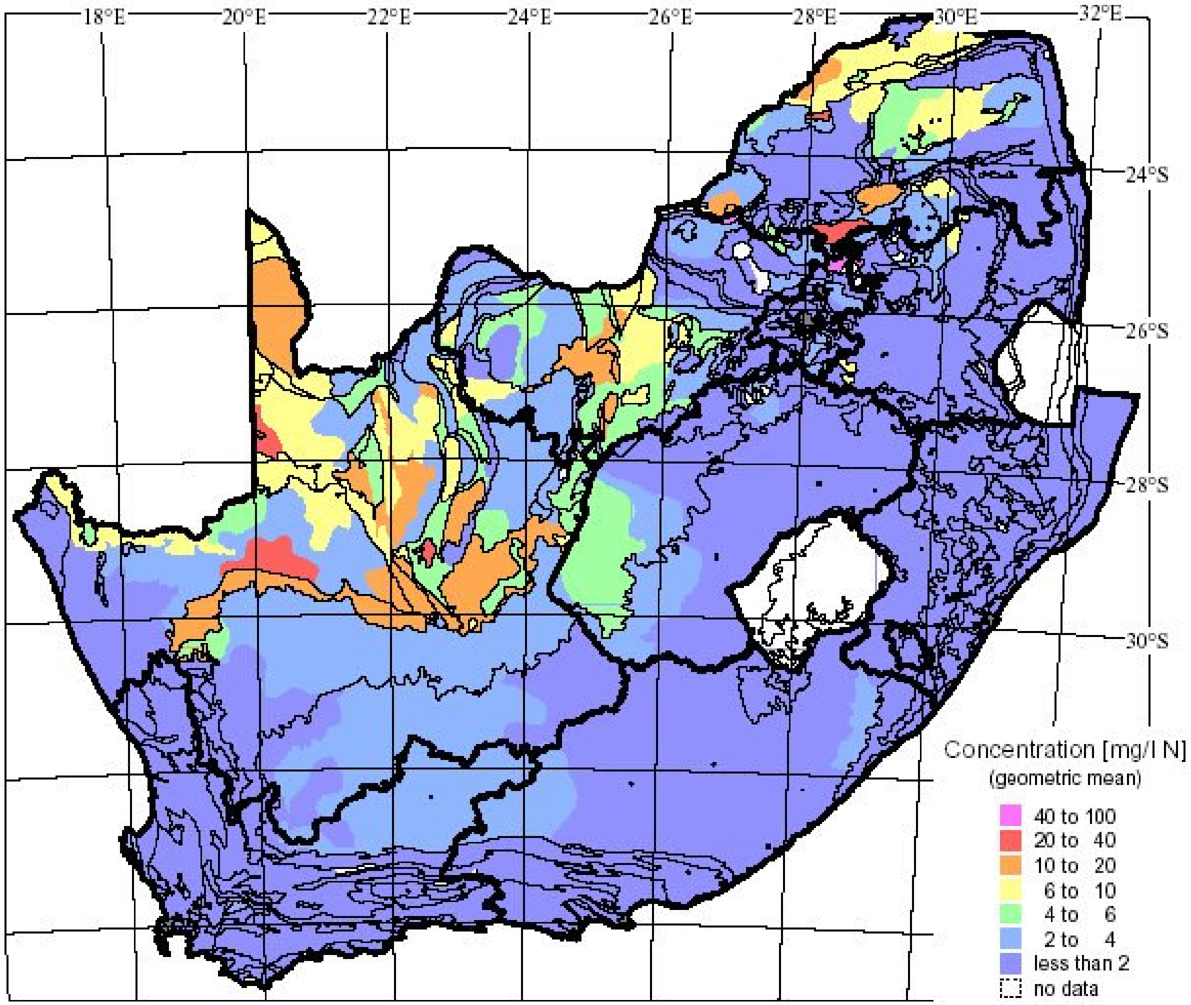

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I. *Where can explanations for the technical phrases used in this guidebook be found?*

Explanations for technical phrases are given in Appendix A.

J. *Is the list of water supply options complete?*

More water supply options than mentioned here, especially desalination technologies, do exist; they are either similar to those described in this guidebook or involve other technological processes. The water supply options provided in this guidebook are however representative of most of those currently in practical use worldwide. More information on these and other water supply options can be obtained by using the list of references given in Appendix C.

K. *How was the research study conducted?*

The content of this guidebook was developed over a two-year period through the integration of a number of inputs. These inputs were:

- Literature study: A comprehensive literature and Internet study, covering more than 200 articles and reports, was conducted to obtain background and supporting information relevant to the scope of the guidebook. The following subjects were researched (most relevant references are given in Appendix D):
  - *Groundwater quality*, with specific reference to TDS, fluoride and nitrate occurrence in South Africa;
  - Reports on *water supply options* for typical target areas, both internationally and locally;
  - *Technical detail* on water supply options; and
  - *Similar studies* carried out internationally

- Wide-ranging consultations: Meetings with authorities involved with rural water supply in typical target areas (West Coast / Northern Cape / Klein Karoo) were held to collect and discuss technical and socio-economic data on existing water supply methods. Two workshops were held at Peninsula Technikon at which more requirements from target users, such as District Municipalities, DWAF and other academic institutions, were identified. Personal meetings and electronic correspondence were also used to obtain and verify technical information.

- o <u>Questionnaires</u>: Visits to typical target communities along the West Coast, in the Northern Cape and in the Klein Karoo were carried out as part of the socio-economic study. A cross-sectional descriptive study was conducted with data collection according to an accidental non-probability sampling method. Questionnaires, based on inputs gathered from experts, were developed to cover socio-economic aspects such as demography, water quality, water source(s) and community involvement. Data was analysed using Statistical Package for Social Scientists (SSPS+). The complete report is presented in Section 4. Technical information on existing water supply options were collected in parallel to the above and processed at the University of Stellenbosch.

From the inputs above, a number of critical factors for inclusion in the guidebook were identified. These factors were then prioritised, and converted into selection criteria (= guidelines) for the identification of potential water supply options for given conditions.

L. *Which Acts and Regulations are applicable for providing the legislative framework for water supply projects such as identified in this guidebook?*

See Appendix B

M. *What are the recommendations in terms of ensuring future relevance of this guidebook?*

The contents of the guidebook need to be adapted to accommodate changes in water supply options, legislation and in the institutional environment. It is recommended that guidebook revision be done bi-annually under the chairmanship of the WRC. Possible additions to, or exclusions from the guidebook content can then be recommended to ensure its relevance.

It is further recommended that a condensed version of the guidebook be compiled and be made available to target water authorities in languages relevant to their areas of jurisdiction.

SECTION 2:

IDENTIFICATION OF WATER SUPPLY OPTIONS

SECTION 2A: CHECKLISTS FOR THE SELECTION OF APPROPRIATE NEW HOUSEHOLD WATER SUPPLY SYSTEMS

2A.1: USING THIS SECTION

This section aims to provide the guidebook user with checklists that can be used to:

(1) assist them in the definition of a particular water supply problem, and
(2) identify sustainable solutions that can be used to resolve the identified water supply problem.

Checklist 1 can be used to confirm that the water supply problem is within the scope of this guidebook.

A number of water supply options can now be identified by completing either checklist 2 or 3. Checklist 2 should be completed if a sustainable saline water source (brackish groundwater or seawater) is available at or near the location of the water supply problem. Checklist 3 should be completed if the existing groundwater source is not sustainable or if no water source exists.

Checklist 4 addresses aspects of community household water supply that may further influence the choice of water supply options, and should be completed with the available information from checklist 3 or 4.

Checklist 5 addresses the sustainability of a particular water supply option. It should therefore be completed only after the water supply options have been identified and it should be done for *each* of the identified options.

The checklists are presented in a series of tables, with cross-references to Section 2B [‘Water Quality Improvement’], Section 2C [‘Household Water Demand‘] and Section 2D [‘Summary of Water Supply Options’].

More information about the water supply options summarised in Section 2D, are provided in Section 3.

An example of how different water supply options can be compared once the checklists have been completed, is given in par. 2A.2.

CHECKLIST 1: PROJECT SCOPE

Does the proposed water supply project fall within the target areas of this guidebook? (Refer to maps in Section 1)
What is the target community size and its predicted growth rate over the next ten years?
Is an existing water source available at the proposed project site (irrespective of the water quality)?

CHECKLIST 2: WHERE AN EXISTING WATER SOURCE IS AVAILABLE

Is an analysis of the water source according to SABS 241 / DWAF guidelines available?
Is the sustainability of the existing water source known or can it be forecast?
Is the existing water source sustainable?
Is land available for construction of a water treatment facility (incl. brine disposal infrastructure)
Are the locations, numbers and sizes of households known?
Can the existing water source meet the expected present and predicted future water demand?
Is the quality of the water source acceptable in terms of TDS and fluoride concentration and nitrate concentration?
Using Sections 2B and 2D, list potential water supply options.

CHECKLIST 3: WHERE AN EXISTING WATER SOURCE DOES NOT EXIST OR THE EXISTING WATER SOURCE IS NOT SUSTAINABLE

Are household water supply schemes available to surrounding communities (towns, farms)?
Does the supply capacity exist to share the water resources of surrounding communities (i.e. to increase supply volumes to include the proposed new project)?
Can reticulated water supply from surrounding water schemes to the proposed new project site be considered?
Is the quality and distances of access routes between the proposed new project site and surrounding water schemes acceptable, so that road transport of household water can be considered?
Is specific meteorological data available for the proposed new project site? (Historical rainfall figures, solar radiation profiles, recurring fog and wind patterns)
Is the average rainfall sufficient to consider it as a sustainable source of household water?
Is electricity available, OR are the year-round solar radiation levels high enough to be able to use solar powered technologies?
Is the community situated in an area suitable for the use of fog harvesting technology?
Using Section 2C and 2D, list potential water supply options.

CHECKLIST 4: COMMUNITY INVOLVEMENT

Can identified community members be trained in ***basic*** O & M responsibilities pertaining to the proposed water supply system?
Can community members be trained to take up ***advanced*** O & M responsibilities pertaining to the proposed water supply system?
Is the community aware of water-related health problems and the importance of good hygiene practice?
Has the community been made aware of the scope and benefits of a new water supply project (e.g. planned per capita supply capacity / planned water quality / description of potential supply systems)?
Can community input on the proposed project be obtained? (Can they be actively involved in the decision making process?)
Has the WSA or WSP the technical and financial capacity to provide the resources to take up those O & M responsibilities that cannot be provided by the community itself?
Can the WSA or WSP take responsibility for ensuring that acceptable hygienic practises be implemented in the community (either by itself or through outsourcing)?

CHECKLIST 5: SUSTAINABILITY

Sustainability refers to the ability of a water supply option to deliver an appropriate level of benefits, and it is evaluated in this checklist (to be carried out for each water supply option).

Can the water supply option deliver the required quantity and quality of water?
Can the water supply option be operated in a convenient manner by the community / WSA?
Can the expected institutionalised levels of service be achieved through the use of this water supply option?
Will continuity in water supply be guaranteed through the use of this water supply option?
Can water be supplied cost-effectively by using this water supply option?
Is information available that shows that the water supply option can be operated efficiently?
Is information available that indicates that the water supply option can be operated reliably?
Can the water supply option be operated in such a manner that water supply will be distributed fairly and equitably?
Can the proposed system be operated so that it poses neither health nor significant environmental threat to the community?
Is the equipment life cycle known i.e. can replacement of components be scheduled?
Does feasible external technical support exist for the supply equipment / process?
Revise suitability as a potential water supply option

2A.2: RATING OF WATER SUPPLY OPTIONS

The following process can be used to prioritise water supply options if more than one water supply options seems appropriate for a new water provision project.

STEP 1: Prioritise the relevance of the following aspects of the proposed new water supply project in terms of critical and non-critical factors (see Section 2D for definitions of the decision factors):

- Technical sophistication
- Scope of use
- Product-water quality
- Supply capacity
- Energy requirements
- Operation and maintenance requirements
- Cost effectiveness
- Socio-economic considerations
- Suitability to local conditions
- Future prospects

STEP 2: List the identified water supply options (from checklist 5)

STEP 3: Use Section 3 to eliminate potential water supply options failing in critical aspects identified in step 1.

STEP 4: List the remaining potential water supply options

RATING OF WATER SUPPLY OPTIONS: *AN EXAMPLE*

An informal community of 50 households (about 300 people) needs to be supplied with fresh and clean household water. Unlimited access to brackish groundwater (TDS ≈ 5000 mg/l) exists. The following water supply options have been identified using section 2B (green and yellow options), namely electrodialysis (ED), reverse osmosis (RO), solar distillation, rainwater collection and reticulation.

It is important that the community be able to manage their own water supply in all respects i.e. only limited assistance from the relevant local authority can be expected. Winter rainfall patterns exist, and summers are characterised by long dry spells. Electricity is available.

*The following were identified as critical success factors: **supply capacity** (should be adequate); **O & M requirements** (must be performed by the community), Socio-economic considerations (community must be able to manage the water supply with minimum external support) and **suitability to local conditions** (seasonal and feed water capacity factors).* "X" *on the form below indicates non-conformity.*

Critical? (Y/N)	Criteria	ED	RO	Solar Dist.	Rain Collection	Reticu-lation
	Technical sophistication					
	Scope of use					
	Product water quality					
Y	Supply capacity			X		
	Energy requirements					
Y	Operation & maintenance requirements					
	Product-water costs					
Y	Socio-economic considerations					
Y	Suitability to local conditions				X	
	Future prospects					
	Result:			*N/a*	*N/a*	

The following options are identified from the above, namely ED, RO and reticulation.

2A.3: CONCLUSION

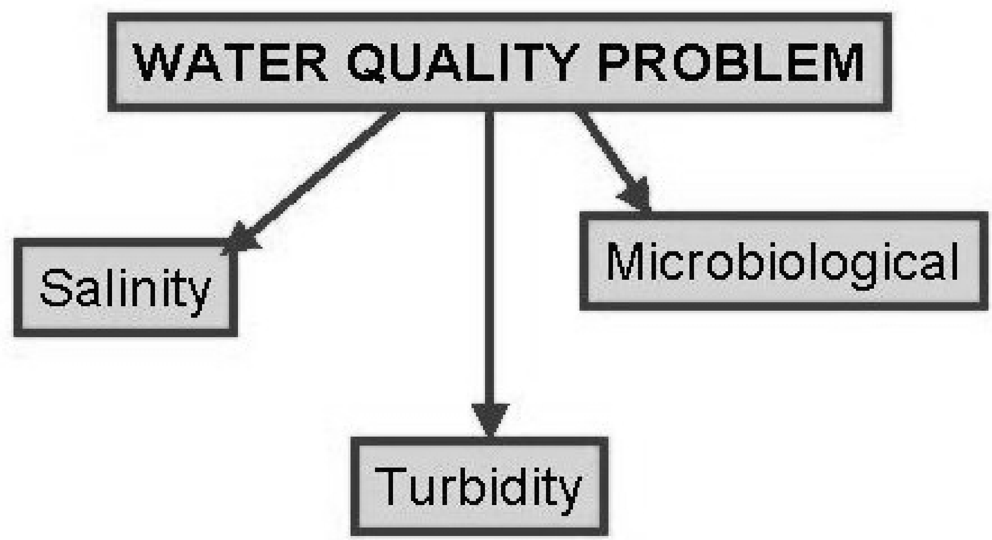
One or more water supply options may now have been identified and prioritised. A formal project can now be undertaken, during which many of the aspects addressed in this guidebook will be revisited in much greater detail.

Note: In the final choice of a water supply option, a trade-off will have to be made between effectiveness, affordability, lifecycle costs, consumer acceptability and environmental impact. Potential end-users should be informed of the available technical choices and related financial implications. Water and sanitation technologies are often be considered together. Technology choices should always be made in the context of an integrated planning process involving community participation.

SECTION 2B:
WATER QUALITY IMPROVEMENT

2B.1: WATER QUALITY

The term "WATER QUALITY" is used to describe the microbiological, physical (or turbidity) and chemical (or salinity) properties of water that determine its fitness for use. A "WATER QUALITY PROBLEM" (abbr: **WQP**) refers to one or more of these properties that make the water unsuitable for a particular application, in this case household use.



This section of the guidebook addresses **WQPs** in terms of possible treatment methods and / or alternative water supply options that can lead to the improvement of water quality to acceptable household standards. Options are presented according to the following colour scheme:

GREEN	Appropriate in most cases
YELLOW	Appropriate under certain circumstances
RED	Inappropriate

2B.2: USING THIS SECTION

First, the specific ***WQP*** (or combination of problems) must be known. In the context of this guidebook, the description and extent of the ***WQP*** can be obtained through analysis of the groundwater source.

Once the ***WQP*** is known, it is necessary to obtain the community description that best describes the potential beneficiaries of a water quality improvement project. Five community (or end-user) categories are defined:

Single, unassociated and scattered households (Basic water supply)
Single farm plus farm workers
A number of adjacent farms with farm workers
Informal settlement < 500 people (Basic water supply)
Formal community settlement > 500 people

If a combination of ***WQPs*** exists, it is advisable to first address the options regarding chemical water quality improvement, then microbiological water quality improvement, and lastly physical water quality improvement. When using this methodology, the water supply options that are rated **green** are preferential and should be first to be investigated further.

The following table summarises general water treatment options for the different ***WQPs***:

Table 2.1: WATER TREATMENT CATEGORIES

		Desalination	Filtration	Disinfection
TYPE OF *WQP*	Chemical	X		
	Physical		X	
	Microbiological		X	X

The following are general definitions given to the above concepts:

Desalination refers to water treatment processes that remove salts from water (also called desalting). High salt concentrations make water unpalatable and cause illness.

Filtration refers to the removal of physical particles from water. The physical quality of water affects the taste, odour and appearance thereof.

Disinfection refers to the removal of organisms such as protozoa, viruses and parasites from water. Many of these organisms are associated with waterborne diseases.

2B.3: *WQP* SALINITY

In the context of this guidebook, too high salinity refers to too high concentrations in water of: dissolved salts (ionic compounds) and / or fluoride and / or nitrate. The following table shows acceptable salinity limits [A] for different types of household water use:

Table 2.2: SALINITY LIMITS FOR HOUSEHOLD WATER

		Drinking water	Food preparation	Bathing	Laundry
DISSOLVED ION mg/l	TDS	< 1000	< 1000	< 3400	< 2400
	Fluoride	< 1,0	< 1,0	-	-
	Nitrate (as NO_3^-)	< 44	< 44	< 177	-

Salinity can be removed or reduced by a number of desalination techniques. If desalination is not cost-effective and affordable, then fresh and clean water must be provided by other means.

[A] : From *QUALITY OF DOMESTIC WATER SUPPLIES, Volume 1: Assessment Guide (2nd Edition), Department of Water Affairs and Forestry, 1998*

2B.4: TDS CONCENTRATION TOO HIGH

The following table shows appropriate options for a fresh and clean water supply to the different community types in areas where the existing water source has too high a TDS content:

TABLE 2.3: WATER SUPPLY OPTIONS FOR HIGH TDS

		WATER SUPPLY OPTIONS: TDS TOO HIGH								
		ON-SITE AUGMENTATION							CONVEY-ANCE	
		DESALINATION								
		ED	RO / NF	Solar distillation	Distillation	Fog harvesting	Rainwater harvesting	Run-off collection	Reticulation	Trucking
COMMUNITY DESCRIPTION	Single, unassociated and scattered households	red	red	green	red	green	green	red	green	yellow
	Single farm plus farm workers	red	red	green	red	green	green	red	green	yellow
	A number of adjacent farms with farm workers	red	red	green	red	green	green	yellow	green	yellow
	Informal settlement < 500 people	yellow	green	yellow	red	yellow	green	yellow	green	red
	Formal community settlement > 500 people	green	green	red	yellow	red	yellow	green	green	red

2B.5: FLUORIDE CONCENTRATION TOO HIGH

The following table shows appropriate options for fresh and clean water supply for different community types in areas where the existing water source has too high a fluoride content.

