Technical review of small-scale, robust household Scale Prevention Methods for use in remote area Aboriginal communities

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EXECUTIVE SUMMARY

Of the 1216 discrete Aboriginal communities in Australia, 1030 (85%) are located in remote locations (ABS 2001). Over two-thirds (69%) of discrete communities rely on groundwater as their main source of drinking water (FRDC 1994; Memmott, P. and M. Moran, 2001; ABS 2001). These deep groundwaters often contain a ‘rich’ chemistry including high concentrations of calcium, sodium, bicarbonates and occasionally elevated nitrates and fluorides (Downing, J.D., 2000; Hostetler, S. et al., 1998; FRDC 1994).

Certain mineral ions such as calcium, magnesium and carbonate can result in scale formation. The most common type of scale is calcium carbonate (CaCO₃) but other forms do occur. The build-up of scale increases the failure rate of water hardware and appliances. Functioning hot water systems, taps, showerheads and air conditioning systems are necessary for maintaining basic environmental health (FaCSIA 2007). The problems associated with the constant failure of these appliances and equipment are exacerbated by the cost and lack of immediate access to technical skills experienced due to the remote location (Downing, J.D., 2000; FRDC 1994).

Water quality and quantity are difficult to maintain in remote regions due, in part, to diseconomies of scale, distances from major services and smaller pools of technical capacity (FRDC, 1994; Beer and Keane, 2000; QDNRM, 2005). Internationally it is recognised that small water supplies suffer from the effects of geographic isolation, a limited economic base and management issues (WHO 2005). Most small remote communities across Australia have populations of less than 1000 people, and many maintain their water supplies with limited technical support. The level of access to technical support differs between the states and territories and community population size; however the effects on living conditions are very similar.

The economic and regulatory assistance of governments is needed to sustain quality of life for citizens reliant on small water supplies. Remote area residents need to secure reasonable access to water services to improve quality of life and suitable adjustments need be made to ensure this service delivery is achieved (APC, 2006). Public policy discourse on the rationalisation of service provision by governments needs to focus on practical strategies for minimising the hardships already felt by isolated remote communities accessing adequate water services (NTDHCS, 2001).

Given the varied issues encountered in regional and remote water supplies, many communities (and even service providers) find it hard to get good quality, independent information about technologies that might assist with overcoming hard water impacts. The information they receive most often comes from suppliers and manufacturers whose main driver are market, profit and sales (McNeill, L.S. and M. Edwards, 2002). There is a growing list of point-of-use (POU) and small-scale technologies; many are touted as the next ‘solution’ in water treatment. These are sometimes utilised by communities with varying levels of success in ad-hoc efforts to reduce scale impacts. However, some of these technologies do not have scientifically valid proof that they will effectively control scale under water conditions in central Australia.

This project reviews the literature on the impact of water hardness in remote, arid regions, and investigates the available treatment technologies aimed at minimising this impact. The technologies were analysed against selection criteria of costs, product design, robustness and
effectiveness. The criteria included robust manufacture to account for the harsh climate with long periods of dry, dusty conditions and exposure to direct heat and occasional heavy rain. Equipment needs to be relatively maintenance-free or the maintenance simple, as remoteness can limit access to spare parts and technical services (ABS, 2001).

This study utilised data sources in scientific and technical literature, discussions with manufacturers, suppliers and prior product users. It was beyond the scope of this study to conduct field trials.

Of the available technologies, none were ideal for remote situations. Water softening by ion exchange and the use of under-sink reverse osmosis (RO) units appear to have the greatest potential. However, small-scale RO units only produce small volumes of good quality drinking water and so their use should be reserved for high-value uses such as drinking water in hard water areas. Water softeners offer good water quality with minimal capital and maintenance costs, and the promise of a low maintenance regime. Nonetheless, a common factor with many of the technologies examined was that in most cases the robustness and effectiveness of these devices have not been tested under central Australian water quality characteristics, arid environmental conditions and remote community use regimes.

Magnetic water treatment systems and water conditioners are small, robust and inexpensive and have been marketed as the ‘solution’ to hard water problems for many years, but there remains no independent scientifically verifiable proof that they work effectively. Conflicting anecdotal evidence also does not support the claims of manufacturers. Consumers may feel compelled to purchase these devices due to their low cost and robustness. In order to avert unnecessary expenses it is important to ensure these devices are effective in remote areas.

