South African Guidelines for the Selection and Use of APPROPRIATE HOME WATER-TREATMENT SYSTEMS by Rural Households

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South African Guidelines for the Selection and Use of Appropriate Home Water-Treatment Systems by Rural Households

Report to the
Water Research Commission

by

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Foreword

In South Africa, the provision of safe drinking water to communities is currently a top priority of the government. Responsibility for the safety of drinking water supplied to consumers is shared by both the Water Services Authorities (WSAs) and the Water Services Providers (WSPs). It is expected that municipalities and private companies provide safe drinking water that complies with the South African National Standard (SANS) 241 for Drinking Water to all communities in the country.

In contrast to metropolitan areas, the South African government still faces a number of challenges in delivering safe drinking water to rural communities, in spite of significant progress made in the provision of this basic service since 1994 through centralised systems such as piped treated water. At least 5 million people in South Africa still have no access to treated potable water within reasonable distances from their dwellings and many thousands are thus forced to use any water source which is available to them, often without treatment. If the country continues to focus only on the implementation of centralised water-supply systems in rural communities that are widely dispersed and peri-urban informal communities that are constantly expanding, the Millennium Development Goals in terms of access to safe drinking water to all will be jeopardised in these areas. This is due to the fact that the implementation of centralised water-supply systems not only requires large financial inputs, generally beyond the financial means of rural villages, but also highly skilled personnel for continuous maintenance and management. However, lack of technical skills in the water sector has been highlighted as one of the major challenges to sustaining quality water provision through small water-treatment plants in non-metropolitan areas of South Africa. Decentralised or point-of-use water collection and treatment systems may therefore be a cost-effective short- to medium-term solution which can be rapidly implemented and bring about improvements in the quality of life of communities in scattered rural areas.

A project was commissioned and funded by the Water Research Commission to source and investigate appropriate home water-treatment systems, to determine the efficiency of the selected devices in removing contaminants (as well as their potential for sustained use), and to provide guidance in the form of a guidebook on both the selection and use of devices for the production of safe drinking water by rural households under local conditions.

The present guidebook is a result of an extensive literature search, laboratory and field studies, workshop series and a social acceptance study aimed at determining the most important influencers of the social acceptance of home water-treatment technologies as perceived by rural households. It is envisaged that this handbook will contribute to: i) a better understanding of how end-users perceive the attributes of selected home water-treatment devices or water technologies and how these in turn affect their social acceptance and sustainability; and ii) provide vital information for establishing useful water-related policies and methods for the safe treatment and distribution of, and access to, clean water by rural and peri-rural communities.

The guidelines could be used by municipal officials and environmental health practitioners, civil society and governmental agencies and other role-players who are responsible for assisting local communities in selecting a particular water-purification system or unit that is appropriate to their situation.

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1. INTRODUCTION

1.1 The need for home water-treatment systems as an alternative for centralised water supply

The health and welfare of people, especially that of vulnerable groups such as children, the elderly and the poor, as well as the immunocompromised, are closely connected to the availability of adequate, safe and affordable water supplies. In South Africa, drinking-water supplies still remain a problem despite its level of development compared to its neighbouring African countries. The problem is particularly acute in peri-urban and rural areas where the large majority of the people are typically low-income earners. Currently, an estimated 1.65 million of the 49.9 million people in South Africa do not have access to a basic water supply. A further 1.98 million have access to a water supply that unfortunately does not meet the SANS 241 recommended limits for microbial contaminants in drinking water (DWAF, 2010).

The implementation of centralised systems in peri-urban and rural areas not only requires large financial inputs, but also highly skilled personnel for continuous maintenance and management of the infrastructures. Though some non-metropolitan areas are provided with treated water supplies, lack of technical skills in the water sector as well as the relatively high costs of providing piped water to dispersed communities have been highlighted as among the major challenges to sustaining safe drinking water. It seems to be unlikely that the communities, especially those in scattered rural areas, will receive a treated, piped water supply in the near future.

While it becomes clear that structural solutions may not be the panacea people once hoped for, science and technology could be a significant tool in designing cost-effective technologies that can be attractive to rural communities and improve their health. Decentralised or point-of-use (POU) water collection and treatment systems are believed to be a cost-effective short- to medium-term sustainable solution to ensure rapid implementation of suitable water supply and improvement in the quality of life, particularly in communities where access to potable water services is lacking. There is a tremendous need to provide cost-effective devices that are efficient enough to remove pollutants, especially waterborne pathogens, in water in order to render the water safe to drink. Where possible, such devices should be designed and constructed using locally-available resources and expertise. They should deliver sufficient quantities of water and further should require little or no electricity or chemicals which have to be purchased, as well as minimal maintenance. The country, as a whole, should therefore invest in the availability of these home water-treatment technologies.

1.2 Purpose of the guidelines

The responsibility of improving the water supply or treating collected water in rural areas generally falls upon individual households. Although various home water-treatment systems and devices are being used by small rural communities without access to potable water services all over the world, people residing in impoverished rural areas often do not have access to vital information about such options; others choose to ignore it as they have used their water sources for some time without major incidences of waterborne diseases within their communities. In the case of South Africa, some exploratory work has been carried out regarding the use of some of these home water-treatment methods. While the Department of Health has been advocating the use of household bleach, boiling or solar disinfection during cholera outbreaks in rural communities, little has been done to assist rural communities to make choices in the selection of a device or whether a particular system will be appropriate to their situation.

This guideline document therefore provides a list of the recommended home water-treatment systems and devices as well as relevant instructions regarding the selection and use of these systems/devices according to the quality of the raw water sources. It also makes available important information on the way forward for the construction and the implementation of an appropriate unit for the required application. Furthermore, these guidelines highlight the issues related to operation and maintenance and the community acceptance of the home water-treatment technologies.

1.3 Who should use these guidelines?

This guideline document is intended to be useful to policy-makers in the water sector, water service providers, municipal officials, environmental health practitioners, civil society, government agencies, consultants and other role-players who are responsible for the implementation of water infrastructure in the country.

The successful implementation of the recommended home water-treatment technologies in communities where access to centralised water-supply systems is lacking depends on the involvement of these communities and commitment of those who have the responsibility in making decisions in collaboration with these communities.

Proper channels should be followed when selected devices are introduced to communities (i.e. Department of Water Affairs and local municipalities). These guidelines further highlight the importance of having chiefs and healthcare workers involved in this process to ensure social acceptance of the devices.

2. RECOMMENDED TREATMENT DEVICES/SYSTEMS

Five different types of home water-treatment methods are recommended in this guideline document. These are:

- Filtration with granular media or a ceramic filter element
- Disinfection using solar radiation and/or heat
- Chemical disinfectants
- Flocculation combined with chemical disinfection
- Basic pre-treatment methods

Membrane systems were not included because they are expensive, and usually require electricity which is not always available in rural communities.

Filtration removes particulate contaminants including microbes and in some cases also dissolved species including metals and organics through sorption or ion exchange. Mechanisms include straining (when particles are larger than the filter pores), attachment to grain surfaces (when particles are smaller than the filter pores – this usually requires chemical pre-treatment to be effective) and sorption to surface sites on the filter media (for particulate or dissolved contaminants, filter media are usually GAC, charcoal or zeolites). The efficiency of filtration depends on the type and concentration of the contaminants to be removed as well as the type of filter.

Solar and thermal methods involve deactivating microorganisms by heating the water and/or exposing them to UV radiation from the sun. These methods do not remove particles or dissolved contaminants but are effective for killing all types of pathogens.

Chemical disinfection is usually very effective for killing bacteria, reasonably effective against most viruses but less effective against pathogenic protozoa such as *Giardia* and *Cryptosporidium* spp. Chemical disinfectants including chlorine and iodine-based compounds generally have a limited impact on the removal of particles and dissolved substances. Exceptions include the oxidation of dissolved iron and manganese in groundwater sources. High doses of disinfectant can also destroy ammonia and other organic compounds but also carry the risk of producing low concentrations of potentially harmful by-products.

Chemical disinfection is most effective and least likely to produce harmful by-products when the treated water is low in particles and dissolved substances to begin with (ideally < 1 NTU).

At least two commercially available products combine a **flocculant** and **a disinfectant** to achieve simultaneous particle removal and disinfection. The use of the flocculant also removes some dissolved contaminants including metals, improves the taste and appearance of the water, as well as the efficiency of disinfection.

Basic pre-treatment methods can be used to reduce the turbidity of the source water prior to disinfection. This can improve the taste and appearance of the water, reduce the disinfectant demand and improve the disinfection efficiency. Two methods are recommended: cloth filtration and plain storage and sedimentation (see **Appendix A**).

2.1 Background to selected treatment methods

2.1.1Potters for Peace silver-coated clay pot filter

The Potters for Peace (PFP) clay pot or Filtrón was originally developed by the Central American Research Institute of Industrial Technology (ICAITI), an industrial research institute in Guatemala, as a low-cost option for domestic drinking water filtration. The design was subsequently adopted and promoted by Potters for Peace (http://www.pottersforpeace.org), an international network of potters which aims to create economic opportunities for potters in the developing world as well as improving access to safe drinking water. The Potters for Peace implementation model is based on the assumption that the filters can be produced at low cost by local potters, thereby also creating employment opportunities in impoverished areas. The disadvantage is that there can be significant issues with quality control. Alternately, commercially produced pots may be of higher and more consistent quality although they may cost more and create fewer manufacturing jobs. The PFP Filtrón resembles a terracotta flowerpot and has a capacity of ~6 ℓ to 8 ℓ and flow rates of between 1 ℓ/h and 3 ℓ/h. The Filtrón is usually coated or soaked in a silver nitrate solution after firing in order to improve microbial removal. There are no Potters for Peace projects currently in South Africa.

Hardware: Ceramic filter pot and receptacle system
Consumables: None
Turbidity limit: Flow rate tends to decrease and cleaning frequency increases with increasing turbidity

Advantages	Disadvantages
• Proven effectiveness against bacteria and protozoa and documented health impact • Simple to use • Long filter life (7+ years) if filter remains unbroken • One-time cost	• Lower removal rates of viruses • Lack of residual protection • Variable quality of locally produced filters • Filter breakage over time and need for spare parts • Need to regularly clean filter element and receptacle especially for turbid waters • Low flow rates (1 ℓ/h to 4 ℓ/h) even for low-turbidity waters

2.1.2 Silver-impregnated porous pot filter (SIPP)

The SIPP device is a clay pot filter manufactured by the Tshwane University of Technology and Cermalab Testing Laboratory, Pretoria, in fulfilment of the objectives of WRC Project No. K8/810, commissioned and funded by the Water Research Commission. Silver nitrate solution is mixed with the clay prior to firing. The expected flow range is between 0.5 ℓ/h and 2.6 ℓ/h. The performance of the SIPP device was evaluated in WRC Project No. K5/1884 (see **Volume 1**).

Hardware: Ceramic filter pot and receptacle system
Consumables: None
Turbidity limit: Flow rate tends to decrease and cleaning frequency increases with increasing turbidity

Advantages*	Disadvantages*
• Produced in South Africa	

* Relative to Potters for Peace Filtrón

2.1.3 Ceramic candle filters

In ceramic candle filter systems, the filter element is a cylindrical ceramic 'candle' as opposed to a pot. The candle is more compact and easier to transport but also more difficult to manufacture than the pot. The filter unit can be wedged between two 25 ℓ buckets by drilling a hole and positioning the candle element in the bottom of the top bucket through the lid of the bottom bucket and collecting the filtered water in the bottom bucket. A spigot can be inserted 5 cm from the base of the bottom bucket. The candle filter element can be covered with a thick cloth to reduce the turbidity of the contaminated water and to trap debris (leaves and insects).

The flow rate of a candle filter system can be increased by using more than one element in each bucket system. High-quality imported candle filters are available and have been demonstrated to significantly reduce disease incidence in controlled field trials, however, their high cost may be a barrier to implementation in the poorest communities. The 'Just Water' ceramic filter element (Winfield and Black Jack Industries, Fairview, Texas) was evaluated in WRC Project No. K5/1884 (see **Volume 1**). Other high-quality NSF certified imported candle filters which have been field-tested are the Katadyn (Katadyn Products Inc., Switzerland) and British Berkefeld (various licensed manufacturers). Ceramic candles of variable quality are also produced in several other countries, particularly in Asia.

Hardware: Ceramic filter pot and receptacle system
Consumables: Ceramic candles containing activated carbon should be replaced twice a year
Turbidity limit: Flow rate tends to decrease and cleaning frequency increases with increasing turbidity

Advantages*	Disadvantages*
• Multiple elements can be used in a single bucket to increase total flow • Filter elements more compact and easy to transport	• More difficult to manufacture

* Relative to ceramic pot filters

2.1.4 Biosand filter

A biosand filter is a household-scale **slow sand filter** designed for intermittent operation. A biologically active layer develops on the top surface of the filter bed which improves the removal of contaminants. The most common version is a concrete container 0.9 m tall and 0.3 m square with the fine sand media layer being 40 cm to 50 cm high.

The filter clogs up over time and water flow is restricted. When the flow drops too low to meet the household's needs, the filter is cleaned by agitating the top few centimetres of the filter media and scooping up the dirty water released. The filters are relatively simple to construct and almost anyone can be trained to produce the filters if the appropriate materials and moulds are provided.

Hardware: Concrete container filled with sand and gravel
Consumables: None
Turbidity limit: Flow rate tends to decrease and cleaning frequency increases with increasing turbidity

Advantages	Disadvantages
• Proven bacteria and protozoan removal • Improves taste and appearance • Some data indicating health impact • Easy to use and low maintenance • High flow (up to 36 ℓ/h) • Can be produced using local materials and labour • Long life (estimated 30 yrs + for concrete filter)	• Poor virus removal • It takes 2-3 weeks for the biological layer to develop • No disinfectant residual • May clog rapidly if high turbidity (> 50 NTU) sources are used • Difficult to transport (concrete body) and high initial cost

Biological sand filter with standard media (BSF-S)

The BSF-S is a scaled-down version of the biosand filter constructed in a 25 ℓ plastic bucket (height 0.41 m and diameter 0.32 m, 15 cm of fine filter media). This makes it significantly cheaper and more convenient to install than the original biosand filter.

A potential disadvantage is that a shallower bed may result in lower removal efficiencies. However, in this type of filter, most contaminant removal occurs in the biologically active top few centimetres of the bed. The BSF-S was developed and tested at Tshwane University of Technology under WRC Project No. K5/1884 (see **Volume 1**).

Hardware: Biosand filter constructed in a 25 ℓ bucket
Consumables: None
Turbidity limit: Flow rate tends to decrease and cleaning frequency increases with increasing turbidity

Advantages*	Disadvantages*
• Requires less space • Easier to transport • Cheaper to construct	• Lower flow • Shorter expected lifespan (plastic vs. concrete body)

* Relative to conventional concrete biosand filter

Biological sand filter with added zeolites (BSF-Z)

The BSF-Z device was also developed and tested at Tshwane University of Technology (see **Volume 1**) and is similar in construction to the BSF-S except that the filter bed includes a 7 cm layer of zeolites. Zeolites have been reported to be effective in removing various types of contaminants through sorption and ion exchange and to have antimicrobial particles. As with other sorbents, zeolites may become exhausted over time resulting in a reduction in performance. The particle size of the zeolites used in the prototype was larger than that of the filter sand used in the BSF-S and BSF-Z resulting in substantially higher flows in the BSF-Z.

Hardware: Biosand filter constructed in a 25 ℓ bucket including a zeolite layer
Consumables: Zeolites may require periodic replacement
Turbidity limit: Flow rate tends to decrease and cleaning frequency increases with increasing turbidity

Advantages*	Disadvantages*
• Higher flow if 3 mm zeolites used	• Zeolite layer may need to be replaced periodically

* Relative to BSF-S

2.1.5 Bucket filter

A bucket filter is a sand filter constructed in a bucket, usually plastic, with a capacity of 10 ℓ to 40 ℓ. The bottom of the top filter bucket is perforated and the filtered water drips into a second similar sized bucket on top of which the filter bucket is placed. Bucket filters are usually used to pre-treat turbid water prior to disinfection. The filter media have to be periodically removed from the bucket and cleaned or replaced (typically after several weeks). A bucket filter system constructed from two buckets with a capacity of 25 ℓ each was tested in WRC Project No. K5/1884 (see **Volume 1**).

Hardware: Bucket filter system
Consumables: None
Turbidity limit: Primarily used for pre-treatment of turbid waters

Advantages	Disadvantages
• Reduces turbidity – improved taste and appearance • Reduces disinfectant demand and improves disinfection efficiency • High flow rate	• Limited pathogen removal • Limited performance data

2.1.6 Drum or barrel filter

Drum or barrel filters are sand filters constructed in 200 ℓ barrels (usually steel). Up-flow filters are easier to clean than down-flow filters and are therefore preferred. In an up-flow filter, raw water is decanted into a reservoir (bucket or drum) which is elevated above the filtered water discharge. The raw water enters the filter below the sand bed and flows up through the media exiting through the filtered water overflow. The filter is cleaned by opening a drain valve at the base of the filter. A drum filter has about four times the flow area of a bucket filter and can therefore probably treat up to four times the volume or up to 600 ℓ/d. To be fully utilised and economical, it would probably be shared by several households.

Hardware: Drum filter system
Consumables: None
Turbidity limit: Primarily used for pre-treatment of turbid waters

Advantages	Disadvantages
• Can process large volumes of water • Reduces turbidity – improved taste and appearance • Reduces disinfectant demand and improves disinfection efficiency	• No disinfectant residual • No performance data available • Difficult to transport – would have to be assembled on site

2.1.7 Activated carbon and charcoal filters

Activated carbon filters are widely used in water-treatment plants to remove organic compounds including those that cause colour, taste and odour. An activated carbon core is also incorporated inside the ceramic filter cartridge of some imported ceramic candle filters and commercial point-of-use filters also contain activated carbon. Some commercially available carbon filters are impregnated with silver to prevent microbial growth. Activated carbon filters may be able to remove cyanotoxins but there are no data indicating that this is effective at household level. Crushed locally available charcoal can be used as a cheaper but generally less effective alternative to activated carbon. Charcoal or carbon is sometimes used as an absorbent layer between sand layers in drum or bucket filters.

Hardware: Carbon/charcoal filter system
Consumables: Carbon/charcoal should be replaced at least twice a year
Turbidity limit: Turbidity is usually removed prior to the carbon layer (ceramic filter or sand layer)

Advantages	**Disadvantages**
▪ Reduces organic compounds which cause colour, taste and odour ▪ May reduce levels of pesticides and cyanotoxins where present ▪ Charcoal is cheap and readily available	▪ Not effective for removing pathogens and can become a breeding ground for bacteria ▪ Absorption sites become exhausted and carbon/charcoal has to be replaced frequently to be effective. ▪ No disinfectant residual ▪ No performance data available ▪ Activated carbon is expensive

2.1.8 Boiling

Boiling is the one of the oldest and mostly widely practised of all water-disinfection methods but is generally not sustainable in the long term due to its high energy consumption. Bringing the water to a full rolling boil is usually sufficient to kill all categories of pathogens. It is therefore the safest method for preparing drinking water for people with weaker immune systems and for preparing infant formula. The WHO guideline is to bring the water to a boil and then boil for 1 min, plus 1 min for each 1 000 m above sea level. Boiling water for 5 min will be sufficient for the highest elevations in South Africa.

It is very important that a full rolling boil is achieved. Merely heating the water may not be sufficient to kill all pathogens which may be present.

Hardware: Pot with lid for boiling. Clean scoop or other means for safely decanting boiled water.
Consumables: Energy source (firewood, paraffin, electricity)
Turbidity limit: None

Advantages	Disadvantages
• Kills all categories of pathogens even in turbid water • Safest option for very young children, pregnant women and immunocompromised individuals • Does not require any special equipment	• High energy and environmental cost • Risks of scalding, especially for children • Risk of fires depending on heating method • No disinfectant residual • Most users don't like to drink warm water and may object to the flat taste • Time-consuming, especially if users have to collect firewood and/or build a fire first • Boiling does not destroy cyanotoxins (from blue-green algae)

2.1.9 The SODIS system

The SODIS method (http://www.sodis.che) involves exposing water in clear plastic bottles or bags to sunlight for 6 h if sunny or less than 50% cloud cover, and for two consecutive days under very cloudy conditions. The combination of heat and UV radiation is effective for deactivating viruses, bacteria and protozoa. The bottles should be placed horizontally either on a dark or reflective surface, usually a roof top or a specially constructed rack. Do not place bottles on inflammable materials, such as straw or cloth. This is an almost zero-cost technology which was originally developed to disinfect water for oral rehydration solutions. Since 1991 it has been investigated and promoted as household water-treatment method by the Swiss Federal Institute of Environmental Science and Technology (EAWAG).

Hardware: Rack or roof top where bottles can be exposed to sun
Consumables: At least two transparent PET bottles with 2 ℓ capacity per household member. Bottles can be reused until heavily scratched and 'blinded'. Smaller bottles can also be used but more will be required.
Turbidity limit: < 30 NTU

Advantages	Disadvantages
• Virtually zero cost • Demonstrated microbial reductions and reduced disease incidence • Water is consumed directly from bottles making recontamination unlikely	• Does not work in rainy weather • Limited to low-turbidity waters • Limited volumes and long treatment times may reduce user acceptability • No turbidity removal • A large supply of clear plastic bottles is required

2.1.10 SOLAIR

The SOLAIR process involves collecting up to 20 ℓ of low-turbidity raw water in a 25 ℓ opaque white jerry can, shaking it vigorously to aerate and placing the container in direct sun for at least 4 h to 6 h, shaking once an hour. The combined action of oxygen and solar energy appears to be effective for deactivating coliform bacteria. This method has been tested under South African conditions using a typical container used for collecting water in rural villages.

Hardware: Opaque white jerry can with capacity of 25 ℓ fitted with screw lid.
Consumables: None
Turbidity limit: Unknown; tested at 2 NTU only

Advantages	Disadvantages
• Uses same container water is collected in • Very simple and low cost • Tested under South African conditions	• Limited to low turbidity waters (tested at 2 NTU only) • Not effective on cloudy or rainy days • No data on disease reduction • No turbidity removal • No disinfectant residual • Warm water may not be palatable to users

2.1.11 Sodium hypochlorite ('Jik')

With the exception of the silver-impregnated ceramic pots and the combined flocculant/disinfectant powders, all the systems and devices discussed in this guideline require post-disinfection in order to meet SANS 241 in terms of microbial removals. Low-turbidity waters (ideally < 1 NTU) will not require filtration but will still require disinfection.

Sodium hypochlorite is widely used for disinfection in drinking-water treatment plants. At household level, it is widely available as regular domestic bleach 'Jik' Only regular unscented bleach should be used as any other chemicals added (fragrances, detergents, etc.) will make the water unsafe for consumption.

According to the standard guidelines for emergency disinfection of water issued by the Department of Health 1 teaspoon (5 mℓ) of 'Jik' is added to 25 ℓ of water. This yields an initial concentration of 8 mg/ℓ of chlorine which will decrease over time but is still like to result in a strong chlorine taste and smell to the water which consumers will find objectionable. Recent studies have shown that chlorine doses of ~2 mg/ℓ (¼ teaspoon of 'Jik' in 25 ℓ) is sufficient for most water sources with turbidity < 10 NTU and ~4 mg/ℓ (½ teaspoon of 'Jik' in 25 ℓ) is recommended for more turbid waters (see Section 2.4.3.1 in **Volume 1**). These levels should be effective without causing taste and odour problems. The lower dose should be sufficient in most cases if the water is pre-filtered.