TABLE 2.4: WATER SUPPLY OPTIONS FOR HIGH FLUORIDE

	WATER SUPPLY OPTIONS: *FLUORIDE TOO HIGH*										
	ON-SITE AUGMENTATION									CONVEY-ANCE	
	DEFLUORIDATION										
COMMUNITY DESCRIPTION	ED	RO	Ion Exchange	Solar distillation	Adsorption	Flocculation	Fog harvesting	Rainwater harvesting	Run-off collection	Reticulation	Trucking
Single, unassociated and scattered households	Red	Red	Red	Green	Green	Green	Green	Green	Red	Green	Yellow
Single farm plus farm workers	Red	Red	Red	Green	Green	Green	Green	Green	Red	Green	Yellow
A number of adjacent farms with farm workers	Red	Red	Red	Green	Green	Green	Green	Green	Red	Green	Yellow
Informal settlement < 500 people	Yellow	Green	Green	Yellow	Green	Green	Red	Green	Yellow	Green	Red
Formal community settlement > 500 people	Green	Green	Green	Red	Yellow	Yellow	Red	Yellow	Green	Green	Red

2B.6: NITRATE CONCENTRATION TOO HIGH

The following table shows appropriate options for fresh and clean water supply for different community types in areas where the existing water source has too high a nitrate content.

TABLE 2.5: WATER SUPPLY OPTIONS FOR HIGH NITRATE

	WATER SUPPLY OPTIONS: [NO_3^-] TOO HIGH									
	ON-SITE AUGMENTATION								CONVEY-ANCE	
	DESALI-NATION			DENITRI-FICATION						
COMMUNITY DESCRIPTION	ED	RO	Solar distillation	Bacteriological degradation	Ion Exchange	Fog harvesting	Rainwater harvesting	Run-off collection	Reticulation	Trucking
Single, unassociated and scattered households	red	red	green	red	red	green	green	red	green	yellow
Single farm plus farm workers	red	red	green	red	red	green	green	red	green	yellow
A number of adjacent farms with farm workers	red	red	green	red	yellow	green	green	red	green	yellow
Informal settlement < 500 people	yellow	green	yellow	yellow	green	red	yellow	yellow	green	red
Formal community settlement > 500 people	green	green	red	green	green	red	red	green	green	red

2B.7: MICROBIOLOGICAL CONTAMINATION

Table 2.6 shows options for fresh and clean water supply in areas where the existing water source may be contaminated with microbes.

TABLE 2.6: WATER SUPPLY OPTIONS FOR DISINFECTION

IMPORTANT NOTE: *Treatment options listed under 'CONDITIONAL' must be evaluated carefully, as they apply to specific applications and (a) do not imply full disinfection [UF, slow sand filtration] or (b) have no residual disinfection power [ultraviolet, ozone].*

		WATER SUPPLY OPTIONS: DISINFECTION TREATMENT OPTIONS								
		TOTAL					CONDITIONAL			
		Chlorine dosage	Dissolved hypochlorite	Other (mixed) oxidants	On-site generation of chlorine	On-site generation of other oxidants	UF / RO	Ultraviolet (solar)	Slow sand filtration	Ozone treatment
COMMUNITY DESCRIPTION	Single, unassociated and scattered households	Red	Yellow	Yellow	Red	Red	Red	Green	Green	Red
	Single farm plus farm workers	Yellow	Green	Yellow	Yellow	Yellow	Red	Green	Green	Yellow
	A number of adjacent farms with farm workers	Yellow	Green	Yellow	Yellow	Yellow	Red	Green	Green	Yellow
	Informal settlement < 500 people	Red	Yellow	Yellow	Red	Red	Red	Green	Green	Red
	Formal community settlement > 500 people	Green	Green	Green	Green	Green	Green	Yellow	Yellow	Yellow

IMPORTANT NOTE REGARDING HYGIENIC PRACTICES: Water contamination can easily occur where hygiene practices are neglected or ignored. Diseases associated with water contamination include trachoma, cholera, malaria and Schistosomiasis. Regular disinfection of drinking water and containers can lead to a reduction in the incidences of these diseases. It thus becomes necessary to educate and raise awareness about hygienic water practices, as the link between such practices, hygiene and health cannot be over-emphasized.

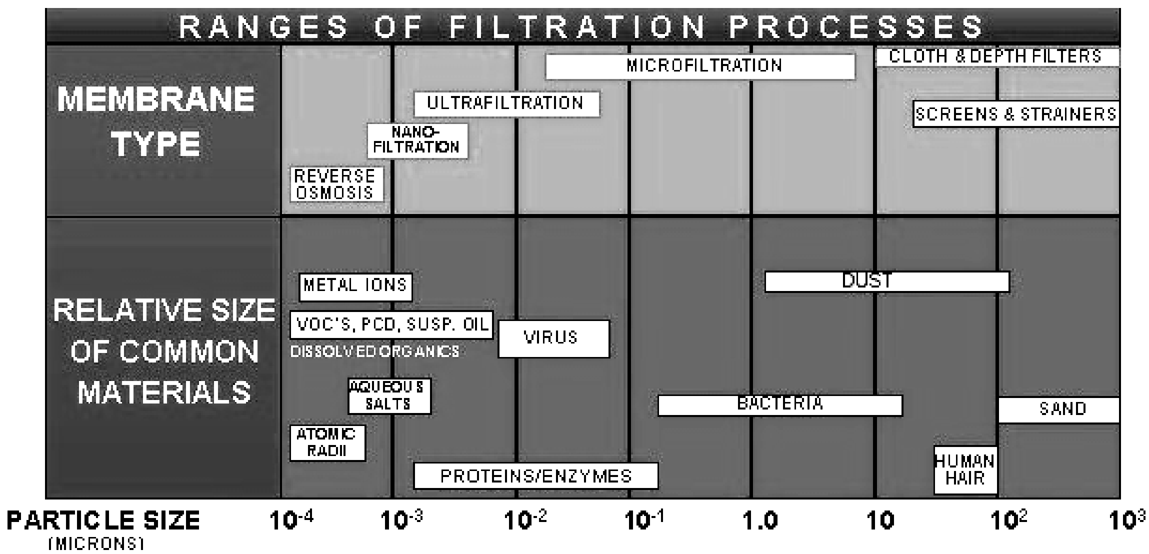
It is therefore also important to educate and make communities aware that, even in areas where the provision of clean accessible water and ideal sanitation facilities are not within community reach, households can still adopt hygiene behaviours, which can lead to better health.

2B.8: PHYSICAL WATER POLLUTANTS

The following table summarises filtration options for fresh and clean water supply for communities in areas where the existing water source is polluted with physical particles.

TABLE 2.7: WATER SUPPLY OPTIONS FOR REMOVAL OF SUSPENDED PARTICLES

(taken from **www.hydrotechnology.com/ newtext/filterspec.htm**)



(Also included in the above table is Reverse Osmosis (RO), which is a desalination process)

SECTION 2C:

HOUSEHOLD WATER DEMAND

2C.1: WATER DEMAND

The term "WATER DEMAND" in this guide is used to describe the basic daily household water requirement per person, excluding water used for sanitation, gardening and agriculture. "WATER DEMAND PROBLEM" (abbr: ***WDP***) refers to the situation where the actual daily water demand, conforming to the required quality, exceeds (or will exceed) the existing water resource capacity (or predicted future capacity). Water demand is expressed in kiloliters per day (kl/d).

The following figure below illustrates use of the term ***WDPs*** in this guidebook:

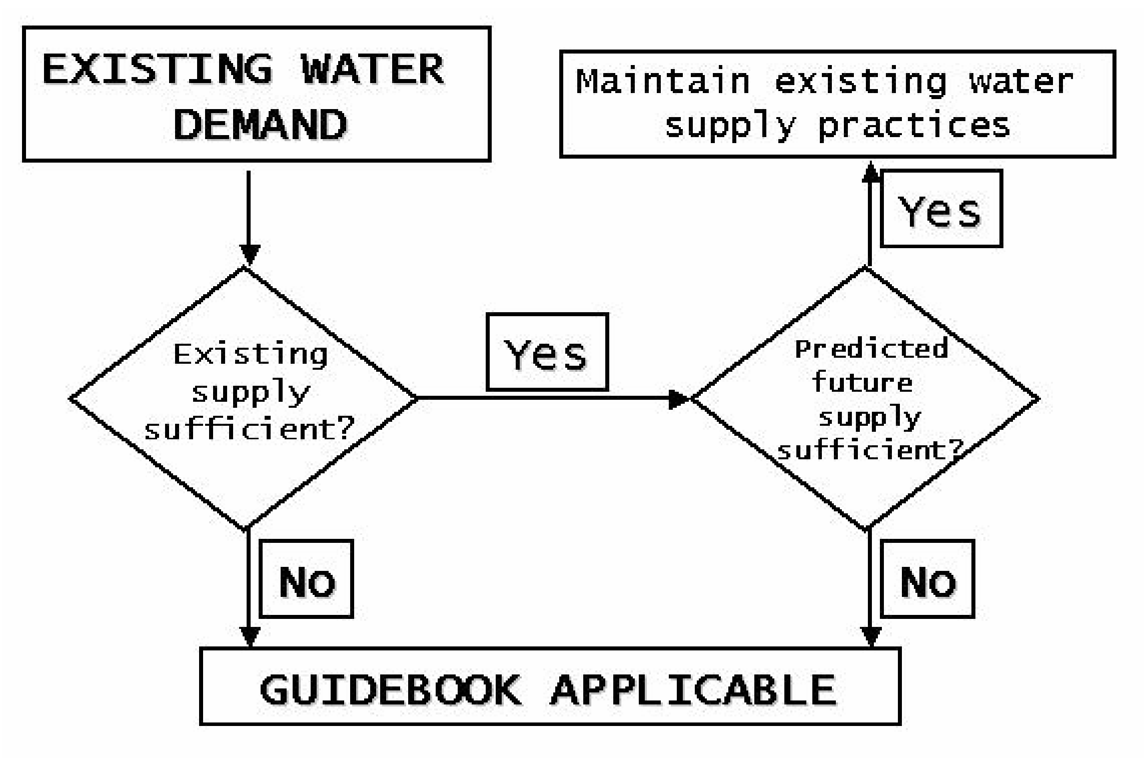


FIGURE 2.A: WATER DEMAND IN THE CONTEXT OF THE GUIDEBOOK

2C.2: USING THIS SECTION

The ***WDP*** must be quantified, either through consultation or through an estimate from the minimum requirements as set out in the previous section. (Example: the *minimum* daily water demand can be calculated by multiplying the number of people by 25). Once the *total* water demand has been determined, it is possible to quantify the ***WDP*** in terms of one of the following categories [A]:

< 0,5 kl per day, only for drinking and cooking purposes (dual water supply potential exists)
< 5 kl per day, for all household purposes (less than 200 people)
> 5 kl per day, for all household purposes (more than 200 people)

Appropriate water supply options can now be identified from the above and presented in terms of relevance according to the following colour scheme:

GREEN	**Appropriate in most cases**
YELLOW	**Appropriate under very specific conditions**
RED	**Inappropriate**

In some cases the water quality may not be suitable for drinking and cooking purposes, although it may be acceptable for washing and/or bathing. As the amount of water required for drinking and cooking has been estimated to be less than 5 liters per capita per day, it is also necessary to identify the potential for such dual water supply systems.

Table 2.8 compares different water supply options in terms of water demand.

[A] : It is important to note that the recommended water supply options are presented with the assumption that a ***WDP*** exists in an area where only the salinity of existing water sources is problematic. Water treatment options for improving turbidity and microbiological content are not discussed but may be necessary (see Section 2B)

	SALINE WATER SOURCE AVAILABLE															NO WATER SOURCE AVAILABLE				
	DESALINATION (TDS REDUCTION)				DEFLUORIDATION						DENITRIFICATION					ON-SITE AUGMENTATION			CONVEY-ANCE	
TOTAL DAILY DEMAND	Electrodialysis (ED)	Reverse Osmosis (RO) Nanofiltration (NF)	Solar Distillation	Distillation	Electrodialysis (ED)	Reverse Osmosis (RO)	Ion Exchange (IX)	Solar distillation	Adsorption	Flocculation	Electrodialysis (ED)	Reverse Osmosis (RO)	Solar distillation	Bacteriological Degradation	Ion Exchange (IX)	Fog Harvesting	Rainwater Harvesting	Run-off Collection	Reticulation	Trucking
Total demand <0,5 kl per day	Red	Green	Green	Red	Red	Green	Green	Green	Green	Green	Red	Green	Green	Yellow	Green	Green	Green	Yellow	Green	Green
Total demand < 5 kl per day	Yellow	Green	Yellow	Red	Yellow	Green	Green	Yellow	Green	Green	Yellow	Green	Yellow	Green	Green	Yellow	Yellow	Green	Green	Red
Total demand >5 kl per day	Green	Green	Red	Yellow	Green	Green	Green	Red	Green	Green	Green	Green	Red	Green	Green	Red	Yellow	Yellow	Green	Red

Table 2.8: Water supply options in terms of water demand

SECTION 2D:
SUMMARY OF
WATER SUPPLY OPTIONS

2D.1: WATER SUPPLY OPTIONS

The term "WATER SUPPLY OPTIONS" in this section refers to small-scale water treatment and supply techniques and technologies that may be used for household water provision in areas with saline water sources. The focus of this section is therefore to provide summarised and comparative information on either total salt removal (through desalination, defluoridation, denitrification) or provision of fresh and clean water through other means. (Detailed information on these processes is provided in the Water Supply Options Database, Section 3). Other treatment methods (such as disinfection or filtration) may be required in addition to the above but this falls beyond the scope of this guidebook (Section 2B).

The following water supply options, as categorised in Section 2C, are discussed in this section:

TABLE 2.9: WATER SUPPLY OPTIONS FOR TARGET AREAS

SALINE WATER SOURCE AVAILABLE															NO WATER SOURCE AVAILABLE				
DESALINATION (TDS REDUCTION)				DEFLUORIDATION						DENITRIFICATION					ON-SITE AUGMENTATION			CONVEY-ANCE	
Electrodialysis (ED)	Reverse Osmosis (RO) Nanofiltration (NF)	Solar Distillation	Distillation	Electrodialysis (ED)	Reverse Osmosis (RO)	Ion Exchange (IX)	Solar distillation	Adsorption	Flocculation	Electrodialysis (ED)	Reverse Osmosis (RO)	Solar distillation	Bacteriological Degradation	Ion Exchange (IX)	Fog Harvesting	Rainwater Harvesting	Run-off Collection	Reticulation	Trucking

2D.2: USING THIS SECTION

The following aspects of the different household water supply options are compared in this section:

- Process sophistication
- Requirement for additional infrastructure
- Scope of use
- Water quality and quantity
- Energy requirements
- Operation and maintenance
- Product water cost
- Socio-economic considerations
- Effectiveness and suitability
- Future prospects

Colour schemes serve as 'at a glance' guide within the context of this guidebook.

2D.3: PROCESS SOPHISTICATION

Process sophistication refers to the degree of technical complexity of the water supply option. This spectrum can range from least sophisticated and generally well understood (e.g. rainwater collection) to highly sophisticated and operated by specialist personnel (e.g. complex water desalination plants).

GREEN	Limited technology involved
YELLOW	Unsophisticated technology
RED	Highly sophisticated technology

2D.4: REQUIREMENT FOR ADDITIONAL INFRASTRUCTURE

Many household water supply systems require additional infrastructure to ensure supply to the end-user(s). Such infrastructure can include piping, filters, pre- and post-treatment, community drinking water tanks, etc.

GREEN	No additional infrastructure requirements
YELLOW	Additional infrastructure requirements may exist – specialist input required
RED	Additional infrastructure always exists – engineering input required

2D.5: SCOPE OF USE

Scope of use refers to extent to which the specific water supply system is used nationally.

GREEN	Well-known and widely used, mature technology
YELLOW	Limited application, pilot phase
RED	Not in use for rural drinking water provision

2D.6: WATER QUALITY AND QUANTITY

Water quality and quantity refers to the capacity of the supply option to continuously supply the required volume of fresh and clean household water conforming to regulatory standards to the end-users. Proper operation and maintenance of the supply option is assumed.

GREEN	Supply option is extremely reliable under normal conditions - no specific control mechanisms necessary
YELLOW	Supply option is reasonably reliable provided that control mechanisms have been implemented
RED	Supply option is generally unreliable and should only be considered as an emergency / temporary option

2D.7: ENERGY REQUIREMENTS

Energy requirements refer to the dependency of the supply option on reliable and constant power supply.

GREEN	None, except 'muscle power'
YELLOW	Infrastructure requires an energy source to function, may include renewable energy sources
RED	Process requires a constant electricity supply to operate

2D.8: OPERATION AND MAINTENANCE

Operation and maintenance (O&M) refers to the need, frequency and level of external intervention required to ensure reliable water supply.

GREEN	O&M checks on an ad hoc basis
YELLOW	Supply option requires O&M checks on a routine basis (e.g. weekly, monthly)
RED	Supply option requires O&M checks on a continuous / daily basis

2D.9: PRODUCT WATER COST

Product water cost refers to the capital and running cost of supplying household water to the end-user(s), expressed in Rand per cubic meter (year 2003 values used).

GREEN	Less than $R5/m^3$
YELLOW	$R5/m^3$ to $R50/m^3$
RED	More than $R50/m^3$

Guidelines to calculate the cost of household water supply exist, such as the *COST BENCHMARKING GUIDE FOR LOCAL AUTHORITIES (http://www.dwaf.gov.za/dir%5Fws/pds/toolbox/PDF/costbenchmarkguidea4-1.pdf)* from the Department of Water Affairs and Forestry, and the PC-based *FINANCIAL MODELLING FOR MUNICIPAL INVESTMENT PROGRAMMES (COMBINED SERVICES MODEL, CSM)*, available from the Development Bank of South Africa.

2D.10: SOCIO-ECONOMIC CONSIDERATIONS

Socio-economic considerations refer to the socio-economic acceptability of the supply option based on international literature reports and feedback from local field surveys.

GREEN	General acceptance and widely used by a wide spectrum of end-users
YELLOW	Limited acceptance OR community cannot manage water supply without continuous external support
RED	Rejected by most end-users OR not suitable for water management by community itself

2D.11: EFFECTIVENESS AND SUITABILITY

Effectiveness refers to the degree to which the supply option can meet water demand and water quality specifications. Suitability refers to the existing or expected degree of implementation success.

GREEN	Generally effective and suitable for most communities and nearly all water types
YELLOW	Effective and suitable for specific communities and limited by raw water quality
RED	Generally considered ineffective or unsuitable for local conditions OR no data available

2D.12: FUTURE PROSPECTS

Future prospects refer to the potential of technological and / or socio-economical improvements of the supply option in the next 5 to 10 years. This may be an indication of its future relevance.

GREEN	Supply option is being actively researched / continuously improved
YELLOW	Supply option is mature and will remain relatively unchanged in short- and medium term
RED	Supply option outdated / will be outdated soon.