None of the small-scale technologies currently available on the market can fully address the scale problem in remote Aboriginal communities. Each technology has strengths and weaknesses and these would need to be weighed against the water quality goals for specific purposes by community councils and resource agencies to achieve positive results. Examining the options for source substitution is also desirable where scale is high and water is unpalatable for drinking. Given the status of the technologies available, instituting regular maintenance regimes to clean off scale, change taps and exchange hot water system elements may be worthy of consideration and could prove more cost effective in the long term in some situations.

No information was found on trials of under-sink reverse osmosis units in water quality conditions similar to central Australia. Independent remote community trials that examine the costs and ability of under-sink technologies to provide low volumes of high-quality water should be conducted in conjunction with remote Aboriginal communities. Independent trials may also be justified on magnetic technologies and water conditioners to definitively confirm or refute their effectiveness. Future trials should consider different water hardness levels and incorporate an assessment of the use and serviceability by householders and community maintenance technicians.
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1 INTRODUCTION

This paper investigates the appropriateness of current technologies aimed at reducing hardness of the predominantly groundwater-sourced drinking water supplies within remote Aboriginal communities. Marshall (1999) conducted a review of such devices nearly ten years ago. The purpose of this review is to update the knowledge of available scale prevention devices and their appropriateness to remote community operating conditions. Hard water is of great concern for remote communities. Water hardness is caused by excessive concentrations of particular mineral ions in the water supply, which can result in a build-up or deposit referred to as ‘scale’ (Figure 1). Scale accumulation can lead to damage to household electrical appliances, taps, reticulation systems, hot water systems and evaporative air conditioners. Use of appropriate technologies may reduce water hardness, minimise maintenance costs, and improve drinking water quality.

Figure 1: An outdoor tap in a remote community with scale deposits clearly visible.

Eighty-five per cent of discrete Aboriginal communities are located in remote areas (ABS, 2001; Memmott and Moran, 2001) with over two-thirds (69%) reliant on groundwater sources for drinking water supply and personal hygiene (ABS, 2001). In arid regions these groundwaters are frequently deep and ancient. They have a ‘rich’ chemistry, often containing high concentrations of calcium (Ca), sodium (Na), bicarbonates and occasionally elevated levels of nitrates and fluorides (Hostetler et al., 1998; Downing, 2000). Remote populations also experience difficulties in maintaining adequate water supply and quality for many reasons, including diseconomies of scale, distances from major services, seasonal extremes and the smaller pools of technical capacity from which to draw (Beer and Keane, 2000; QDNRM, 2005).

Point-of-use (POU) and small-scale technologies designed for household use are increasing in popularity and availability. Many are touted as the next ‘solution’ to remote community water quality problems but manufacturer claims are seldom tested by independent bodies. In
an environment of innovation and change, many communities experience difficulty in obtaining good quality, independent information about which household technologies might best suit their needs for improved water quality. Common scale prevention technologies include reverse osmosis, water softeners, solar desalination, chemical treatment, magnetic water treatment, and water conditioners.

The evaluation criterion for this study was guided by technical, physical, financial and environmental factors. The claims of manufacturers and suppliers were investigated in an attempt to remove as much bias as possible by drawing from scientific literature. Discussions with product users, critical evaluation of the literature and internet searches provided information on the available technologies and their likely performance and operational applications. Resource agencies and Essential Services Officers (ESO’s) from communities were also contacted regarding their experiences of previous use of any scale prevention devices.

The information gathered in this study identified a small number of technologies worthy of field trials.

2 BACKGROUND

Many remote area Aboriginal communities only have access to groundwater as their primary water supply (ABS, 2001). Groundwaters high in dissolved minerals increase the risk of scaling in water distribution pipes and fittings. It also reduces the effects of soaps and detergents (Marshall, 1999; Smothers et al., 2001; Huchler, 2002; WHO, 2006). Hard water is widely considered safe to drink (Downing, 2000; Ong, 2005; WHO, 2006) but not always palatable. Its palatability decreases with elevated concentrations of total dissolved solids, particularly if concentrations exceed 800mg/L TDS. Bore water in remote locations is often above 800mg/L and sometimes above 1000mg/L, which is classified as brackish water (ANZECC, 2000; Hill and Kolb, 2004). Fitzgerald et al. (1999) found 40% of bores surveyed in the Anangu Pitjantjatjara Lands were above 1000mg/L, with 15% greater than 1500mg/L. Such high concentrations may reduce overall water consumption in remote areas leading to inadequate hydration (Hostetler et al., 1998; Fitzgerald et al., 1999; Willis et al., 2004). Dehydration is a major factor in renal disease, and may mask other serious health problems (Fitzgerald et al., 1999; Willis et al., 2004; NTDHCS, 2005; WHO, 2006).