When chlorine disinfection is used, it is imperative that the local authority establishes a monitoring programme to check chlorine residuals in stored household water. The chlorine residual should be at least 0.2 mg/ℓ but not more than 5 mg/ℓ at least 30 min after the disinfectant is added.

Chlorine disinfection is ideally carried out in the final step of water treatment following pre-treatment to remove turbidity but disinfectant is sometimes added to the raw water prior to filtration to simplify the treatment process and prevent biological growth in the filter.

However, disinfectant should **NEVER** be added to the raw water prior to **biofiltration** because in this case, the active biological layer in the biofilter is critical for effective treatment.

Hardware: Safe storage container with capacity of 25 ℓ, dropper or measuring spoon – ¼ teaspoon, a means of stirring or agitating the water without contaminating it
Consumables: Hypochlorite solution or unscented bleach
Turbidity limit: < 100 NTU; optimal < 1 NTU

Advantages	Disadvantages
• Proven effectiveness and health impact • Residual protection against contamination • Low cost and ease of use • Scalability	• Lower effectiveness against some parasites and in turbid waters and waters high in organics and some inorganics such as ammonia. Less effective at pH > 8. May be ineffective above pH 9. • Potential taste and odour objections • Necessity of quality control of hypochlorite solutions

2.1.12 Calcium hypochlorite (HTH)

Calcium hypochlorite is similar in its action to sodium hypochlorite (see discussion above) but provides chlorine in a more concentrated form and therefore is used to treat larger volumes of water. The standard Department of Health guideline has been 1 teaspoon of granules in 200 ℓ of water, yielding a dose of ~8 mg/ℓ chlorine. As discussed above, this dose is likely to result in excessively high residual chlorine levels; a ¼ teaspoon of granules in 200 ℓ for turbidity < 10 NTU or filtered water and ½ teaspoon granules for more turbid water should be sufficient in most cases.

As in the case of sodium hypochlorite, chlorine residual monitoring is an essential part of implementing a household disinfection programme.

Hardware: Drum or barrel with capacity of 200 ℓ, measuring spoon – ¼ teaspoon, a means of stirring or agitating the water without contaminating it
Consumables: Calcium hypochlorite (HTH) granules
Turbidity limit: < 100 NTU; optimal < 1 NTU

Advantages*	Disadvantages*
• Longer shelf life if properly stored	• Not convenient for treating small volumes of water • Care must be taken to ensure that all granules dissolve

* Relative to sodium hypochlorite

2.1.13 PUR

The PUR Purifier of Water™ is a home water-treatment/emergency disinfection product developed by Procter and Gamble in conjunction with the US Centers for Disease Control and Prevention. It consists of a sachet containing ferric sulphate, a coagulant, and calcium hypochlorite and can be used to effectively clarify and disinfect 10 ℓ of turbid water. The treatment process is designed to mimic the multiple barrier approach of a conventional water-treatment plant.

PUR™ has been widely used in disaster relief and its efficacy in removal turbidity, viruses, bacteria and protozoa is well documented. Data are also available indicating that PUR™ can remove some pesticides and heavy metals including arsenic. It has also been reported that two sequential treatments with PUR™ can reduce algal cell and cyanotoxin concentration to levels considered safe for drinking water.

Hardware: Two buckets, with capacity of at least 10 ℓ, stirring device and cloth filter
Consumables: One PUR™ sachet per 10 ℓ
Turbidity limit: Suitable for turbid water

Advantages	Disadvantages
• Proven effectiveness and demonstrated health impact • Also removes heavy metals and pesticides • Effective in turbid waters • Provides disinfectant residual • May be effective against cyanotoxins • Visual improvement in water increases user acceptability • Sachets are easy to transport and stockpile due to their small size and weight, long shelf life and classification as non-hazardous material.	• Multiple steps required – requires demonstration for new users • Users need to have and maintain necessary equipment: 2 buckets, cloth and stirring device • Expensive relative to other POU methods

2.1.14 Chlor-Floc

Chlor-Floc Watermaker™ is a similar product to PUR™ developed by Control Chemicals (Pty) Ltd., South Africa. The disinfectant in Chlor-Floc is sodium dichloroisocyanurate.

Although its performance in the field is less well documented than PUR™, it is expected to be similar and it is also widely used in disaster relief as well as by the US Army and South African National Defence Force. One sachet treats 20 ℓ of water.

Hardware: Two buckets, with capacity of at least 20 ℓ, stirring device and cloth filter
Consumables: One Chlor-Floc sachet per 20 ℓ
Turbidity limit: Suitable for turbid water

Advantages*	Disadvantages
• Manufactured in South Africa • One sachet treats 20 ℓ which is more appropriate for meeting household needs.	• Same as PUR™

* Relative to PUR™

2.1.15 Storage and plain sedimentation

Storage and plain sedimentation is a cheap and simple method of pre-treating turbid water prior to filtration and/or disinfection. Raw water is allowed to stand undisturbed for several hours up to two days in one container before the relatively clear supernatant is carefully ladled or poured into another similar sized container or filtration device. The efficiency of sedimentation can be increased by using two consecutive sedimentation steps.

Microbial removals due to plain sedimentation are usually low (< 90%) but clogging will be reduced in a subsequent filtration step and disinfection demand will be reduced and disinfection efficiency increased. Plain sedimentation is most appropriate for turbid surface water sources containing high concentrations of sediment. In general, sedimentation efficiency increases with increasing concentration of suspended solids.

Hardware: Two or more vessels of similar size vessels, clean ladle or scoop (optional)
Consumables: None
Turbidity limit: Suitable for turbid water

Advantages	Disadvantages
• Very cheap and simple • Suitable for very turbid waters • Improves efficiency of subsequent treatment processes	• Low microbial removals • Long treatment time (hours to days)

2.1.16 Cloth filtration

A cloth filter can easily be constructed by securing one to eight layers of cloth over the mouth of a bucket or collection device. Floating material such as grass, leaves and insects and some turbidity and microbes will be strained out when raw water is poured through the cloth into the bucket.

Using old cotton cloth (laundered multiple times) and increasing the number of layers has been found to improve removals. Filtering through eight layers of cotton cloth has been found to reduce concentrations of algal cells and *Vibrio cholerae*. Cloth filtration is especially appropriate for removing floating material including algae. Cloth filters are also used to strain out flocs in the PUR™ and Chlor-Floc Watermaker™ treatment processes.

Hardware: Bucket, sufficient old cotton cloth to provide eight layers and means to secure it to the mouth of the bucket
Consumables: Cloth will have to be replaced once it rips
Turbidity limit: Suitable for turbid water.

Advantages	Disadvantages
• Very cheap and simple • Familiar to many communities, e.g. use cloth filters to strain traditional beer • Suitable for turbid waters, especially those containing significant amounts of floating material • Faster flow rate than plain sedimentation (minutes instead of hours to days)	• Low microbial removals • Filter may clog rapidly with very turbid waters • Lower turbidity removal than plain sedimentation

2.2 Cost and performance of home water-treatment systems

Table 2.1 summarises the estimated water production, costs, sources and available training materials for the various home water-treatment systems recommended in these guidelines. The volume produced by a given system depends on the capacity of the device, the flow or treatment time required and the number of times the householder is able to refill it during the day. It is assumed that the maximum volume a single household would produce in a given day is 150 ℓ or 25 ℓ each for six people.

The costs of the SIPP, CCF, BSF-S, BSF-Z and bucket filter systems were determined in WRC Project No. K5/1884 (see Chapter 3 in **Volume 1**). The costs of purchasing Chlor-Floc Watermaker™ sachets in bulk were obtained from Control Chemicals (Pty) Ltd. Other costs are estimates obtained from the international literature. All cost estimates are intended for **comparison purposes only**. The actual costs of any given system will depend on the local cost and availability of materials and components as well as any economies of scale which can be achieved.

The costs in Table 2.1 are for hardware and consumables only. They do not include the costs of training and monitoring which are critical to the successful implementation of any of these systems. The costs are for the listed system only and do not include the costs of additional pre-treatment or post-treatment steps which may be required. In general, the costs of additional steps would be additive except where common equipment could be used, e.g. chlorine can be added directly to a bucket used to collect settled or filtered water.

Table 2.1: System costs and availability of training materials

Device/system	Water production per day	Hardware	Consumables	Cost per kℓ	Contacts/educational materials
Potters for Peace Filtrón	10-20 ℓ	R150-R330	None	R7-R30[1]	www.pottersforpeace.org
SIPP	10-20 ℓ	R290	None	R13-R26[1]	WRC K5/1884 (**Vol. 1**)
CCF	20-40 ℓ	R501.15	None	R33-R65[2]	http://shop.monolithic.com/products/just-water-ceramic-drip-filter

1. Assuming 3-year lifespan
2. Assuming 3-year lifespan of filter assembly, ‘Just Water’ filter element replaced every 6 months

Table 2.1: (cont.) System costs and availability of training materials

Device/ system	Water production per day	Hardware	Consumables	Cost per kℓ	Contacts/educational materials
Biosand filter	Up to 150 ℓ	R540	None	R1-R2[3]	www.cawst.org www.biosandfilter.org
BSF-S	Up to 100 ℓ	R134	None	R1-R3[4]	WRC K5/1884 Vol. 1
BSF-Z	Up to 150 ℓ	R164	Zeolites	R1-R2[5]	WRC K5/1884 Vol. 1
Bucket filter (BF)	Up to 150 ℓ	R150	None	R1-R2[6]	WRC K5/1884 Vol. 1
Drum or barrel filter	Up to 600 ℓ	Unknown	None	R1-R2[7]	
Charcoal filter	Up to 150 ℓ	Varies	Replace charcoal at least every 3 months	R2-R5[8]	
Activated carbon filter	Up to 150 ℓ		Replace carbon filter at least every 6 months	> R75[11]	
Boiling	Depends on size of pot. Limited by high energy requirements	Use ordinary cooking pots	Energy source	Depends on energy costs; 1 kg firewood to boil 1 ℓ of water for 1 min	
SODIS	Limited by number of bottles, minimum 6 hour exposure time			Zero cost technology	http://www.sodis.ch
SOLAIR	20 ℓ per batch, 4-6 h exposure time	Cost of 25 ℓ jerry can with screw lid (R50)	None	R0-R2[9]	Meyer and Reed (2001)

3. Assuming 10-year lifespan, 75-150 ℓ/d
4. Assuming 3-year lifespan, 40-100 ℓ/d
5. Assuming 3-year lifespan, 75-150 ℓ/d
6. Assuming 3-year lifespan, 75-150 ℓ/d
7. Assumed same as bucket filter
8. Assuming 3-year lifespan, charcoal replacement 4 times per year, 75-150 ℓ/d
9. Assuming 3-year lifespan, 20 ℓ/d per can. No additional cost if householders already use jerry cans to collect water
10. From international literature

Table 2.1: (cont.) System costs and availability of training materials

Device/ system	Water production per day	Hardware	Consumables	Cost per kℓ	Contacts/educational materials
Sodium hypochlorite ('Jik')	25 ℓ per batch, at least 30 min contact time	25 ℓ bucket with lid and spigot (R75)	R16 (750 mℓ 'Jik')	R0.8-R4[11]	CDC Safewater System
Calcium hypochlorite	200 ℓ per batch, at least 30 min contact time	200 ℓ plastic (food grade) drum	R90 (1 kg HTH)	R0.8-R4[11]	
PUR™	10 ℓ per sachet, 30 min treatment time. Could use 2 sachets for 20 ℓ	2 buckets + cloth filter (R55)	10 US cents ~ZAR 0.75 per sachet = 10 ℓ of water Replace cloth when ripped	R80[11]	http://www.pghsi.com/pghsi/safewater/relief.html
Chlor-Floc Water-maker™ tablet or powder	20 ℓ per sachet, 30 min treatment time	2 buckets + cloth filter (R55)	R0.85 per sachet = 20 ℓ of water. Replace cloth when ripped	R43[12]	Appendix B
Storage and plain sedimentation	Depends on size of container	Two or three similar sized buckets or other open-necked vessel. Scoop or cup for transferring water (optional)	None	R0-R2[13]	See Appendix B
Cloth filtration	Up to 150 ℓ	1 bucket, cotton cloth and means of securing it to bucket (R30)	Replace cloth when ripped	R0-R1.40[14]	See Appendix B

11. From international literature
12. Cost data for bulk purchase supplied by Control Chemicals (Pty) Ltd
13. Based on cost of two 25 ℓ buckets, assumed 20-60 ℓ /d, and 3-year lifespan. Zero cost if buckets/containers already available
14. Based on cost of one 25 ℓ bucket, 20-150 ℓ /d, and 3-year lifespan. Zero cost if appropriate container already available

Table 2.2 summarises the data available on the performance of the various systems and devices. Microbial removals are usually determined in laboratory studies. In Table 2.2, microbial removals are classified as follows: 'low' is < 90% (< 1 log); 'medium' is 90-99% (1 log – 2 log); 'high' is > 99% (> 2 log). Performance in the field is generally expected to be lower than in laboratory studies due to operator errors and a more contaminated operating environment. Field studies usually look for a significant decrease in water-related diseases in users of the technology compared to controls. Some studies have also looked at the microbial quality of treated water.

Table 2.2: Summary of device performance

	Microbial removal[1]			**Turbidity removal**	**Evaluated in field**	**Other contaminants**
	Viruses	**Bacteria**	**Protozoan parasites**†			
Potters for Peace Filtrón	Low	High	High	30-100%	60-70% reduction in diarrhoea	No data
SIPP♠		High	High	> 90%	No data	Ca, Fe, Mg, As PO_4, NO_3, F (See Volume 1)
CCF♠		Medium-high	Medium	> 90%	No data	Ca, Fe, Mg, As PO_4, NO_3, F (See Volume 1)
Biosand filter	Low	Medium-high	High	~80%	30-60% reduction in diarrhoea 70–99% reduction in bacteria	Modified version (Kanchan™ arsenic filter) removes arsenic
BSF-S♠		Medium-high	Medium	>90%	No data	Ca, Fe, Mg, As PO_4, NO_3, F (See Volume 1)
BSF-Z♠		Medium-high	Medium	> 90%		Ca, Fe, Mg, As PO_4, NO_3, F (See Volume 1)
Drum or barrel filter	No data	No data	No data	Depends on raw water quality. 50-99% removal possible	No field studies	No data
Bucket♠ filter (BF)		Low to high	Low	> 90%		Ca, Fe, Mg, As PO_4, NO_3, F (see Volume 1)
Charcoal filter	Unknown	Low	Unknown	No data	No field studies	Organics, taste and odour

♠ It is acknowledged household water-treatment systems and devices are generally accepted not to be primarily suited to chemicals removal. Since these units had been evaluated over a relatively short period of time, the removal rates achieved may not be sustainable in the longer term.

†*Cryptosporidium* and *Giardia*

Table 2.2 (cont.) Summary of device performance

	Microbial removal[1]			Turbidity removal	Evaluated in field	Other contaminants
	Viruses	Bacteria	Protozoa			
Boiling	High	High	High	N/A	Average 97% reduction in thermotolerant bacteria, 37% of stored water negative for thermotolerant bacteria (rural Vietnam)	Unknown
SODIS	High	High	High	N/A	8-96% reduction in diarrhoea	Unknown
SOLAIR	Un-known	High	Unknown	N/A	No data	Unknown
Sodium hypochlorite ('Jik')	Medium	High	Low	N/A	22-84% reduction in diarrhoea (CDC Safe Water System)	No data
Calcium hypochlorite	Medium	High	Low	N/A	Assumed same as sodium hypochlorite	No data
PUR™	Medium to high	High	High	Most filtered turbidity < 1 NTU	16-90% reduction in diarrheal disease	Arsenic, heavy metals, some pesticides, algae (limited data)
Chlor-Floc Water-maker™	Medium to high	High	High	Most filtered turbidity < 1 NTU	Assumed same as PUR™	Assumed same as PUR™
Storage and plain sedimentation	No data	No data	No data	< 90%	No field studies	**No data**
Cloth filtration	No data	Low to medium	No data	~50%	48% reduction in cholera (Bangladesh)	Algae

- **†*Cryptosporidium* and *Giardia***

1. In laboratory studies

Devices or systems introduced to rural communities must all be able to achieve an adequate treated water quality under local conditions. There tends to be a trade-off between water quality, quantity and cost and rural users may be tempted to choose high-flow low-cost devices which do not achieve an adequate water quality whereas pathogen removal should be the priority.

3. GUIDELINES FOR THE SELECTION OF HOME WATER-TREATMENT SYSTEMS/DEVICES

In order to select the most appropriate home water-treatment system/device (HWTS/D) for the required application, it is important that the correct process be followed and that all aspects influencing the efficient and sustainable use in the home are considered. To this effect, the following three broad steps should be followed as a guideline to come to a final decision as to the most appropriate unit to use in the home:

Use the categorisation of raw water in Section 3.1 '**Classification of Raw Water Quality for South African Raw Water Sources**' to establish which category (or categories) of water will be used as feed water to treat.

↓

Use the decision support tools outlined in Section 3.2 '**Decision Tools to Be Used in the Selection of Suitable HWTDs'.** Follow the decision flow diagram (decision tree) with accompanying criteria in Section 3.2.1 '**Decision Tree with explanatory criteria' and use Table 3.1 'Selection of Home Water-Treatment Devices**' in Section 3.3.2 to derive your options for the best suited candidates(s) and pretreatment required.

↓

Should more than one possibility be indicated after following the decision tree and the decision matrix, make the final choice on the unit to use based on specific, local circumstances and preferences.

It is important to note that, if a device cannot treat the water to the required quality on its own, post- or pre-treatment will be required. In this instance, the options should be re-evaluated, using the available, suggested, pre-treatment and post-treatment options provided.

Basic survival needs

Both quantity and quality of water need to be taken into account when determining basic survival needs for a person.

Basic survival water needs per person in terms of quantity: 7.5 ℓ/d to 15 ℓ/d.

Survival needs: water intake (drinking and food)	• 2.5 ℓ/d to 3 ℓ/d • Depends on the climate and individual physiology
Basic hygiene practices	• 2 ℓ/d to 6 ℓ/d • Depends on social and cultural norms
Basic cooking needs	• 3 ℓ/d • Depends on food type, social as well as cultural norms

Basic need in terms of water quality: See the SANS 241: 2011 guidelines for the recommended water quality for drinking purposes (SABS, 2011)

3.1 Classification of water quality for South African raw water sources

To be able to select the most appropriate water-treatment device for a particular application, it is necessary to know and understand which impurities in or characteristics of the feed water need to be removed or altered. The user of this guideline document should therefore have a basic knowledge of water-quality aspects of raw water sources and of the desired drinking-water quality. The following sections were drawn up for this purpose in the Water Research Commission Guidebook on the Selection of Small Water Systems for Potable Water Supply to Small Communities (WRC Report No. TT 319/08) (Swartz et al., 2007). Because the principles for selection of home water-treatment devices are largely the same, the following section is a summary of the classification of water quality, taken from the guidebook.

3.1.1 Raw water sources in South Africa

The background knowledge of raw water sources in South Africa is necessary in order to establish a classification system of raw water types, which will lead toward the selection of appropriate home water-treatment devices or point-of-use (POU) systems, which will be able to produce a final water quality complying with the drinking water specifications.

The paragraphs below provide the essential background information on the characterisation of the different main raw water types, in order to obtain a purified drinking water complying with the requirements of the updated SANS 241 of 2011.

a. Turbidity

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

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

STAGE 1: Reduction of turbidity (preferably to < 10 NTU) to protect the fine filter from frequent clogging and ensure effective operation.

STAGE 2: Further reduction of turbidity to levels of less than 5 NTU by fine filtration, and preferably less than 1 NTU, to produce water that is aesthetically acceptable and also facilitates effective disinfection.

b. Coloured water

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

Colour, as it is the case with taste, odour and turbidity, forms a primary aesthetic quality parameter when water is supplied from any raw water source for human consumption. From a health perspective, the organic substances in the water result in reduced disinfection efficiency, and can also lead to the formation of undesired disinfection by-products.

Organic compounds in water may also serve as nutrient source for microorganisms which can lead to bacterial growth in treatment and storage units. This results in deterioration of the water quality and slime formation in tanks and pipes, and may also lead to biological corrosion.

c. Brackish water

For raw waters with high salinity, such as seawater or brackish water, treatment processes must remove most of the dissolved salts (desalinate) in order to make the water potable (i.e. lower the TDS to less than 1 000 mg/ℓ or EC to less than 150 mS/m)). This can unfortunately not be achieved by most of the fine filtration technologies, so that there are no affordable filtration devices for application in rural communities. Saline raw water sources would therefore not be a suitable water sources at household level for rural communities, with the exception of solar stills (Goldie, 2005).

d. Hard and soft water

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

Public acceptance of hardness varies from community to community and consumer sensitivity relates to what the consumer is accustomed to. Hard (150 mg/ℓ to 300 mg/ℓ $CaCO_3$) and very hard water (>300 mg/ℓ $CaCO_3$) results in high soap consumption and the scaling of pipelines, boilers, geysers and kettles. Precipitation from hard water could potentially also result in irreversible clogging and flow reduction in ceramic filters. This would have to be assessed in extended trials with the raw water in question.

On a household level, fine filtration is not able to soften hard waters, and only nanofiltration and reverse osmosis can be used for this purpose, both of which are expensive and beyond the means of households in rural communities.

e. Microbially contaminated water

Most waters, natural or treated but without disinfection, would usually have some extent of contamination that makes the water unsafe to drink. This contamination can be reduced to some extent by filtration processes, especially slow sand filtration, but not completely. Disinfection by chlorination is widely used to treat microbial contamination. The disinfectant applied must also be able to adequately protect the water from microbial re-growth for a reasonable storage period, usually 2 days.

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

f. Eutrophic water

The deterioration of surface water quality due to pollution from point-source discharges (wastewater-treatment works and industrial effluent) and diffuse surface runoff (modern agriculture, industrialisation and urbanisation) has been recognised as a major global water resource concern. One of the primary effects of pollution is nutrient enrichment of receiving waters commonly referred to as eutrophication. This results in the stimulation of an array of symptomatic changes including production of algae, cyanobacteria and aquatic macrophytes, deterioration of water quality and other undesirable changes which interfere with water use. Chlorophyll *a* is typically used as in indicator of the algal content and degree of eutrophication of source waters.

The taste and odour problems in drinking water can often be linked either directly or indirectly to cyanobacteria which can produce compounds such as geosmin and 2-MIB (2-methylisoborneol) in spring, summer and autumn months in South Africa. It causes the drinking water to have an earthy-muddy-musty taste and odour. Although the taste and odour compounds themselves are not toxic to the consumers they can co-occur with cyanotoxins which are discussed next.

g. Cyanotoxins

Cyanotoxins are toxic metabolites produced by some cyanobacteria species. They include hepatotoxins, neurotoxins and dermatotoxins. The hepatotoxic microcystins are the most studied of the cyanotoxins and among the most likely to occur at high concentrations (> 1 μg/ℓ). The WHO has established a health-based guideline of 1 μg/ℓ for microcystin-LR, one of the most toxic microcystins and this guideline has also been adopted in SANS 241. The guideline value includes both free and cell-bound toxin.