Table 2.10 compares the different water supply options of this guide:

Table 2.10: Comparison of different water supply options

		Electrodialysis (ED)	Reverse Osmosis (RO) Nanofiltration (NF)	Solar Distillation	Distillation	Adsorption	Flocculation	Reverse Osmosis (RO)	Bacteriological Degradation	Ion Exchange (IX)	Fog Harvesting	Rainwater Harvesting	Run-off Collection	Reticulation	Trucking
Process sophistication		Red	Red	Yellow	Red	Yellow	Yellow	Red	Red	Red	Green	Green	Green	Yellow	Green
Additional infrastructure requirement		Red	Red	Yellow	Red	Yellow	Yellow	Red	Yellow	Red	Yellow	Green	Yellow	Yellow	Green
Scope of use (nationally)		Yellow	Yellow	Yellow	Red	Green	Yellow	Green	Yellow	Green	Yellow	Green	Yellow	Green	Green
Water quality and quantity		Green	Green	Yellow	Green	Green	Green	Green	Yellow	Green	Green	Red	Yellow	Green	Red
Energy requirements		Red	Red	Yellow	Red	Green	Green	Red	Yellow	Red	Green	Green	Yellow	Green	Yellow
O & M requirements		Red	Red	Yellow	Red	Yellow	Yellow	Red	Yellow	Yellow	Yellow	Green	Green	Yellow	Yellow
Product water cost	Capital	Red	Red	Red	Red	Yellow	Yellow	Red	Yellow	Red	Yellow	Green	Green	Red	Red
	Running	Yellow	Yellow	Green	Green	Green	Green	Yellow	Yellow	Yellow	Green	Green	Green	Green	Red
Socio-economic considerations		Yellow	Green	Yellow	Red	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Yellow
Effectiveness and suitability		Green	Green	Yellow	Red	Green	Red	Yellow	Yellow	Green	Yellow	Yellow	Red	Green	Red
Future prospects		Green	Green	Green	Yellow	Yellow	Yellow	Green	Yellow	Green	Green	Red	Red	Yellow	Red

HOUSEHOLD WATER SUPPLY OPTIONS DATABASE

3.1 NOTES ON THE USE OF THE DATABASE

This section contains more information on household supply options discussed in **Section 2D** and is presented according to the headings of Table 3.1. Details of the following desalination technologies are provided:

- Electrodialysis
- Membrane desalination (Reverse osmosis, Nanofiltration)
- Solar distillation
- Flash distillation
- Adsorption (*defluoridation*)
- Flocculation (*defluoridation*)
- Bacteriological *denitrification*
- Ion exchange (*denitrification*)

In addition the following household water augmentation methods are also presented:

- Fog harvesting
- Rainwater harvesting
- Run-off collection
- Reticulation
- Trucking (transport)

General information on *disinfection* is presented at the end of this section (also see **Section 2.B**).

TABLE 3.1: LAYOUT OF TECHNICAL DATABASE

FIELD	DESCRIPTION
Definition	A definition (description, summary) of the water supply system
Technical considerations	A description of the water supply system including the process, equipment and components, additional infrastructure
Scope of use	Degree of implementation locally and internationally, including examples
Advantages	Advantages of this water supply system in terms of factors related to sustainability and product water quality
Disadvantages	Disadvantages and application limitations of the water supply system
Energy requirements	Energy source(s) and typical consumption per unit of product water delivered
Operation & maintenance	Operation & maintenance requirements in terms of the process and manpower
Economics	Typical product water costs, including capital and running costs
Socio-economic considerations	Conditions for community acceptance and participation (case studies)
Effectiveness and / or suitability	Indicates the effectiveness and / or suitability of the water supply option within the scope of this guidebook
Future prospects	International and national tendencies in terms of applications and related developments
A diagrammatic process description is provided at the end of each water supply option	

3.2 TECHNOLOGIES

3.2.1 ELECTRODIALYSIS (DESALINATION)

Definition	Electrodialysis (ED) is a desalination process based on the separation of ions through membranes as a result of the application of a direct electric current. Electrodialysis reversal (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.
Technical requirements	In the ED process, two sets of membranes, having alternate charges, are installed. The cation membrane will allow only positively charged ions to pass through, while the anion membrane will allow only negatively charged ions to pass through (see figure 3.1). Desalination is achieved by the removal of the charged ions from the water. An ED unit is made up of the following basic components: • Pre-treatment arrangement • Membrane stack • Low-pressure circulating pump • Power supply for direct current (a rectifier) • Post-treatment infrastructure The design of the various components can make a large difference in the overall performance of the system. The membrane selection is critical since selectivity will affect the purity of the product and the efficiency of the separation.
Scope of use	In South Africa the use of this technology has largely been limited to mining operations. Of the large-scale desalination plants that exist internationally, ED makes about 5% of the world's installed desalination capacity.
Advantages	• Capability for high recovery (more product and less brine), • Ability to treat water with a higher level of suspended solids than can be done by RO, • No interference from non-ionic substances such as silica, • ED can be used for the removal of TDS, fluorides and nitrates, • High selectivity, • EDR is useful in breaking up and flushing out scale, slimes and other deposits in the cells before they can build up, • Flushing allows the unit to operate with fewer pre-treatment chemicals, minimising membrane fouling, • Flexible operation (stop & go).
Disadvantages	• Major problem of fouling and scaling of the membranes, • The use of ED is limited to waters with TDS values < 5000 mg/l (therefore not seawater), • ED does not lend itself readily to small-scale applications due to its high capital and operational costs, and the requirement for highly trained operators, • Treatment of the product water can be required if it is to be

	used for potable purposes, • Micro-organisms are not removed (no disinfection), • Disposal / treatment of brine can be problematic.
Energy requirements	ED units require a reliable source of electrical power for the direct current used to separate the ionic substances in the membrane stack. This is a significant component of their operational costs. Small units can be connected to both AC circuit (through a rectifier) and DC sources (batteries, solar batteries). Energy efficient technology: energy consumption requirement as low as 0.9 kWh to treat 1 kg of salt; energy usage for brackish water: 1.5 – 4 kWh/m^3
Operation & maintenance	Depending on the design of the system, pre-treatment chemicals may need to be added to reduce the potential for scaling and to prevent damage to the membranes in the cells. Post-treatment consists of stabilizing the water and preparing it for distribution. The amount of waste brine that can be handled must be known. ED is a continuous / batch process.
Water cost per m3	Economy of scale exists. Running costs vary between R2-00 to R20-00/m^3 for small units Capital costs vary between R2000 and R10000/m^3/day capacity
Socio-economic considerations	ED units are relatively easy to operate, but knowledge of electricity, pumps, plumbing is required. Monitoring of plant operations and output water is also required.
Effectiveness and / or suitability	The effectiveness and efficiency of ED units is generally measured by the amount of water produced per kilowatt hour (kWh) of electricity used. ED plants remove up to 80% of the salts in the feed water, and are particularly effective where such salinity is less than 3000 mg/l. It may also be effective for brackish feed waters where the TDS exceeds 10 000 mg/l, but is not economically viable for seawater desalination. Generally less than 50% effective as a nitrate-removal process, although selective nitrate removal membranes are available. ED can be used in any climate, although it can be damaged if the lines or membrane stacks are frozen.
Future prospects	ED is a mature technology with efforts being concentrated on producing components which are more effective and longer lasting.

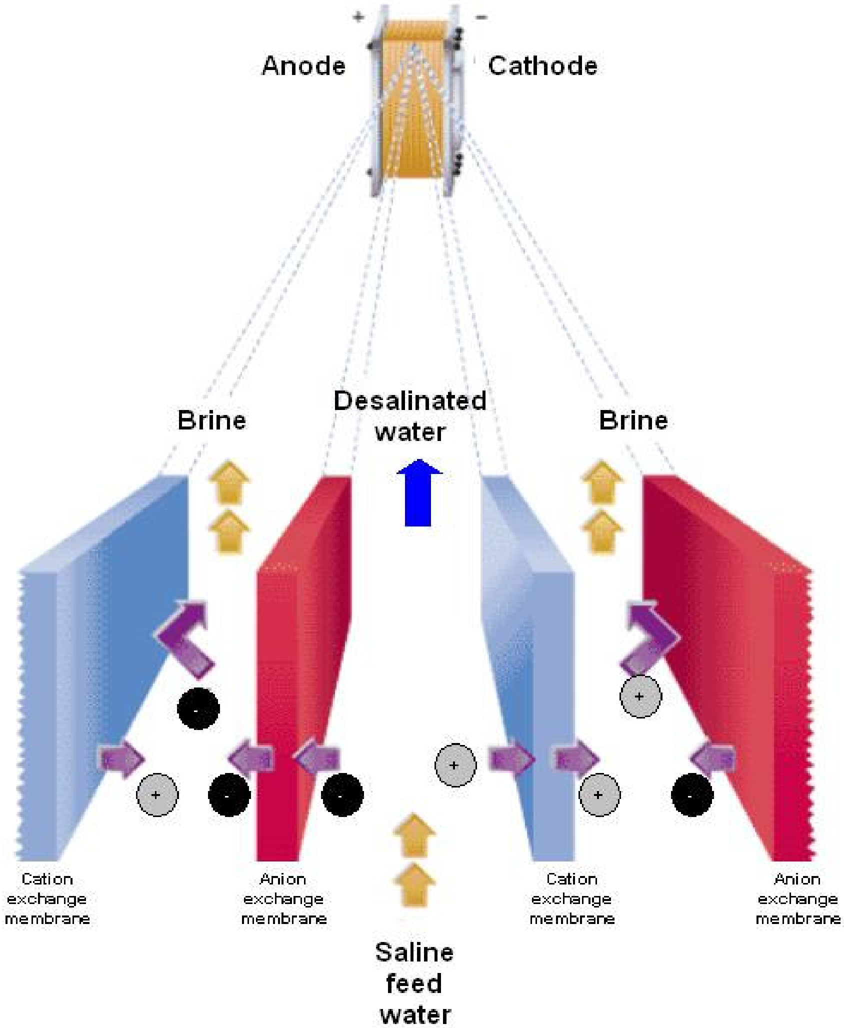


FIGURE 3.1: DIAGRAM OF ELECTRODIALYSIS CELL

(from: http://www.hansei.com/filtra/ion-b.htm)

3.2.2 REVERSE OSMOSIS

Definition	Reverse osmosis desalination (RO) is the process whereby a membrane under pressure is used to separate relatively pure water from a less pure solution. It is the finest filtration known.
Technical considerations	A RO system consists of four major components/processes: • pre-treatment, • pressurization, • membrane separation, and • post-treatment stabilization. Since water quality may vary from time to time, pre-treatment is required so that the dissolved solids and the bacterial level of the feed water can be controlled to within design limits. Feed water is passed through a pre-filter after pH adjustment, then pumped to the membrane modules at the designed pressure. The product water is then pumped to a storage tank and the concentrate is drained. Several kinds of RO membranes are available, but the majority of the commercially available membranes are made from cellulose acetate, polysulphonates and polyamides.
Scope of use	RO is used widely in the RSA. Worldwide it currently makes up about 30% of the world's installed desalination capacity. It is the fastest growing desalination technology as a result of cost reductions and technological advances.
Advantages	• RO removes many inorganic impurities from drinking water, including nitrates and fluorides, • Levels of organic substances and microorganisms can also be reduced, • Pre-packaged RO modules can supply product water ranging from a few liters per day to hundreds of thousands of liters per day, • Modular systems allow for mobility, making RO plants also suitable for emergency water supply.
Disadvantages	• Membranes are sensitive to abuse and may become clogged or damaged, • Membranes are sensitive to oxidation • Another problem is fouling (the gradual build up of rejected dissolved solids on the feed water side), • RO systems may not be appropriate for treating water contaminated by micro-organisms, • If not properly designed, operated or maintained, RO systems can use large quantities of feed water to produce relatively little treated water.
Energy considerations	RO units require a reliable source of electricity, which is the most significant component of their operational costs. Energy use to process brackish water ranges from 1 - 3 kWh per m^3 of product water and 4,5 – 6,5 kWh per m^3 (seawater). Solar energy may also be used.

Operation & maintenance	Operating pressures vary between 15 to 70 bar according to salinity of feed water. Skilled supervision is required to operate and maintain an RO plant to ensure reliable performance. Preventive maintenance includes instrument calibration, pump adjustment, chemical feed inspection and adjustment, leak detection and repair, and structural repair of the system according to a planned schedule. Clogged RO membranes, filters, or flow controls will decrease water flow and the system's performance. Membranes are sensitive to chlorine. As damage to membranes cannot be seen easily, the treated water must be analysed routinely to determine whether it is intact. A membrane module should last up to five years. RO is a continuous process.
Water cost per m^3	Economy of scale exists. Total costs vary from R7-00 to R100-00/m^3, of which about 70% is running costs (dependant on TDS). Capital costs can vary between R2 000 and R12 000/m^3/day capacity.
Socio-economic considerations	Specialised training of community members in operation and maintenance (including water analysis) is essential for effective operation.
Effectiveness and / or suitability	Reverse osmosis can be used for desalination of brackish or seawater. Its effectiveness depends on membrane type, flow control, feed water quality (e.g. turbidity, TDS and pH), temperature, and operating pressure. The nominal rejection ratio of common ionic salts is 85 to 98%. RO is 50% to more than 90% effective as a nitrate-removal system, and can also be used for the effective removal of fluorides. This technology is suitable for use in regions where seawater or brackish groundwater is readily available, and can be used in nearly any climate, although the membranes can be ruined if frozen with water in them.
Future prospects	Very good, with the development of membranes that are less prone to ***fouling***, operate at lower pressures, and require ***less pre-treatment*** of the feed water. Attention will be also be focussed on the possibilities to use renewable energies for RO.

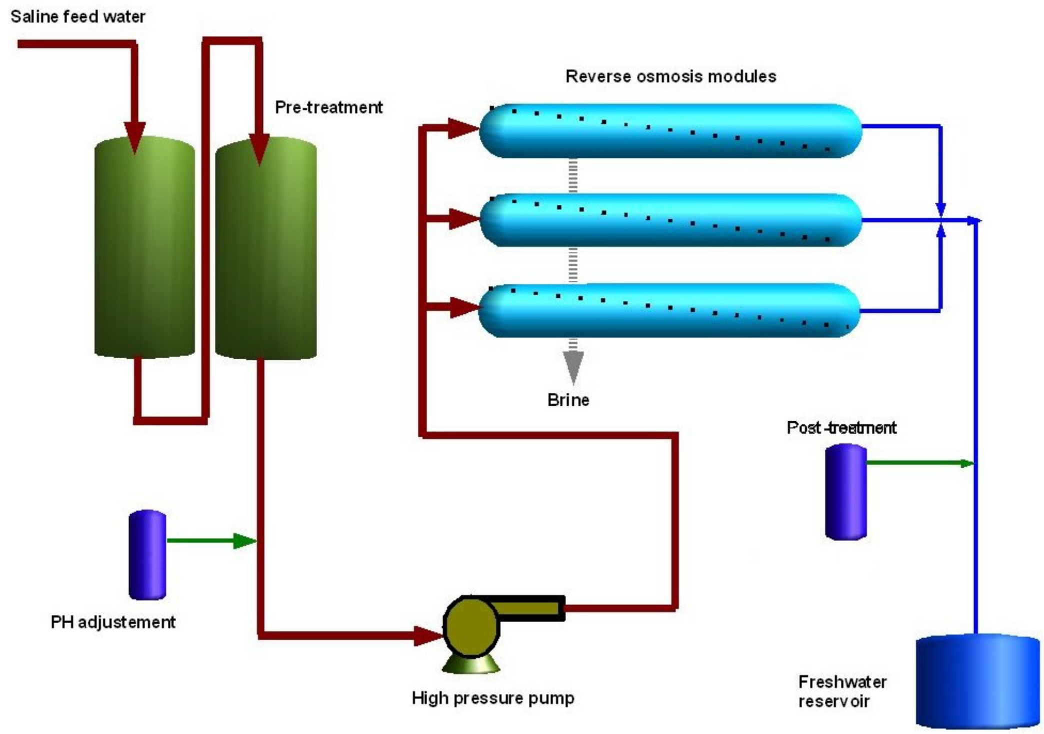


FIGURE 3.2: SIMPLIFIED REVERSE OSMOSIS PROCESS DIAGRAM

3.2.3 NANOFILTRATION

Definition	NF is a form of filtration that uses membranes to preferentially separate ions.
Technical considerations	NF is essentially a lower-pressure version of reverse osmosis and is especially suited to treatment of well water or water from many surface supplies like rivers or lakes. While RO can remove the smallest of solute molecules, in the range of 0.0001 micron in diameter and smaller, nanofiltration (NF) removes molecules in the 0.001 micron range.
Scope of use	Internationally in use for water softening and removal of organics from drinking water. No commercial RSA application to date.
Advantages	• NF is used where the high salt rejection of reverse osmosis is not necessary, as it is not as fine a filtration process, • NF can be viewed as a chemical free softening process as no regenerating chemicals are used. • NF is capable of removing multivalent ions such as calcium or magnesium (hardness ions), • NF can remove 80–95% of natural organic matter and colour without generating undesirable chlorinated hydrocarbons and trihalomethanes (THMs), • NF is capable of removing bacteria and viruses
Disadvantages	• NF is not effective on single charged ions (e.g. Na or Cl), • NF is not effective against small molecular weight, organics, such as methanol • Pretreatment is needed to avoid precipitation of hardness ions on the membrane.
Energy considerations	At least 80% of water hardness is removed with low operating pressure and high flux, and the energy costs are lower than for a comparable RO treatment system.
Operation & maintenance	Dependent on pre/post-treatment and membrane cleaning needs. Operational parameters of membranes need to be monitored and include the physical and chemical properties of the membrane, the pore size or molecular weight cut-off and configuration. Operating pressures are usually between 600 kPa and 1,000 kPa. Blending raw water and product water or adding alkalinity may be needed to reduce corrosivity of the product water. NF is a continuous process.
Water cost per m^3	About 10% less than RO
Socio-economic considerations	Similar to RO, apart from lower operating pressures required.
Effectiveness and / or suitability	Nanofiltration membranes have good rejection rates of larger ions, and is preferred over reverse osmosis for purifying groundwater and surface water up to 2000 TDS where the high salt content is due to divalent ions. Depending upon the membrane process hardness rejection can range from 70 to 95 percent.
Future prospects	Increased use for water softening and removal of organics are foreseen (especially if NF becomes economically attractive for water softening when compared to IX).

3.2.4: SOLAR DISTILLATION

Definition	The use of solar energy to desalinate salty, brackish or contaminated water, to obtain fresh and clean water
Technical considerations	Different types of solar distillation units (also called 'solar stills') exist: e.g. basin, wick, multiple effect stills etc. High levels of solar ***r***adiation, on average more than 20 MJ/day or 7300 MJ annually, are required to make solar distillation economically viable.
Scope of use	Worldwide solar desalination is not extensively used; it remains largely experimental. There are no large-scale installations. It is almost exclusively used for drinking and cooking water supply to small rural households in countries like India, Mexico and West Indies. There are only a few experimental plants in South Africa.
Advantages	• 'Free' renewable energy resource, • Environmentally friendly, • Applicable to water of almost any level of salinity, • Low operating and maintenance cost (lowest operating cost: capital cost ratio of desalination plants), • Excellent product water quality, • Solar stills can ensure supplies of water during times of drought, • Ideal for dual water supply systems.
Disadvantages	• High capital costs resulting in high water costs, • Low productivity, dependant on solar radiation level, • Not suitable for bulk water provision (i.e. sanitation and washing).
Energy requirements	Solar energy. Infrastructure can be operated from solar power or electricity
Operation & maintenance	Generally low level of O & M is required, which includes visual inspection and water quality checks, occasional cleaning of solar stills, and replacement of broken glass panes, waterproofing etc. Solar still operate on a batch or continuous basis, depending on type of still used.
Water cost per m^3	Economy of scale normally insignificant Total costs vary between R50-00 to >R100 / m^3, of which 90% is capital cost component.
Socio-economic considerations	Due to its low operational and maintenance impact, rural communities easily understand and accept the technology. Simple solar stills can be operated and maintained by people with basic technical skills. However, solar stills do require constant maintenance if they are to perform efficiently.
Effectiveness and / or suitability	The technology must be carefully matched to the application. Solar stills are effective in specific target areas, also where winter rainfall can be combined with summer-time water production. Suitable for use as potable water source for rural communities in arid regions.
Future prospects	Future R & D can lead to productivity improvement and / or cost reduction that will increase the application scope of the technology.