2.1 The distinction between hard and soft water

Increased concentrations of mineral ions in underground aquifers can result from the dissolution of calcium, magnesium, carbonate and other minerals from rocks and soils. In solution, mineral carbonate ions (CO$_3^{2-}$) combine with calcium ions (Ca$^{2+}$) to form calcium carbonate (CaCO$_3$) scale, a precipitate often found in solid form on heater elements and water distribution hardware in hard water areas. This is the most common form of scale, but other scale types do exist according to the minerals present in the water supply (Marshall, 1999).

There are no set regulatory limits for water hardness (WHO, 2006), but Australian drinking water guidelines recommend water hardness not exceed 500mg/L CaCO$_3$, with 80-100mg/L most desirable (ANZECC, 2000; Downing, 2000; NHMRC, 2004). Concentrations below 60mg/L are regarded as soft water with increasing corrosiveness to water distribution pipes and hardware (Downing, 2000). Good quality water has concentrations between 60-200mg/L CaCO$_3$. Above 200mg/L is hard with an increased risk of scale accumulation; with severe
scaling occurring at levels greater than 500mg/L (ANZECC, 2000; Downing, 2000; NHMRC, 2004; Willis et al., 2004).

2.2 Temperature variation in scale formation

Water hardness has two distinct categories – temporary and permanent. Carbonate hardness can be removed as a precipitate and is regarded as temporary. Non-carbonate, permanent hardness results from chlorides and sulphates, which are not precipitated by boiling.

There are two major factors that increase the risk of scaling - rising temperatures and concentrations greater than 200mg/L CaCO$_3$. Therefore, the degree of deposition increases considerably with the combination of both conditions. The removal of carbon dioxide from the water supply will also increase the supersaturation rate followed by quick deposition of CaCO$_3$ (Perez, 2000). Other water characteristics can also alter the deposition rate of CaCO$_3$ including pH, water pressure, and an increase in hardness ion concentrations in solution (Marshall, 1999).

Temperature variation can alter the structure of the crystalline CaCO$_3$ in particle size distribution and electrokinetics potential (Kobe et al., 2002; 2003). There are three known species of CaCO$_3$ - calcite, aragonite and vaterite, with each having a deposition preference (Marshall, 1999; Rowling, 2004). Vaterite is often found in caves systems and will convert to calcite and aragonite over time. Calcite and aragonite are more common and can co-exist within a temperature range between 50°C and 60°C. Aragonite is present at temperatures greater than 60°C (Marshall, 1999). Calcite forms a harder scale and is more difficult to remove than aragonite (Marshall, 1999; Smothers et al., 2001; Huchler, 2002; Caciagli and Manning, 2003; Rowling, 2004).

Scale deposition in water at cooler temperatures is not affected in the same way as in warmer waters. Water evaporation from air conditioners will result in a higher accumulation of concentrated salts regardless of temperature (Marshall, 1999). This is because evaporation will always yield the total dissolved solids in the water source (mineral salts).

2.3 Concerns regarding hard water and scale formation

Maintenance, particularly access to spare parts, is a major concern in remote areas. Scale deposit leading to damage or failure of hot water systems, evaporative air conditioners, taps, showers and water pipes add to the many and diverse costs associated with remote living. Within hot water systems, scale-fouled heater elements can result in overheating and eventual failure. The same effects occur in other household appliances with heating elements, such as kettles, and the effectiveness of air conditioning systems will be diminished with excessive build-up of salts.

Solid precipitate can form as a result of reactions between ions in detergents and soaps reducing their effectiveness. An unpleasant milky film can also be left on glassware and other surfaces as the water evaporates (Fitzgerald et al., 1999; Marshall, 1999; Downing, 2000). Without lather formation larger quantities of cleaning agents may be used, thus increasing living costs.