Cyanotoxins usually become concentrated in water as the result of 'bloom' events. These tend to be seasonal in nature and recur in the same water bodies. While not every algal bloom is toxic, any bloom has the potential to be toxic and once microcystin is detected in a water body, it should be assumed to be a recurring problem.

Microcystins are typically more than 95% cell-bound in healthy cells, therefore treatment aims to remove as many of the cells before they die and release their toxins. Methods to remove intact algal cells before releasing metabolites include coagulation, sedimentation, flotation (treatment plants only), straining and filtration while GAC (granular activated carbon) and chemical oxidation can remove and destroy extracellular toxins. However, there are limited data on the effectiveness of these methods when applied at household level and there are currently no proven or recommended household-scale methods for removing cyanotoxins.

GAC is used to remove algal toxins in some treatment plants but there appear to be no published studies on either its successful or unsuccessful application to household-scale treatment. Specific concerns include its high cost, and the fact that the required replacement frequency varies widely with the type of GAC and water quality. Design recommendations that err on the side of caution will make the units even more unaffordable. Anecdotal evidence on the removal of toxins by other HWTS methods is summarised in Section 2.5 of **Volume 1**. Further research is required to determine whether any of these methods can be used to produce safe drinking water from sources contaminated by cyanobacteria.

A general concern about all HWTSs is that even if they can effectively remove cyanotoxins from the finished product, they may produce a concentrated toxic sludge that the user is exposed to. Furthermore, cells which are trapped and die in filters between cleaning cycles may result in toxins breaking through into the treated water. These safety aspects need to be considered in any future research.

In the meantime, the one recommendation from the WHO which may be helpful to communities relying on eutrophic water sources is the use of in-bank filtration. This involves digging wells at a sufficient distance from a river or water body to allow several days of travel time through the soil. This is effective for removing both algal cells and toxins and has the advantage that the user does not have to come into contact with any of the algal scum. Of course the wells themselves also have to be protected from contamination.

h. Nitrates

High concentration of nitrates in raw water can be reduced by a number of technologies. These include membrane desalination, ion exchange and biological nitrate removal (also called bio-denitrification), none of which can be readily or affordably applied on household scale in rural applications.

All nitrate removal technologies are expensive and require well-trained operators and specialised maintenance. The reader is referred to WRC Report No. 1443/1/07 (Swartz et al., 2007) for more information on treatment options for nitrate removal in small centralised systems.

i. Fluoride

High concentration of fluoride in raw water can be reduced by a number of technologies. These include membrane desalination (reverse osmosis, see section on brackish water), flocculation and adsorption. Adsorption fluoridation is more suited towards local application. In involves the downward flow of raw water through a column packed with a strong adsorbent, typically activated alumina but activated charcoal or ion-exchange resins are also used (the latter when the fluoride concentration is less than 10 mg/ℓ).

Economy of scale normally exists so that community-based defluoridation plants are normally cheaper per capita than the installation of household units (RO and activated alumina seem most appropriate). The reader is referred to WRC Report No. 1433/1/07 (Swartz et al., 2007) for more information on community-based defluoridation systems.

3.1.2 Classification of main raw water types according to treatability

Based on the treatability of the different main raw water types, as summarised above, a classification of main raw water types is shown in Table 3.1 below. More detailed information on the treatability of different raw water types commonly found in South Africa can be obtained from the WRC Guidebook for the Selection of Small Water Treatment Systems for Potable Water Supply to Small Communities (WRC Report No. TT 319/08) (Swartz et al., 2007).

Table 3.1: Raw water classification

Quality parameter	Raw water class type	Quality parameter range
Turbidity	Very high turbidity	> 500 NTU
	High turbidity	50-500 NTU
	Medium turbidity	10-50 NTU
	Low turbidity	< 10 NTU
Colour	Very high colour	> 300 mg/ℓ as Pt
	High colour	100-300 mg/ℓ as Pt
	Medium colour	25-100 mg/ℓ as Pt
	Low colour	< 25 mg/ℓ as Pt
Brackish Water	Highly brackish	> 370 mS/m
	Moderately brackish	150-370 mS/m
	Low brackish	70-150 mS/m
Hard Water	Very hard water	TH > 200 mg/ℓ as CaCO3
	Moderately hard water	TH: 100-200 mg/ℓ as CaCO3
Microbially (MB) contaminated	Highly MB contaminated	> 100 faecal coli/100 mℓ
	Moderate MB contaminated	5-100 faecal coli/100 mℓ
	Low MB contaminated	< 5 faecal coli/100 mℓ
Eutrophic Water	Highly eutrophic	Chlorophyll *a* > 100 µg/ℓ
	Moderately eutrophic	Chlorophyll *a*: 30-00 µg/ℓ
	Low eutrophic	Chlorophyll *a:* < 30 µg/ℓ
pH	Low pH	<5.5
	Medium pH	5.5-9.5
	High pH	>9.5
Nitrate and nitrite	Low	<10 mg/ℓ as N
	High	>10 mg/ℓ as N
Iron and manganese	Low	<0.3 mg/ℓ as Fe; <0.1 mg/ℓ as Mn
	Medium	0.3-10 mg/ℓ as Fe; 0.1-4 mg/ℓ as Mn
	High	>10 mg/ℓ as Fe; >4 mg/ℓ as Mn
Fluoride	High	>1.5 mg/ℓ as F
	Medium	0.5-1.5 mg/ℓ as F
	Low	<1.5 mg/ℓ as F
Other Group B	Sulphate	Contained in brackish water above
	Chloride	Contained in brackish water above
	Arsenic	Requires special attention
	Total coliforms (FC)	Contained in FC above
Group C	Cadmium	Requires special attention
	Copper	Requires special attention
Other Group D	Zinc	Requires special attention
	Potassium	Contained in brackish water above
	Sodium	Contained in brackish water above
	Calcium	Contained in hard/soft water above
	Magnesium	Contained in hard/soft water above
	Total hardness	Contained in hard/soft water above

3.1.3 Water quality standards

Water quality standards set limits for the presence of physical, chemical and microbiological substances in water to be used for drinking purposes. In South Africa a set of standards has been compiled by the South African Bureau of Standards (SABS), after consultation with all stakeholders.

The World Health Organization's guidelines on water quality have served as basis for the development of many national water-quality standards. Besides the presence of national standards, individual water-supply organisations (e.g. Rand Water, Umgeni Water) and water services authorities (e.g. City of Cape Town Metropolitan Municipality) usually develop their own internal standards, which exceed national standards. Therefore, when evaluating and selecting any water-treatment technology the water-quality standards against which the technology performance shall be assessed must be known.

> **Note**
>
> The interpretation of water-quality data and standards is critical as it determines the suitability of a given water quality for respective applications and guides the extent of treatment to be applied to the available raw water.

As a decision-maker, knowledge of water-quality standards is therefore very important because it helps to classify the water for its suitability for either direct use or treatment by given technology options that can achieve the production of the desired final water that satisfies local water-quality standards.

3.2 Decision tools for use in the selection of suitable home water-treatment systems/devices

To assist in the selection of suitable home water-treatment systems/devices (HWTSs/Ds), the following two decision tools are used after the assessment and identification of the raw water quality to be treated:

- A flow diagram (decision tree) for the step-wise decision-making in the selection process (accompanied by a full list of criteria to take into account when using the decision tree).
- A decision-support matrix.

3.2.1 Flow diagram (decision tree) for the selection of HWTDs

The flow diagram (decision tree) is portrayed in Figure 3.1. From the decision tree, the 10 steps described below should be followed to select the appropriate HWTSs/Ds:

1. Ability to deliver a product water which is safe and pleasant to drink and use for cooking (regulatory compliance with SANS 241) – without further deterioration during storage.
2. Ability to deliver an adequate quantity of water for drinking and cooking.
3. Ease of operation and maintenance.
4. Robustness of the unit.
5. Ability to deliver safe water without further deterioration during storage.
6. Safety of container/unit and materials.

7. Ease of construction/supply.
8. Social acceptance and use.
9. Potential for local enterprise and support.
10. Cost of the units (absolute/comparative) to the provider.

To assist in the use of the decision tree, each of the above main criteria is discussed in greater detail in the section following the decision tree diagram (Figure 3.1) to assist stakeholders in the decision-making process.

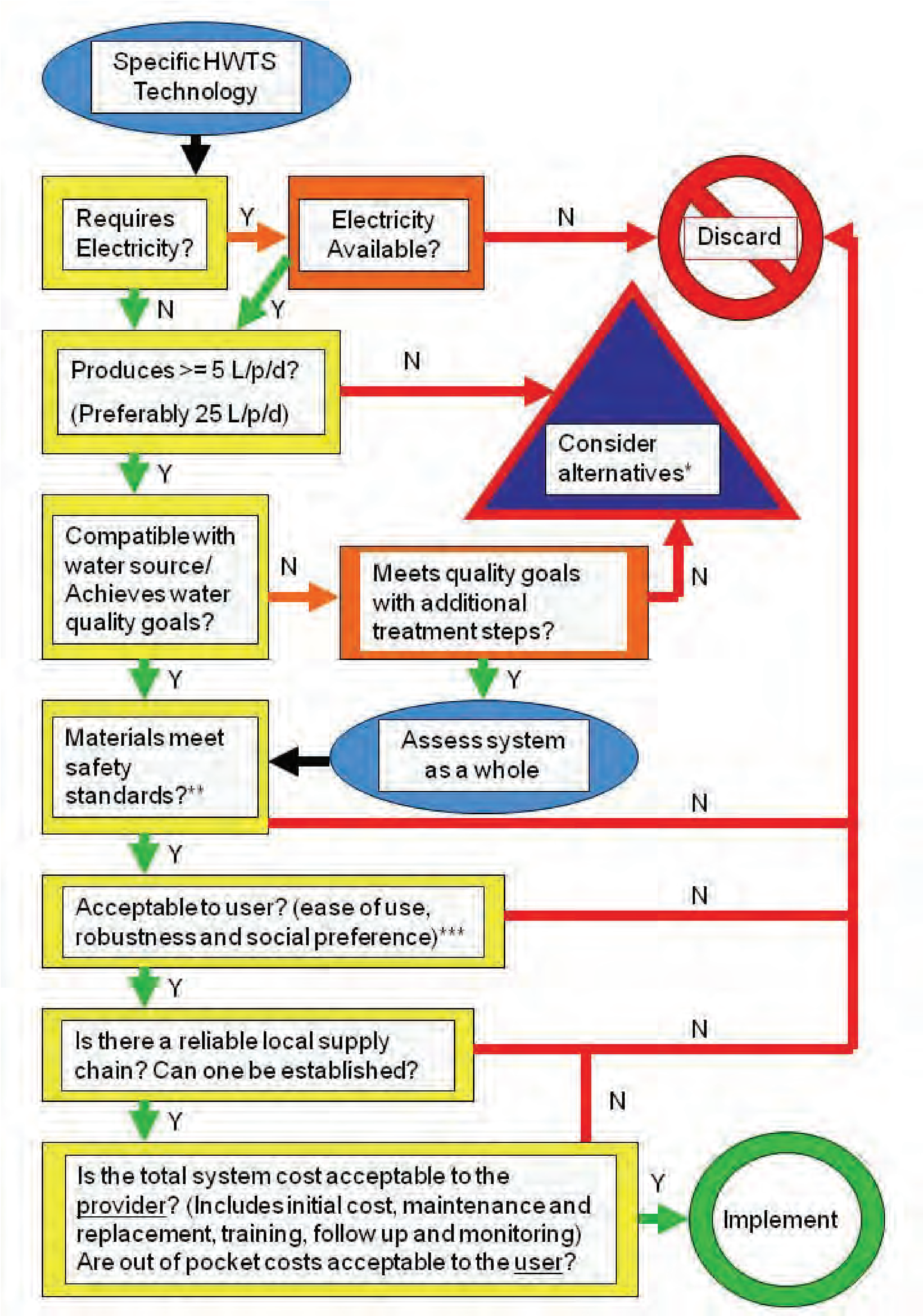

Figure 3.1: Decision diagram (decision tree) for the selection of the appropriate HWTD(s)

Set of standard criteria for the selection of home water-treatment systems/devices

As mentioned above, a set of 10 standard criteria, flowing from the decision tree, is provided below to assist users in making decisions on the selection of the appropriate HWTSs/Ds to use. Criteria and sub-criteria to consider in the selection of the appropriate HWTSs/Ds include the following:

Ability to deliver a product water which is safe and pleasant to drink and use for cooking (regulatory compliance with SANS 241) - without further deterioration during storage

- Effective removal of microbiological contaminants
  - bacteria
  - viruses
  - parasites
- Effective removal of physical and chemical contaminants
  - suspended and colloidal material (turbidity)
  - metals (Fe, Mn, Al)
  - taste and odour (algae)
  - organics (colour)
  - organics (AOC), to ensure biological stability
- Ability to handle various water qualities and variations in raw water quality
- Ability to sustain product water quality (and not deteriorate over time)
- Ability to deliver acceptable quality of water on its own and not require pretreatment

Ability to deliver an adequate quantity of water for drinking and cooking

- Delivery of an adequate quantity of water (preferably 25 ℓ/person·d or at least 5 ℓ/person·d for drinking and cooking)
- Ability to sustain product water quantity (and not deteriorate over time)

Ease of operation and maintenance

- Getting water to/into the device
- Ease of operation by household members (setting flow rates and dosing rates, etc.)
- Cleaning and servicing of the device and its components

Robustness of the unit

- Ability to withstand rough handling
- Ability to provide adequate water quality and quantity at various feed qualities
- Ability to last and be sustainable with minimum care
- Ability to produce safe water over the lifespan of the device

Ability to deliver safe water without further deterioration during storage

- Ability to retain water quality when stored in the unit
- Ability to retain water quality when the water is transferred to a storage container
- Potential and ease of re-infection of the water

Safety of container/unit and materials

- Chemical safety of materials (leaching of contaminants, toxicity of material itself)
- Potential of materials or components to cause physical harm

Ease of construction/supply

- Availability of unit and ease of obtaining a unit
- Availability of materials/components
- Sophistication of configuration and components

Social acceptance and use

- Will the users 'like' the system?
- Will the users use the system?
- Will the users keep on using the system?
- Can the unit work without electricity supply?
- Can and will the users use the system for something else (some other purpose)?
- Are the users able, and will they, maintain the system?
- Are the users able to judge the water quality (clarity/turbidity) to ensure safe usage?

Potential for local enterprise and support

- Potential for production of units/replacement parts within rural communities
- Potential for local business opportunities, e.g. involving village shops/local vendors in marketing and distribution
- Availability of local resources for technical and educational support

Cost of the units (absolute/comparative)

- Capital cost for a fully functional unit
- Additional capital costs should it be necessary to add another treatment step/unit to ensure adequate water quality
- Operating costs, specifically as petaining to what the users will have to pay to ensure sustainability

3.2.2 A decision-support matrix for the selection of the appropriate HWTDs to use

A decision-support table (matrix), derived from the studies and evaluations performed on the HWTDs (refer to **Volume 1**), is provided (Table 3.2) to assist the funder/supplier/consultant (water service provider, NGO, funding agency, consulting person or institution, etc.) further in selecting the appropriate HWTDs.

Note

Table 3.2 should be used with caution and it is recommended that **Volume 1** (and appropriate literature or supplier information) should be studied before using this table. The table should further be used in conjunction with Chapter 2, and Section 3.2.1.

Table 3.2: Decision matrix for the selection of home water-treatment systems/devices

(Not requiring electricity. Use Table 3.2 in conjunction with Chapter 2, Section 3.2.1)
Scores: *A = acceptable/easy/efficient; C = conditionally acceptable/moderately difficult/moderately efficient; P = poor (unacceptable)/difficult/not efficient*

EVALUATION CRITERIA		FILTERS									SOLAR & HEAT				PRE-TREATMENT		DISINFECTANTS			DISINFECTANT & FLOCCULANT COMBINED	
		Silver-impregnated porous clay pot (SIPP)	Porous clay pot (e.g. Potters for Peace)	Ceramic candle filter (CCF)	Modified biological sand filter with added zeolite (BSF-Z)	Standard biological sand filter (BSF-S)	Drum or barrel filters	Bucket filter (BF)	Activated carbon filter	Charcoal filters (UNICEF)	Boiling (5 minutes)	SODIS system	Solar cookers	SOLAIR process	Storage & plain sedimentation	Cloth filtration or straining	Sodium hypochlorite ('Jik')	Calcium hypochlorite (HTH; granules or tablets)	Iodine	Chlor-Floc Watermaker™	PUR™
Ability to deliver adequate quantity of water	0.3-5 ℓ/h	●[1]	●[1]	●[3]		●[2]						●[8]	●[9]	●[10]	●[11]						
	5-25 ℓ/h				●[2]					●[6]	●[7]					●	●[2]		●[2]	●[12]	●[11]
	25-100 ℓ/h							●[2]	●[5]												
	> 100 ℓ/h						●[4]											●[4]			
Ability to deliver safe water (including storage)	Aesthetics (turbidity, including algae)	C[13]	C[13]	C[13]	C[13]	C[13]	P	P	P	C[6]	P	P	P	P	C[14]	C[14]	P	P	P	A	A
	Chemicals (including taste & odours)	P	P	P	P	P	P	P	A	C[15]	P	P	P	P	P	P	P	P	P	C[16]	C[16]

	Microbiological	A	C[17]	C[17]	C[17]	C[17]	P	P	P	P	A	C[18]	A	C[18]	P	P	C[18]	C[18]	C[18]	A	A
Ease of operation & maintenance	Getting water to/into device	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	Cleaning and servicing	A	A	A	C	C	C	A	A	C	A	A	A	A	A	A	A	A	A	A	A
	Operation by household	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Mechanical robustness	Ability to withstand rough handling/ breaking	C[19]	C[19]	C[19]	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	Ability to last under taxing use/durability	C[20]	C[20]	C[20]	A[21]	A[21]	A[21]	A[21]	C[22]	C[22]	A	A[21]	A	A	A	A	A	A	A	A	A
Robustness in ability to handle varying water quality	Changes in water quality	C[23]	C[23]	C[23]	A	A	A	A	C[24]	C[24]	A	P	A	P	A	A[23]	C[25]	C[25]	C[25]	A	A
	Ability to maintain performance over the lifespan of the device	C[26]	C[26]	C[26]	A[27]	A[27]	A[27]	A[27]	C[27]	C[27]	A	A[27]	A	A	A	A[27]	C[28]	C[28]	C[28]	A	A
Availability	Local supply/off the shelf if imported	C[29]	C[30]	A							A	A	A	A	A	A	A	A	A	A	A
	Constructed				C[31]	C[31]	C[31]	A	C[31]	C[31]	A	A		A	A						
Social acceptance	Does community 'like' it?	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]	C[32]
	Will they use it?																				
	Will they keep using it?																				
	Use it for something else?																				
	Will they maintain it?																				
Ease of construction	Availability/accessibility of materials	C[33]	C[33]	C[33]	C[33]	C[33]	C[33]	A	P	P	A	A	C[33]	A	A	A	A	C[3]	C[33]	C[33]	C[33]
	Sophistication	C[33]	C[33]	C[33]	C[33]	C[33]	C[33]	A	A	A	A	A	C[33]	A	A	A	A	C[33]	C[33]	C[33]	C[33]
Cost of unit/ affordability	For the sponsor (NGO, municipality, international) capital cost & parts replacement	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	For the community. Running costs	A	A	A	A	A	A	A	A	A	P	A	A	A	A	A	P	P	P	P	P

Notes:

[1]Based on a 5 ℓ to 8 ℓ filter pot

[2]Filter constructed in or disinfection carried out in a 25 ℓ bucket (32 cm diameter, 41 cm high)

[3]Based on one candle (10 cm in diameter, 10 cm high; bucket size: 32 cm diameter, 41cm high; pore size 0.1 µm to 10 µm)

[4]Based on a standard 200 ℓ drum

[5]Based on bucket-sized units with granular activated carbon

[6]Based on the standard UNICEF design which has a layer of charcoal between layers of sand (Chaudhuri and Singh, 1993)

[7]Depends on container size; do not boil algae containing water; remove algae before boiling by filtration (not straining)

[8]Depending on bottle size and time required in the sun (normal bottle size used is 2 ℓ transparent PET plastic bottle)

[9]Based on 10 ℓ cooker, and depending upon availability of direct sunlight

[10]Based on a 25 ℓ jerry can and 6 h of exposure

[11]Delivery can be higher, depending on the sizes of the pots used; the main constraint is settling time

[12]Based on a powder sachet for 10 ℓ water; multiple sachets will increase volume delivery in multiples of 10 ℓ; Chlor-Floc sachets for 20 ℓ of water are also available.

[13]Depends on raw water quality; may require pre-treatment

[14]Plain sedimentation usually does not remove algae; filtration through 8 layers of cloth may remove ~50% of algae

[15]Charcoal typically has lower removal efficiencies than activated carbon

[16]Flocculant/disinfectants can remove some heavy metals and organics, not necessarily to SANS 241 levels

[17]May require post-disinfection

[18]Depends on turbidity being within recommended limits (see Table 3.4)

[19]Breakage of the filter element is a concern; will last if handled with care

[20]Expected lifespan is normally between 2 and 3 years; candle filters containing activated carbon should be replaced more frequently

[21]Sand will eventually need replacement because of losses; SODIS bottles deteriorate and will need replacement

[22]Activated carbon and charcoal will need regular replacement (as frequent as once per month) depending on water quality

[23]Flow will decrease with increasing turbidity and algae; number of layers of cloth can be reduced to increase flow through cloth filter

[24]Carbon and charcoal filters rapidly exhausted by high background organics

[25]Disinfectant demand varies with water quality (in particular turbidity and organics); dose should be doubled for turbid water; pre-treatment is preferable

[26]Ceramic filters may become irreversibly clogged if not properly maintained or if substances like iron precipitate in the internal pores; silver depletion may reduce microbial

removal over time

[27]Depending upon the timely replacement of sand/zeolite/activated carbon/charcoal/cartridge/bottle/cloth, etc.; with the exception of the adsorbents, it should be obvious when this needs to occur

[28]Disinfectants must be stored properly to maintain their effectiveness; hypochlorite solutions including bleach should not be stored longer than 1 month

[29]Local production only started; availability will increase with time

[30]Currently imported, but local manufacture, where clay and saw dust are available, is fairly easy

[31]Depending on the availability of the right media (sand, zeolite, activated carbon, charcoal)

[32]When comparing treatment devices and methods, community acceptability needs to be determined by a local opinion survey

[33]These units will normally not be constructed or manufactured by local communities but by some manufacturing facility

3.2.3 Selecting pre-treatment methods for turbidity removal

Most raw water sources will require some degree of turbidity removal prior to disinfection in order to meet turbidity standards and guidelines for efficient disinfection. For more turbid waters, this may require a two-step process as discussed in Section 3.1.1. For turbid waters it is recommended that one of the following simple and inexpensive pre-treatment methods is used:

i. plain sedimentation
ii. cloth filtration (preferably using 8 layers of tightly woven cotton)
iii. sand filtration (bucket or drum filters as shown in Table 3.2)

The turbidity-removal efficiencies of all three methods are highly variable unless a coagulant is used and depend on the type and concentration of solids to be removed. They are most effective for removing settleable solids including sand and silt and larger microorganisms including algae as well as floating material such as leaves and grass. In the absence of a coagulant, they are not effective for removing turbidity due to clay particles. In practice, they are most effective for pre-treating turbid surface water sources, e.g. from rivers and ponds. None of these methods are likely to reduce the turbidity to < 1 NTU on their own.