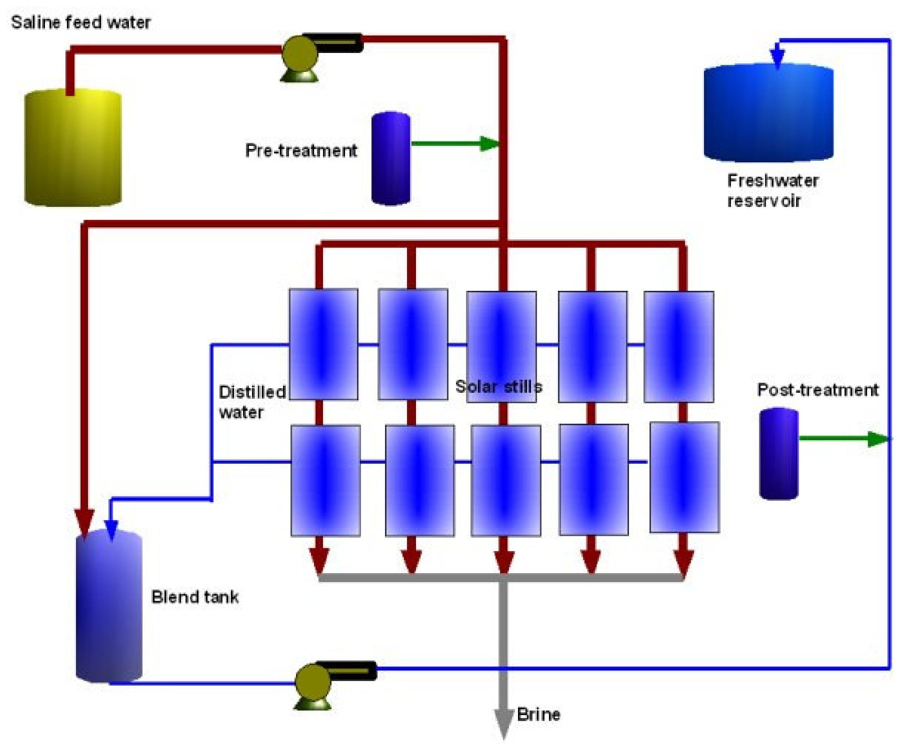
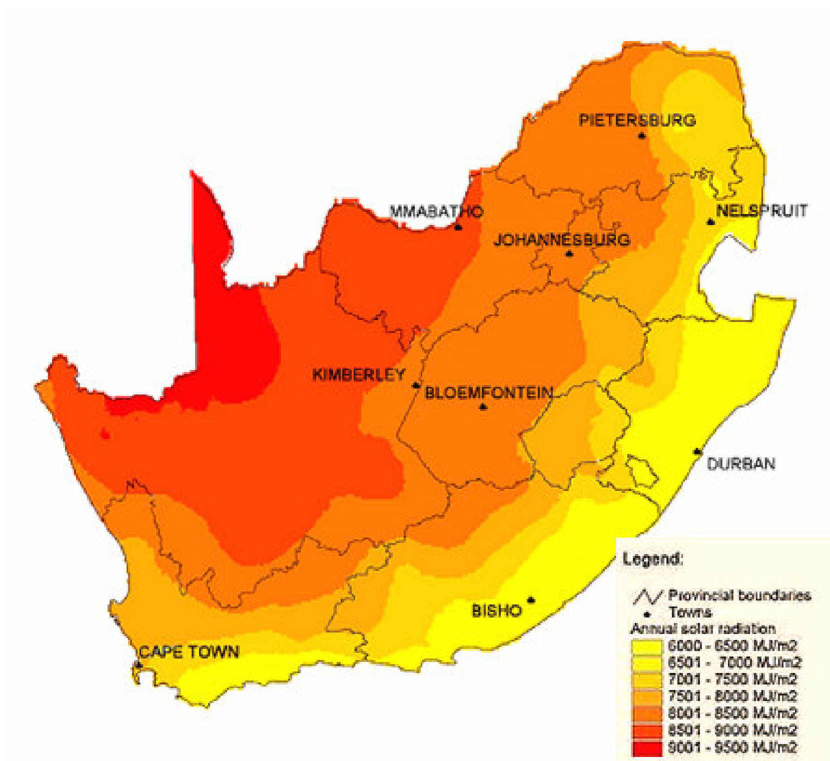


FIGURE 3.3: TYPICAL LAYOUT OF A SOLAR DISTILLATION PLANT



MAP 3.1: SOLAR RADIATION MAP OF SOUTH AFRICA

3.2.5: FLASH DISTILLATION

Definition	A method of desalinating seawater by “flashing” it into steam, which is then condensed. It can be done over a number of stages (technology is also called MSF = Multi Stage Flash Distillation).
Technical considerations	Steam is used to heat the saline water. A plant can consist of up to 40 in-line evaporation chambers, each operating at a lower temperature and pressure than the preceding one. Water is ‘flashed’ off in each stage. This process of decompression, flashing and condensation is repeated all the way down the plant by both the brine and distillate streams as they flow through the subsequent stages. The freshwater is formed by condensation of the water vapour, which is collected at each stage and passed on from stage to stage in parallel with the brine. At each stage, the product water is flash-boiled so that it can be cooled and the surplus heat recovered for preheating the feed water. For small plants, the process can be simplified by removing the heat rejection section at the expense of process efficiency. ***These plants are normally associated with the utilisation of waste heat from other industrial thermal processes.***
Scope of use	None in SA. Distillation accounts for about 65% of the world's installed desalination capacity, with the MSF process making up the highest proportion of plants (Middle East, North Africa, and the Caribbean).
Advantages	• Distillation plants can be fully automated and, except for brine disposal, have a minimal environmental impact, • When they are operated properly, maintenance costs are low, • Low temperature distillation reduces energy requirements and production costs, • High quality water can be produced, • Distillation is generally more tolerant of poor quality feed water than other desalination processes.
Disadvantages	• High capital costs, • Require large energy inputs, regardless of plant size, • Brine disposal may be a problem, • Distillation requires a high level of technical skill and training, • Distillation requires the use of process chemicals and other materials, which must be handled carefully.
Energy requirements	Electrical energy consumption typically between 4 – 6 kWh / m^3 Solar option requires massive investment.
Operation & maintenance	Specially trained personnel are required for its operation and associated high levels of maintenance. Maintenance includes repair of cracks in the system; removal of biological growth in the system; cleaning and inspection of the vacuum system, pumps, and motors; and the addition of anti-corrosive chemicals to the water to avoid corrosion and equipment breakdown. The operation of desalination plants is usually continuous.
Water cost per m^3	Economy of scale exists. Total costs between R8-00 to R50-00 / m^3 depending on the type of process used, plant capacity, salinity level, and the skill level of local personnel. MSF is a very economical process for large-scale desalination, both in terms of capital investment and running costs. Capital costs vary between R8 000 and R20000/m^3/day capacity.

Socio-economic considerations	This technology is highly technical and expensive, and its operation requires careful planning, well-trained operators, and continuous adequate operation and maintenance procedures to guarantee the supply of good quality water. Small rural communities are generally not exposed to MSF.
Effectiveness and / or suitability	The effectiveness and efficiency of distillation units is generally measured by the amount of water produced per unit of steam delivered to the plant. MSF is very efficient when properly maintained, and can produce product water with a TDS content of less than 50 mg/l. It is almost exclusively used for seawater desalination, with capacities ranging from 15 to 1 000 m^3/day. MSF has limited suitability for rural water supply, due to sophisticated plant operation and the lack of fuel, chemicals, spare parts, and trained personnel in such areas. Distillation or thermal desalination is suited to any climate.
Future prospects	There probably will not be major significant technical improvements in distillation processes. Future development may focus on reduced costs and improvement of system efficiency; reduction in required operating temperatures; ensuring a high level of thermal efficiency; and reduction of overall energy costs.

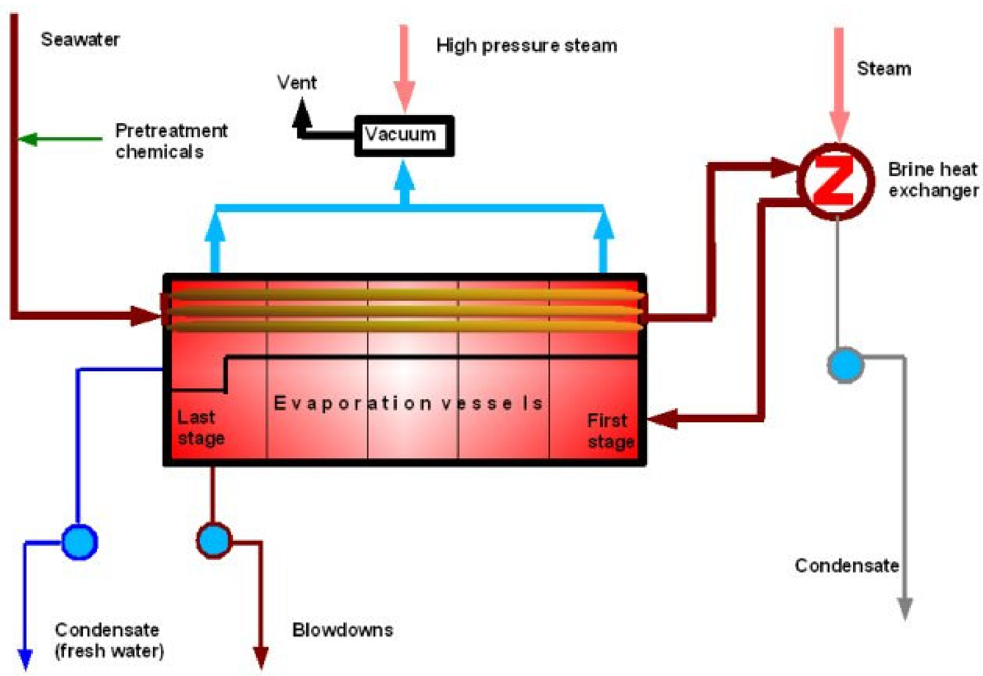


FIGURE 3.4: FLASH DISTILLATION DIAGRAM

3.2.6: ADSORPTION (DEFLUORIDATION)

Definition	The defluoridation of drinking water by filtering fluoride-contaminated water through a column with a strong adsorbent (e.g. aluminium oxide, also called activated alumina)
Technical considerations	A vessel/column packed with the adsorbent is required. The adsorbent needs to be activated before defluoridation. The product water output can be connected to hand pumps or standpipes (community systems), or taps (household systems). The design of flow rate through the packed bed is important. Equipment and chemicals for activation and regeneration of the adsorbent are necessary. It is often used in conjunction with other filtration systems. Effluent disposal facilities may be required.
Scope of use	Used in rural communities in the RSA. Alumina technology, especially, regarded as mature.
Advantages	• Process is reliable, relatively safe and simple, • Continuous supply of drinking water can be achieved, • Activated alumina process can reduce fluoride in feed water from 20 mg/l to less than 1,5 mg/l, • Activated alumina not seriously affected by chlorides and sulphates.
Disadvantages	• Limited efficiency e.g. effective defluoridation will not occur in feed water with TDS >1500 mg/l, • Alumina adsorption of fluoride in specific pH ranges may require pre-and post- pH adjustment of water, and handling of hazardous regeneration chemicals (alkali and acids) may be problematic, • Regeneration generates effluent rich in accumulated fluoride, causing disposal problems, • Breakthrough of fluorides may occur unnoticed, • Process is adversely affected by high alkalinity associayed with high silicate and bicarbonate concentrations (pH adjustment required) • Effective lifespan is limited due to the reducing adsorption efficiency of the activated alumina with increasing number of usage-regeneration cycles.
Energy requirements	Can be operated without an energy source.
Operation & maintenance	Activated alumina requires periodic cleaning with an appropriate regenerant such as mild alkali (e.g. NaOH) and acid (e.g. H_2SO_4) Waste regenerated should be disposed of safely e.g. into lined, fenced evaporation ponds, or off-site regeneration needs to be performed.
Water cost per m^3	Slight economy of scale advantage exists. Running costs dependent on fluoride concentration in the feed water; varying between R0.50 for low [F^-] and R4.50 for high [F^-]. Waste handling can be expensive. Community sized defluoridation units costs from R5000 upwards.
Socio-economic considerations	Good community organisation is necessary to ensure proper maintenance. Training of community members (for community systems) is necessary as handling of chemicals for regeneration and pH adjustments may be difficult.

Effectiveness and / or suitability	Activated alumina will only remove fluoride (not a general desalination process) and is only applicable where the total TDS <1500 mg/l
Future prospects	Newer adsorption materials are continuously being studied in order to (1) increase defluoridation effectiveness, (2) improve socio-economic sustainability. These materials include granulated bone-, which removes fluoride with moderate efficiency and are applicable in situations when drinking water contains up to 5 mg/l fluoride. Reducing the cost of the adsorbent regeneration operation will contribute to making column bed adsorption more efficient and more economically viable

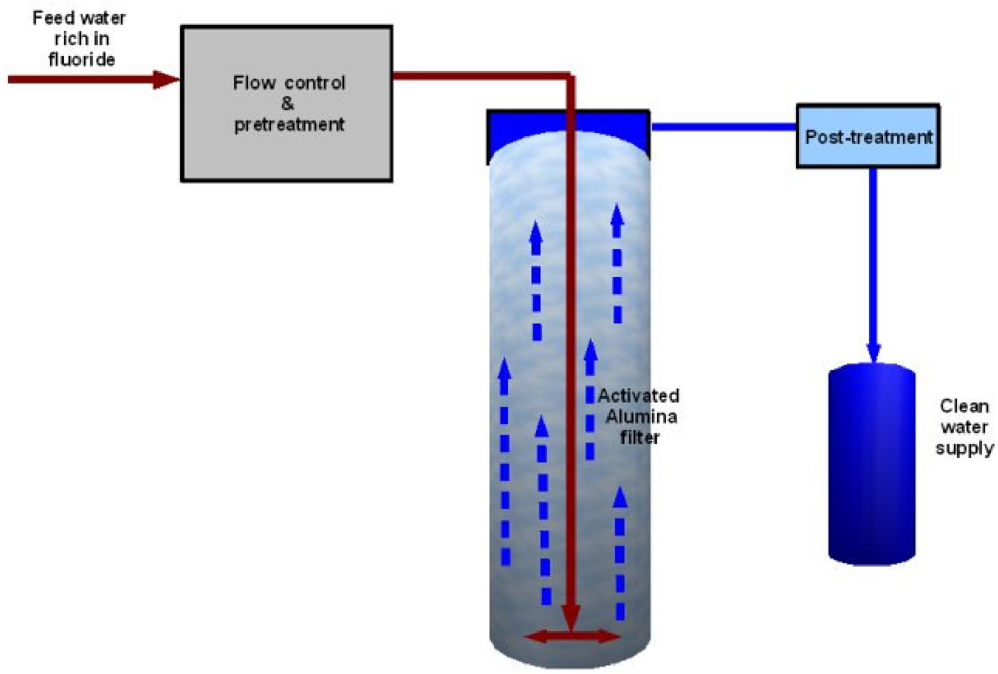


FIGURE 3.5: DIAGRAM OF ACTIVATED ALUMINA FILTER

3.2.7: FLOCCULATION (DEFLUORIDATION)

Definition	The defluoridation of drinking water by flocculation of fluoride ions in the water. (Also known as the Nalgonda technique).
Technical considerations	The technique is a combination of several unit operations and co-precipitation processes, incorporating: rapid mixing, chemical interaction, flocculation, filtration, disinfection and sludge concentration, to recover water and aluminium salts. Fluorides are absorbed by coagulants (such as aluminium hydroxide-complex compounds, poly aluminium chloride or alum) and settle as sludge at the bottom of reactors. Calculated amounts of alum, lime and bleach are added to pre-treated water and the mixture is stirred.
Scope of use	Developed and used extensively in India. Alkalinity problems restrict local use.
Advantages	• Low cost technology based on generally available chemicals and materials, • No regeneration required, • No handling of strong acids and alkalis, • Highly efficient removal of fluorides, from levels as high as 1.5 to 20 mg/l to desirable levels, • Simultaneous removal of colour, odour, turbidity, bacteria and organic contaminants, • Bacterial contamination can also be significantly reduced, • Little wastage of water and few disposal problems, • Needs minimal mechanical and electrical equipment.
Disadvantages	• Additional desalination may be necessary when the TDS > 1500 mg/l, • The process is less satisfactory when the fluoride content in the feedwater is > 20 mg/l, • Possibility of aluminium contamination of the water due to the large dosage of aluminium sulphate, (700 - 1200 mg/l), that may be required, • Huge sludge volumes.
Energy requirements	No energy source required for community treatment plants, although electrical powered stirrers are preferable.
Operation & maintenance	To ensure optimum fluoride removal, alum and lime need to be added in certain proportions requiring a trained operator. The required dose of aluminium salt increases as the fluoride and alkalinity levels of the raw water increase.
Water cost per m^3	Economy of scale insignificant. Total costs vary between R20 and R100/m^3.
Socio-economic considerations	The operation can be carried out on a large or a small scale. The technique is therefore suitable for both community and household use.
Effectiveness and / or suitability	Total dissolved solids must be below 1500 mg/l. This technique was found not to be useful for African waters of high fluoride content and low alkalinity, where lime should be added at a much higher dosage in order to achieve the pH for optimum removal.
Future prospects	Due to recent concerns regarding health hazards (aluminium-caused), alternative coagulants and coagulant aids are being researched.