Drinking hard water is generally not considered to have a detrimental effect on human health (NTDHCS, 2005; WHO, 2006). In fact, a number of important minerals found in
groundwater may be beneficial in improving certain medical conditions such as cardiovascular disease [CVD] (WHO, 2006). However, excessively high levels, i.e. greater than 500mg/L, have been weakly linked to a higher risk of gall stones and kidney stones (WHO, 2006).

2.4 **Scale control technologies**

The technologies available for scale control include the use of chemicals, ionic exchange, thermal and membranous desalination, magnetic treatment and water conditioning.

2.4.1 **Desalination**

The desalination process removes dissolved salts and other materials from the water supply. Desalination technologies usually have two distinct modes of operation: thermal and membranous (Winter *et al.*, 2002; QDNRM, 2003; Burgess and Lovegrove, 2005).

Thermal technologies include multiple effect distillation (MED), multi-flash distillation (MFD), vapour compression and solar desalination (Winter *et al.*, 2002). MED and MFD are often large-scale and use waste heat sources such as the steam displaced from a gas turbine (Winter *et al.*, 2002; QDNRM, 2003). Vapour compression is often used in combination with other processes, and where the heat for evaporation comes from the compression of vapour (Winter *et al.*, 2002). These three methods have been noted for the purpose of completeness, but they are currently not available in a form that could be usefully employed in remote Aboriginal communities, and will not be discussed further in this report.

Thermal desalination works by heating the water to high enough temperatures to cause water vapour to disperse into the air and collect on a suitable type and shape of material, usually glass. They are designed to minimise heat transfer losses to the environment, and maximise heat transfer rates within the system. Solar energy is mostly used for this process. The fuel source for solar energy is free and reliable in central Australia which has very little annual cloud cover. Diesel is also used to power some hybrid solar-diesel systems to overcome inefficiency, costs and to increase the functioning capacity of the unit. Thermal processes are generally used to treat highly saline waters, where large volumes of water are required, and in locations where energy costs are low (QDNRM, 2003).

2.4.2 **Reverse osmosis**

Membranous technologies include electrodialysis reversal (EDR) and reverse osmosis(Genders, R., 1997). Electrodialysis reversal is very reliable but expensive with specialised servicing requirements that are difficult to obtain within Australia (FRDC, 1994). Therefore it will not be discussed further in this report. Reverse osmosis (RO) is now a cheaper and more recognised product. Other advantages include local manufacturers and more easily accessible parts and service.

Osmosis is a natural process whereby the pores in a living cell allow water molecules on either side of a membrane to move from low to high salt concentrations to equalise the salt concentration on both sides. Water molecules therefore move from one side of the membrane to the other to dilute salts on the other side (Figure 2). The exact opposite of this process is termed reverse osmosis (Figure 3). RO uses membranes of different sizes to force water molecules away from unwanted particles (e.g. salts) to deliver a water supply according to the
types of target materials to be eliminated (Binnie et al., 2002; WHO, 2006). An energy source is required to push the osmosis process (under pressure) into reverse. Pressure pumps are used where mains power is unavailable to move the treatment water through the RO unit.

![Normal Osmosis Diagram](source: www.zenon.com)

**Figure 2: Normal action of osmosis (Source: www.zenon.com)**

![Reverse Osmosis Diagram](source: www.zenon.com)

**Figure 3: Reverse osmosis (Source: www.zenon.com)**

This method does not remove viral organisms, and some organic and inorganic compounds that may be smaller than the membrane pore size (WHO, 2005). With waters containing high levels of minerals, as total dissolved solids (TDS), pre- and post-treatment filters are used to provide additional biological and membrane protection (Genders, R., 1997). Many RO systems use antiscalant chemicals to prevent scale build-up within the unit (QDNRM, 2003).
2.4.3 Water softeners

Water softeners usually consist of two or more fibreglass pressure vessels (tanks). Ion exchange resin beds sit inside the tanks and contain natural or synthetic granular materials. Multiple tanks are used to allow the regeneration of one without disrupting household water supply. The substances attract sodium cations (Na\(^+\)) courtesy of a slight electrical charge. As the treatment water flows through the tank the Na\(^+\) are displaced (exchanged) by calcium or magnesium hardness ions (Ca\(^{2+}\) or Mg\(^{2+}\)). The Na\(^+\) is not damaging to water hardware and is subjected to removal by the flowing water.