The actual performance of any one of these methods is strongly dependent on the type of particles present in the raw water and should be determined experimentally for each candidate source as part of raw water quality monitoring. However, Table 3.3 below, which summarises the available data on the turbidity-removal efficiency of these methods, can be used as a guide in the preliminary selection process. Note that these are reported removal efficiencies without the use of coagulant.

Table 3.3: Turbidity-removal efficiencies for simple pre-treatment methods

Treatment method	Reported turbidity-removal efficiencies†	Notes
Plain sedimentation (24 h)	80-90%	Turbidity removal may improve with settling time but is limited by fraction of solids which is settleable.
Cloth filtration (2 layers of tightly woven cotton cloth)	0-60%	Most appropriate for floating material including algae. Removal efficiency tends to increase with increasing turbidity although actual filtrate turbidity also increases. Turbidity removal increases but flow may decrease with increasing number of layers.
Cloth filtration (8 layers of tightly woven cotton cloth)	48-64%	
Sand filtration (23 cm of 0.2 mm-0.5 mm sand)	60-99%	Most effective method but least likely to be to be used and maintained correctly over the long run. Removal efficiency tends to increase with increasing turbidity. Turbidity removal increases and flow decreases with decreasing sand size
Sand filtration (20 cm of 0.95 mm sand) (BF)	10-96%	

†Removal efficiencies without the use of a coagulant

The pre-treatment method selected must bring the turbidity within the required limits of the subsequent treatment step. These are summarised in Table 3.4.

Table 3.4: Turbidity limits for recommended filtration/disinfection technologies

Device/treatment method	Turbidity limit	Notes
Ceramic filters (clay pots: SIPP, PFP; ceramic candles(CCF))	50 NTU	More turbid waters may result in reduced flow rates and increased cleaning efficiency
Biological sand filters (BSF-S, BSF-Z)	50 NTU	More turbid waters may result in reduced flow rates and increased cleaning efficiency
Bucket and drum filters	Appropriate for turbid waters	Pre-sedimentation or cloth filtration may be beneficial for very turbid and algal-laden waters, respectively
Carbon filters (GAC, charcoal)	No data	Turbidity should be as low as possible to reduce clogging and masking of sorption sites
Boiling	Effective for turbid waters	Pre-treatment to remove visible (> 30 NTU) turbidity recommended for aesthetic reasons
Solar cooker	Not affected by turbidity	Pre-treatment to remove visible (> 30 NTU) turbidity recommended for aesthetic reasons
SODIS	30 NTU	
SOLAIR	2 NTU	
Chlorination ('Jik', HTH)	10 NTU	Disinfection can be effective up to 100 NTU in emergency situations but pre-treatment to the lower limit is recommended for improved aesthetics, more efficient disinfection and lower required doses
Flocculation + disinfection (PUR™, Chlor-Floc Watermaker™)	Appropriate for turbid waters. Pre-treatment to < 100 NTU recommended	The flocculation step provides very efficient turbidity removal. An upper limit of 100 NTU is recommended based on the upper limit for disinfection only; however, the products have been shown to be effective at much higher turbidities

Whether one or two turbidity-removal steps are required, the final step (typically a ceramic or biological sand filter) should be able to bring the turbidity to within aesthetically acceptable limits and within the required limits for disinfection. Table 3.5 summarises the turbidity-removal efficiencies of the filters evaluated in WRC Report No. K5/1884 (**Volume 1**). These values can be used in the preliminary selection process to identify the most promising candidate technologies but the actual removal efficiencies for a given source water and treatment sequence should be evaluated in experimental trials.

Table 3.5: Expected turbidity removals in ceramic and biological sand filters

Filter	Turbidity-removal efficiencies	Flow rates
Silver-impregnated porous pot (SIPP)	0-83%*	0.7-1 ℓ/h
Ceramic candle filter (CCF)	10-79%*	1-2.2 ℓ/h
Biological sand filter with conventional media (BSF-S)	58-92%*	1.5-4 ℓ/h
Biological sand filter with zeolites (BSF-Z)	46-92%*	7.6-7 ℓ/h

* Higher % removals correspond to higher raw-water turbidities

3.3 How to use the guidelines

3.3.1 Overview of the selection steps

In this section, some examples are provided for the selection of the most appropriate home water-treatment device (HWTD) for the required application. Examples are provided for the following classes of raw water:

- High-turbidity water source
- Low-turbidity water source
- Moderate algal content and moderate turbidity

The following is assumed:

- All these classes of water contain unacceptably high concentrations of pathogens.
- The water has been analysed by a reputable laboratory over an adequate time period to ensure that 'worst-case' scenarios of water qualities have been identified.

The action of the HWTDs considered in this guideline is generally limited to the reduction of turbidity and microbial contaminants with the following possible exceptions:

- Carbon filters (GAC or charcoal) are used to remove organics including algal toxins.
- The flocculation/disinfection systems (PUR^{TM} and Chlor-Floc) can remove heavy metals including arsenic, high-molecular-weight organics including pesticides and also algal toxins.

All the particle-removal technologies (flocculation, sedimentation, filtration and straining) will remove some proportion of the chemical contaminants which are in a precipitated or sorbed form which may improve the aesthetics of the water, but with the above exceptions, chemical removal efficiencies of HWTDs are too inconsistent and uncertain over the long term to recommend HWTDs for waters with chemical parameters exceeding limits recommended in SANS 241.

In particular, none of the HWTDs including carbon absorption and flocculation/precipitation will remove nitrates, nitrites or fluorides which are all highly soluble and require specialised technologies which are not suited for household use. Chlor-Floc and PUR^{TM} are also not suited for very high metal concentrations such as found in mine tailings.

GAC and especially PUR^{TM} and Chlor-Floc are relatively expensive (see Table 2.1) and also require a constant, reliable and affordable supply of consumables. However, they may provide a cost-effective interim or long-term alternative to a specialised centralised system for more problematic waters. This must be carefully evaluated on a case-by-case basis and is beyond the scope of the current guidelines

The most appropriate HWTDs are selected for field evaluation following the process described in Section 3.1 and using the decision tools (decision tree and decision matrix and turbidity removals and limits) described in Section 3.3.

3.3.2 Selection example for a water source with HIGH turbidity

Consider the following water quality:

Table 3.6: Water quality parameters for the 'high turbidity' example

Parameter	Value
pH	7.2
Turbidity (NTU)	120
Conductivity (mS/m)	54
Colour (mg/ℓ Pt)	10
Calcium (mg/ℓ Ca)	28
Magnesium (mg/ℓ Mg)	12
Alkalinity (mg/ℓ as $CaCO_3$)	38
Sulphates (mg/ℓ SO_4)	22
Chloride (mg/ℓ Cl)	68
Nitrate + nitrite (mg/ℓ NO_3 + NO_2)	8.5
Iron (mg/ℓ Fe)	0.15
Manganese (mg/ℓ Mn)	0.08
Taste & odour	None
Total coliforms (# per 100 mℓ)	180
Faecal coliforms (# per 100 mℓ)	12

Step 1: Identify the main raw water problems

Comparing the raw water-quality values with the SANS 241 water quality standards, it is found that the only constituents exceeding acceptable limits are turbidity and microbiological quality. Both are high, clearly placing this water in the 'High turbidity' category, when referring to the water quality categorisation outlined in Section 3.1.1. Assume the taste and odour of the water has been found as being acceptable. Therefore, the following water-quality parameters are out of line with the SANS 241 requirements:

- Turbidity: 120 NTU vs. < 5 NTU and preferably < 1 NTU required
- Total coliforms: 180 per 100 mℓ vs. < 10 per 100 mℓ required
- Faecal coliforms: 12 per 100 mℓ vs. 0 per 100 mℓ required

Should nitrates + nitrites, fluoride or heavy metals be outside of the SANS 241 standards, then home water-treatment devices should not be used. Chlor-Floc, PUR™ or GAC may be considered if organic removal is required but extensive field trials would be required. Otherwise, specialised treatment should be implemented.

Follow the decision tree (Figure 3.1) and the decision matrix (Table 3.2) from now on:

Step 2: Can the unit deliver adequate quantity of water?

Decide on how important quantity of water is – and allow for the possibility of having more than one unit per household. This must be decided in consultation with the householders and take into account their typical habits and practices. For example, it is not necessary to have filtered water to wash your hands or to disinfect water prior to boiling to make tea or cooked porridge.

Basic survival needs for a person: > 7.5 litres per day (see above)

For six people in the house (assume adult consumption) a minimum quantity of 45 ℓ/d of purified water is needed.

From the decision matrix, Table 3.2, devices delivering low flow volumes of 0.5 ℓ/h to 5 ℓ/h, or 16 ℓ to 40 ℓ in an 8-hour day **per unit,** include the following:

i. Silver-impregnated porous clay pot (SIPP)
ii. Porous clay pot (Potters for Peace pot)
iii. Ceramic candle filter (CCF)
iv. SODIS
v. Solar cooker

Should one of these units be selected eventually, at least two units will be required.

Devices producing from 5 ℓ/h to 25 ℓ/h, or 40 ℓ to -200 ℓ per 8-hour day per unit, include the following:

i. Standard biological sand filter (BSF-S)
ii. Modified biological sand filter with added zeolite (BFS-Z)
iii. Bucket filter
iv. Charcoal filters
v. Boiling
vi. SOLAIR
vii. Cloth filtration
viii. Chlor-Floc (in conjunction with straining after flocculation)
ix. PUR^{TM} (in conjunction with straining after flocculation)

Devices or treatment methods producing flows in excess of 25 ℓ/h, or 200 ℓ per 8-hour day include:

i. Drum or barrel filters

Let us first accept all of the possibilities. This may entail eventually needing more than one unit of the selected HWTD, but discarding the lower flow units at this point may unnecessarily rule out the units' efficiencies at removing microorganisms (being the most important property).

Step 3: Can the unit deliver a product water, after pre-treatment where required, which is safe and pleasant to drink and use for cooking (regulatory compliance with SANS 241)

Turbidity removal should be considered first while the need for post-disinfection will be assessed subsequently.

From Table 3.3 it can be seen that the following water quality parameters are not in line with the SANS 241:2011 requirements:

- Turbidity: 120 NTU vs. <5 NTU and preferably < 1 NTU required
- Total coliforms: 180 per 100 mℓ vs. < 10 per 100 mℓ required
- Faecal coliforms: 12 per 100 mℓ vs. 0 per 100 mℓ required

The primary concerns are therefore aesthetic and microbial.

High turbidity = Pre-treatment advised

Pre-treatment is required to bring the turbidity to within the recommended limits in Table 3.4 except in the case of Chlor-Floc and PUR™ which can probably be used without pre-treatment.

From Table 3.3, cloth filtration with 8 layers of cotton could reduce the turbidity to between ~43 NTU and 62 NTU. The higher removal efficiencies may be sufficient for the ceramic and biosand filters but this would have to be determined empirically. The product water could subsequently be disinfected by boiling or solar cooking (pasteurisation); however, the turbidity would remain well above the required limit of < 5 NTU.

Plain sedimentation for 24 h should be able to bring the turbidity down to ~24 NTU which is within in the limits for boiling, the ceramic and biosand filters and the SODIS system. This is probably a more appropriate treatment option than cloth filtration for this water source. SODIS would, however, not reduce the turbidity any further so it would remain well above 5 NTU

As shown in Table 3.3, sand filtration could potentially bring the turbidity down to < 10 NTU which would make chlorination without further treatment a possibility although the turbidity should ideally be < 1 NTU. Turbidity removal tends to increase with decreasing sand size but at the expense of lower flows and more frequent cleaning. If the sand filtration is the only pre-disinfection step then the smaller sand size is likely to produce a better quality final water. However, if a second filtration step is to be used then the coarser sand is recommended to reduce the rate of clogging and required cleaning frequency of the first filter.

Based on the above:

- Chlor-Floc Watermaker™ and PUR™ could be used without pre-treatment.

- Plain sedimentation for 24 h (or possibly cloth filtration depending on the community's preference) would have to be followed by another filtration technology (ceramic or biosand filter) prior to disinfection.

- Sand filtration (bucket or drum, preferably 0.2 mm to 0.5 mm sand) may provide sufficient pre-treatment for subsequent disinfection (SODIS, boiling, solar cooker, 'Jik', HTH). This would need to be determined in field trials.

- Sand filtration (bucket or drum, preferable 0.95 mm sand) followed by ceramic or biological sand filtration would probably provide the best final water quality but would be the most complex to operate and maintain.

The filtration technologies which could follow pre-treatment are:

i. Silver-impregnated porous clay pot (SIPP)
ii. Porous clay pot (Potters for Peace pot)
iii. Ceramic candle filter (CCF)
iv. Standard biological sand filter (BSF-S)
v. Modified biological sand filter with added zeolite (BFS-Z)

Turbidity removals by these devices for a range of raw water sources as evaluated in WRC Report No. K5/1884 are summarised in Table 3.5. Note that if the influent water for the filter has been pre-treated to remove turbidity then much of the easily settleable/filterable fraction of the turbidity will already be gone, and therefore the removal efficiencies by the filter itself may be in the lower end of the ranges listed in Table 3.5. However, the clogging rates and required cleaning frequencies of the filters will be decreased which is the primary purpose of the pre-treatment step.

Reducing the turbidity from ~24 NTU to < 5 NTU requires a > 80% turbidity reduction in the filtration step or a 95% overall reduction based on the raw-water turbidity.

From Table 3.5, the biological sand filters (BSF-S and BSF-Z) are more likely to achieve the turbidity standards and with higher flows. The actual turbidity removals and flows for a given source water should be determined by laboratory or field trials. However, as discussed below, the advantage of the SIPP is that no further disinfection is required as all indicator bacteria were removed in laboratory trials regardless of the final turbidities.

Chemical removal

From Table 3.6 it is clear that no chemical removal is required. Therefore, only the sub-criteria 'Aesthetics (turbidity)' and 'Microbiological' are relevant here and the current list of possible HWTDs generated can be retained without any addition of chemical removal units (such as charcoal or activated carbon).

Microorganism removal to non-detectable levels of *E. coli*, faecal coliforms, cytopathogenic viruses and protozoan parasites:

From Table 3.2, the SIPP, Chlor-Floc Watermaker™ and PUR™ devices or methods are listed as efficient for microbially contaminated water and require no further disinfection (from the final report for WRC K5/1884, it can be also seen that, among the filters, only the SIPP device can remove microorganisms to the SANS 241:2011 requirements on its own). However, other units marked 'Conditional' in Table 3.2, in this case, the Potters for Peace pot, the ceramic candle filter and the biological sand filters, could still be employed, in conjunction with post-disinfection, and may be retained for the moment. Therefore, we are still left with the following list of possible devices (incorporating turbidity removal pre-treatment as discussed above, as well as post-treatment recommended where required) to use:

i. Chlor-Floc (in conjunction with straining after flocculation)
ii. PUR™ (in conjunction with straining after flocculation)
iii. Pre-treatment + silver-impregnated porous clay pot (SIPP)
iv. Pre-treatment + porous clay pot (Potters for Peace pot) + post-disinfection
v. Pre-treatment + ceramic candle filter (CCF) + post-disinfection
vi. Pre-treatment + standard biological sand filter (BSF-S) + post-disinfection
vii. Pre-treatment + modified biological sand filter with added zeolite (BFS-Z) + post-disinfection

The disinfection methods available and their limitations are as follows:

a. Boiling (limiting factor is cost of fuel)
b. Solar cooker (20 ℓ/d to 30 ℓ/d max per unit for optimal weather conditions)
c. SODIS (< 30 NTU)
d. SOLAIR (~2 NTU)
e. Chlorination (< 10 NTU)

It is unlikely that it will be possible to achieve a final water turbidity of ~2 NTU for this raw water source so SOLAIR may be eliminated from consideration.

The choice of disinfection method will depend on cost and local preferences. Boiling would typically be the most expensive method. Solar cooking with a darkened vessel and reflectors and SODIS are essentially zero-cost technologies but the volumes produced are limited and the treatment times are long. Chlorination is a cheap way of disinfecting any volume of water and the water is ready to drink within 30 min to 2 h. However, there is still a cost associated with the purchase of the chlorine and some communities do not like the taste of chlorinated water. Concerns about the taste of the water can be mitigated by ensuring that appropriate doses are used (see Section 2.4.3.1 of the final report for WRC K5/1884 (**Volume 1**)).

Step 4: Ease of operation & maintenance

Regarding all of the three sub-criteria under this criterion, Table 3.2 shows that all the remaining units in our list are easy to fill with water and none of the units may be regarded as 'P', or unacceptably difficult to clean or operate.

The use of multiple treatment steps does, however, increase the training requirements, labour, hardware and space requirements for the householder, making them less attractive and more difficult to implement successfully than simpler treatment sequences. However, they may be the most affordable way to produce high-quality final water and therefore should be retained for further evaluation and consultation with the community (this logic is especially valid for units exhibiting good performance in the most important criterion of 'Ability to deliver safe water', as well as delivering an 'Adequate quantity of water').

Step 5: Mechanical robustness

None of the units on our list are marked as 'P' (unacceptable/poor) in Table 3.2 and the list should be retained as is (this logic is especially valid for units exhibiting good performance in the most important criterion of 'Ability to deliver safe water').

Step 6: Robustness in ability to handle varying water quality

None of the units on the list are marked as 'P' (unacceptable/poor) in Table 3.2 and the list should be retained as is (this logic is especially valid for units exhibiting good performance in the most important criterion of 'Ability to deliver safe water').

Step 7: Availability of the devices

None of the units are marked as 'P' in Table 3.2. All of the units on the provisional list are available in the country, although it may take some time to source some of the units, should large quantities be required. It is assumed that some form of disinfectant (such as household bleach) will be available everywhere. The list of provisional units should, therefore, be retained. This criterion should, however, always be applied taking the local situation into account.

Step 8: Social acceptance

As social acceptance depends on so many factors (see Chapter 4 in **Volume 1**), the range of systems retained until this stage should be tested against requirements and preferences of the community into which the units are intended to be introduced.

Step 9: Ease of construction

None of these units will normally be self-constructed when communities are supplied with HWTDs by a funder or water-supply authority. However, if units are to be constructed locally, this will be to the benefit of those units in terms of their ranking to use (see Chapter 6 in **Volume 1** for details of construction). If all units are manufactured elsewhere, this criterion is not really applicable.

Step 10: Cost of the unit

This criterion takes into account two types of costs:

- Capital cost (normally borne by the funder, e.g. municipality, government, NGO, funding agency, etc.)
- Daily operating cost (normally borne by the users themselves).

Table 2.1 provides some cost estimates for the various units; however, these estimates are only intended to provide a rough idea of the relative costs of the different systems.

Capital costs

Regarding capital costs, the Chlor-Floc (in conjunction with straining after flocculation) + post-disinfection, and the PUR™ (in conjunction with straining after flocculation) + post-disinfection methods of treatment will be the least costly. This is because only a container to mix the water and chemicals in, and a straining cloth to filter the flocs formed, will be required.

Capital costs of the various units will be highly dependent on factors such as local manufacture, materials used, standard of manufacturing finish, number of units required, etc. Therefore, capital costs will have to be established by the funder just before purchase. The shortlist of units is therefore retained.

Operating costs

Since the daily operating costs will be carried by the users themselves, this sub-criterion is crucial regarding the sustainable use of the HWTD.

The PUR™ and Chlor-Floc methods would be the simplest treatment sequence for this high-turbidity water source; however, the cost of chemical sachets is an order of magnitude greater than the costs of the other treatment methods, therefore these methods are unlikely to be a viable option unless the consumables are heavily subsidised.

The zero daily operating cost options are:

i. Pre-treatment + SIPP
ii. Pre-treatment + ceramic candle filter or Potters for Peace pot + SODIS or solar cooker
iii. Pre-treatment + biological sand filter + SODIS or solar cooker
iv. Sand filter (bucket or drum) + SODIS or solar cooker (if the sand filter can achieve ~95% turbidity reduction)

The overall rate of production for all of these treatment systems falls in the range of 16 ℓ/d to 40 ℓ/d and multiple units (ceramic filter and/or solar cooker) or a large amount of space for SODIS bottles may be required. The SIPP device which does not require a post-disinfection step is more expensive than the biological sand filters + solar disinfection (Table 2.1), but the treatment time is much shorter making it more convenient for the user.

The following sequences can produce higher flows (40 ℓ/d to 200 ℓ/d) at a low daily operating cost:

i. Pre-treatment + biological sand filter + chlorination
ii. Sand filter (bucket or drum) + chlorination (if the sand filter can achieve ~95% turbidity reduction)

Summary of decisions and conclusion for a high-turbidity water source

Chlor-Floc Watermaker™ and PUR™ (flocculation + disinfection with straining) are the only methods which can treat high-turbidity raw water without additional steps. However, they are unlikely to be selected for long-term use by rural communities because of their high cost.

Pre-treatment + SIPP is the simplest treatment sequence which consistently achieves the required microbial quality without post-disinfection and with zero daily operating cost and may therefore be the preferred unit. Its disadvantages are low flows requiring multiple units and the high cost of replacing broken and damaged filter elements.

The biological sand filters are cheaper and produce higher and more consistent flows and turbidity removals than the SIPP device, but require post-disinfection which increases the complexity of the process and requirements of the user.

SODIS and solar cooking are essentially zero-cost disinfection technologies but can only treat small volumes at a time, require long treatment times and are highly dependent on the weather.

Chlorination provides rapid disinfection for any volume of water but there are concerns about whether users will be willing to purchase the chlorine required, will be able to dose the chlorine correctly, or will object to the taste of chlorinated water.

Pre-treatment + SIPP is the simplest treatment sequence which consistently achieves the required microbial quality without post-disinfection and with zero daily operating cost and may therefore be the preferred unit. The final choice will, however, depend on the candidate sequences' ability to actually produce the required quality and quantity of water, the costs involved, the preferences of users and funders, the feasibility of users installing, operating and maintaining the systems in their homes, and feasibility of establishing the necessary supply chains to ensure their sustained use.