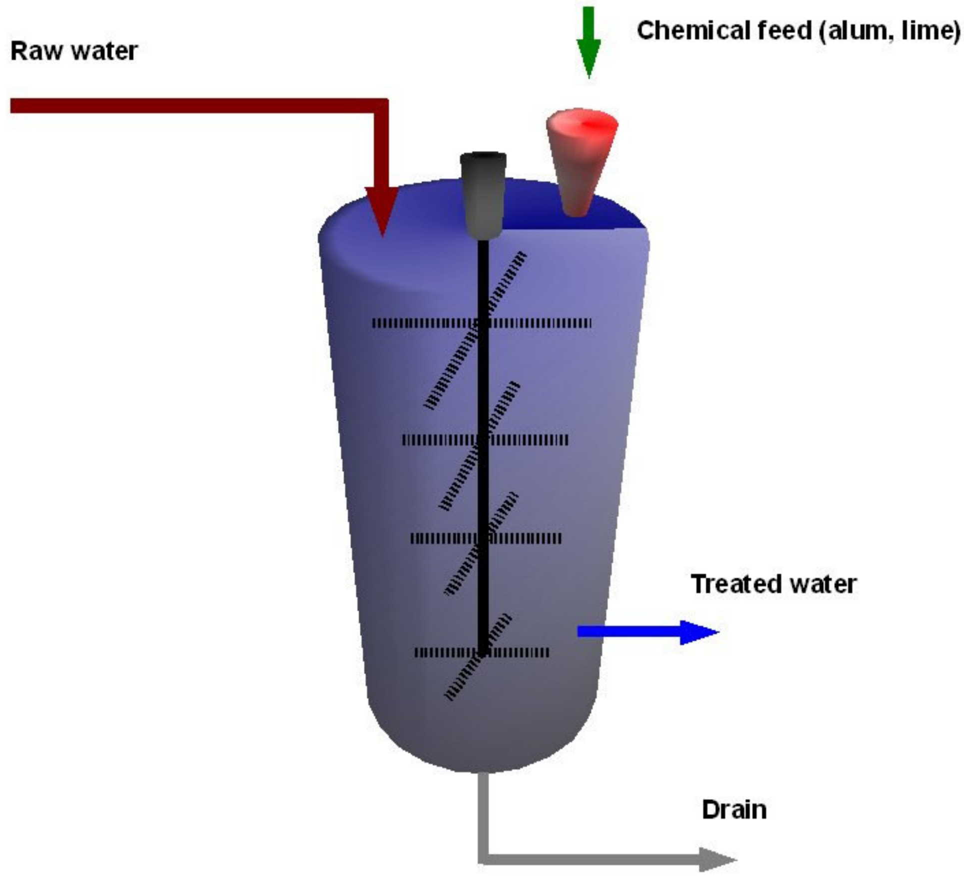


FIGURE 3.6: DEFLUORIDATION (FLOCCULATION) REACTOR

3.2.8: BACTERIOLOGICAL DENITRIFICATION

Definition	The denitrification process by which toxic nitrate ions are removed from water and converted by bacteria to nitrogen gas.
Technical considerations	A 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 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 (disinfection / oxygenation) of product water is generally required
Scope of use	Existing technology with limited application for rural household water provision (no plants in South Africa)
Advantages	• Nitrate specific, • High yield and low process costs, • No requirement for regeneration of media, • Few problems with brine disposal, • Reduced need for infrastructure, • Operational stability, with no loss of denitrification capacity over time.
Disadvantages	• Fluctuations in product water quality can be expected, • Nitrites are formed if insufficient carbon or energy is available and substrate is in excess, • Adding water-soluble organic material as an energy source is not a sustainable solution, leads to secondary pollution problems, • Bacteriological denitrification rarely occurs naturally in groundwater, and so large bacterial populations, free of pathogens, has to be developed, • Remnant microbes may be present in the treated water, which must then be post-treated.
Energy requirements	Electrical energy may be required in order to keep the bacterial floc in suspension by stirring.
Operation & maintenance	Very limited data exists - to date, the process is mostly run by scientists, under controlled conditions.
Water cost per m^3	R2.00 – R4.00/m^3 (excl. capital), R8.00/m^3 + (including capital). The cost for a denitrification plant varies between about double to 12 times that of ion exchange, while operating costs are equivalent or less.
Socio-economic considerations	This technology requires specialised skills and knowledge to operate effectively. Water authority participation is required to design, install, operate and maintain the systems.
Effectiveness and / or suitability	The nitrate removal efficiency is between 70% and 90%. This technique is more suitable used for treatment of wastewater, or the reclamation of nitrate-contaminated groundwater. Its use as an option for drinking water is still largely experimental (emerging technology).
Future Prospects	The development of Biofilm reactors where the denitrifying bacteria and the carbon energy source are separated from the treated water. Biodegradable plastic as the source of organic matter is being investigated. R&D is needed to ensure a more constant output water quality from these systems.

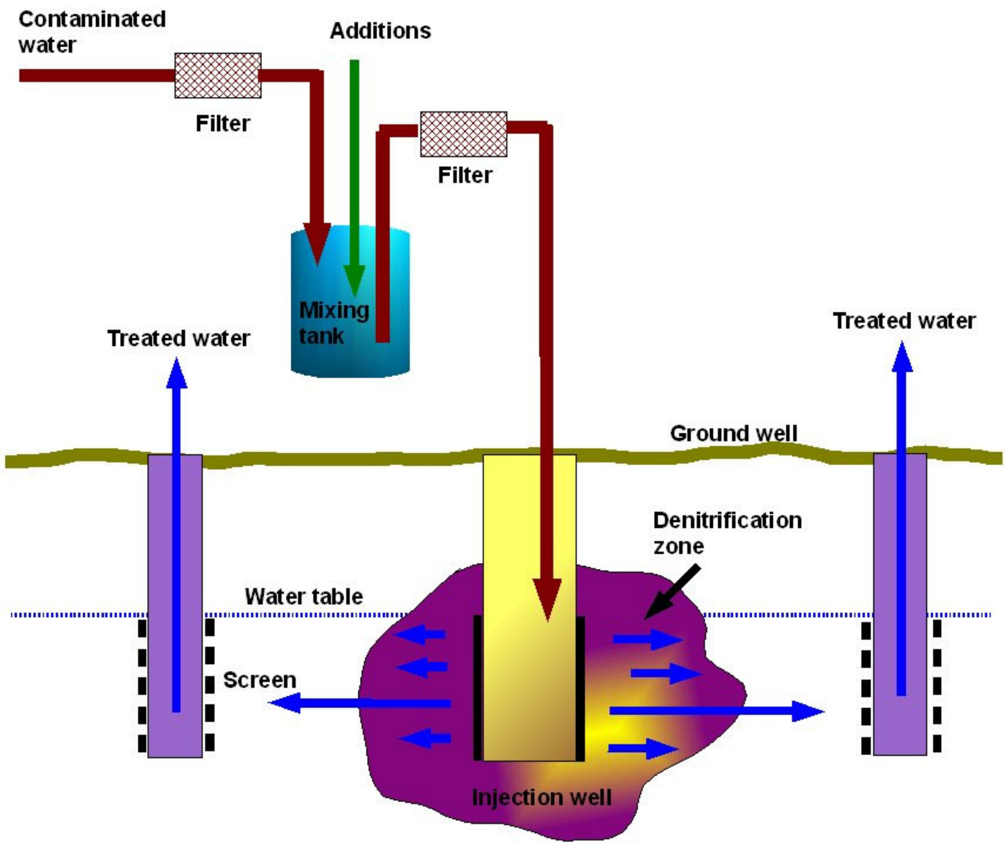


FIGURE 3.7: EXAMPLE OF *in situ* BIODENITRIFICATION PLANT

3.2.9: ION EXCHANGE (NITRATE REMOVAL)

Definition	Ion exchange (IX) denitrification is the reversible process by which nitrogen and nitrogen-containing compounds are removed from water through interchanges with an ion on an ion exchange medium.
Technical requirements	An IX column and an IX resin are required (an anion exchange resin consists of polymers of positively charged sites that are bonded to negatively charged ions; sodium chloride is generally used to charge the column). The capacity is a function of the amount of resin in the column, the amount of nitrate and sulphate in the feed water, and the amount of salt used for each regeneration. Nitrate-specific resins are available.
Scope of use	Established and proven technology, used locally and internationally.
Advantages	• Nitrate reduction of 80-93% can be achieved, • High nitrate concentrations can be reduced to < 2 mg/l, • IX systems can treat large volumes of water, • Modern selected resins are selective for nitrate ions, retaining them until regenerated with chloride ions, • Capital investment for ion-exchange plants can be 2.5-3 times less than that for biological denitrification.
Disadvantages	• High sulphate concentrations can reduce the efficiency of conventional IX resins, • Chemicals are needed for regeneration, • Pre-treatment of feed water may be necessary, • Disposal of spent regenerated brine may be problematic, • In water with high TDS an increase in chloride concentration may occur, • The resin is often fouled due to the presence of organic matter in the feed water, • The resin may make the water corrosive so that the product water must go through a neutralising system after the IX unit, • Effluent from chloride exchange resins may extract zinc from pipe fittings (due to its increased chloride concentration and reduced alkalinity).
Energy requirements	Electrical power for low pressure pumps
Operation & maintenance	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
Water cost per m3	Economy of scale exists. Total costs R3.50 to R10.00/m^3, running costs vary from R2.00 to R4.00 /m^3.
Socio-economic considerations	The equipment requires frequent, careful maintenance and sampling, to achieve and confirm effective operation, making specialised training of community members necessary. Brine disposal may pose a problem to rural communities.
Effectiveness and / or suitability	Only nitrates (and sulphates) are removed i.e. IX not a general desalination process. The nitrate removal efficiency is high: between 80% and 99%. This technology is suitable where the TDS of the feed water < 3000 mg/l, preferable <1500 mg/l.
Future prospects	Biological denitrification of used regenerant may achieve multiple use of brine thus making the process more effective. More selective IX media are continuously being developed.

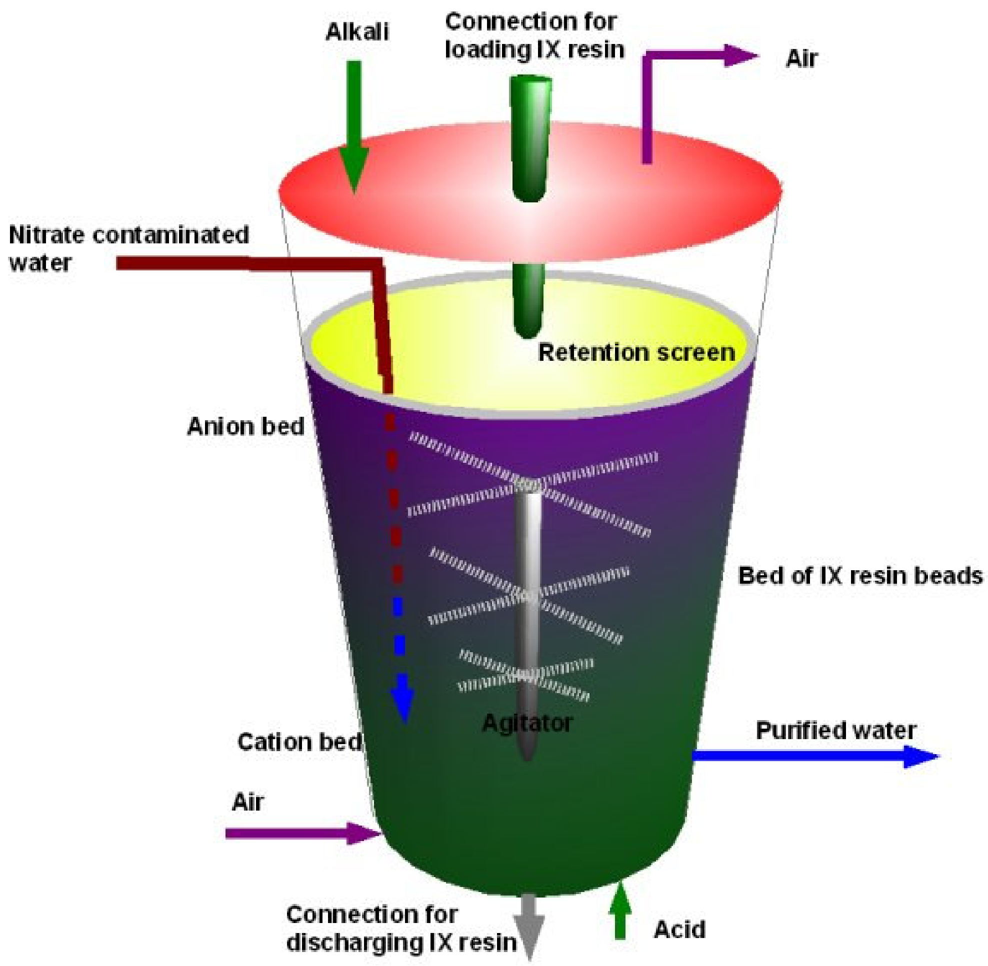


FIGURE 3.8: DIAGRAM OF IX REACTOR

3.2.10 FOG HARVESTING

Definition	The collection of water in fog through relatively simple systems known as fog collectors.
Technical considerations	The fog water content, the frequency of fog in the geographic area determines the overall design of the system. Fog collectors are usually made of fine nylon net strung between (wooden) poles in areas known to have frequent fogs. The nets face into the wind. These systems can be made up of individual panels, each with a surface area of up to 50 m^2, or they can be composed of a group of joined panels. Water droplets in the fog condense on the net and, when enough have gathered, coalesce and run off into a conveyance system, which carries the water to a cistern or other storage area. Conveyance and storage systems are also required.
Scope of use	Limited to geographical locations with high levels of fog and recurring winds. Fog harvesting plants exist in Chile and Namibia. Successful demonstration tests have been carried out along the RSA West Coast and in the Soutpansberg region
Advantages	• Fog harvesters are easy to install and generally less expensive than most other sources of potable water, • They can create viable communities in inhospitable areas, • Water quality is often better than existing water sources used for domestic purposes.
Disadvantages	• A pilot project must first be undertaken to evaluate the feasibility of fog harvesting in any given region, • A back-up system is recommended in case fog conditions change, • High costs may result from pipeline lengths required.
Energy requirements	Wind. An energy source for pumps, if used, is also required.
Operation & maintenance	Maintenance includes periodically tightening the nets, cables and cable fasteners, cleaning or replacing the nets as wear occurs, and ensuring that the conveyance system and cisterns are free from contamination by cleaning periodically with chlorine and calcium chloride.
Water cost per m^3	Economy of scale insignificant. Total costs from R30.00 /m^3 upwards, low running costs
Socio-economic considerations	This is a relatively largely experimental technology, with positive community feedback. Acceptability may be limited until its effectiveness has been demonstrated.
Effectiveness and / or suitability	Fog harvesting is one of the most effective water augmentation technologies for arid and mountainous areas (30% of the water contained in fog can be harvested). Meteorological constraints limit degree of application.
Future prospects	The distribution system should be made more cost-effective, the design of the collectors needs to be improved and made more durable, and the community should receive basic information about this technology before it is implemented.

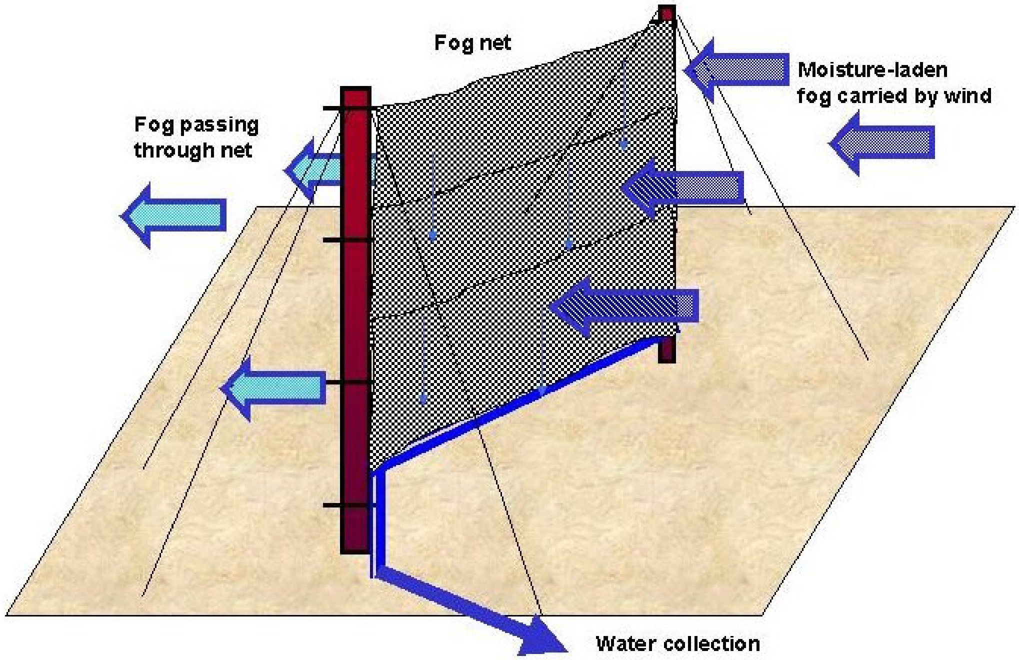
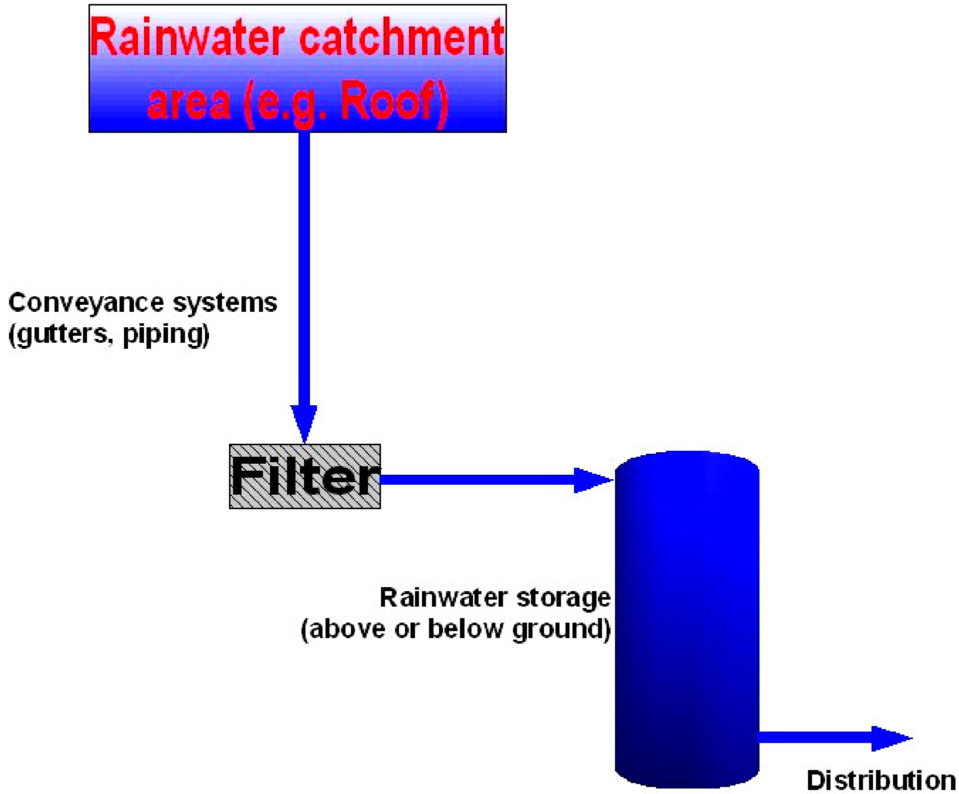


FIGURE 3.9: BASIC FOG HARVESTING SET-UP

3.2.11: RAINWATER HARVESTING

Definition	Rainwater captured from the roofs of residential properties.
Technical considerations	There are normally three components to a rainwater harvesting system: the collection area, the conveyance system, and the storage facility.
Scope of use	This technology is extensively used, mainly for household purposes.
Advantages	• Rooftop systems are easy and generally inexpensive to construct, owner operated and managed, • They are an essential form of back-up water supply in times of emergency, • Rainwater quality may be higher than that of other water sources, • Rainwater provides a freshwater supply where surface and groundwater are unavailable, scarce, or contaminated.
Disadvantages	• Rainfall is not a dependable water supply source during droughts, • Animals and organic matter may contaminate rainwater, and standing water in the cistern may provide potential breeding sites for mosquitoes; creating health risks, • The cost of constructing a home with a cistern is higher.
Energy requirements	Nearly always gravity feed. If the rainwater tank is a distance from the home(s) then (electrical / solar powered / wind powered) pumping may be necessary.
Operation & maintenance	Operation requires little attention. Maintenance includes periodic cleaning, preferably with a chlorine solution; repair of occasional cracks in the cistern; regular cleaning and maintenance of the gutters; and inspection to ensure that the system is free of organic matter.
Water cost per m^3	Economy of scale insignificant. Total costs vary between R1.00 to R50.00/m^3, mainly capital costs. Costs vary depending on the location of the storage facilities and the types of construction materials used.
Socio-economic considerations	Communities need to be educated on its hygienic collection, storage and usage.
Effectiveness and / or suitability	Provision for rainwater harvesting is widely made in the target areas, as it is generally inexpensive. In times of low or no rainfall deterioration in infrastructure may result. Water quality is seldom monitored. Most suitable in semi-arid regions with a degree of seasonal rainfall. Suitability decreases as other sources of water supply become available.
Future prospects	There is a need for better quality control of rainwater harvesting systems and for promoting rainwater harvesting as a supplement for other water sources e.g. groundwater (dual water supply systems).