Regeneration of the resin beds is required when they are completely saturated with hardness ions. This can be done manually with clean water, or by an automatic device that flushes the tank with concentrated Na\(^+\) brine. An unspecified contact time is required to allow the regenerant to effectively replace the hardness ions with Na\(^+\) ions (Genders, R., 1997). The used regenerant and rinse water flow into a holding tank. This used water should be disposed of off-site or to a sewer (Genders, R., 1997).

2.4.4 Chemical softening

Chemicals are often added to drinking water to reduce or eliminate waterborne disease and improve aesthetic water quality (Genders, R., 1997). Some chemicals allow the unwanted mineral impurities to remain in solution for expulsion by the water flow, or have their nucleation characteristics changed to prevent chemical elements precipitating out of solution.

In 1989 the National Health and Medical Research Council (NHMRC, 2005) approved seven chemical substances for human consumption according to their efficacy and toxicity. One such chemical, sodium hexametaphosphate ((NaPO\(_3\))\(_6\)), under the brand name Calgon\textsuperscript{TM}, has been trialled in WA and NT by their respective water authorities and recently a study by the Centre for Appropriate Technology was conducted (Beard, 2007). In completing this study it was found that there was little data available on the effectiveness of Calgon as a scale amelioration additive, despite its long history of use in water supplies in the US and UK (Beard, 2007). The field trial did not develop definitive conclusions on the effectiveness of Calgon due to a number of influencing factors, and further research on the additive under a range of water quality conditions was recommended.

2.4.5 Magnetic field treatment

Magnetic water treatments appear promising with a relatively low cost, simple and environmentally sound method of water treatment (Downing, 2000). Different methods use permanent magnets or electro-magnets in conjunction with water turbulence through the distribution system to alter the molecular composition of the water supply (Downing, 2000; WAWC, Undated). In both methods hard calcite is converted to softer aragonite for easier removal as the water flows through the distribution network (Kobe et al., 2002; 2003). The turbulence is crucial and must be enough to increase the strength of the magnetic field to improve effectiveness.

Devices that use only permanent magnets rely on water turbulence to increase the energy capacity of the magnet. The magnets are placed in the internal diameter of the pipe and use the turbulence provided by the water flow. In those devices utilising electrical pulses, a similar effect can be produced within the water flow (Krauter et al. 1996; Kobe et al. 2003).
The electrical charge should increase the magnetic intensity but these require a power source. They use electrical wires wrapped around the external diameter of the treatment pipe to create the pulsing effect required to increase the magnetic field within the pipe (Downing, 2000). These devices do not interfere with the water yield and appear to be robust with little maintenance requirements.

2.4.6 Water conditioning

Water conditioning treatments reduce hardness by converting calcite to aragonite. This process is claimed to reduce the complexation and precipitation of hardness compounds and allows them to flow out of the system.

Inside these devices is a movable core. It is constructed in such a way as to provide turbulence when the water passes through. This turbulence is claimed to strip away electrons from the internal diameter of the device. During this process, a positive charge is said to occur. An earth is used to prevent corroding the internal parts of the device through an electrical wire. Corrosion minimisation within the device allows the exchange of electrons to occur more readily. Without proper maintenance these devices can foul internally and reduce in effectiveness.

The water quantity is not impeded as the device is placed in-line with the water distribution system.

3 METHODOLOGY

The methodology for this report was based on that of an earlier study at the Centre for Appropriate Technology (Marshall, 1999). Information on issues related to water quality in remote Aboriginal communities was obtained from suppliers, manufacturers, relevant tradespeople and product users. The Yellow Pages and Internet sources including university library websites were used to find technical and scientific literature.

Consultations with consumers, tradespeople and industry professionals helped define the problems with hard water and how effectively, if at all, water treatment products had dealt with the various situations.

Trials on the reviewed water treatment technologies were not conducted. However, a matrix of the available technologies was developed and describes their operation, capital costs, maintenance procedures and related expenses, robustness, life expectancy, daily yield, water usage and/or wastage (Appendix 1).

Where specific data could not be obtained on a particular criterion, the author estimated likely performance based on the available information on similar technology characteristics.