3.3.3 Selection example for a water source with LOW turbidity (such as groundwater or low-turbidity surface water)

Consider the following water quality:

Table 3.7: Water quality parameters for the 'low turbidity' example

Parameter	Value
pH	7.6
Turbidity (NTU)	4.5
Conductivity (mS/m)	62
Colour (mg/ℓ Pt)	6
Calcium (mg/ℓ Ca)	32
Magnesium (mg/ℓ Mg)	15
Alkalinity (mg/ℓ as $CaCO_3$)	52
Sulphates (mg/ℓ SO_4)	28
Chloride (mg/ℓ Cl)	75
Nitrate + nitrite (mg/ℓ NO_3 + NO_2)	6.6
Iron (mg/ℓ Fe)	0.12
Manganese (mg/ℓ Mn)	0.05
Taste & odour	None
Total coliforms (# per 100 mℓ)	122
Faecal coliforms (# per 100 mℓ)	10

Step 1: Identify the main raw water problems

Comparing the raw water quality values with the SANS 241 water quality standards, it is found that the only constituents exceeding acceptable limits are turbidity and microbiological quality. The turbidity exceeds the < 1 NTU level required by SANS 241:2011 but falls within the < 5 NTU deemed reasonable and acceptable for low-cost HWTS and within the ‘Low turbidity’ category in Section 3.1 ‘Classification of raw water quality for South African raw water sources’. Assume the taste and odour of the water has been found as being acceptable. The following SANS 241:2011 parameters are thus exceeded:

- Turbidity: 4.5 NTU vs. < 5 NTU required and < 1 NTU recommended
- Total coliforms: 122 per 100 mℓ vs. < 10 per 100 mℓ required
- Faecal coliforms: 10 per 100 mℓ vs. 0 per 100 mℓ require

Should nitrates + nitrites, fluoride or heavy metals be outside of the SANS standards, then home water-treatment devices should not be used. Chlor-Floc Watermaker™, PUR™ or GAC may be considered if organic removal is required but extensive field trials would be required. Otherwise, specialised treatment should be implemented.

Follow the decision tree (Figure 3.1) and the decision matrix (Table 3.2) from now on:

Step 2: Can the unit deliver adequate quantity of water?

Decide on how important quantity of water is – and allow for the possibility of having more than one unit per household. The analysis is the same as in Step 2 of the previous example.

Step 3: Can the unit deliver a product water, after pre-treatment or post-treatment, where required, which is safe and pleasant to drink and use for cooking (regulatory compliance with SANS 241)

From Table 3.7 it can be seen that the following water quality parameters are out of line with the SANS 241:2011 requirements:

- Turbidity: 4.5 NTU vs. < 5 NTU required, < 1 NTU recommended
- Total coliforms: 122 per 100 mℓ vs. < 10 per 100 mℓ required
- Faecal coliforms: 10 per 100 mℓ vs. 0 per 100 mℓ required

The primary concern is therefore microbial quality.

Given the low turbidity of the source water, pre-treatment to reduce turbidity (Table 3.3.) is not recommended because the marginal improvement in quality that could be achieved would not justify the additional cost, effort and equipment required. The exception would be if householders are already using straining to remove floating material or raw water storage with the intended or unintended benefit of reducing settleable solids.

The turbidity of the raw water falls within the recommended limits for all the filtration and disinfection technologies listed in Table 3.4 except for the SOLAIR process (< 2 NTU).

While this source water is a candidate for disinfection with or without filtration, the use of a filtration technology would have the advantage of reducing the turbidity, possibly to < 1

NTU, increasing the efficiency of disinfection, and is recommended prior to chlorination which has limited effectiveness against pathogenic protozoa.

The filtration options are:

i. Silver-impregnated porous clay pot (SIPP)
ii. Porous clay pot (Potters for Peace pot)
iii. Ceramic candle filter (CCF)
iv. Standard biological sand filter (BSF-S)
v. Modified biological sand filter with added zeolite (BFS-Z)

Chemical removal
From Table 3.7 it is clear that no chemical removal is required. Therefore, only the sub-criteria 'Aesthetics (turbidity)' and 'Microbiological' are relevant here and the current list of possible HWTDs generated can be retained without any addition of chemical removal units (such as charcoal or activated carbon).

Microorganism removal to non-detectable levels of *E. coli*, faecal coliforms, cytopathogenic viruses and protozoan parasites:

If a filtration step is used, it would have to be followed by disinfection except in the case of the SIPP device which was found to remove all indicator bacteria. Chlorination should be preceded by filtration to remove pathogenic protozoa.

The treatment candidates are therefore:

i. Disinfection only (boiling, SODIS, solar cooking)
ii. Silver-impregnated porous clay pot (SIPP)
iii. Porous clay pot (Potters for Peace pot) + post-disinfection
iv. Ceramic candle filter (CCF) + post-disinfection
v. Standard biological sand filter (BSF-S) + post-disinfection
vi. Modified biological sand filter with added zeolite (BSF-Z) + post-disinfection

The candidate disinfection methods and their limitations are:

a. Boiling (limitation is cost of fuel)
b. Solar cooker (20 ℓ/d to 30 ℓ/d per unit for optimal weather conditions)
c. SODIS
d. SOLAIR (if turbidity is reduced to < 2 NTU)
e. Chlorination (pre-filtration recommended)

Step 4: Ease of operation & maintenance

Regarding all of the three sub-criteria under this criterion, Table 3.2 shows that all the units in the list are easy to fill with water and none of the units may be regarded as 'P', or unacceptably difficult to clean or operate.

The use of multiple treatment steps does, however, increase the training requirements, labour, hardware and space requirements for the householders, making them less attractive and more difficult to implement successfully than single step treatment processes.

The single step treatment processes appropriate for this raw water are:

i. SIPP
ii. Boiling
iii. Solar cooking
iv. SODIS

However, these technologies are all limited in terms of the volume of water than can be produced (in the 16 ℓ/d to 40 ℓ/d category with the exception of boiling which is limited by the cost of fuel).

By contrast, post-chlorinating water produced by one of the higher flow filters (BSF-S, BSF-Z) requires little extra effort on the part of the householder although ensuring that the correct dose is used does require special attention.

The filtration technologies all have higher maintenance requirements than the thermal technologies. Ultimately, the final choice will depend on local costs and preferences therefore all the technologies listed in Step 3 may be retained for further consideration.

Step 5: Mechanical robustness

None of the units on the list are marked as ‘P’ (unacceptable/poor) in Table 3.2 and the list should be retained as is (this logic is especially valid for units exhibiting good performance in the most important criterion of ‘Ability to deliver safe water’).

Step 6: Robustness in ability to handle varying water quality

None of the units on our list are marked as ‘P’ (unacceptable/poor) in Table 3.2 and the list should be retained as is (this logic is especially valid for units exhibiting good performance in the most important criterion of ‘Ability to deliver safe water’).

Step 7: Availability of the devices

None of the units are marked as ‘P’ in Table 3.2. All of the units on the provisional list are available in the country, although it may take some time to source some of the units, should large quantities be required. The list of provisional units should, therefore, be retained. This criterion should, however, always be applied taking the local situation into account.

Step 8: social acceptance

As social acceptance depends on so many factors (see Chapter 4 in **Volume 1**), the range of systems retained until this stage should be tested against requirements and preferences of the community into which the units are intended to be introduced.

Step 9: Ease of construction

None of these units will normally be self-constructed when communities are supplied with HWTDs by a funder or water supply authority. However, if units are to be constructed locally, this will be to the benefit of those units in terms of their ranking to use (See Chapter 5 in **Volume 1** for details of construction). If all units are manufactured elsewhere, this criterion is not really applicable.

Step 10: Cost of the unit

This criterion takes into account two types of costs:

- Capital cost (normally borne by the funder (municipality, government, NGO, funding agency, etc.)
- Daily operating cost (normally borne by the users themselves)

Capital costs

Regarding capital costs, boiling, SODIS, and chlorination will be the least costly. Sand filters are more costly than the disinfection only methods while the ceramic filters are the most expensive. Capital costs of the filtration units will be highly dependent on factors such as local manufacture, materials used, standard of manufacturing finish, number of units required, etc. Therefore, capital costs will have to be established by the funder just before purchase.

Operating costs

Since the daily operating costs will be carried by the users themselves, this sub-criterion is crucial regarding the sustainable use of the HWTD.

Of the units on the shortlist, the following options have a zero daily operating cost:

i. SIPP
ii. Solar cooking
iii. SODIS

However, the rate of production for all three devices ranges between 16 ℓ/d and 40 ℓ/d and therefore multiple units (SIPP or solar cooker) or many SODIS bottles (requiring a large amount of space) may be required to provide the amount of treated water needed by the household. Of these three systems, the SIPP is the most expensive; however, the treatment efficiency and time do not depend on the weather and the treated water can be used immediately.

Alternately, sand filtration followed by chlorination can produce higher flows (40 ℓ/d to 200 ℓ/d) at a low daily operating cost:

i. Biological sand filter (BSF-S or BSF-Z) + chlorination
ii. Sand filter (bucket or drum, 0.2 mm to 0.5 mm sand)

Since there will be no other pre-treatment, smaller sand sizes are recommended for the sand filter (see Table 3.3).

Due their higher costs and low flows, ceramic filters which require post-disinfection (e.g. the CCF evaluated in WRC Report No. K5/1884) would not be recommended

Summary of decisions and conclusions for a low-turbidity water source

SIPP is the simplest treatment sequence which consistently achieves the required microbial quality without post-disinfection and with zero daily operating cost and may therefore be the preferred unit. Its disadvantages are low flows requiring multiple units and the high cost of replacing broken and damaged filter elements.

SIPP is the simplest treatment sequence which consistently achieves the required microbial quality without post-disinfection and with zero daily operating cost and may therefore be the preferred unit. The final choice will, however, depend on the candidate sequences' ability to actually produce the required quality and quantity of water, the costs involved, the preferences of users and funders, the feasibility of users installing, operating and maintaining the systems in their homes and the feasibility of establishing the necessary supply chains to ensure their sustained use.

The biological sand filters are cheaper and produce higher and more consistent flows and turbidity removals than the SIPP filters, but they require post-disinfection which increases the complexity of the process and requirements of the user.

SODIS and solar cooking are essentially zero-cost disinfection technologies but can only treat small volumes at a time, require long treatment times and are highly dependent on the weather.

Chlorination provides low cost, rapid disinfection for any volume of water but there are concerns about whether users will be willing to purchase the chlorine required, will be able to dose the chlorine correctly, or will object to the taste of chlorinated water.

3.3.4 Selection example for a water source with moderate algae and moderate turbidity

Consider the following water quality:

Table 3.8: Water quality parameters for the 'moderate algae' example

Parameter	Value
pH	7.8
Turbidity (NTU)	18
Conductivity (mS/m)	64
Colour (mg/ℓ Pt)	10
Chlorophyll *a* (µg/ℓ)	50
Microcystin as LR (µg/ℓ)	0.08
Calcium (mg/ℓ Ca)	31
Magnesium (mg/ℓ Mg)	17
Alkalinity (mg/ℓ as $CaCO_3$)	55
Sulphates (mg/ℓ SO_4)	31
Chloride (mg/ℓ Cl)	66
Nitrate + nitrite (mg/ℓ NO_3 + NO_2)	7.5
Iron (mg/ℓ Fe)	0.15
Manganese (mg/ℓ Mn)	0.06
Taste & odour (TON)	3
Total coliforms (# per 100 mℓ)	89
Faecal coliforms (# per 100 mℓ)	12

Step 1: Identify the main raw water problems

Comparing the raw water quality values with the SANS 241 water quality standards, it is found that the constituents exceeding acceptable limits are turbidity and microbiological quality. The algal level is moderate, and at 50 µg/ℓ chlorophyll *a*, it is not yet in the 'moderately eutrophic' category of 30 µg/ℓ to 100 µg/ℓ chlorophyll *a*. Water containing this level of chlorophyll *a* may not yet show a greenish tint – but will still contain numerous algal cells. However, at a turbidity of 18 NTU, it will not be aesthetically pleasing.

The following SANS 241 levels are exceeded:

- Turbidity: 18 NTU vs. < 5 NTU required, < 1 NTU recommended
- Total coliforms: 89 per 100 mℓ vs. < 10 per 100 mℓ required
- Faecal coliforms: 12 per 100 mℓ vs. 0 per 100 mℓ required

Should any of the other chemical constituents, such as nitrates + nitrites, fluoride, microcystin or heavy metals be outside of the SANS standards, then home water-treatment devices should not be used. In such instances, specialised treatment should be implemented.

In this example, the microcystin level is well below the 1 µg/ℓ standard and taste and odour (TON) is also within aesthetic guidelines; however, there is clearly the potential for the formation of toxic algal blooms and this water source should be closely monitored over time.

Note that while algae or cyanobacterial toxins in drinking water are always undesirable due to chronic health effects, some algal blooms are acutely toxic and pose an immediate health risk. There is no way of knowing whether an algal bloom is toxic or not from its physical appearance; however, people and animals which come in contact with it may develop skin irritations and respiratory problems. Animal deaths have occurred in extreme cases. If a toxic algal bloom is suspected, people should avoid all contact with the affected water and notify the local health authorities. The home water-treatment methods discussed in this section are NOT suitable for the treatment of water containing acutely toxic algae.

Step 2: Can the unit deliver adequate quantity of water?

Decide on how important quantity of water is – and allow for the possibility of having more than one unit per household. The analysis is the same as in Step 2 of the previous example.

Step 3: Can the unit deliver a product water, after pre-treatment or post-treatment, where required, which is safe and pleasant to drink and use for cooking (regulatory compliance with SANS 241)

From Table 3.8 the following SANS 241 levels are exceeded:

- Turbidity: 18 NTU vs. < 5 NTU required, < 1 NTU recommended
- Total coliforms: 89 per 100 mℓ vs. < 10 per 100 mℓ required
- Faecal coliforms: 12 per 100 mℓ vs. 0 per 100 mℓ required

It is important to note that algae are also microorganisms. Units that will remove microorganisms well, will normally also remove algae well. However, algal toxins and exudates, as well as the associated taste and odours, are chemicals which are dissolved in the water. Should such chemicals be present, they will have to be removed by appropriate, more sophisticated technologies, such as charcoal filters or activated carbon treatment – see Step 3 below.

Follow the decision tree (Figure 3.1) and the decision matrix (Table 3.2) from now on to select the main device(s):

Pre-treatment requirements

A turbidity level of 18 NTU falls within the requirements of the technologies listed in Table 3.4 with the exception of chlorination and SOLAIR. However, high algae concentrations cause rapid clogging of filters and therefore pre-treatment may be used to reduce the algal load to subsequent treatment units which can reduce the rate of filter clogging and the risk of dissolved toxin breakthrough should these be present.

Algae removal

The best way to manage algal problems is to minimise the amount of algae in the raw water by selecting a collection point where algae concentrations are lower, e.g. avoiding visible algal blooms, collecting water from the upwind side of water bodies, collecting water from below the water surface rather than skimming the surface, or collecting water from wells dug some distance from the main water body.

When significant quantities of algae are present in the raw water, they should be removed as soon as possible. Cloth filtration (with eight layers of cloth) is an efficient means of removing algae at the point of collection if the filter is fastened over the top of a bucket used to collect water. Cloth filtration is expected to be less efficient for small unicellular algae. Overall removals in the range of 40% to 70% are expected depending on the species present. Cloth filtration with eight layers of cotton can potentially reduce both the chlorophyll a and turbidity by about half, bringing this water into the categories of low turbidity and low eutrophication.

Alternately, a coarse media bucket filter (0.95 mm) could be used to reduce the load on a subsequent fine media filter (biosand or ceramic). There are no data available on algae removal by these filters; however, coarse media roughing filters are sometimes used to reduce turbidity and algal loads to full-scale slow sand filters. Algae do result in clogging and lower flow rates in bucket filters (see Chapter 7 of WRC Report No. 1884); however, since the flow is so much higher than in the other filters, this will not be a limiting factor in the overall treatment train. A bucket filter on its own may also reduce turbidity and chlorophyll *a* levels sufficiently so that no further filtration step is required prior to disinfection; however, this would have to be established in field trials.

Since living algal cells are buoyant, sedimentation is not a recommended treatment method.

Since algae are photosynthetic and can reproduce when exposed to sunlight, it is important that the raw water is collected in opaque vessels and is stored away from direct sunlight if algae are an issue.

The following treatment steps may be considered for removing turbidity and algal cells following pre-treatment:

i. Silver-impregnated porous clay pot (SIPP)
ii. The standard porous clay pot (e.g. Potters for Peace pot)
iii. Ceramic candle filter
iv. Biological sand filter with zeolite
v. Standard biological sand filter
vi. Chlor-Floc (in conjunction with straining after flocculation)
vii. PUR^{TM} (in conjunction with straining after flocculation)

Since a substantial number of algae cells are still likely to pass through the pre-filtration/straining stage, rapid clogging of a subsequent filter is still a possibility. The finer the filter, the greater the negative impact on the filter flow is likely to be. Therefore, a higher flow unit, specifically the biological sand filter with 3 mm zeolite (BSF-Z) is recommended. The lowest flow option, namely the SIPP device, has the advantage that it does not require post-disinfection to achieve SANS 241 bacterial standards; however, it would be necessary to demonstrate that an adequate flow could be maintained with pre-treatment before selecting the SIPP device.

In conventional water treatment, coagulation, flocculation, sedimentation, filtration and chlorination are effective for removing algae and algal toxins. Consequently, PUR^{TM} and Chlor-Floc are potential candidates for the treatment of source waters with high algal content. Unfortunately, there are very limited data on actual algal removal efficiencies for PUR^{TM} and none at all for Chlor-Floc. A potential limitation of the flocculant/disinfectant powders is that the high organic content of eutrophic waters will exert a high chlorine demand such that the disinfectant dose may not be sufficient to maintain a chlorine residual in the treated water. This may be mitigated to some extent if a substantial fraction of the algae can be removed by pre-treatment. Either of the flocculant/disinfectant products can be considered a viable candidate for treatment of eutrophic water if field trials can demonstrate that a single treatment with the product can achieve a chlorine residual of at least 0.5 mg/ℓ after 30 min (this will also be adequate to ensure that bacterial standards are met). In the case of the moderately eutrophic water, a single treatment is likely to be sufficient but source waters with higher concentrations of chlorophyll *a* may be more challenging to treat.

Chemical (algal toxins, taste & odour)

From Table 3.8 it can be seen that algal toxins (expressed as microcystin-LR) and TON number fall within the recommended limits for chemical requirements of SANS 241 and no chemical removal units are strictly required. However, given the eutrophic nature of the source and presence of TON compounds, there is the potential for the occurrence of elevated levels of organics, algal toxins and TON. A carbon-based adsorption unit may be considered, particularly if it results in a detectable improvement in the aesthetics of the finished water from the point of view of the user. From Table 3.2, activated carbon is the only system rated as ‘A’ for chemical removal; however, it is expensive and will not be effective if it is not replaced frequently. Alternately, charcoal filters could be used for the removal of low concentrations of organics at much lower cost.

Note that some ceramic candle filters contain activated carbon inside the ceramic element which means that they combine particle and chemical removal in a single treatment step. The disadvantage is that the volume of the carbon used is limited by the dimensions of the ceramic element and may be insufficient for high pollutant loads. Furthermore, when the carbon becomes exhausted (it should be changed at least every six months) the whole unit has to be discarded.

Further, note the following:

Add the carbon unit directly *after* the main HWTD eventually selected (this is to protect the expensive adsorbent from being blocked and saturated too quickly), but before disinfection. If chlorine is added before a carbon filter, the dose must be increased to ensure that an adequate residual is maintained in the final water. Furthermore, bacteria can proliferate in carbon filters; therefore the filtered water always requires some kind of disinfection.

Carbon filters should not be used post-treatment with PUR™ or Chlor-Floc because the carbon would also remove the chlorine residual. Due to their high cost, the flocculant/disinfectants would only be considered if they could achieve the required removals without subsequent treatment steps.

Carbon filters are also not recommended after the SIPP because a subsequent disinfection step would be required, negating one of the main advantages of the SIPP, or after candle filter models which already contain carbon

We are thus left with the following remaining HWTD options:

i. Pre-treatment + silver-impregnated porous clay pot
ii. Pre-treatment + the standard porous clay pot (e.g. Potters for Peace pot)
iii. Pre-treatment + ceramic candle filter
iv. Pre-treatment + biological sand filter with zeolite + activated carbon unit
v. Pre-treatment + standard biological sand filter + activated carbon unit
vi. Pre-treatment + Chlor-Floc (in conjunction with straining after flocculation)
vii. Pre-treatment + PUR™ (in conjunction with straining after flocculation)

Microbiological (the most important criterion)

As shown in Table 3.2, only the following units from the previous list are marked as 'A' for microbiological safety (and not 'Poor' or 'Conditional', requiring additional pre-treatment or post-treatment):

i. Silver-impregnated porous clay pot (SIPP)
ii. Chlor-Floc (in conjunction with straining after flocculation)
iii. PUR™ (in conjunction with straining after flocculation)

If disinfection is done as post-treatment (*after* the carbon filter, if used), or if a higher-volume delivery option is required, the following units may be added for further evaluation as primary units *before* the activated carbon unit (if used). These units are desirable to use for the treatment of source waters with high algal loads since they will physically filter out the algal cells – **but disinfection as post-treatment will have to be added to ensure the microbiological safety of the water**:

iv. The standard porous clay pot (e.g. Potters for Peace pot)
v. Ceramic candle filter
vi. Biological sand filter with zeolite
vii. Standard biological sand filter

Thermal/light exposure methods of disinfection (boiling, SODIS, SOLAIR, solar cooking) kill algae but do not destroy algal toxins if present and in some cases can make them more toxic. Therefore these methods should not be used for water with high algae concentrations. Even with the use of activated carbon, there is always a risk of breakthrough of algal toxins, especially as the filter becomes exhausted.

Chlorination destroys algal toxins and is the disinfection method of choice for waters with high algal and algal toxin loads. The recommended dose is 3 mg/ℓ with a residual of at least 0.5 mg/ℓ after 30 min.

Therefore, the list of possible HWTD treatment trains to treat this water type is the following:

i. Pre-treatment + silver-impregnated porous clay pot (SIPP)
ii. Pre-treatment + Chlor-Floc (in conjunction with straining after flocculation)
iii. Pre-treatment + PUR™ (in conjunction with straining after flocculation)
iv. Pre-treatment + the standard porous clay pot (e.g. Potters for Peace pot) + (carbon adsorption) + post-chlorination
v. Pre-treatment + ceramic candle filter + post-chlorination
vi. Biological sand filter with zeolite + (carbon adsorption) + post-chlorination
vii. Standard biological sand filter + (carbon adsorption) + post-chlorination

Note: Post-chlorination' can be with sodium hypochlorite ('Jik') or calcium hypochlorite (HTH).

Step 4: Ease of operation & maintenance

Regarding all of the three sub-criteria under this criterion, Table 3.2 shows that all the individual units in our list are easy to fill with water and none of the units may be regarded as 'P', or unacceptably difficult to clean or operate. However, the necessity of using multiple treatment steps does increase the training requirements, labour, hardware and space requirements for the householder making them less attractive and more difficult to implement. On paper, the pre-treatment + flocculation/disinfection powder options appear to be the simplest among the systems but in reality, the Chlor-Floc Watermaker™ and PUR™ processes include multiple treatment steps in themselves. The relative advantages of the two types of treatment trains in terms of operation and maintenance are summarised in Table 3.9.