<u>FIGURE 3.10:</u> COMPONENTS OF A SIMPLE RAINWATER HARVESTING SYSTEM

3.2.12: RUN-OFF COLLECTION

Definition	Run-off from structures such as tarred and untarred roads that is collected in ground dams or gutters, and stored temporarily.
Technical considerations	This water may be transported through pipes from the containing structures to households where it can be used.
Scope of use	Limited. This technology of run-off capture and storage may be used in semi-arid areas with hillside or mountainous geography.
Advantages	• Run-off dams are easy to operate and maintain, • Dams may reduce erosion and sedimentation problems if properly designed and operated.
Disadvantages	• Runoff-based water supply systems will run dry during the dry season and drought periods (i.e. it is a secondary water source), • Water storage areas need to be fenced to control animal access, • The technology requires appropriate soil conditioning to be implemented, • Collected runoff water may be contaminated and serious turbidity problems may be experienced.
Energy requirements	Pumping infrastructure (electrical, solar, wind).
Operation & maintenance	Dams must be cleared of debris. Control of insects and plants in standing water may be required.
Water cost per m^3	Economy of scale may exist. Determined by cost of collection areas and infrastructure required.
Socio-economic considerations	Communities in arid and semi-arid regions accept the use of run-off water.
Effectiveness and / or suitability	Technology is more suited for agriculture, as runoff water will nearly always require physical treatment before household use. Run-off collection can be considered as a secondary water source e.g. for sanitation.
Future prospects	This technology should be combined with other collection and storage technologies.

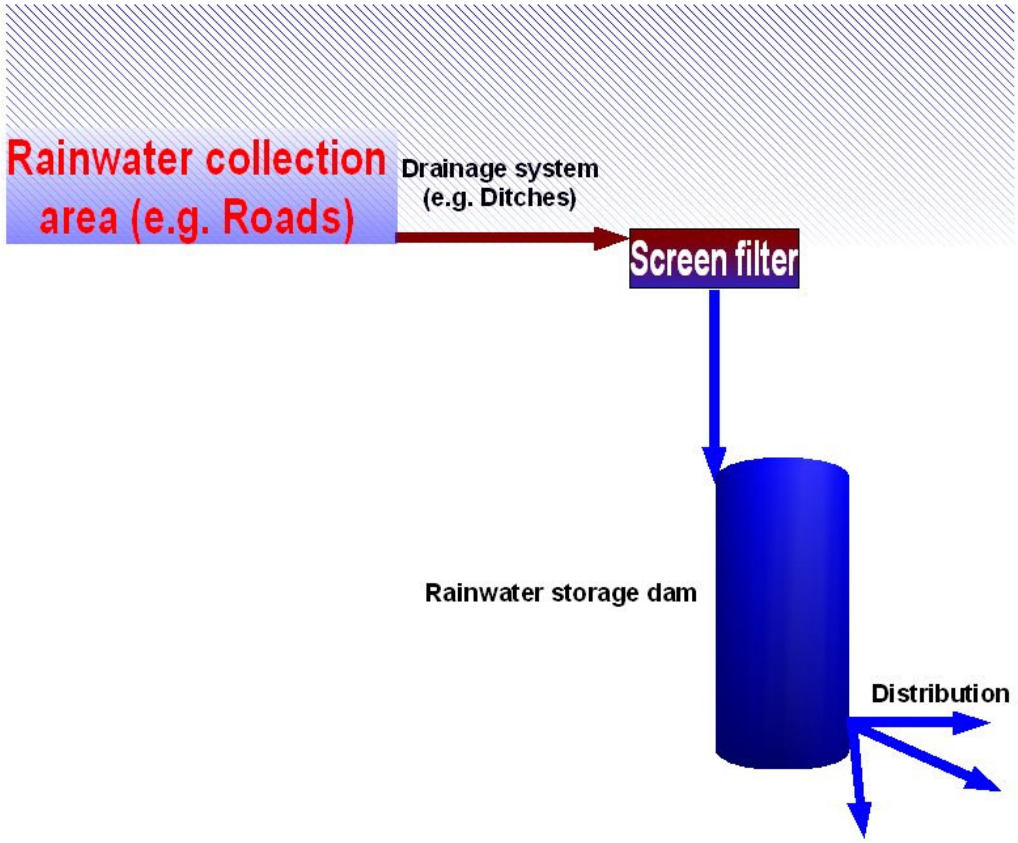


FIGURE 3.11: DIAGRAM OF TYPICAL RUN-OFF COLLECTION SYSTEM

3.2.13: RETICULATION

Definition	The transfer of water through a network of pipelines from ground and surface water sources in an area where the available resources exceed demand to an area where demand exceeds available resources.
Technical considerations	Storage containers, both at points of provision and reception, plus feed lines (pipe lines). The system of conveyance may be gravity-flow or pumped.
Scope of use	Water conveyance via pipelines is found throughout South Africa.
Advantages	• Generally reliable, • Easy to maintain, • Rural pipelines allow for large volume transfers of water.
Disadvantages	• Pipelines involve high capital costs, especially over long distances, • Transfer could cause environmental impacts, • Leaks may go undetected, • Sustainable water sources of acceptable quality are seldom found in target areas.
Energy requirements	Electrical, solar or wind pumps.
Operation & maintenance	Maintenance of pipelines requires some technical skills and periodic repairs and cleaning of the system.
Water cost per m^3	Economy of scale insignificant. Costs vary depending on the distances and complexity the system. Costs can be between R10-00 to more than R100/m^3 (mainly capital costs).
Socio-economic considerations	Water distribution projects have a high level of national and provincial government participation. Planning and design of these systems usually involves private consultants. Community participation may be required in the operation and maintenance of the systems.
Effectiveness and / or suitability	Highly effective if sustainable water source is available within a reasonable range. Suitable for regions where there is an "excess" of water in one area and a "deficit" in another.
Future prospects	Development of improved, low-cost pipe materials would increase the use of this technology. Better quality control and training of local users is necessary.

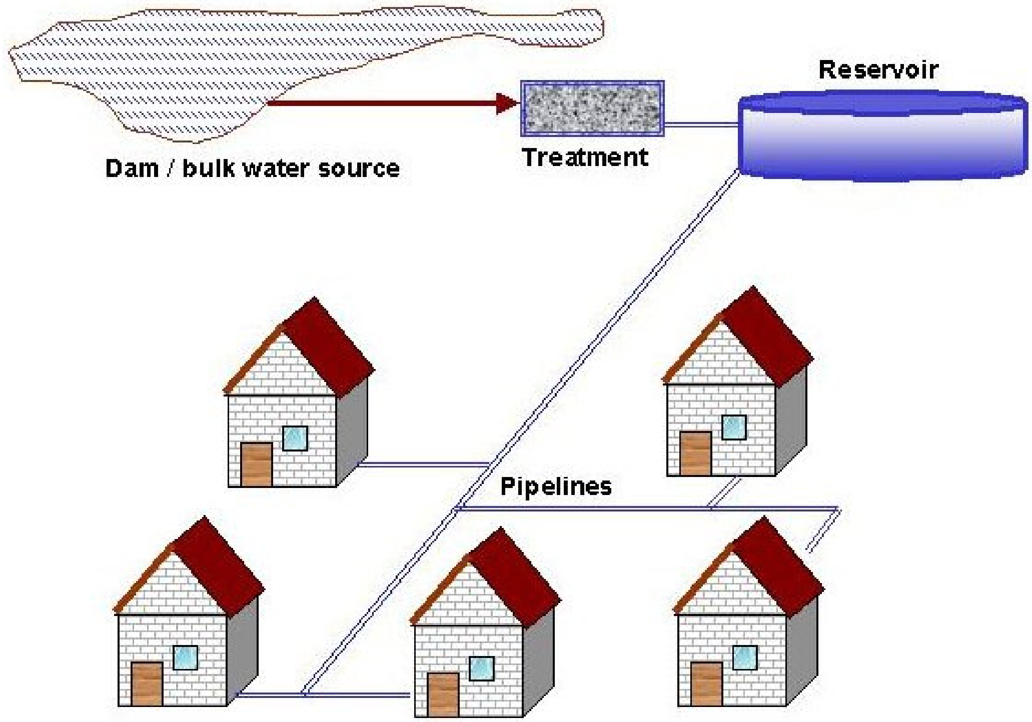
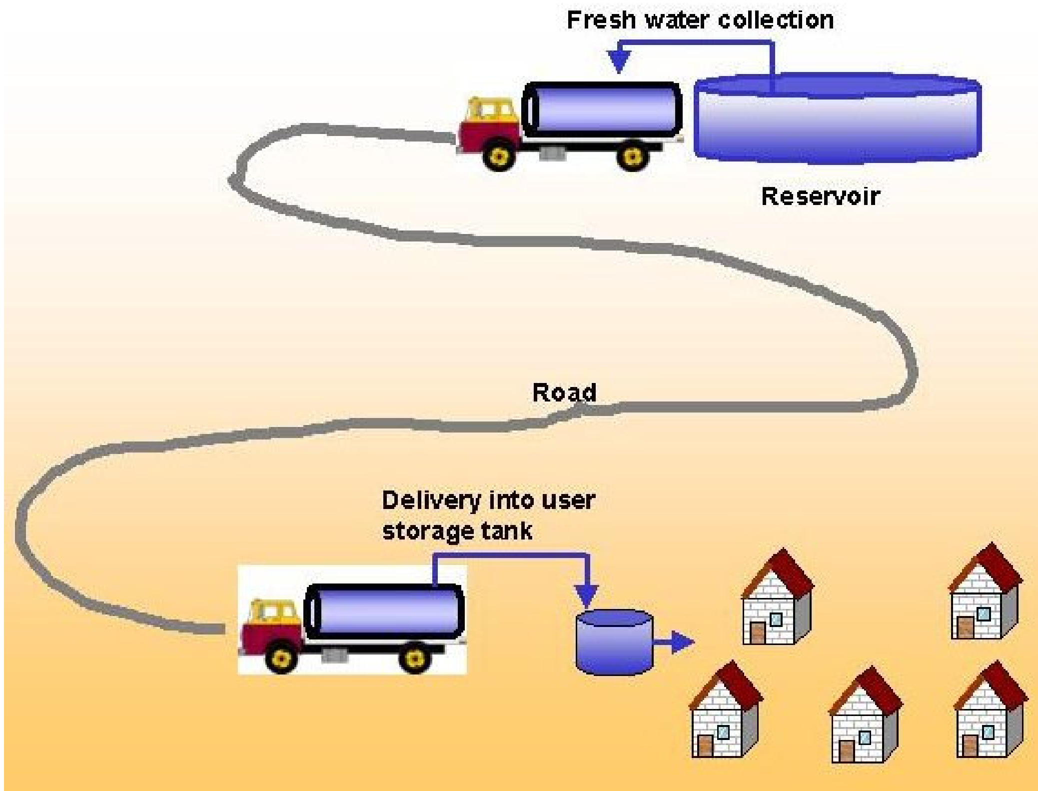


FIGURE 3.12: BASIC RETICULATION SUPPLY SYSTEM

3.2.14: TRUCKING (ROAD TRANSPORT)

Definition	Conveyance of water by tanker trucks involves the transfer of water from ground and surface water sources in an area where the available resources exceed demand to an area where demand exceeds available resources.
Technical considerations	Water tankers with pumps, water storage facilities at source and recipient sites.
Scope of use	Widely, in times of drought (emergency procedure).
Advantages	• Water tankers are less complex than other supply systems, • Suitable as emergency backup supply systems.
Disadvantages	• Unreliable (trucks may break down or be needed for other essential purposes), • Expensive due to high capital and running costs of water tankers, • Water tankers require adequate road infrastructure.
Energy requirements	Fuel.
Operation & maintenance	Maintenance of trucks requires technical skills. Periodic repairs and cleaning of the storage systems are required.
Water cost per m^3	Economy of scale insignificant. Normally very high, R60-00/m^3 upwards. Costs vary depending on the specific mode of transport, the delivery distance and materials used to construct the storage systems.
Socio-economic considerations	It is a well-accepted water supply method in areas with insufficient water supply.
Effectiveness and / or suitability	Trucking of water is only effective as a last-resort water supply option. Suitable in regions where there is an “availability” of water in one area and a "deficit" in another neighbouring area.
Future prospects	Road transport will remain an emergency water supply system but should not be included in emergency planning (rather look at other alternatives).



<u>FIGURE 3.13:</u> TRUCKING OF FRESH WATER

3.2.15: DISINFECTION

Definition	A process designed to kill micro-organisms in water.					
Technical considerations	The primary methods used for the disinfection of water in very small (25-500 people) and small (501-3,300 people) treatment systems are ozone, ultraviolet irradiation (UV) and chlorine. There are alternative disinfection processes that have been less widely used in small and very small water treatment systems, including chlorine dioxide, potassium permanganate, chloramines and peroxone (ozone/hydrogen peroxide).					
General background information	**Disinfection type**	**CHLORINE**	**SODIUM HYPOCHLORITE**	**CHLORINE DIOXIDE**	**OZONE**	**UV**
	Advantages	▪ Efficient general disinfectant ▪ Efficiently eliminates tastes and odors ▪ Capable of controlling the growth of algae, biological slimes and micro-organisms ▪ Decomposes organic contaminants ▪ Iron and magnesium oxidant. ▪ Low operational costs ▪ Low capital investment	▪ Effective against most of pathogen micro-organisms ▪ Relatively safe during storage and use ▪ Can be generated on-site ▪ Low operational costs ▪ Low capital investment	▪ Operates in low doses ▪ Does not form chloramines ▪ Does not facilitate THM formation ▪ Destroys source of unpleasant taste and odor ▪ Effective oxidant and disinfectant for all types of micro-organisms and viruses ▪ Low capital costs ▪ Moderate running costs	▪ Strong disinfectant and oxidation agent ▪ Very effective against Giardia, Cryposporidium and any other pathogenic microflora ▪ Facilitates removal of turbidity from water ▪ Removes foreign tastes and odors ▪ Does not form chlorine containing THMs ▪ Environmentally friendly ▪ Low operational costs ▪ Moderate capital cost	• Does not require storage and transportation of chemicals • Does not form byproducts • Environmentally friendly
	Limitations	▪ Strict require-ments for transporta-tion and storage ▪ Potential danger for health in case of a leak. ▪ Formation of disinfection byproducts, such as chloroform	▪ Ineffective against cysts (Giardia, Cryptospo-ridium) ▪ Loses its activity during long-term storage ▪ Potential danger of gaseous chlorine emission during storage ▪ Forms THM	▪ Weak disinfectant and oxidation agent compared to chlorine ▪ Not effective against viruses and cysts (Giardia, Crypto-sporidium) ▪ Considerable dosages and prolonged contact time are required for disinfection ▪ Forms nitrogen-containing byproducts	▪ Forms byproducts, including: aldehydes, ketones, organic acids. ▪ Necessitates the use of biologically active filters to remove byproducts ▪ Does not ensure residual disinfection effect ▪ Considerable expenses for operators` training and installation support ▪ High capital costs	▪ No residual effect ▪ Not efficient against cysts (Giardia, Crypto-sporidium) ▪ Disinfection activity depends on the water turbidity, its hardness, precipitation of organic impurities on the bulb surface, and deviations in the power supply, which effect the wavelength variation ▪ High running costs ▪ High capital costs

SOCIO-ECONOMIC BACKGROUND REPORT

Research Report

SOCIO-ECONOMIC STUDY TO GUIDE ALTERNATIVE SMALL SCALE DESALINATION TECHNOLOGY FOR POTABLE HOUSEHOLD WATER AUGMENTATION IN SOUTH AFRICA

by

Seconna, J.D., Delcarme, B.A., Daries, L.M., Lodewyk, L-A., Bartlett, R.

December 2002

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ABSTRACT:

Many small remote and poor communities in South Africa face severe constraintsrelating to terms of the quantity and the quality of household water due to their particular geographical and climatic conditions (e.g. along the West Coast, Namaqualand and Bushmanland, and in the Karoo regions). Consistent saline water sources, e.g. sea or brackish ground water, are often readily available, meaning the potential for production of fresh water through desalination exists. Desalination technologies are frequently considered to be too expensive or sophisticated for long-term implementation and maintenance at these communities. It may be possible that economically feasible and community-acceptable desalination options do actually exist, but that relevant authorities do not have access to the information at the point of decision making.

Because socio-economic conditions may impact on the technologies acceptable and affordable to communities, a socio-economic study was undertaken.

OBJECTIVE:

That the proposed desalination guide, together with the Assessment Guide for the Quality of Domestic Water Supplies will guide the user with socio-economic guidelines applicable to typical target communities.

METHODOLOGY:

This is a cross-sectional descriptive study. The target population consists of communities with either a limited or poor access to water as well as those who have access, but to a water source of which the quality is poor.

RESULTS:

The main findings indicate that the bulk of the poorer communities are willing to pay for water and are willing to participate in water provision projects. More affluent communities regard water provision as a responsibility of government, i.e. Local Municipal Authorities.

1. INTRODUCTION

79% of the Metros and Local Municipalities are providing free basic water to approximately 26.8 (57.6%) million people. On average, South Africans in rural households were forced to travel in excess of 500 meters away from their homes to obtain water for their daily needs. Discriminatory laws and practices of the previous government e.g. the Water Act of 1965, (which was framed to provide an unlimited supply of water to the privileged few, rather than to provide drinkable water and sanitation to all South Africans brought this about).(1) For many rural inhabitants the situation has remained unchanged, e.g. where water is available the quality thereof relating to taste, odour, turbidity (colour) is unacceptable. Currently 20% of South Africans depend on small water systems for their well-being and an additional 20% do not have access to basic services for which the implementation of small water systems may serve relief. (2)

Consistent saline water sources in the form of sea or brackish ground water is readily available along the West Coast, i.e. freshwater through desalination can be produced. However, economically feasible and community acceptable desalination options need to be considered and the relevant authorities should have access to this information at the point of decision-making. To this end Peninsula Technikon undertook a socio-economic study of which this information will guide the water supplier, as to the most affordable option for supplying potable household water to the specific target community. This information will guide decision makers as to cost effective and acceptable water treatment and augmentation solutions to the communities they serve. The University of Stellenbosch is compiling a database of technical and economic information on existing small-scale desalination and augmentation technologies, and on new and emerging technologies.

2. PURPOSE

Socio-economic conditions play a major role in the acceptability and affordability of technology. This socio-economic study was conducted with the sole purpose of identifying the social and economic conditions that will impact on the implementation of small desalination technologies. The findings of this study will therefore be utilized to develop a guidebook for decision makers which will assist them on deciding which technology, taking into account the socio-economic status of the target community, would be the most appropriate water treatment and augmentation options.

3. METHODOLOGY

3.1. Research Design:

The research design used was a cross-sectional descriptive study. One-day workshops were held with experts to develop the questionnaire. Variables that were considered were: demography, housing structure, waters source, water quality, community involvement, participation and willingness to pay.

3.2. Data collection:

Study population: This study targeted the following types of communities for data collection:

(1) have access to water but the quality is poor (i.e. exceeding SABS maximum allowable limits for TDS, nitrates and fluorides), and

(2) have no or limited access to water but the quality is good.

Sampling Procedure: the study was conducted during the agricultural sowing season and it was therefore difficult to obtain fixed appointments with respondents. For this reason accidental non-probability sampling was done and only those at home during study were interviewed on the basis of 1 person per household, which was administered to 210 households in seven communities including six farms.

Geographical Area

South Western Cape:

– Spieskamp

Northern Cape:

– Spoegrivier
– Kheis

Western Cape:

– Kleinhoekie
– Moorreesburg
– Klipfontein
– Sam-sam Hoek

3.3. Questionnaire development:

A one day workshop with experts was held to develop the questionnaire. Variables that were considered are: demography, housing structure, waters source, water quality, community involvement, participation and willingness to pay

3.4. Pilot study:

A pilot study, to test and modify the questionnaire, was conducted at a site with an existing small-scale desalination technology.

3.5 Data Analysis:

Statistical analysis was done by making use of the Statistical Package for the Social Scientists (SPSS). After cleaning, data is presented in the form of frequency tables and charts, cross-tabulations, etc. In addition the results of this study were compared to those from other studies after extensively reviewing literature. Findings from the reviewed literature are highlighted when relevant.