Table 3.9: Treatment trains based on filtration vs. flocculation/disinfection

Multiple filtration steps + post-chlorination	Cloth filtration at collection + flocculant/ disinfectant
Operation can take place in the home, while the householder undertakes other tasks nearby.	The entire process, including washing of the cloth filters, can potentially take place at the water-collection place, in under one hour – only clean water needs to be transported home.
The filter-cleaning procedures are time consuming but are not carried out every day.	Washing of the cloth filters is relatively easy but needs to be carried out after every treatment.

Note: the carbon filters will become saturated and ineffective with time. A regular and managed replacement programme will have to be followed in replacing the activated carbon filters well before saturation.

Step 5: Mechanical robustness

None of the units on our list are marked as ‘P’ (unacceptable/poor) in Table 3.2 and the list should be retained as is (this logic is especially valid for units exhibiting good performance in the most important criterion of ‘Ability to deliver safe water’).

Step 6: Robustness in ability to handle varying water quality

None of the units on our list are marked as ‘P’ (unacceptable/poor) in Table 3.2 and the list should be retained as is (this logic is especially valid for units exhibiting good performance in the most important criterion of ‘Ability to deliver safe water’). It should just be noted that the carbon filters may become saturated faster during times of algal blooms and this needs to be catered for in the carbon replacement programme.

Step 7: Availability of the devices

None of the units are marked as ‘P’ in Table 3.2. All of the units on the provisional list are available in the country, although it may take some time to source some of the units, should large quantities be required. The list of provisional units should, therefore, be retained. This criterion should, however, always be applied taking the local situation into account. Although activated carbon is expensive, availability itself should not be a problem once the correct units have been specified and sourced.

Step 8: Social acceptance

As social acceptance depends on so many factors (see Chapter 4 in **Volume 1**), the range of systems retained until this stage should be tested against requirements and preferences of the community into which the units are intended to be introduced. In this example, up to four HWTDs or techniques are required. The preferences of the users in terms of the operation and maintenance requirements of the various systems and how easily they can be integrated into their daily lives will be a major factor in the choice of system and in its potential to be successfully implemented.

Chlorination can leave an unpleasant taste in the water which may be objectionable to some users. This may lead to problems in acceptance by the community. Careful acceptance studies should be carried out beforehand in this instance. On the other hand, the source water is of poor aesthetic quality to begin with and the dramatic improvement in the taste and appearance of the water which can be achieved with treatment should provide a strong incentive for most users to keep using and maintaining their systems.

Step 9: Ease of construction

None of these units will normally be self-constructed when communities are supplied with HWTDs by a funder or water supply authority. However, if units are to be constructed locally, this will be to the benefit of those units in terms of their ranking to use. See Chapter 5 in **Volume 1** for details of construction. If all units are manufactured elsewhere, this criterion is not really applicable.

Step 10: Cost of the unit

This criterion takes into account two types of costs:
- Capital cost (normally borne by the funder (municipality, government, NGO, funding agency, etc.)
- Daily operating cost (normally borne by the users themselves)

Capital costs

Regarding capital costs, Chlor-Floc (in conjunction with straining after flocculation + activated carbon), and PUR^{TM} (in conjunction with straining after flocculation) methods of treatment will be the least costly. This is because only a container is required to put the water in, or mix the water and chemicals in, and a straining cloth to filter the flocs formed.

Capital costs of the other units will be highly dependent on factors such as local manufacture, materials used, standard of manufacturing finish, number of units required, etc. Therefore, capital costs will have to be established by the funder just before purchase. The shortlist of units is therefore retained.

Operating costs

Since the daily operating costs will be carried by the users themselves, this sub-criterion is crucial regarding the sustainable use of the HWTD.

Of the units on the shortlist, only the silver-impregnated porous pot (SIPP) does not entail spending money on a daily basis in order to ensure safe water. *Therefore, these will be the preferred units in terms of operating cost.* However, the SIPP filter flow is limited to 20 ℓ/d in general and using multiple units will substantially increase the capital cost.

Carbon adsorption adds substantially to the operating costs of the systems because the carbon must be replaced periodically. From Table 2.1, activated carbon would be out of reach to rural households and would have to be provided by the municipality or other funder. Charcoal filters are much more affordable and some households might be able to cover their cost.

The Chlor-Floc and PUR^{TM} systems require the use of expensive sachets of a blend of flocculation chemicals and disinfectant and may be too expensive for the user to ensure sustainability. Therefore, unless sponsored on a continuous basis by the funder, Chlor-Floc and PUR^{TM} may be discarded at this stage.

Treatment based on the higher flow filters (biosand and bucket filters) + post-chlorination can provide > 40 ℓ/d at moderate capital and operating cost but are more complex to operate and maintain, especially if an adsorption unit is added.

Summary of decisions and conclusions for a moderately eutrophic source

HWTS cannot be recommended for eutrophic waters which exceed microcystin-LR levels of 1 µg/ℓ because of the lack of published data on their effectiveness and other safety concerns. For toxin levels < 1 µg/ℓ, pre-treatment (cloth or sand filtration, not sedimentation) is recommended to reduce clogging of subsequent filtration steps by algae.

A carbon adsorption step may be used after filtration but before disinfection to reduce organics and algal toxins if present. Carbon adsorption should not be used after the SIPP or a candle filter which already contains carbon or after a flocculant/disinfectant. Activated carbon is most effective but probably too expensive. Charcoal is less effective but much more affordable.

As in the other examples, Chlor-Floc and PUR™ are very effective but substantially more expensive than the other options (with the exception of GAC adsorption). The SIPP device does not require post-disinfection and therefore is one of the simplest options with zero operating cost; however, the flows produced are the lowest of all the available options.

The biosand or bucket filters plus post-chlorination offer higher flows at low operating cost but are more complex to operate and maintain.

Thermal and light-based methods of disinfection are not recommended for waters containing algae.

The final choice of treatment sequence will probably be based on community and funder preferences.

4. GUIDELINES FOR IMPLEMENTATION

As a result of the high incidences of waterborne disease outbreaks and diarrhoeal diseases, the high cost of providing and low rate of provision of water services in rural communities of Southern Africa, there is an urgent need to provide safe drinking water through decentralised water-treatment systems. Household water-treatment systems/devices (HWTDs) which produce sufficient drinking water for a household can be a cost-effective short- to medium-term solution for rural households.

This section discusses a number of important factors that influence the rate of adoption and sustained use of home water-treatment devices (HWTDs). The factors could have a direct or indirect effect on the long-term success of the implementation HWTDs in rural communities with no access to or inadequate piped drinking water supply.

4.1 Community acceptance

Community participation and acceptance of new water supply systems are crucial in ensuring the success of intervention projects. These aspects must therefore be an integral component of the field-testing requirements and of standards or criteria based on which home water-treatment devices are assessed and selected.

4.1.1 Socio-economic guidelines to be considered

Socio-economic factors that influence the acceptance of systems are as follows:

- ***Cost and willingness to pay*** – Cost and affordability are important factors as most of the community members in rural areas are unemployed or they have a low income.

- ***Efficiency of the new technology*** – Communities need to have evidence that the new HWTDs will actually deliver an improved quality of water, and would want a sample of purified water first.

- ***Awareness raising/informed community*** – If the community is not properly informed and made aware of the advantages of the new system, they may not accept the unit. It is suggested that community members be thoroughly informed via a community meeting so that all may understand, or at least have an idea of how the unit works. The new system must be tested by a group of the community members who will be able to provide their own first-hand perception and experience of the system.

- ***Community needs*** – Community needs should be determined prior to implementing any project. This will make it easier to suggest options which are likely to be accepted by community members.

- ***Job creation*** – As unemployment rates are high, the prospect of community members getting employment from the installation and operation of the new technology will increase enthusiasm for the project, if applicable.

- ***Security and location of the HWTD*** – The systems should be completely secured, because children may interfere with or cause breakage to the unit.

- ***Performance and involvement of local government*** – There seems to be a relationship between the performance of local government and the community's acceptance of a new technology. In order for the HWTD devices to be successfully implemented, the water authorities and government of South Africa should be involved in supporting household water-treatment projects on a social and financial level if possible.

- ***Current community practices*** – Communities are used to dealing with the problems of their existing water resources and will continue using it even if it means running the risk of contracting water-related and waterborne diseases.

- ***Long-term success of HWTD*** – The most appropriate technology will depend on the situation, the quality of the raw water, the availability of the required materials and equipment, the time frame in which it is to be used, the customer's preferences and education levels of the local population, and the availability of personnel to provide the necessary training and monitoring for the technology to be successfully implemented. Long-term success can be achieved by identifying and implementing approaches that will convince potential users to adopt the devices and by promoting increased and sustained use of HWTD products.

4.1.2 Attributes to be taken into consideration

- ***Relative advantage (convenience)*** – This is the degree to which an innovation is perceived by potential adopters as being better than the idea, product or service it supersedes. An important factor here is that superior performance of an innovation is only as *subjectively* perceived by the consumer. Most respondents in the community must perceive this attribute very favourably in terms of the convenience it affords over previous water-purification methods. In the case of the selected HWTD, both the *SIPP and BSF-Z* devices were accepted by the community (refer to Chapter 7 in **Volume 1** for details on the community acceptance study that was performed).

- ***Compatibility*** – Compatibility is the degree to which an innovation is perceived as being consistent with past values, experiences and the needs of the potential adopter. In the case of household water-treatment technologies, the concept of compatibility may refer to a consumer's being comfortable with the use of such technologies. Both the *SIPP and BSF-Z* devices were found to be very compatible to the Makwane villagers' lifestyles.

- ***Complexity*** – Complexity of an innovation is the degree to which an innovation is perceived as being difficult to use. Clearly, the HWTDs need to be seen as being relatively easy to use if their social acceptance is to be enhanced.

- ***Trialability*** – Trialability **r**efers to the degree to which an innovation is perceived as being possible to try on a limited basis prior to any decision to adopt. Clearly if an innovation can be easily trialled, this can have important effects on lowering perceived risk levels. In the case of trialability, there were mixed reactions from respondents for both the *SIPP and BSF-Z* devices. The trials were somewhat restricted by the survey method rather than the HWTDs themselves.

- ***Observability*** – The observability of an innovation such as these HWTDs describes the extent to which an innovation is visible to other members of a social system. It follows then that the more recognisable an innovation is (and its benefits), the greater the likelihood of its acceptance. Follow-up surveys must be conducted at least one to two months after the introduction of the HWTDs to communities and their testing by households. It is important that all respondents have the opportunity to test and observe the functioning of systems in a full manner.

- ***Perceived usefulness*** – This dimension refers to the perceived *utility* of the HWTD. All the respondents must find that these HWTDs are *socially acceptable* and useful for the production of safe drinking in their dwelling. This is critical in terms of their potential long-term acceptability and usage.

- ***Perceived risk*** – *T*his dimension refers to the perceived dangers of using or handling the devices. The reaction of the respondents in terms of acceptability of HWTD by the community must be taken into consideration prior to any implementation. The manner in which the survey (the questionnaire is presented to respondents) is conducted plays an important role. Acknowledgement of the fact that the device could break if mishandled or could be subject to contamination is not a negative; rather it is an important positive in terms of how well respondents understand the nature of the HWTD being presented to them. These responses are very useful in the future development of these HWTD, their promotion and in the training of respondents.

- ***Social cost*** – The social cost refers to the perceived risk of *losing face or feeling like* an outcast as a consequence of what product one uses. Most of the respondents must agree on whether the household water-treatment device reduces their sense of *social cost* and enhances their *social standing*. *Social reference groups* and *opinion leaders* who community members rely on for social status and recognition play an important role because once these opinion leaders champion a technology then it is likely to be widely accepted.

4.1.3 Factors which hinder acceptance

The following factors can hinder the individual's acceptance of the HWTDs:

- Increase in the cost of water treatment, making the unit unaffordable

- The poor quality of the water produced by individual systems or deterioration in water quality over a long period of use, resulting in a poor end-product

- More illnesses experienced by community members

- If the unit is not considered beneficial by community members

- Community members are used to untreated water and prefer the taste thereof

- Community members will have to abide by what the decision-makers decide even if it does not suit individual householders

- If the unit is damaging to nature or compromises the safety of the community, it will not be accepted.

4.1.4 Practical phases to adopt

To ensure that the community is involved in the project and accepts the systems from the implementation stage, the following phases are imperative:

- ***Phase 1: Pre-implementation phase*** – Hold initial and preparatory meetings with the community.

- ***Phase 2: Implementation phase*** – Hold further meetings and discussions with community members on installation of the devices, and during the project life cycle.

- ***Phase 3: Post-implementation phase*** – On completion of the implementation phase of the intervention, a survey should be conducted to assess the reaction of individual members of the communities and their perceptions based on the attributes mentioned above, and especially those related to the operation of the household water-treatment device and its ability to produce a sufficient quantity of improved quality drinking water to the community.

4.2 Training and monitoring

4.2.1 Training

Although many community members may understand English, the technical nature of the questions to be asked, means that intermediaries who are fluent in both English and the local language need to be involved for the purposes of interviewing respondents and accurately recording their perceptions and information. Suitable candidates should be selected and given training on:

- The general and specific aims of the study
- The nature and operation of the relevant technologies
- How to introduce and conduct the research interviews in a way that minimises respondent biases and protects the integrity of the instrument and study

4.2.2 Community education and health promotion

It is generally believed that maximum health benefits are achieved when training of householders in home water treatment and improved storage is accompanied by simultaneous education in hygiene practices.

Three key hygiene behaviours which yield the greatest benefit are (WHO/UNICEF, 2000):

- hand-washing with soap, ash or other aid
- safe disposal of faeces (improved sanitation)
- safe water handling and storage

All technology-based home water-treatment options with documented health impacts are based on a three-pronged approach: making the technology available, safe storage, and behavioural change through communication/social marketing/hygiene promotion.

4.2.3 Monitoring and evaluation

Community members should be confident that a HWTD is delivering the expected quality. This is critical to building acceptance in a new intervention to ensure continued use. Consumers must have trust that the product performs as advertised, and that the water it delivers not only tastes good, but is also safe to drink.

Assurance is guaranteed in two ways: by technology verification prior to implementation, and **by subsequent, occasional or even frequent monitoring.**

4.3 Monitoring the impact of implementation

Sobsey et al. (2008) stressed the importance of understanding and documenting the use of point-of-use technologies (HWTDs) towards ensuring successful interventions. This documentation is important to ensure:

- continued HWTD use
- consistent water quality improvement
- reduced risk of water-borne disease

The impact of HWTD interventions can be monitored by:

- number of diarrhoea incidents
- regular sampling and analysis of treated water for microbiological and chemical parameters and checking against health-based performance targets
- evaluation of flow rates
- whether the households use the HWTDs on a continuous basis
- post-implementation surveys on user satisfaction

4.4 Installation, operation, maintenance and troubleshooting

The single most critical factor in the adoption and sustained use of any given HWTD product may be its successful installation, operation and maintenance. This is the case whether the systems are provided as charity, distributed during emergency situations, sold as a subsidised government or NGO product, or purchased commercially.

If proper installation and operation and maintenance are not provided during start-up, or technical support is not available when a problem arises, users will express their dissatisfaction and stop using the system.

It is imperative that assistance be provided to the new users by means of simple installation, operation and maintenance brochures, flyers, posters and stickers. Different HWTD products reflect different degrees of technical expertise in terms of their installation and operation and maintenance, instructional information, so that generic information sheets will not suffice.

4.4.1 Installation

Installation and instruction manuals should always accompany the treatment devices. Some HWTD systems reduce costs to consumers by enabling the user to assemble and/or install the product themselves, often following some training workshop.

4.4.2 Operation

Operational instructions for a HWTD should:

- be expressed in a standardised format
- be written in the local language
- include graphic, diagrammatic and textual schemes
- indicate methods that are safe for all users at all skills levels
- be easy to understand

4.4.3 Maintenance

Maintenance is the first step towards long-term sustainability and use. Maintenance tasks should be safe to carry out, easy to perform and not be excessively strenuous or tedious. Maintenance should be able to be performed by any member of the household, young or old, male or female.

Maintenance instructions should:

- be expressed in a standardised format
- be written in the local language
- include pictorial and textural schemes
- communicate clearly the duration between cleanings, which should be conservative and precise

Section 4.4 of this guideline document provides general guidelines on designing HWTSs to facilitate their operation, maintenance and cleaning.

a. General maintenance guidelines on the HWDTs based on the study

Investigation of filter maintenance was fundamental in this study to make necessary recommendations on how the filters need to be handled for the production of good quality water and long lifespan.

Collection vessels for all the filters must be cleaned thoroughly with deionised water and soap and sterilised with household bleach. It is recommended that rural households use water filtered through the filter to wash collection vessels.

In cases where household bleach cannot be afforded, thoroughly washed collection vessels may be left in the sun for sterilisation by drying and heating.

The BSF, CCF and BF can be cleaned when the flow rates are observed to have decreased significantly.

In cases where the flow rates of the filters are observed to be high but the filters look dirty, it is recommended that the filters be washed as described in this study. Figure 4.1 shows what the BSF, CCF, BF and collection vessels look like when they are dirty.

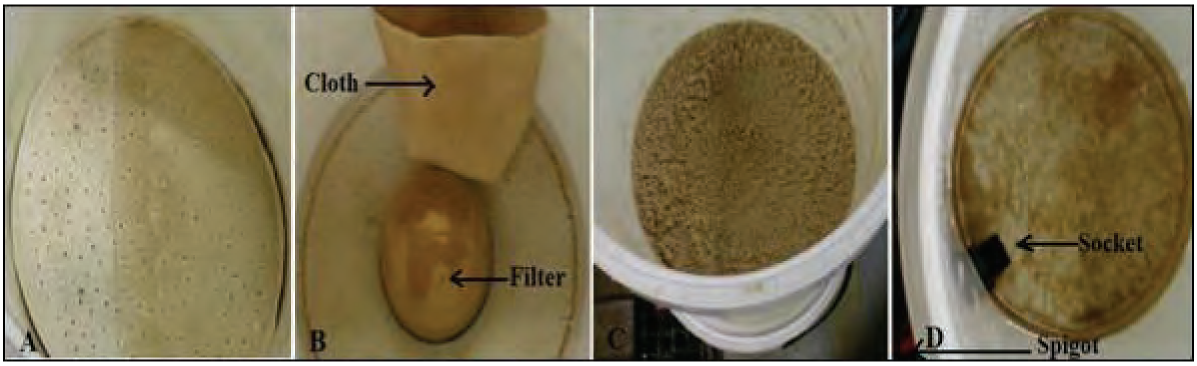

Figure 4.1: Illustration showing dirty filters and a collection vessel: A – BSF with dirty perforated diffusion plate; B – CCF with candle filter and cloth; C – BF showing filter media and collection vessel; and D – dirty collection vessel with a spigot fitted in a socket

BSF – The BSF can be cleaned by removing the top 5 cm layer of fine sand, thoroughly washing it and replacing it.

- It may be recommended that if new sand (with same particle size) is available, the old sand may be replaced with thoroughly washed new sand.
- When cleaning the sand, it is advised that filtered water is used to reduce the level of re-contamination.
- Removing the top few centimetres of the top sand bed is appropriate based on the observation that particles resulting in clogging cannot penetrate deep into the sand bed.

BF – Washing of the bucket filter media is performed in the same manner as the BSF media but the top 10 cm layer of sand must be removed, washed and replaced.

- The reason for removing 10 cm can be justified based on the difference in the particle size of the sand used as the BF filter media particles are larger.
- Contaminant particles are often observed to penetrate deeper into the sand.

CCF – Sludge or dirt on the filter (CCF) could be cleaned periodically when unsatisfactory flow rates are obtained as a result of filter clogging.

- Scrubbing with a cloth or soft brush, followed by rinsing with hot water once a week, is recommended.
- Care must be taken not to cause cracks during cleaning. Dirt from the CCF is removed by scrubbing the candle filter with a soft brush followed by rinsing with deionised water.

VERY IMPORTANT

Movement of the filters should be avoided since this disturbs the sand bed in the BSF and BF and the biological layer in the BSF might be disturbed too.

Care needs to be taken when removing the top and bottom buckets of CCF and BF because the seal in the BF may be disturbed and the candle filter might be dislodged too.

Care must be taken when opening the taps as leakages may result from detached taps.

- The ceramic candle filter is easier to wash compared to the biosand filter and the bucket filter in the sense that it takes less time and effort.

b. Specific maintenance and troubleshooting guidelines on filters evaluated in this study

The filters evaluated in this study are cleaned when a drastic decrease in flow rate (< 1 ℓ/h) is observed. The process of running and cleaning the filters is not tedious and/or time consuming and is done with little or no cost.

Biological sand filters (BSF-S, BSF-Z) and fast sand filter (BF) – The biosand-sand filter and the biosand-zeolite filters are cleaned using the same procedure.

- The diffusion plate is removed and the resting water level is removed with a cup.
- One centimetre (1 cm) of the top layer of sand is removed and thoroughly cleaned with clean water and is placed back.
- Alternatively, the 1 cm layer of sand that is removed can be discarded and replaced with new clean sand. The diffusion plate is then cleaned and placed back, 20 ℓ of water is poured into the filter, and the flow rate is measured. If the flow rate does not recover to previous levels, the cleaning process should be repeated.

Bucket filter – The bucket filter is cleaned by removing both the sand layers packed in the top of the bucket.

- The two layers are kept separate and washed thoroughly with several volumes of water.
- The bucket is washed with soapy water and the sand is repacked into the bucket.
- The collection bucket is cleaned weekly with soapy and chlorinated water.

Troubleshooting

During the initial use of the biosand filters and the bucket filter, the treated water can appear to be highly turbid.

- Do not drink this water, discard it, and filter more water until the treated water appears to be clear.
- It is recommended that bleach ('Jik') is added to the water treated by these filters for complete disinfection (1 teaspoon 'Jik' in 25 ℓ of water).
- Do not add bleach to the water prior to filtration as it will damage the biologically active layer.

Ceramic candle filter (CCF) – The ceramic candle is cleaned by scrubbing the candle filter with a brush and rinsing with clean water. This is only cleaned when a drastic decline in flow rate is observed. A Scotch-Brite™ pad can be used instead of a brush.

- The inside of the bucket containing the candle filter is scrubbed using a Scotch-Brite™ pad and is thoroughly rinsed with clean water.
- The jacket of the candle is cleaned weekly using clean water.
- The collection bucket is cleaned once a week using soapy water, scrubbing with a Scotch-Brite™ pad and is rinsing with clean filtered water.
- It is recommended to clean the ceramic candle as soon as it becomes stained as shown in Figure 4.2 below.

Figure 4.2: Photographs of stained ceramic candle: A – filtration of high-turbidity water; B – dirty jacket of candle filter after filtration; and C – clogged/dirty candle filter

Troubleshooting

If the ceramic candle breaks, it must be replaced.

Silver-impregnated porous pot (SIPP) filter – The filter element is cleaned using clean water and a brush.

- The inside of the pot is thoroughly scrubbed using the brush and rinsed several times with clean water.
- The receptacle, collection bucket, and spigot are cleaned with soapy or chlorinated water on a weekly basis in order to prevent recontamination.
- A clean unused toothbrush can be used if a cleaning brush cannot be obtained.

Troubleshooting

- The filter element is made of clay and is thus fragile.
- It must be handled with care to avoid cracks and breakage.
- If cracks in the clay pot are noticed, it should be discarded and replaced with a new element, as the cracks would reduce the ability of the filter to remove bacteria.
- If the spigot breaks, it can be replaced with a new spigot.

4.5 Procurement

4.5.1 Supply-chain requirements

Consistent use of HWTDs will be affected by access to hardware. The need for a periodic or continuous supply of replacement parts, materials or units can be a hindrance to sustained use of a technology, and currently available technologies have supply-chain requirements. In this context, supply chain refers to logistical components the user requires to continue using the technology once received or introduced, not the logistical components necessary to make the technology available to the user by implementers. The supply chain therefore entails the flow of goods and information from suppliers to consumers. It ensures that affordable, good quality products are available when and where customers want to buy them. Some examples are cited below.

4.5.2 Building a reliable supply chain

Experience with water and sanitation products in developing countries has revealed the importance of effective planning and management of a supply chain. To fully understand the challenges facing the supply chain requires technology evaluation and market assessments, maintaining product quality and ensuring the availability of spare parts. It is also important to ensure an effective documentation of sales and inventory levels, so retailers can place orders as needed and suppliers can plan for the anticipated demand.

The supply chain does not end with the delivery of a product. Service and maintenance, including readily available replacement parts, are essential to retain customers and ensure the systems' long-term viability.

Manufacturers should consider the entire life cycle of any product they launch. With good planning, products can be designed for a long life of easy maintenance and repair. This will also keep costs down for system users.

Depending on the nature of the product, it is recommended that manufacturers build a reliable and convenient supply chain for consumables, replacement parts, and technicians.

4.6 Funding and budgeting

Funding sources that are available in South Africa for the three cost components of water-supply projects (capital, operating and capacity building costs) are shown in Figure 4.3.

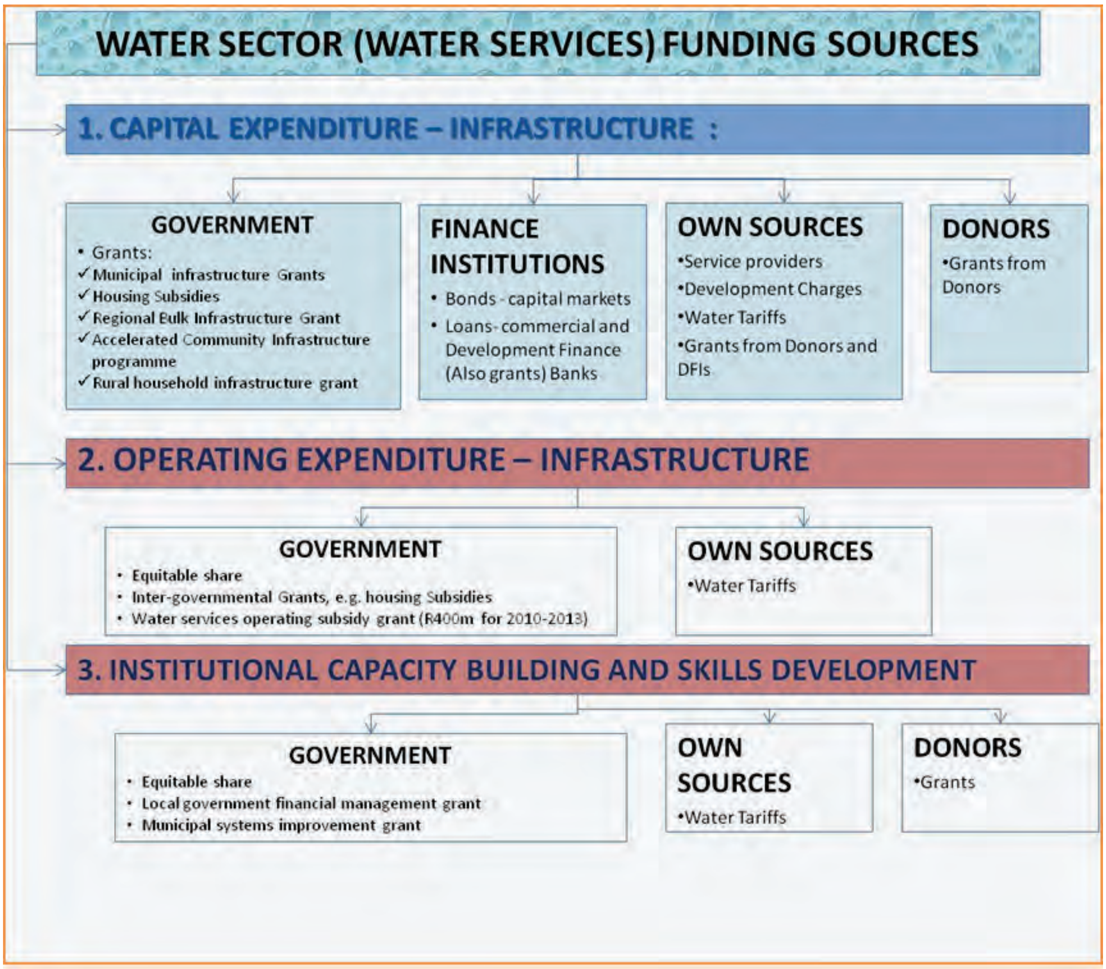

Figure 4.3: Funding sources in South Africa for water supply projects

With the exception of the CCF, all the materials used in the construction of the HWTDs can be purchased locally. Table 4.1 illustrates the total cost involved in manufacturing each HWTD unit.

Table 4.1: Total manufacturing costs of household water-treatment devices (cost in 2012)

HWTS devices	Rand (ZAR)	Dollars (USD)
BSF-S	133.16	16
BSF-Z	164.23	20
BF	149.18	19
CCF	501.15	64
SIPP	290.56	36

4.7 Other aspects

4.7.1 Sustainability

Although HWTDs may demonstrate effectiveness both in laboratory and field studies, this does not necessarily mean that they will do so over long periods of time in actual use. The effectiveness of these technologies will be seriously undermined and waterborne disease risks and burdens will remain high if people treat water intermittently, go for long periods without treating, and treat only some of the water they consume, or provide treated water to only some household members while others consume untreated water. People must be sufficiently motivated and committed to integrate HWTDs into their daily lives long after intensive study interventions have ended.

The overarching need for any HWTD is that it is sustainable: it becomes a part of the daily routine of every household member who uses it for drinking and other high level purposes (e.g. food preparation and hand-washing) all of the time.

Key features of a sustainable HWTD

- Able to consistently produce sufficient quantities of microbiologically safe water to meet daily household needs.
- Effective for treating many different water sources and quality levels including waters high in turbidity and organic content.
- Requires relatively small user time to treat water, thereby not significantly contributing to already substantial household labour time burdens.
- Low cost; relatively insensitive to income fluctuations, not causing households to stop treating water because they cannot afford to purchase the technology or continuously replace it.
- Have a reliable, accessible and affordable supply chain for needed replacement units or parts for which consumers are willing and able to pay.
- Maintain high post-implementation use levels after cessation of intensive surveillance and education efforts, as in field trials and marketing campaigns.

5. GUIDELINES FOR CONSTRUCTION OF HOME WATER-TREATMENT DEVICES

Some household water-treatment devices are simple enough that they can be constructed from locally available materials by community members with minimal training. Other devices require special skills, materials or components to fabricate or construct. In this case, householders need to be supplied with either a fully assembled system or a kit with instructions. Having the devices or components manufactured or assembled within the communities may reduce costs and provide local employment opportunities however this may also require a significant investment in start-up and support and quality control may be problematic. Commercially produced devices sourced from outside the communities using them may have a higher unit cost but may also be of better and more consistent quality. Table 5.1 lists those parts of device production and assembly which can be undertaken by communities and householders as opposed to those parts where specialised tools and skills and strict quality control are essential.

Table 5.1: Construction of home water-treatment systems by communities and companies

Can be undertaken by communities with minimal training	Can be set up as local micro-enterprises with significant training and support	Should be manufactured by commercial laboratories or manufacturing facilities[1]
Construction of cloth filters Cleaning and sieving of local sand and gravel (sieves would have to be provided) Production of charcoal for carbon filters Packing granular media filter beds	Production of clay pot filter elements Production of concrete biosand filters (steel moulds would have to be provided)	High-quality ceramic candle and pot elements Filter receptacles and buckets with spigots Interconnecting fittings

[1]Requires strict quality control

5.1 Construction by communities

Cloth filters

The construction of cloth filters is described in **Appendix A.**

Preparing filter media – The preparation of filter media for bucket and drum filters is described in **Appendix A.**

Making charcoal

1. Start with a clean, dry and empty 20 ℓ metal can or drum.
2. Fill with small pieces of wood or agricultural waste such as maize stalks.
3. Shake the can to see if more wood can be added and keep adding material until it is completely full.
4. Turn the can over with the wood inside and build a fire around and over it. Make sure there are no flammable materials close to the fire.
5. Remove the can after the fire has burnt out and the ashes have cooled, preferably after a day.
6. The carbonised material should then be crushed to increase the surface area for filtration.
7.

5.2 General guidelines for design and construction by companies

The following website can be used for the design and construction of HWTDs by the companies (PATH Safe Water Project, 2008):

http://www.path.org/hwts-design-guidelines/guidelines.php

Format and dimensions

Format: A free-standing table-top format design is generally preferred for smaller systems. Wall-mounted units may have advantages such as increased head for filtration but the construction of many low-income dwellings would make it difficult to mount these units on a wall.

Water-storage capacity: The storage capacity of the device for both treated and untreated water should take into account the users' needs and the amount of time required to operate the device.

- Ideally the raw water reservoir should be similar in size to the water collection vessels used. The user should be able to empty the water collection vessel in one or two pours.
- There should be sufficient treated water storage to ensure water is available when it is needed; however, the storage capacity should not exceed 1 or 2 days' supply as this can lead to deterioration of microbial quality.
- The higher the flow/shorter the process time, the less storage is required.

***Height*:** The installed height of the device should provide sufficient water head to ensure an adequate flow without exceeding the median shoulder height of the target user who needs to pour water into the device from a different vessel.

Footprint: The device should occupy the minimum counter space without comprising its stability or exceeding height guidelines.

Water head: There must be sufficient water head to ensure an adequate flow of water through the device.

Shipping volume: The shipping volume and mode of transportation of the finished product need to be taken into account.

Key design features

Safe water spigot: Collection vessels for treated water should be fitted with a tap or spigot so that users do not need to reach their hands or utensils into the container to obtain water.

- The container, as well as the spigot and its seal must be durable and of high quality. Broken spigots are a common reason for the discontinued use of HWTSs.
- The height of the spigot must be sufficient to allow a typical clean water collection vessel, e.g. a cup, to be placed under it without touching the spigot. However, it should not be so high up that a substantial volume of the stored water is below the level of the spigot. A stand may be required if the device is installed at floor level.
- In the case of intermittently operated **biological sand filters** (traditional biosand, BSF-S and BSF-Z) the spigot should be located 5 cm to 6 cm above the sand bed. This is to ensure sufficient oxygen diffusion to the biological top layer during the filter pause period.
- The spigot must be readily accessible to most household members.
- Self-closing taps which cannot be left open should be considered.

Lids and covers: All units should have a lid or cover which is easy to remove in order to add raw water but remains closed the rest of the time to prevent additional contamination of the water by dust, insects, leaves, etc.

Pre-filter: If a pre-filter is used (e.g. cloth filter wrapped around a ceramic filter element):

- It must be easy to remove and wash by hand.
- It must not reduce the overall flow through the device.

Diffuser plates: For granular media filters where raw water is poured directly into the filter container, a diffuser plate should be fitted over the top of the bed to prevent disruption of the media.

Interconnection fittings: It is critically important that any interconnection fittings are durable and leak-free for the expected life of the product.

- The interconnection fittings should provide clear feedback to the user when the connection is fully made, e.g. ‘clicks’ or stops.
- Low insertion force required.
- Designed so parts cannot be assembled incorrectly, i.e. only fits one way.
- Filter elements, e.g. ceramic candles, are positively retained in their platform, i.e. will not be dislodged if inverted.
- Routine cleaning does not degrade integrity of connection over product lifetime.
- Assembly and disassembly does not allow untreated water to leak into the treated water container.

Materials

All materials used in device fabrication should meet all relevant national or equivalent international standards (see **Appendix B**) and should be able to withstand the harsh environmental conditions expected in rural areas. This includes any paints, colorants, inks or glazes.

- Materials should not leach any harmful substances into the water and should be resistant to chemical disinfectants where applicable.
- Plastics should be UV and shatter resistant and translucent unless algae re-growth is an issue.
- The break strength of ceramic elements is related to their porosity which is in turn related to their flow. There is therefore a trade-off between break strength and flow. This can be offset by strengthening key areas, in particular the rim of a clay pot filter.
- Metals should be corrosion resistant and able to withstand frequent cleaning.
- Metals used as bactericides, e.g. silver, remain subject to toxicity limits.

Durability and lifespan

The expected lifespan of the device should be at least **2 years**.

- Product safety should not be compromised by normal wear and tear over the two-year lifespan.
- The appearance of the device should not be significantly degraded over the service life.
- The efficacy of the device should not degrade during storage. A minimum **shelf life** of 2 years and preferably 5 years is recommended under realistic storage conditions.

Exceptions would include devices which use an absorbent material such as charcoal, zeolites or activated carbon which may need to be replaced more frequently. In this case, it should be possible to change the absorbent without replacing the rest of the device.

Any other components, e.g. taps which may need to be replaced more frequently should be readily available and easy to replace.

Safety

- All materials used in the device and especially those which come into direct contact with the water should meet all relevant safety standards (**Appendix B**).
- The user should be able to operate the device without risk of injury or coming into contact with harmful substances.
- The product design should minimise the risk of recontamination of the treated water.
- Potential hazards related to the final disposal of the device, components, effluent and spent absorbents need to be considered.
- The device is stable and resists tipping during normal use even when mounted on an uneven surface. This is a particular concern in the case of the ceramic and bucket filter systems which become top-heavy when the treated water receptacle is emptied.

Quality control

- Quality control test protocols and criteria must be defined for product performance:
  - Flow rate
  - Contaminant removals
  - Required cleaning frequency (rate of clogging)
- Durability test protocols and criteria should be defined for the product as a whole as well its constituent components, including:
  - Taps/spigots

- Interconnection fittings
- Interconnection seals
- Upper and lower containers (abrasion and impact resistance)
- External surfaces (abrasion, chemical disinfectant and UV resistance, fading and staining)
- Flow limiters/diverters
- End-of-life indicators
- Structural features including handles, feet, flanges, tabs and stops

5.3 Issues related to operation and maintenance

Ease of filling the device

Devices which are difficult, inconvenient or messy to fill will have reduced consumer appeal. The device should be designed to minimise spills as these waste water, increase the risk of contaminating the clean water spigot and may create a slipping hazard. Key issues include:

- The height and number of times the user has to lift the container used to transfer water to the device (see **Format and dimensions** above) should be minimised.
- The opening through which the raw water is poured should be at least 25 cm in diameter.
- A concave lid can reduce splashing and spills.
- The device and in particular the rim should be able to support the full weight of a water collection vessel since the user is likely to rest the transfer vessel on the rim while pouring.

Operation

The user should be able to tell when the device is operating correctly and be able to see water levels without opening the device.

Cleaning

Regular cleaning is usually essential to maintaining the performance of the device:

- It should be evident to the user when cleaning is required.
- Routine cleaning should require minimal disassembly of the device.
- The device should be easy to disassemble, clean and re-assemble.
- The device and components should be able to withstand regular cleaning.
- Components at risk of clogging due to physical obstruction, scale or biofilm should be easy to disassemble and clean.
- The device should have no crevices which could harbour microorganisms that cannot be reached by normal cleaning methods. Ideally, no part should have a diameter of less than 12 mm so that it can be cleaned by a finger tip.

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APPENDIX A

GUIDELINES FOR THE PRACTICAL APPLICATION AND OPERATION OF HOME WATER-TREATMENT DEVICES AND METHODS

Application and Step-Wise Procedures for Pre-treatment of Drinking Water at Household Level

Straining process – How to strain turbid surface water sources?

Straining is used when **surface water is taken from turbid water sources**. By simply pouring water through a fine mesh or a clean piece of cotton cloth, a certain amount of the suspended silt and solids (i.e. grass, leaves, insects, etc.) are removed.

Steps to be considered during the straining process

Preparation for the collection of water from the source

Before going to collect the water from the river, streams, lakes, small dam or pond, prepare the following:

- A clean container of 20 ℓ to 40 ℓ
- A clean piece of cotton cloth or a fine mesh
- A clean scoop

Collection of water

- Use the clean container to collect water from the source
- Take water with the flow using a clean scoop

Strain water through the cloth or fine mesh

- Pour water through a fine mesh or a clean piece of cotton cloth into the clean container.
- The cloth should be secured to the neck of the water collection container
- When the flow rate decreases, it is a signal that the pores of the mesh/cloth are clogged
- Remove the mesh/cloth carefully from the collection container and put it in another vessel for washing

Cleaning of the mesh/cloths:

- Rinse the mesh or the cloth in the river or pond water.
- Rinse the mesh/cloth in previously filtered water.

– Clean the cloth using soap and clean water.
– Finally the mesh/cloth should be air-dried in sunlight and placed in a safe and clean place for further use.

Storage/settlement process

Storage and settlement process may be used where **households have an ample supply of water containers** (i.e. pots, buckets, large settling basins, reservoirs or storage tanks). At least **two vessels** are required. The first vessel functions as the sedimentation tank and settled water is transferred to the second.

Useful steps to consider in storage and settlement of drinking water at household level

Preparation of clean containers

- Use two clean containers of 20 ℓ to 40 ℓ
- The containers should have a lid to avoid recontamination
- The container should have a neck wide enough to facilitate periodic cleaning
- For example, a bucket with a lid should be used for storage and settlement

Collection and storage/settlement of water

- Collect water from the source (river, lake, pond, etc.) using the first container
- Keep water in this container, cover and store above the ground away from children
- Store water in the first container for a period of 3 h to 2 days.
- Always cover the lid during the storage period to avoid recontamination

Transfer of stored water to a second container

- Slowly pour water stored in the first container into the second container
- Using a clean scoop, stored water should be drawn from the top of the first container where it will be cleanest and will contain fewer pathogens and suspended materials
- This water is ready for filtration
- Wash the first container for further use

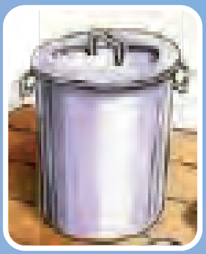
By allowing the raw water in the water container to stand for 3 h to 4 h or to settle overnight, most solids settle out. The top clean water can then be transferred to another pot and the residue must be discarded.

Note: *Longer periods of storage of one to two days generally lead to better water quality. Reductions in helminth ova and some protozoan cysts can exceed 90% after a few days. Fine clay particles, viruses and bacteria are too small to settle, therefore reductions in viruses and bacteria are usually < 90%.*

Cloth filtration

The filtration of water through cloths **improves its appearance** prior to disinfection. This can also improve the microbiological quality to a limited extent.

Steps to be considering for cloth filtration of drinking water



Preparation of container and cloth

Before going to collect the water from the river, streams, lakes, small dam and pond, prepare the following:

- Use a clean container of 20 ℓ to 40 ℓ
- Use clean sari, nylon or cotton fabric
- Do not use very old cloths because laundry causes the threads to become softer and looser.
- Fold the cloth at least 4 times to produce 8 layers

⇩

Producing a cloth filter

- Make a filter by folding over a clean cloth 4 times to produce 8 layers

⇩

Place the cloth filter on top of the clean container

- Place the 8 layers of the cloth on top of a clean container
- The cloth filters should be secured to the necks of the water collection vessels

⇩

Pour water through the cloth filter

- Use a clean scoop to pour water through the cloth filter
- When the flow rate decreases, it is a signal that the pores of the cloth filter are clogged
- Remove the cloth filter carefully from the collection vessel and put it in another vessel for washing
- Filtered water is ready for disinfection

Cloth filtration is effective for removing parasites including **helminths**. **Bacteria** and **viruses** are small enough to pass through cloth but may be attached to larger particles which are retained by the cloth. Pouring water through **8 layers of cotton cloth** will also remove a certain amount of the suspended silt and solids.

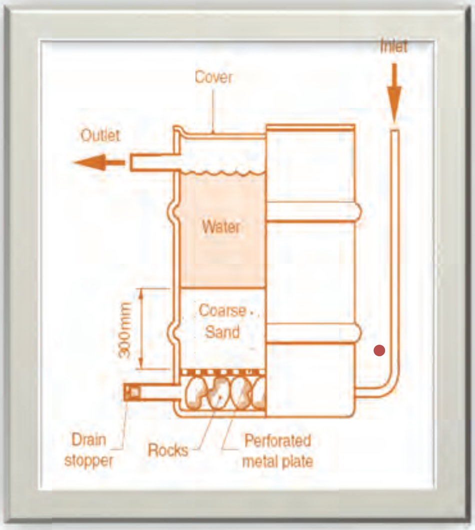
Note: *Steps for cloth filtration are useful only for cloudy, murky and coloured water or water contaminated by algae.*

The use of 8 layers of clean cotton fabrics or polyester fabrics is recommended to reduce the concentration of coliform bacteria and the level of turbidity in water prior to the disinfection of the filtered water.

The following fabrics usually found in any household are recommended to be used as cloth filters prior to disinfection: clean cotton T-shirts, cotton bed sheets, cotton dishtowels and polyester T-shirts.

It is also important to note that none of the above fabrics reach the target limits (which are 0 cfu/100 mℓ to 10 cfu/100 mℓ for coliform bacteria and < 1 NTU for water that is used for domestic purposes) set down by the South African National Standard (SANS 241) for Drinking Water. There is therefore a need to disinfect the filtered water before drinking.

Drum filters/bucket filter systems



Drum filters are usually constructed in 200 ℓ steel drums. Buckets with 10 ℓ to 40 ℓ capacity are generally used.

These filter systems consist of two or three drums/buckets, one of which has a perforated bottom and is filled with a layer or layers of sand, gravel and/or other granular media. This serves as the filter and is suspended above a second similar size drum/bucket into which the filtered water drains.

The drums/buckets are generally covered to keep out airborne contaminants.

Steps to be considered for drums/bucket filtration systems

Preparation the media

- Use sand and gravel as the filter media.
- Pass sand and gravel through a series of metal sieves with different mesh sizes (0.1 mm to 1 mm for sand and 1 mm to 10 mm for the gravel).
- Clean new media by flushing with water until the turbidity is low or at least it appears clean.
- **Note:** Gravel and sand of specified sizes can also be purchased locally in some areas.

Preparation of the filter

- Use two clean drums or buckets of similar size.
- Punch small holes in the bottom of the first bucket which is used as the filter.
- Fit this first bucket with mesh such as window screen or cloth which retains the media but allows the filtered water to drain out.
- Place several centimeters of gravel on top of the mesh.
- Add a deeper layer of sand (40 cm to 75 cm) on top of the gravel.
- Several cm of gravel and 40 cm of sand will not fit into a 10 ℓ bucket. Does your studies not show that 20 cm sand were already feasible? Maybe one should check what can fit into a 10 ℓ bucket?