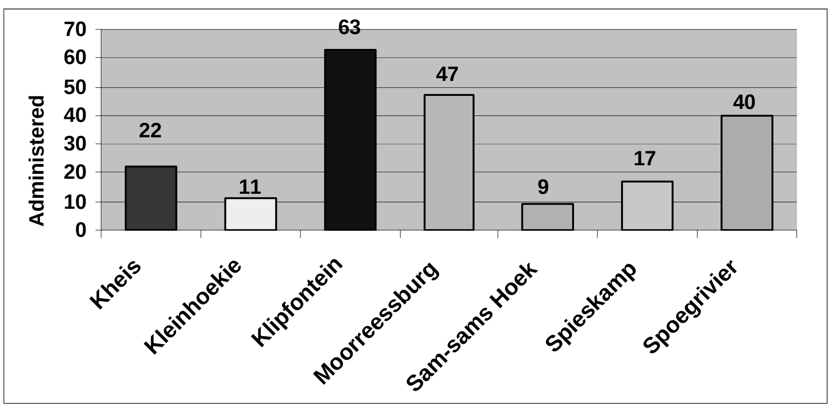
4. LIMITATIONS

Some of the interviewers had language problems because Afrikaans was not their first language and the questionnaire-training period was too short. In certain areas some respondents were not available or willing to participate in the study due to personal reasons. The study was conducted during the rainy season, which, together with long travelling distances and poor infrastructure, limited access to identified communities.

5. RESULTS AND DISCUSSION

210 questionnaires were administered within 7 communities, which includes 6 farms.

Figure 1: Questionnaires administered



5.1. Community Description

The communities can be described as small (population<100 households) isolated rural communities with low levels of education, average occupancy of 4 persons and a monthly household income ranging from R500 –R 1000. Water is limited with regards to quality and access, and infrastructure is poorly developed.

5.2. Demographics

Gender-wise, the respondents consisted of 59% females and 41% males. The majority of respondents, 40% (n=210), did not complete primary school (*Table 1*) while 75.5% of the population is unemployed with an average income of between R500 – R1000 per month (*Table 2*).

Table 1: Education Levels of the sample population

Education level of respondent

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Primary school incomplete	84	40.0	40.0	40.0
	Primary school complete	49	23.3	23.3	63.3
	High school incomplete	42	20.0	20.0	83.3
	High school complete	19	9.0	9.0	92.4
	Post high school qualifications	4	1.9	1.9	94.3
	No schooling	12	5.7	5.7	100.0
	Total	210	100.0	100.0	

Technology employed should thus be appropriate to the needs and skills of the community so that they can operate and maintain it.[(3)] In addition to this, the technology implemented should be affordable to the community and be energised at a sustainable level.

Table 2: Employment Status and Income

Monthly household income* Employment status of respondent
Cross tabulation

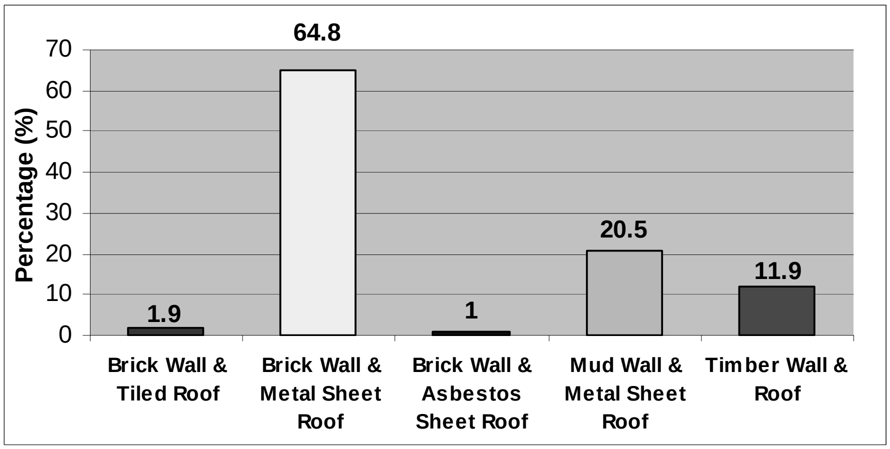
Count

Monthly household income	Employment status respondent		Total
	Employed	Unemployed	
R0- R100		4	4
R100 – R500	8	31	39
R500 – R1000	24	58	82
R1000 – R2000	19	34	53
R2000 – R4000	6	8	14
R4000 – R6000	1		1
More than R8000	2	1	3
Total	60	136	196

5.3. Housing Structure

64.8% of residential dwellings are constructed with brick walls and metal roof sheeting, while only 1% of residential dwellings had asbestos roof sheeting. It was important to ascertain structural composition especially where rainwater roof collection would be considered as an option for water augmentation.

Figure 2: Household building construction materials used



5.4. Water Sources

The main water source appears to be communal taps. 43.5% of respondents obtain household water from a communal tap of which the feeding source varies from boreholes, rainwater reservoirs, rivers and streams. Water from the boreholes requires desalination in order for it to be fit for human consumption. Only 14% of respondents have taps inside their houses.

On average water collection time ranges between 0 – 10minutes(62.9%), and 21 – 30minutes (7.6%), and daily water usage per household is between 11 – 20L (*Table 4*). Water is normally collected in either buckets (33%) or watering cans (52.4%) which on average (44.8%) are cleaned on a daily basis. Cleaning agents used to clean water containers includes sand, Jik, soap and washing powder (*Table 3*).

The water feeding sources has not changed but the quantity and quality has. Salinity, brackish and odour remains the dominant water quality problems. Water quantity and accessibility is influenced by remoteness from major water sources and communication routes, isolation from dynamic economic sectors, location in water-scarce area and low level of living.

5.5 Hygiene: Community involvement

At the heart of any social challenge, is the premise that appropriate development cannot take place without considerable participation from local communities. It is therefore important for communities to undertake an active role in hygiene and sanitation practices. Water contamination can easily occur where hygiene practices are neglected or ignored. Diseases associated with contamination include, water-washed disease e.g. Trachoma, water-borne diseases e.g. Cholera, water-related diseases, e.g. Malaria, and water-based diseases, e.g. Schistosomiasis. Regular disinfection of drinking water and containers lead to a reduction in the incidences of these diseases.

The study revealed that even in the absence of awareness, education or training around water hygiene and sanitation, households are in the habit of cleaning their collection containers every time water is collected. The frequency of cleaning in this case varied between one (01) and three (03) times per day using cleaning agents ranging from Handy Andy, to sand to washing powder as illustrated in figure 3.

Collected water is normally decanted over into home-storage containers. It thus becomes necessary to educate and raise awareness about hygienic storage practices, as the link between sanitation, hygiene and health cannot be over-emphasized.

It is important to educate and make communities aware of the fact that, even in areas where the provision of clean accessible water and ideal sanitation facilities are not within community reach, households can still adopt hygiene behaviours, which can lead to better health.

Figure 3: Types of cleaning agents used

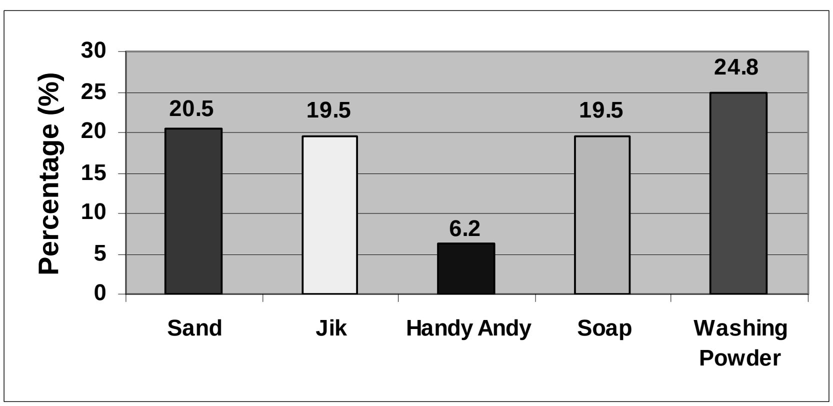


Table 4: Daily Water Usage (Litres)

Daily water usage (Litres)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0 - 10	45	21.4	22.1	22.1
	11 - 20	63	30.0	30.9	52.9
	21 - 30	47	22.4	23.0	76.0
	31 - 40	10	4.8	4.9	80.9
	41 - 50	21	10.0	10.3	91.2
	51 - 60	5	2.4	2.5	93.6
	71 - 80	3	1.4	1.5	95.1
	91 - 100	8	3.8	3.9	99.0
	More than 100	2	1.0	1.0	100.0
	Total	204	97.1	100.0	
Missing	System	6	2.9		
Total		210	100.0		

5.6. Water Quality

76,2% of respondents felt that the water was safe to drink. Respondents regards water quality as water that does not affect health and that has no objectionable taste or odour: “ Water must be clean, fresh and healthy”, “Must be no problems with water”, “Water that doesn’t make you sick”. Some respondents included accessibility to water, as part of their opinion of water quality: “ Water that is good, safe and accessible…” and “Clean water piped to houses”, “Drinkable water that is affordable and accessible…”, “ Level (standard) of water cleanliness, hygiene and its availability”.

26,2% of respondents indicated that they had experienced health problems in the form stomach pains and cramps (24,3%), which they ascribed to the water.

5.7. Community Involvement:

Respondents provided information as to community organisation that they, or persons from their households belong to:

- 54.3% belong to an organisation which includes the following: Church, School, Work, Sports, Political, and Community

5.8. Community Participation:

Respondents were asked whether they would be willing to participate in any future water projects (Table 5). 8.1% of the respondents were exposed to water related training while 67.6% of untrained persons indicated a willingness to be trained. Should technical breakdown of the technology employed arise, trained community members, as a result of collective willingness, would know how to deal with it. [5,6]

Participation would be in the form of administration, water educators, water inspectors, maintenance and cleansing, drivers, etc.

Reasons for non-participation includes: lack skills and proper training, employed currently, not interested, too old, medical condition, community participation process lacking.

Table 5: Participation in future water projects

Participation in future water projects

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	176	83.8	85.0	85.0
	No	31	14.8	15.0	100.0
	Total	207	98.6	100.0	
Missing	System	3	1.4		
Total		210	100.0		

It is important (for the sustainability of any intervention) that the community be consulted and participate fully in decision making, implementation, evaluation, and maintenance thereof. This needs to occur in order to avoid inappropriate services, conflict, and vandalism of water treatment equipment [(7)].

5.9. Water payment:

Only 12.9% of the respondents indicated that they are not willing to pay for water. However, the others are willing to pay especially if water access and quality is to improve and appropriate payment plans are made for the unemployed and pensioners.

Table 6: Commitment to pay for Water

Commitment to pay for water

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	181	86.2	87.0	87.0
	No	27	12.9	13.0	100.0
	Total	208	99.0	100.0	
Missing	System	2	1.0		
Total		210	100.0		

Only 12.9% of respondents indicated a non-commitment to pay for water. Those willing to pay will do so on condition that water quality improves, payment plans be worked out especially for low income groups, employment opportunities accompany water projects and taps inside homes are provided. They also indicated that others could be encouraged to pay by ensuring water safety, affordability, and better access to water.

The interviewers noted that the bulk of poorer respondents are willing to pay for water and are willing to participate in water provision projects whereas affluent respondents regard water provision as a responsibility of government i.e. local municipal authorities.

Community participation and involvement in every aspect of project may bring about social sustainability as ownership may come automatically be accompanied by responsibility and acceptance which is essential for co-operation and maintenance of such project. This in itself may lead to financial sustainability, i.e full cost recovery for operation and maintenance replacement costs. [3]

5.10 Water Demand Management

Nationally, water demand has increased due to greater human rights demands since 1994. Government and the responsible ministries pledged to spent more than R1bn for the period 2001 – 2003 to bring clean water to a million people. An additional EU grant of R613m for the same period was given to boost the increased access to clean water.

A national water audit and the National Water Act 36/1998 allows for the effective management of South Africa’s water.

The National Water Act (Act.36/1998) recognizes that it is neither practical nor realistic to expect that all impacts on water quality can be avoided. Without impacts there will be minimal socio-economic growth. Challenges are to marry development for socio-economic growth such as agriculture, mining, industry, power generation and the urban settlement with maintaining water that is fit for use and protection of the aquatic ecosystem This is the principle of sustainability which is the basic foundation of Agenda 21, The South African Constitution and the Bill of Rights.

Numerous cities in South Africa experience water crises and forecasts show a demand for the Uni-city of Cape Town to rise between 4 – 5% annually. Desalination technologies came as a possible solution to this increasing demand, over and above the fact that the proposed Skuifraam Dam planned to be completed in 2011 is going ahead.

This project will supply extra 81billion litres of water per year to the Western Cape’s dams and ensure a sustainable water supply to the Province. The city also explored the possibility of establishing a pilot desalination reverse osmosis plant removing salt from seawater in the West Coast Region

The limited water resources of South Africa is a national asset that must be properly managed if they are to bring maximum benefit to the people as a whole. The Department of Water Affairs and Forestry has the national responsibility in the three-tier government system of ensuring that both the needs of the people and of the economy, which sustain them, are effectively met. National water demand management should be centred on lowering or mitigating proposed demands in a more socially beneficial manner. Water demand signals a shift to management of the water sources for sustainability, therefore both the quality and quantity aspects of water must be preserved to support public health and socio-economic development.

The other two tiers, Provincial and Regional Governments, Water Boards and Local Governments, identify priorities and critical areas of need, and provide the services.

Water demand management relies on the implementation of a range of tools and techniques to promote better water use. Increasing conservation and promoting sustainability in the use of water resources with monetary incentives and disincentives will inform users of the value of water. Water pricing is one of the fundamental keys to water demand management, but must not substitute other measures of management, due to the greater effect it may have on the poor. Structural and operational techniques (internal and external re-use), improving household equipment (redesigning) must complement economic measure such as pricing and social techniques (policy, education, laws, etc). These techniques are mutually reinforcing and most effective when implemented jointly.

5.11 Effective Water Usage

Effective use of water is an important aspect in addressing the consumption-supply dichotomy as in certain areas consumption exceeds supply. According to the study the community demonstrate the effective use of water in the following ways:

1. In some communities certain days and stipulated times are put aside for the unlimited collection of clean water. Although this water could be used for any purpose, the majority of community members prefer to utilise it for cooking and drinking purposes. The borehole water, collected on a regular basis, is then used for other purposes such as washing, cleaning and gardening.

2. Abuse and wastage of water is drastically reduced by the fact that the operator locks the taps at regular intervals.

6. CONCLUSION

Most poor rural communities express their willingness to pay for water on condition that this is affordable or that an economically acceptable payment plan be designed to suit them. Further conditions are that water quality be improved, training and employment opportunities be provided to community members. Accessibility, i.e. a water point in the home is also a requirement for sustainability of any water treatment and augmentation project.

Due to the wide geographical dispersal of the water-short population it seems highly unlikely that a single conventional scheme could be conceived to eliminate all existing shortages in this region. But one should always bear in mind that if any project wants to be successful then community participation does not begin at the end of the project but the start. Communities need to be part of the entire project cycle. This will include their involvement in decision-making, planning, implementing, operation, evaluation, and maintenance of the project.

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APPENDICES

GLOSSARY OF TERMINOLOGY

ANALYSIS	*A means of establishing the purity and safety of water in terms of various chemical, physical and microbiological contaminants.*
ACCEPTABLE HOUSEHOLD WATER STANDARDS	*Contaminant levels in water do not exceed those set down by legislation that may negatively affect household activities and/or be detrimental to human health.*
ACCEPTABLE HYGIENIC PRACTICES	*(Household) practices that do not contaminate water, ensuring that water quality remains suitable for human consumption, dermal contact, cooking or washing.*
ADSORBENT	*A water treatment medium, usually a solid, capable of the adsorption of liquids, gases, and/or suspended matter (e.g. alumina and activated carbon).*
BASIC WATER SUPPLY	*The prescribed minimum standard of water supply services necessary for the reliable supply of a sufficient quantity and quality of water to households to support life and hygiene.*
BRACKISH WATER	*Water containing significant levels of dissolved salts, normally > 1000 mg/l but < 30 000 mg/l (seawater).*
BRINE	*Waste water from a desalination process containing high quantities of sodium chloride and/or other dissolved salts.*
COMMUNITY DESCRIPTION	*Number of households and people in a community.*
CONSTANT WATER SOURCE	*See sustainable water source.*
COST-EFFECTIVENESS	*Achieving a given water supply of required quality at minimum cost*
DAILY HOUSEHOLD WATER REQUIREMENT	*The average daily consumption of water for household activities (including drinking, cooking, bathing, washing).*
DEFLUORIDATION	*Reduction of fluoride levels in water.*
DENITRIFICATION	*Reduction of nitrate concentrations in water.*
DESALINATION	*The process improving water quality by removing salts and other minerals from raw water to produce fresh and clean household water.*
DISINFECTION	*A process designed to kill microorganisms in water, including all disease-causing organisms.*
DISSOLVED SOLIDS	*The mass of solid matter in solution in a specific volume of water; includes both inorganic and organic matter.*
DUAL WATER SUPPLY SYSTEMS	*Systems supplying water of two qualities: one of drinking water quality and the other of a quality that is not safe for drinking but which is suitable for other purposes such as sanitation or washing.*
EFFECTIVENESS	*The ratio: unit of output per unit of input.*
EFFICIENCY	*The effectiveness of the operational performance (of a water supply process).*
END-USERS	*Single households,*
EQUITABLE SHARE	*Fairness in the provision of resources (in this case household water of good quality) to enable decent living standards.*
EXTERNAL TECHNICAL SUPPORT	*Back-up O & M support supplied by technology provider after hand-over of water supply system to community / local authority.*

FEED WATER	*Water as it enters a treatment system, untreated water.*
FILTRATION	*A process by which particulate matter is removed from feed water by passing the water through a filter (filter = a device or system for the removal of suspended solid particles).*
FOG HARVESTING	*A household water supply option making use of nets to collect fresh water from fog, see Section 3.*
FLUORIDE CONCENTRATION	*Level of fluoride ions in water, in mg/l.*
FOULING (OF MEMBRANES)	*The deposition of retained particles, colloids, emulsions, suspensions, macromolecules, salts, etc. on or in a membrane*
FRESH AND CLEAN WATER SUPPLY	*Water suitable for human consumption, also termed potable water.*
HOUSEHOLD WATER SUPPLY	*Water used by a household for drinking, cooking, washing and bathing purposes (excludes sanitation).*
INFRASTRUCTURE	*Parts and components additional to the main water treatment process, that is necessary to supply water to a community or household (e.g. pipes, reservoirs, pumps).*
LEVEL OF SERVICE	*The proximity of the household water point to the household (distance to water collection point).*
MEMBRANE	*A selective barrier between two volumes of water of different salinity levels and which allows passage of water but not of dissolved solids*
NANOFILTRATION, NF	*A membrane process that treats water between reverse osmosis and ultrafiltration the filtration/separation spectrum. Nanofiltration may be used for selective removal of hardness ions.*
NITRATE CONCENTRATION	*The level of nitrate ions in water, expressed in mg/l.*
OPERATION AND MAINTENANCE, O & M	*Routine prescribed actions undertaken by trained operators to ensure continuous and safe water supply from a water treatment or collection system.*
PRE- AND POST-TREATMENT	*Water treatment processes additional to the main treatment process, necessary for the provision of household water supply. These can be carried out on the feed water and / or the product water (e.g. softening, filtration, pH adjustment).*
POTABLE WATER	*Water suitable for human consumption / drinking water that does not impose a health risk.*
RAINWATER HARVESTING	*Rainwater collection for household use, normally from rooftops.*
RECOVERY	*Volume of fresh water obtained from a volume of saline feed water after desalination, normally expressed as a percentage.*
REGULATORY STANDARDS	*Standards or specifications set by national authorities prescribing the acceptable limits of different contaminants in water.*
RENEWABLE ENERGY SOURCES	*Energy resources that are replaced rapidly by natural processes e.g. solar, wind.*
ROAD TRANSPORT	*The use of vehicles and road infrastructure to transport water from a source to the end-user.*