Filtration of the water

- Suspend the bucket filter (first bucket) above the second similar size bucket.
- Use a clean scoop to pour water through the bucket filter.
- Let the filtered water drain into the second bucket.
- When the flow rate decreases, it is a signal that the filter media are clogged.
- Remove the filter media from the bucket filter, clean as indicated above and replace media regularly.
- Filtered water is ready for disinfection.

Note: *The media should be cleaned as stated in Step 1 to remove the accumulated particles and prevent excessive microbial growth.*

Finally, the media should be air-dried in sunlight and placed in a safe and clean place for further use.

The cleaning frequency of the filter media will depend on the quality of the water source, but will typically be after several weeks of use.

Aeration can be used at household level to improve the chemical quality of drinking water. This is a treatment process in which water is brought into close contact with air for the primary purpose of increasing the oxygen content of the water.

With increased oxygen content, there will be:

- Removal of volatile substances such as hydrogen and methane which affect taste and odour in drinking water.
- Reduction of carbon dioxide content of water.
- Oxidation of dissolved minerals such as iron and manganese so that they form precipitates, which can be removed by sedimentation and filtration.

Steps to be considered for the aeration of drinking water at household level

Rapidly shake a container part-full of water for about 5 min

Stand the water for a further 30 min to allow any suspended particles to settle to the bottom

Strain water through the cloth filter

Practical considerations

- When disinfection is necessary, disinfectants are less effective in cloudy, murky or coloured water.
- The first step should be to strain the water and allow it to settle or filter murky/coloured water. It is better to combine all three methods.
- After filtering until the water is clear or allowing all dirt and other particles to settle, draw off the clean and clear water for disinfection.
- Water prepared for disinfection should be stored only in clean, tightly covered containers, not subject to corrosion.

Application and Step-Wise Procedures for Disinfection of Drinking Water at Household Level

Disinfection is the destruction or the inactivation of disease-causing microorganisms.

Destroying/inactivating microbes at household level can be accomplished by applying one of the following disinfection methods:

- **Physical:** heat (boiling, pasteurisation) and UV light
- **Chemical:** chlorine and chlorine compounds, iodine and certain metals (e.g. silver and copper)

Following emergencies or disasters, **boiling** and **chemical treatment** are two general methods recommended to effectively disinfect settled and filtered water at household level.

Alternatively, settled and filtered water may be disinfected using **ultra-violet (UV) radiation** (also called solar disinfection).

The best option of emergency disinfection methods should be selected according to local requirements following the type of emergencies or disasters.

Use only water that has been properly disinfected for cooking purposes, making any prepared drink or for brushing teeth.

General recommended disinfection methods in emergencies

Disinfection of household drinking water by boiling

Boiling is a simple and effective method of destroying all classes of waterborne pathogens. Bacteria and bacterial spores, viruses, protozoan eggs and cysts, fungi and helminth ova present in water can be killed by **bringing water to a full rolling boil**.

Boiling method should be selected by considering firstly the type of situations and secondly the socio-economic means of the affected community.

In which circumstances should boiling be recommended as a disinfection method?

Whenever there is an existing or potential risk of microbiological contamination of a community water supply

- A **boil water alert** for drinking water should be issued immediately by the Water Service Providers whenever there is an existing or potential risk of microbiological contamination of a community water supply due to the failure of a central water-treatment and distribution system to meet quality standards.

Whenever the microbial quality of drinking water poses a threat to public health

- **Examples of situations** which may present such threats include but are not limited to:
  - Loss of pressure due to equipment or pipe failure.
  - Persistent (one month) and/or severe violation of SANS 241 for bacteria.
  - Evidence that an epidemiological incident may be water-supply related.

Individuals most susceptible to infection

- Boiling is recommended for **individuals most susceptible to infection** including infants, pregnant women and those with compromised immune systems.

Note: *Never ever boil water that contains algae*.

In which circumstances should boiling water as disinfection method not be recommended?

In emergency situations such as floods and tsunamis, boiling is not always an option for the following reasons:

For example, it requires a kilogram of firewood to boil 1 ℓ of water for 1 min and an average person requires 2 ℓ of drinking water per day.

- It requires a large amount of fuel and there are no pots or dry wood.
- There is a risk that people may heat the water without boiling, and consider the water purified.
- Large-scale boiling is not a feasible option for drinking water as fuel cost would be prohibitive.
- Boiling is not usually a cost-effective or sustainable long term solution for underdeveloped areas unless there is an affordable supply of suitable fuel which does not result in environmental damage (e.g. deforestation for firewood).

Steps to be considered for the aeration of drinking water at household level

Bring settled and filtered water to a rolling boil

- Make sure that large bubbles rise briskly and continuously to the surface.
- Bringing the water to a rolling boil provides a visual assurance that the temperature achieved is sufficient to kill the majority of pathogens.

Make sure to achieve the correct boiling period

- Start counting the minutes for the boiling period once large bubbles come to the surface.
- Boiling should be continued for periods ranging between 3 min and 5 min

Allow water to cool

- Allow water to cool on its own without the addition of ice which will result in recontamination.

- *One minute at a rolling boil is sufficient to kill most waterborne pathogens at sea level.*
- *But since water boils at lower temperatures at higher altitudes, one minute should be added for each 1 000 m above sea level.*
- *Boiling drinking water for more than ten minutes wastes time and fuel.*

Practical considerations to improve the flat taste of boiled water

First method	• Stir vigorously or shake the water in a sealed container after it has cooled.
Second method	• Aerate water by pouring it back and forth from one clean container to another. • Allow the water to stand for one to two hours.
Third method	• Add a pinch of salt for each quarter or litre of boiled water.

Disinfection of drinking water using chemicals at household level

Chemical disinfection of settled and filtered water collected from a borehole, spring, river or other surface water sources provides a health benefit if **the correct doses** of the disinfectants are applied.

Following emergencies, **chlorine or iodine tablets** should be distributed and water should be treated using the directions that come with the chlorine compounds.

Alternatively, water should be disinfected by the use of existing types of **chlorine compounds** in the country.

Disinfection using chlorine

Chlorine is very effective against most bacteria and some viruses. However, chlorine is ineffective against protozoan cysts and relatively ineffective against some enteroviruses.

The most common forms of chlorine suitable for household level treatment of water during emergency situations are:

- Sodium hypochlorite solution (e.g. household bleach)
- Calcium hypochlorite tablets (e.g. HTH)
- Calcium hypochlorite powder (bleaching powder).

Chlorine tablets are the most commonly used method of disinfecting small volumes of water in disaster settings.

The most common form is the rapidly dissolving formulation sodium dichloroisocyanurate (NaDCC), which is available locally.

Other, combined chlorine/flocculant powders, as used by the USA armed forces, are manufactured locally and available in sachet form.

- ***Do not use scented chlorine bleach to disinfect water unless nothing else is available.***
- ***All forms of chlorine are harmful to health. Avoid skin contact and do not inhale the fumes. Chlorine should always be stored in cool, dark, dry and sealed containers and out of reach of children.***

Note: *Too much chlorine affects the taste of the water and may also have serious effects on the health of the communities.*

Too little chlorine will not remove pathogens and viruses. Incorrect dosage can therefore result in disease and sickness.

What are the requirements for the use of chlorine compounds?

- Communities should be aware that any inappropriate use of disinfection methods always results in significant consequences.

- Trained personnel or trained community members should prepare a 1% chlorine stock solution from the available source of chlorine in the affected area.

- To prepare the solution, add the quantity of **one of the chlorine sources** shown below to water, mix and **make up to 1 ℓ** in a glass, plastic or wooden container.

- Qualified staff members should provide the affected community with the instructions for mixing the chlorine solution.

Preparation of 1% chlorine stock solution			
Chlorine source	**% Available chlorine**	**Quantity required**	**Approximate measure**
Bleaching powder	35	30 g	2 Heaped tablespoons
High-test hypochlorite	70	14 mℓ	1 Heaped tablespoon
Liquid laundry bleach	5	200 mℓ	1 Teacup or 6-oz milk tin
Liquid laundry bleach	7	145 mℓ	10 Tablespoons
‘Javel’ water	1	Is itself a 1% stock solution	

- *A 1% solution contains 10 g of chlorine per litre = 10 000 mg/ℓ (parts per million)*
- *1 tablespoon = 4 teaspoons*
- *This stock solution should be fresh, i.e. made every day, and protected from heat and light*

Step 1
- Prepare a 1% chlorine solution (consult table given above).

Step 2
- Take 4 non-metallic containers (i.e. 20 ℓ plastic containers) and add 10 ℓ of the water to be chlorinated.

Step 3
- Using a syringe or another measure, add progressively greater doses of 1% chlorine solution to the containers:
  - 1st container: 1 mℓ — 3rd container: 2 mℓ
  - 2nd container: 1.5 mℓ — 4th container: 5 mℓ

Step 4
- Wait for 30 min and then measure the residual free chlorine concentration, using a comparator or test strip.

Step 5
- **Choose the sample with 0.2 mg/ℓ to 0.5 mg/ℓ of free residual chlorine.**

Step 6
- Calculate the amount of 1% chlorine solution needed for the quantity of the water to be treated and wait for 30 min before using it for drinking.

These six steps should be followed in disinfecting water using 1% chlorine solution and producing potable water with free residual chlorine of 0.4 mg/ℓ to 0.5 mg/ℓ after 30 min. In order to ensure that the chlorine dose is adequate therefore requires, at minimum, the ability to measure chlorine residual.

The strength of disinfectants may decline with time depending on how they are stored; it is therefore recommended that in emergency situations, particularly those involving displaced persons, **qualified personnel** should determine the required doses and dispense chlorine solutions (usually 1%) to users at central locations along with standard containers for collecting/storing water and chlorine droppers and instructions for correct dosing and mixing.

- ***The chlorine residual should ideally be checked with a swimming pool test kit or other chlorine measurement device and the residual in treated water should be not less than 0.2 mg/ℓ after 2 h.***
- ***Designated individuals recruited from affected populations can be trained to monitor chlorine residuals in household storage containers on a daily basis.***

Choice of chlorine type and recommended dose for disinfection of filtered and settled water at household level

The form of chlorine should be selected according to the availability and cost of the compound and the methods or technologies that are readily available and which are most applicable and acceptable to the affected community.

In South Africa, the recommended doses are:

- One teaspoon of bleach ('Jik') per 25 ℓ
- One teaspoon of HTH granules per 200 ℓ yielding an initial chlorine concentration of 8 mg/ℓ and ensure that the granules are completely dissolved at the beginning of contact time.

In either case, the water should be protected from sunlight and allowed to stand for at least 2 h and preferably overnight before use.

Twenty-four hours after adding chlorine, the following are recommended in household water storage containers:

- ***For normal circumstances, a minimum chlorine residual of 0.2 mg/ℓ.***
- ***For high-risk circumstances, a minimum residual of 0.5 mg/ℓ is recommended.***

Chlorine takes time to kill microorganisms. In water above about 18°C, the chlorine should be in contact with the water for at least 30 min. If the water is colder, then the contact time must be increased.

Practical procedures, recommended doses and contact times for disinfecting drinking water with chlorine compounds

Practical methods and recommended doses that can be used when selecting a form of chlorine to disinfect filtered and settled water at household level are as indicated below.

Alternative disinfection methods in emergencies

- **Disinfection using iodine**

Iodine can be used to disinfect filtered and settled water following removal of turbidity to as low a level as possible. Disinfection using iodine can be used only for a short period.

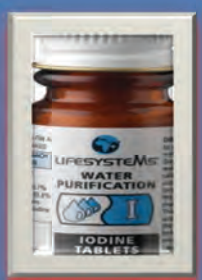
Practical procedures, recommended doses and contact times for disinfecting drinking water with iodine

The following practical procedures, doses and contact times are required when selecting the iodine for the disinfection of filtered and settled water at household level.

Iodine tincture

Use common household iodine from the medicine chest or first-aid kit.

- Add 5 drops of the approved pharmacopeia tincture of iodine to 1 ℓ of clear water.
- Allow the treated water to stand for at least 30 min before consumption.



Iodine tablet

- Purchase commercially prepared iodine tablets containing necessary dosage for drinking water disinfection at drug stores and sporting goods stores.
- Use iodine tablets as stated in the instructions.
- When instructions are not available, use one tablet of iodine for each litre of filtered and settled water to be purified.
- Allow the treated water to stand for at least 30 min before consumption.

- **Solar disinfection of drinking water**

Exposing water in transparent containers to sunlight for several hours is an extremely simple, low-cost and relatively effective way of inactivating microbes through the combined effects of heating and UV radiation.

During the exposure, the UV-A radiation (wavelength 320 nm to 400 nm) of the sunlight destroys the pathogens. A synergy of UV-A and temperature occurs, if the water temperature rises above 45°C. The solar disinfection method is currently recommended in South Africa, although it is not extensively used by the communities.

Several different solar disinfection systems are described in the literature. The SODIS system developed by EAWAG (The Swiss Federal Institute of Environmental Science and Technology) is one of the simplest and cheapest. It is also one of the best documented.

The SODIS method involves exposing water in clear plastic bottles or bags to sunlight for 6 h for up to 50% cloud cover and two consecutive days for complete cloud cover.

Plastic bottles made from PET (polyethylene terephthalate) are preferred as they are cheaper, lighter and relatively unbreakable compared to glass and chemically stable compared to PVC (polyvinylchloride). Their disadvantages relative to glass are that they deform at temperatures of above 65°C and are susceptible to scratches and other ageing effects.

Note: *Bottles must be clear, not coloured, to maximise UV transmission and the water depth should not exceed 10 cm when the bottles are laid on their sides to ensure adequate UV penetration. Bottles with volume of up to 2 ℓ are suitable*

How to apply SODIS?

Clean PET bottle

- **Wash the bottle well for the first time you use it**

Fill bottles partially to 3/4 full

- **Fill the bottles ¾ full with filtered and settled water to be disinfected**

Aerate the water by shaking

- **Shake bottles for 20 seconds**

Expose bottles to the sun

- **Place the bottles on a corrugated iron sheet or put them on the roof**

Expose the bottles for six hours

- **Place the bottles on a corrugated iron sheet or put them on the roof from morning until evening for at least six hours**

Water is disinfected and ready for consumption

In warmer climates where the water temperature reaches at least 50°C after exposure to the sun, the efficiency of SODIS can be improved by blackening one side of the bottle to increase energy absorption.

The bottles should be placed with the transparent side up. At high altitudes where the water remains relatively cool, the bottles should be completely transparent to maximise the effect of UV.

The efficiency of SODIS is further improved by placing the bottles on either a dark or a reflective surface such as corrugated iron or aluminium foil which increases the maximum water temperature which can be achieved.

Note: *SODIS does not sterilise water, so some risk of infection still remains.*

Boiled water should still be used for children under 18 months and people with compromised immune systems. The water will also be warm and unpleasant to drink until properly cooled down

What are the advantages and limitations of SODIS?

Advantages	Limitations
• Simple, easy to understand and affordable for even the poorest householders. • Requires no large or costly infrastructure. • Reduces need for traditional fuels, e.g. firewood and kerosene • Reduces environmental damage (deforestation, emissions from burning fuel). • Reduced fuel costs/time spent collecting firewood. • Proven to reduce incidence of diarrhoeal disease.	• Requires sufficient solar radiation – treatment time depends on weather and climatic conditions. • Requires turbidity < 30 NTU • Does not improve chemical quality of water. • Not suitable for disinfecting large volumes of water. • SODIS does not sterilise water so some risk of infection still remains. • Boiled water should still be used for children under 18 months and people with compromised immune systems.

Other combined household water-treatment methods

Recent research has revealed new strategies in the ongoing fight to eradicate cholera in underdeveloped communities. A combination of flocculation and filtration processes has therefore been identified as vital steps in the prevention of waterborne diseases such as cholera outbreaks.

Among a number of these processes, Watermaker™ Technology has been addressing this very issue for over 10 years at household level during emergency situations such as floods in Africa, South America and south-east Asia as well as during several refugee crises.

Watermaker™ Technology is a combined flocculation-disinfection technology developed by Control Chemicals (Pty) Ltd., based in Johannesburg, South Africa.

The product is presented in two forms:

Tablet: Chlor-Floc which contains:

- < 2.5% sodium dichloro-s-triazine-trione
- Polyacrylamide polyelectrolyte (flocculant and coagulant) not exceeding 0.5 mg per one 600 g tablet (1 ℓ water).

Powder: Watermaker™ Water Purification sachets which contain:

- < 2.5% sodium dichloro-s-triazine-trione
- Polyacrylamide polyelectrolyte not exceeding 10 mg per one 5 g sachet (20 ℓ water); 2.5 g sachets are also available, treating 10 ℓ of water.

Practical procedures, recommended doses and contact times required when selecting the Watermaker™ product for the treatment of drinking water at household level

Preparation and collection of the water

Before collecting the water from the river, stream, dam, lake or pond, prepare the following:

- **A 20 ℓ to 25 ℓ container.**
- **A clean piece of cotton cloth and a single Watermaker sachet.**

Mix water with chemical

Add the content of a standard 5 g sachet to the bucket containing water.

Stir water

- The water can be stirred with a stick or by hand for 5 min.
- Wait for another 5 min.
- If the water is not clear after 5 min, stir it again and leave for a further 5 min.

Filter treated water through a clean cloth

- Pour the treated water through a clean cloth into another container to remove the dirt.

- After 15 min the water will be safe for drinking, cooking and washing.
- Remove the cloth filter carefully from the collection vessel and put it in another vessel for washing.

Safe Household Storage and Handling of Drinking Water

Safe household water management to protect against microbiological contamination begins with **safe storage** and **handling.**

Safe storage is defined as a standard-sized container with (i) a narrow mouth or opening; (ii) a lid; and (iii) a tap to access the stored water and to prevent contact with hands, cups or dippers.

Other factors, such as storage time, water temperature, airborne particulate concentrations, and inadequate hand-washing and food preparation using stored water may also contribute to unsafe water in the home.

People need vessels to collect water, to store and use it for washing, cooking and bathing. These vessels should be clean, hygienic and easy to carry and be appropriate to local needs.

Many poor families cannot afford separate containers for transporting and storing drinking water. Drinking-water storage containers must meet user's habits in terms of size, shape, design, weight and durability.

The amount of storage capacity required depends on the size of the household and the consistency of water availability.

There are a variety of pathways for faeces to enter stored water in the home, and stored water is often more contaminated than the source water.

Minimising the amount of faeces in the household environment through sanitation interventions and raising awareness of safe water handling and personal hygiene are prerequisites for improving the quality of drinking water at home.

What are the requirements for safe storage of drinking water at household level?

To safely store drinking water in homes, containers should have the following characteristics:

- Containers should have 10 ℓ to 25 ℓ capacity.
- Secure tight-fitting lid, preferably a screw cap.
- Robust enough to withstand rough handling without cracking. High density polyethylene or propylene is light-weight, oxidation and shock resistant.
- If the vessel is to be used for transporting water, it should be easy to lift from the ground and carry from the collection to the storage point. A flat bottom and one or more handles are desirable.
- Easy to clean and fill so contact with hands is minimised. A 6 cm to 9 cm diameter neck is large enough to facilitate cleaning but small enough to discourage the introduction of hands and dipping vessels which could contaminate the water.
- Easy to remove water from the container without hands touching the water or internal surfaces of the container.
- Compatible with the treatment method used. For example, boiled water should ideally be stored in the same vessel in which it is boiled. In this case, plastic would be inappropriate.
- Affordable and locally available.

Note: *Ideally, storage containers should be fitted with a spigot which allows water to be safely dispensed without risk of contamination from dirty hands or utensils.*

If the vessel is also used for transporting water, the spigot could easily be contaminated or broken off. Cups or dippers are often used to remove water and this carries a high risk of contamination. Using a clean ladle which is left permanently in the storage container is a safer option.

Safe handling and storage of drinking water and behaviour change should be promoted at the household level to reduce/prevent the risk of waterborne diseases such as diarrhoea during emergencies and disasters.

Practical considerations for the cleaning of containers

- Cleaning of containers and steps to be considered at household level

After each use, householders should clean their containers with chemical means to prevent biofilm build-up on the walls.

- **Containers have to be cleaned after use with household bleach (e.g. 'Jik').**
- **Add a teaspoon of household bleach to one cup of water.**

- **Pour the mixture into the container.**

- **Shake the container vigorously for about 5 min and rinse it with clean water.**
- **Do not use sand or any other abrasive material to clean containers. This can worsen the problem.**

Safe storage practices

To safely store drinking water in homes, the following should be considered:

Store drinking water safely

- Keep water in a clean container
- Store water above the ground away from the children.

Use a clean cup

- Use only a clean cup or scoop for removing disinfected water from the storage container.
- Avoid contact between hands and stored water.

Cover container

Water-storage container needs to be kept covered to prevent dust and germs entering the water.

Time of storage

Do not store drinking water longer than 2 days.
This means that stored drinking water should be used within 2 days

APPENDIX B

Relevant SANS and International Standards for HWTS Chemicals, Components and Performance

Treatment Systems and Components

SANS standard	**Scope**	**International relatedness**
SANS 1160 Drinking water system components – Health effects **Edition 1.00** **Approved: July 2011**	Covers specific materials or products that come into contact with drinking water and evaluation of contaminants or impurities that are indirectly imparted to drinking water.	NSF/ANSI 61
SANS 1865 Point-of-use drinking water treatment units **Edition 1.1** **Approved: December 2006** **Technically identical to SABS 1865: 2002**	Covers performance and constructional requirements for point-of-use drinking water treatment units intended to be used for lowering the concentration in drinking water of substances that are considered to be potential health hazards or that might reduce the aesthetic attractiveness for potable usage of such water.	ANSI/NSF 42, *Drinking water treatment units – Aesthetic effects*. ANSI/NSF 53, *Drinking water treatment units – Health effects*. ANSI/NSF 55, *Ultraviolet water treatment systems*.

All treatment chemicals used in the point-of-use treatment of drinking water must comply with the relevant standard for chemicals used in the treatment of water intended for human consumption. The chemicals most commonly used in HWTS for which SANS standards have been published are listed below.

Chemicals Used for Treatment of Water Intended for Human Consumption

SANS standard	Scope	International relatedness
SANS 50901 – Sodium hypochlorite (2007)	Applicable to chemicals used for treatment of water intended for human consumption. It describes the characteristics of the chemical and specifies the requirements and the corresponding test methods for the chemical. It gives information on its use in water treatment.	EN 901
SANS 50878 – Aluminium sulphate (2008)		EN 878
SANS 50888 – Iron (III) chloride (2008)		EN 888

Chemicals for Emergency Use

SANS standard	Scope	International relatedness
Chemicals for emergency use	Applicable to chemicals used for treatment of water intended for human consumption. It describes the characteristics of the chemical and specifies the requirements and the corresponding test methods for the chemical. It gives information on its use in water treatment.	
SANS 52931 – Sodium dichloroisocyanurate, anhydrous (2008)		EN 12931
SANS 52932 – Sodium dichloroisocyanurate, dihydrate (2008)		EN 12932
SANS 52933 – Trichloroisocyanuric acid (2008)		EN 12933

Currently there don’t appear to be any SANS standards for the use of silver nitrate or sodium hypochlorite in drinking-water treatment.