RUN-OFF COLLECTION	*The capture and storage of rainwater runoff from paved and unpaved roads.*
SALINITY	*The measure of total dissolved salt in water.*
SMALL-SCALE WATER SUPPLY	*Water supply to isolated communities or households i.e. not bulk or metropolitan water supply.*
SOCIO-ECONOMIC	*Interaction of social and economic factors*
SOLAR RADIATION LEVELS	*The amount of solar energy reaching a particular point on earth, normally expressed per unit of time (annually, monthly, daily).*
SUITABILITY	*Degree of appropriateness.*
SUPPLY CAPACITY	*The maximum volume of water that can be supplied by a particular water supply system, normally expressed in volume per time unit (e.g. kiloliters per day).*
SUSTAINABILITY, SUSTAINABLE	*General: Ability to deliver an appropriate level of benefits over a prolonged period of time without negatively affecting the environment, and with all O&M and replacement costs covered coupled to feasible external support.* *Specific: Continuous delivery of an appropriate quantity of water of the desired quality after external support has stopped.*
TARGET AREAS OF GUIDEBOOK	*Rural geographical areas where access to clean and fresh household water is problematic due to the salinity of the existing water source(s)*
TARGET GROUP	*A group that has been identified for a particular set of reasons.*
TDS, TOTAL DISSOLVED SOLIDS, TDS	*The weight of solids per unit volume of water, which are in true solution. Total dissolved solids are a measurement of any minerals or salts in water.*
TREATMENT METHODS	*The use of a specific process / method / technology to reduce the level of a contaminant in drinking water.*
ULTRAFILTRATION, UF	*Filtration through a medium (membrane) which allows water to pass but holds back larger molecules (e.g. proteins, viruses)*
WATER DEMAND	*The amount of water that needs to be provided to an end-user (or group of end-users) to meet minimum daily usage requirements.*
WATER QUALITY	*The physical, chemical and biological content of water.*
WATER SUPPLY OPTION	*The assembly of one or more pumps, pipes, storage structures, treatment equipment, and distribution network to a water user or community.*
WATER TREATMENT FACILITY	*Plant and/or equipment used for water treatment (e.g. desalination).*
WATER SERVICES AUTHORITY, WSA	*Municipal authority with institutional responsibility for ensuring access to water*
WATER SERVICES PROVIDER, WSP	*Institution tasked by the WSA to provide water services to communities (may be WSA itself)*

LEGISLATIVE FRAMEWORK

B1. Local government transformation

It is now possible for local government to assume full operational responsibility for water and sanitation services as provided for in the **Constitution** of the **Republic of South Africa (Act 108 of 1996).** This means that the role of the Department of Water Affairs and Forestry (DWAF) will change from being a direct provider to being a sector leader, supporter and regulator. The 2002 Division of Revenue Act provides a timetable for the phasing out of the DWAF's operational role over the next three years.

B2. New water policies

The **Water Services Act 108 of 1997** made important policy advances specifically with respect to the institutional framework. The free basic water policy represents a further policy development within broad municipal and intergovernmental policy towards the goal of access to basic water services by all. Water resources policies have been fundamentally overhauled subsequent to the 1994 White Paper, as reflected in the White Paper on a National Water Policy for South Africa (April 1997) and the **National Water Act 36 of 1998**. A White Paper on Basic Household Sanitation (referred to hereafter as the **Sanitation White Paper**) was published in 2001 and extends the sanitation-related policies in the 1994 White Paper. The White Paper on Municipal Service Partnerships (April 2000) sets out policies and procedures for engaging with public and private agencies. These extend the policies embedded in the Water Services Act.

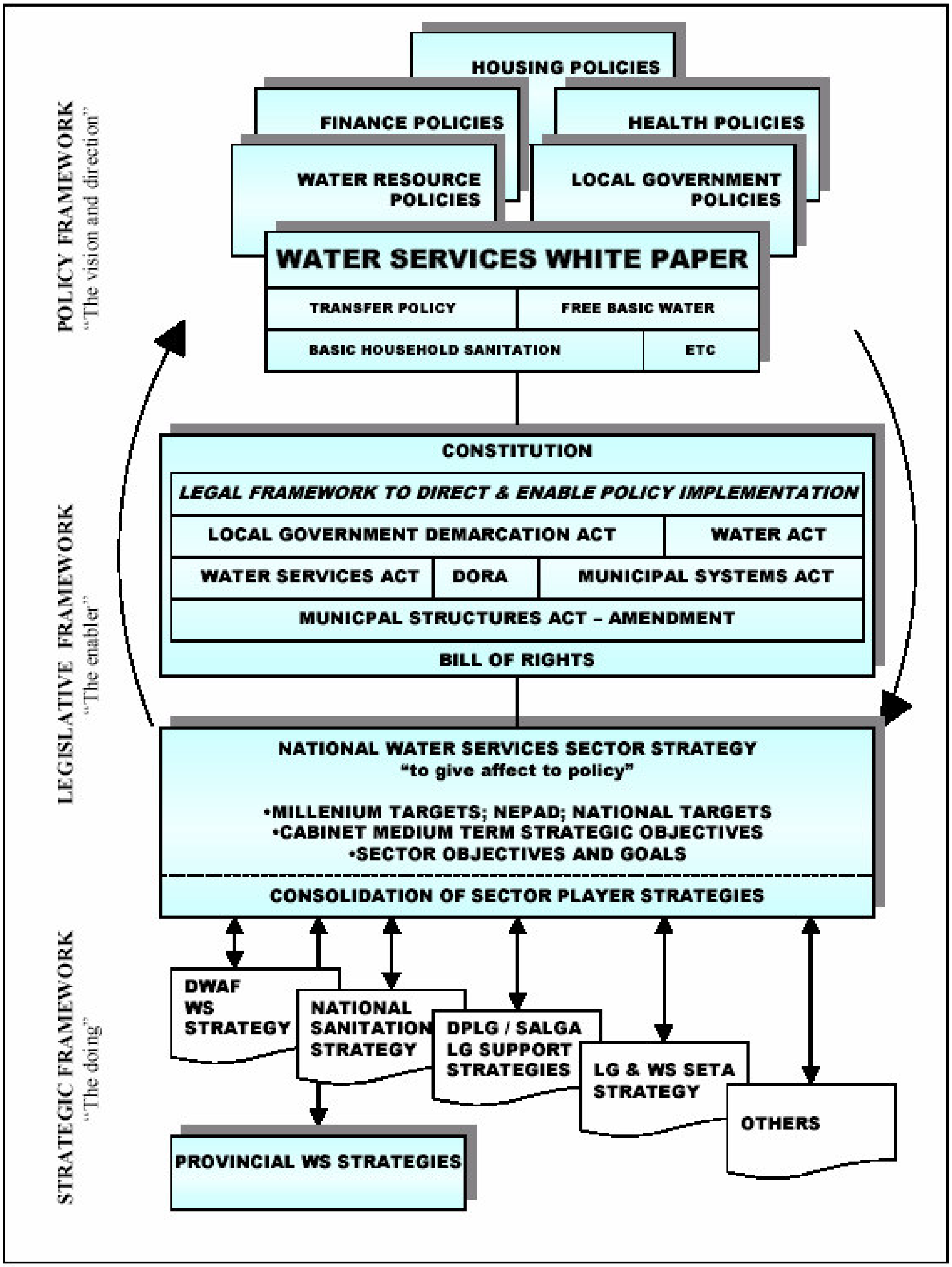

Figure 1: Water services policy context

B3. Change in the definition

The definition of water supply services is not restricted to potable water (as in the **Water Services Act**) but includes all water supplied by or on behalf of a water services authority. The definitions of water supply services and sanitation services also include all aspects of the service necessary for the provision of an adequate service, specifically the business processes (such as billing and revenue collection) and hygiene and water-use education. The definitions in the Water Services Act need to be amended accordingly.

A basic water supply is defined as the provision of appropriate education in respect of effective water use as well as a minimum quantity of 25 litres of potable water per person per day (or 6 000 litres per household per month) within 200 metres of a household, which is not interrupted for more than seven days in any year; and with a minimum flow of 10 litres per minute in the case of communal water points (**Section 9(1) regulations of the Water Services Act** need to be amended to apply the minimum flow of 10 litres per minute to communal water points only and not all water connections). (Potable water is defined as drinking water that does not impose a health risk).

B4. Definition of water services authority (WSA)

The definition of a water services authority remains unchanged from that in the **Water Services Act 108 of 1997 (Chapter III, Sections 11 to 21)**.

B5. Social principles

Everybody has a right to a basic water supply and sanitation. Everyone has the right to have access to sufficient water, to an environment that is not harmful to his or her health or well-being and to have the environment protected, for the benefit of present and future generations. The state must take reasonable legislative and other measures, within its available resources, to achieve the progressive realisation of these rights. **(Constitution, Sections 24 and 27)**

B6. Environmental and technological principles

Water services should take into account their impact on the natural environment and seek to minimize any negative impacts through remedial measures. Integrated and sustainable management of the environment, now and in the future, is the basis of sustainable development in everything that people do. **(Environmental Management Policy White Paper, 1999)**.

B7. Rational choice of technology

In the choice of technology, a trade-off must be made between effectiveness, affordability, lifecycle costs, consumer acceptability and environmental impact. Users should be fully informed of the available technical choices and related financial implications. Water and sanitation technologies should be considered together. Technology choices should be made in the context of an integrated planning process involving community participation.

B8. Designation as a water services authority

In terms of **Section 84** of the **Municipal Structures Act**, the responsibility for providing water services rests with district and metropolitan municipalities. However, the **Act allows** the **Minister of Provincial and Local Government Affairs** to authorise a local municipality to perform these functions or exercise these powers. The district (or authorised local) municipality is the water services authority as defined in the Water Services Act. There can only be one water services authority in any specific area (that is, water services authority areas cannot overlap).

B9. The role of national government

The Constitution obliges the state, that is, all three spheres of government, to realise the rights entrenched in the **Bill of Rights. Sections 154(1) and 155(7) of the Constitution** task both provincial and national government, by legislative and other measures, to support and strengthen the capacity of local government to manage their own affairs, to exercise their powers and to perform their functions. The **Bill of Rights** also gives provincial and national governments the legislative and executive authority to see to the effective performance by municipalities of their functions in respect of matters listed in **Schedules 4 and 5**, by regulating the exercise of this executive authority.

Section 152(1)(b) of the **Constitution** states that one of the objectives of local government is to ensure the provision of services to communities in a sustainable manner and **Schedule 4B** specifically identifies water and sanitation services (limited to potable water supply systems and domestic wastewater and sewage disposal systems) as a local government function. The provision of access to water services is thus a functional area of concurrent national and provincial legislative competence.

The **Water Services Act** provides a developmental regulatory framework for the provision of water services. The **Act enables** national government to set national norms and standards for tariffs to ensure efficient, reliable, affordable and equitable water services, while building capacity in and assisting local government (defined as water services authorities in the Act) to perform its functions.

B10. National Water Advisory Council

The National Water Advisory Council, established in terms of the **National Water Act**, deals with both water resource and service issues and has an important role to play in strengthening the voice of civil society at national level and regional co-operation based on a services delivery agreement: (e.g.) Municipality A is a water services authority but is reliant on a bulk water supply system located in neighbouring Municipality B. Municipality A contracts with Municipality B in terms of a contract (service delivery agreement) to provide Municipality A with bulk water at the point where the pipeline crosses the municipal boundary. In this context Municipality B is a bulk water services provider to Municipality A.

B11. Regional co-operation based on the establishment of a municipal entity

Two municipalities agree that there are practical and economy-of-scale advantages to operating their water services on a regional scale. After considering various options, as required under the **Municipal Systems Act**, they decide to set up a municipal entity in the form of a company with each municipality a shareholder. They decide that this entity will be the water services provider for their whole area, taking responsibility for bulk and retail services. (This arrangement could apply to bulk water services only.)

B12. Choosing water services providers

Community-based organisations (CBO's) run small water schemes in rural areas. The **Municipal Systems Act** classifies CBOs acting as water services providers as an external mechanism. This means that the selection of CBOs as water services providers requires a competitive tendering process. This is not appropriate and a recommendation to change the **Municipal Systems Act** will be made. A water services authority may undertake a "generic process" (in terms of **Section 78 of the Municipal Systems Act**), which identifies the general conditions under which the selection of CBOs as water services providers is appropriate. This means that a water services authority does not need to undertake a Section 78 process for every decision to appoint a CBO as a water services provider.

B13. Selection of CBOs and the Water Services Act

The feasibility of CBOs acting as water services providers should be considered prior to engaging with private operators in terms of the **Water Services Act**.

B14. DWAF ownership and control of water boards

This is the current policy as reflected in the **Water Services Act**. The Minister of Water Affairs and Forestry has the power to establish and disestablish water boards. The Minister is responsible for the regulation of water boards, including economic and financial regulation in terms of the **Public Finance Management Act**. In terms of the **Water Services Act**, water boards are also required to enter into contracts with water services authorities and other water services providers to whom they provide services. There is a need to distinguish between the accountability arrangements for water boards to national government as “owners” on the one hand and through contractual obligations with other water services institutions on the other.

The **National Water Act** gives effect to integrated water resources management (IWRM) by ensuring that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways which take into account at least the following water services related matters:

- meeting basic human needs;
- promoting equitable access to water;
- redressing the results of past racial and gender discrimination;
- promoting the efficient, sustainable and beneficial use of water;
- facilitating social and economic development;
- providing for growing demand for water use; and
- reducing and preventing pollution and degradation of water resources.

B15. Water Management Institutions

Three types of water management institutions are conceived by the **National Water Act** to give effect to integrated water resource management:

- catchment management agencies;
- water user associations; and
- bodies responsible for international water management.

Catchment management agencies will be established to manage water resources in each of the 19 water management areas (which cover the entire country), as defined in the **National Water Resource Strategy**. The DWAF regional offices will act as the catchment management agency in water management areas where catchment management agencies have not yet been established.

B16. Capacity in municipalities

• User charges (tariffs) are set by water services authorities. These are regulated in terms of **Section 10 of the Water Services Act** and regulations gazetted in terms of **Section 10** and the **national economic regulatory framework**.

• Contract or service delivery agreement: a key instrument of regulation is the contract or service delivery agreement between the water services authority and the water services provider. In terms of **Section 19(5) of the Water Services Act** the Minister has regulated the content of such contracts by means of regulations. (Notice

R 980 of 19 July 2002 in the Government Gazette.)

The **Water Services Act** specifically authorizes bulk water services providers to limit and/or disconnect bulk water services to water services providers that default on payment for services provided. However, in view of the implications of this for ordinary consumers, this should be regarded as a last resort. The extent and scope of credit control processes, procedures and mechanisms should be addressed in the contractual relationship between the water services authority and the bulk water services provider. In terms of the **Water Services Act**, these should provide for at least:

- adequate notice to a water services authority to pay for services provided;
- an opportunity for the water services authority to make representations;
- alternative arrangements for payment of the amount due;
- notification of the mechanism that will be applied in the event of non-payment;
- notification of the MEC for local government and the Minister of Water Affairs and Forestry.

B17. Planning by water services authorities

A framework for planning by water services authorities is set out in the **Water Services Act**. The key instrument of planning is the water services development plan. This is designed and intended to be part of the **relevant municipality's IDP** and should ideally be prepared as part of the same process.

B18. Technology and service levels: Making choices

The choice of technology for water supply and service levels can have a very significant impact on the financial viability and sustainability of services. Hence these choices are a critical component of water services development planning. It is especially important that these choices are made in an informed way, taking into account all of the relevant factors.

B19. The role of minimum standards

National government has defined a set of compulsory minimum "norms and standards" in terms of the **Water Services Act**. The intention of these standards is to protect the interests of consumers by ensuring that certain basic minimum standards are met.

Both the **Water Services Act N°. 108 of 1997** and the **Water Act N°. 36 of 1998** require details on socio-economic aspects, physical attributes and demographic attributes of each area when considering a pricing strategy.

B20. Water conservation and demand management

Water resources need to be managed in an integrated manner. Historically, more emphasis has been placed in South Africa on water supply than water demand management. However, in the context of water scarcity and the present unequal distribution of water resources in South Africa, water conservation and water demand management are becoming increasingly important. Where appropriate planning has not been done, licence to abstract additional water may be denied in terms of the **National Water Act**.

B21. Interventions

In terms of the Constitution, local government is an independent sphere of government. The Constitution assigns to local government the executive authority forwater supply and sanitation (water services), including setting tariffs and making by-laws. Provincial and national government may not take actions that undermine local government's ability to exercise this executive authority. This decentralised structure of governance relies on co-operation between the different spheres of government and means that a national regulator must respect the independent rights and duties of local government when regulating. Nevertheless, national government can enforce legislation provided due process is followed (see below).

B22. Enforcing legislation: inter-government issues

National government and provincial governments are obliged to support and strengthen the capacity of municipalities and to see to the effective performance by municipalities of their functions, by regulating the exercise of this executive authority. In exercising these roles, national government must apply the principles of co-operative governance and intergovernmental relations as set out above and contained in **Section 41** of the Constitution. These principles require all spheres of government (and all organs of state within each sphere) to co-operate with one another in mutual trust and good faith by assisting and supporting one another, avoiding legal action against one another; and making every reasonable effort to settle disputes and exhaust all other remedies before approaching a court to resolve a dispute.

B23. Direct interventions

Interventions can range from providing assistance with drafting by-laws to running of the water services for a limited period of time. Although intervention by national and provincial governments is supported by the Constitution and provided for in legislation (**Constitution, Sections 100 and 139; the Water Services Act, the Municipal Systems Act and the draft Municipal Finance Management Bill**), direct intervention should be a last resort. Where interventions are undertaken, these must be co-ordinated through provincial government and DPLG. Section 63 of the Water Services Act needs to be reviewed to improve its effectiveness.

B24. National Environmental Management Act N°. 107 of 1998

To provide for co-operative environmental governance of establishing principles for decision-making on matters affecting the environment, institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state: and to provide for matters connected therewith.

This act states that everyone has the right to an environment that is not harmful to his or her well-being and that sustainable development requires the integration of social, economic and environmental factors in planning, implementation and evaluation of decisions to ensure that development serves present and future generations.

B25. Drinking Water Guidelines (SABS 241: 2001)

This specification lays down the minimum physical, chemical and bacteriological requirements of drinking water as delivered to the consumer.

B26. List of Relevant Policies and Legislation Relating to Water Services

White Papers

White Paper on Basic Household Sanitation – September 2001
White Paper on Municipal Service Partnership – April 2000
South Africa's National Housing Policy – March 2000
White Paper on Environmental Management Policy – April 1999
White Paper on Local Government – March 1998
Transformation of the Health System White Paper – April 1997
Water Policy White Paper – April 1997
Water Supply and Sanitation Policy White Paper – November 1994

Legislation

The Division of Revenue Act 5 of 2002
The Draft Health Bill, 2001
The Local Government Financial Management Bill, 2000 (in Parliament)
The Local Government: Municipal Systems Act 32 of 2000
The Public Finance Management Act 1 of 1999
The Local Government: Municipal Demarcation Act 27 of 1998
The Local Government: Municipal Structures Act 117 of 1998
The National Water Act 36 of 1998
The Water Services Act 108 of 1997
The Intergovernmental Fiscal Relation Act 97 of 1997
The Local Government Transition Act 97 of 1996
The Constitution of the Republic of South Africa Act 108 of 1996
The Health Act 63 of 1977

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