This study seeks to enhance current knowledge on available technologies and their functionality for remote community applications. Remote area Aboriginal Community councils and resource agencies can use this matrix as a guide (Appendix 1) to help determine the most appropriate technology according to their budget constraints and specific needs.
4 RESULTS

A matrix on the various available technologies reviewed has been produced as a result of this study (Appendix 1), which may assist communities and resource agencies. Not all available treatment technologies were analysed in full for this report. This study discounted some new innovations, and products in development due to their lack of field trials or the lack of technical and scientific information. In addition, many existing methods were discounted because they were viewed as inappropriate to remote applications due mainly to size and maintenance intensity.

4.1 Solar distillation

The major factors associated with distillation are capital costs, and operation and maintenance costs (Winter et al., 2002; Barron, 2006). The capital costs are often high with large installation areas required (Chaibi, 2000) but they have low operation and maintenance costs (Chaibi, 2000; Winter et al., 2002). Kunze (2001) indicates their capital costs should be measured against the high water quality produced and ease of maintenance. However, the maintenance schedule is time consuming (Binnie, C. et al., 2002; Genders, R., 1997). To reduce the costs it may be necessary to investigate the use of local materials and labour (Chaibi, 2000). The overall costs associated with distillation have been significantly reduced in recent years through improved technology and more efficient operation (Burgess and Lovegrove, 2005).

Problems often linked to solar distillation include vapour leakage, heat absorption, the accumulation of salts and other organisms. For efficient operation these units should be airtight to avoid vapour loss, maintain high basin temperature, and maintain a regular cleaning schedule (Chaibi, 2000).

Energy is often required to power the unit and pumps required to circulate the water in reticulated systems. Free solar energy is a tremendous asset in arid regions. In comparison, an estimated equivalent electrical energy requirement at 100°C is about 625kWh (Binnie, C. et al., 2002). The Northern Territory energy authority, Power and Water, attempts to maintain a constant electricity charge tariff for users in remote areas. At present remote area residents either pay a nominal rate of $0.1438/kWh, plus an access fee of $0.2834/day, or use pre-payment cards at $0.1642/kWh (PWC, 2006).

Cost per unit production estimates for the conversion of brackish water to fresh water are about $0.10-$0.20/m$^3$. Estimates from Western Australia vary from $0.75$-1.00/m$^3$ in the south-west to greater than $10/m^3$ in remote areas (Barron, 2006). Due to the nature of solar distillation a salty water by-product is produced (Winter et al., 2002). This highly concentrated waste water could contribute to environmental degradation if not properly disposed of (Chaibi, 2000). Some suggestions to remove or utilise this concentrated brine include establishing salinity evaporation ponds. However there are clear environmental management issues and these may be difficult to deal with appropriately in some areas.

4.2 Reverse osmosis

Reverse osmosis has very high water quality with an ability to remove up to 99% of contaminants (FRDC, 1994) but it may need 3-6 times the production water amount to clean the unit membrane. One manufacturer’s website indicated a system using a 1:1 ratio of
production water to waste water will require more cleaning maintenance and could reduce the life of the membrane.\(^1\) The usual rate is approximately 20-70% of the feed water (DAFFA, 2002), and this has clear implications for communities where water quantity and availability is limited.

Pre-treatment is required to improve the life of the RO membrane in hard water areas. With such high removal rates of salts, it is possible to soften the water too much (WHO, 2005). Water that is too soft may become corrosive, which then has other equally undesirable implications for the water distribution system, and possibly consumer health. RO units often require mineral re-addition to result in a water of appropriate mineral composition before use. The use of reverse osmosis should be in conjunction with a suitable method of increasing the pH level to reduce its ability to corrode the water distribution network. Many RO units use antiscalant to reduce scale build-up (QDNRM, 2003).

Recent design innovations include packaged under-sink or wall-mounted units. These smaller units are less expensive but only provide scale removal protection to one section of the house, e.g. kitchen. More than one unit is required to treat scale throughout the house. Capital costs should consider the overall treatment required and the number of units to be installed. Smaller under-sink or wall-mounted units can cost up to $1000.\(^2\) Conversations with manufacturers indicate capital costs could be as high as $100 000 for large units depending on location and specific requirements.\(^3\)

Energy consumption can add considerable costs to water treatment. Solar radiation is a free source of energy in central Australia but this can be nullified through on-going maintenance on solar equipment. Maintenance can also be time consuming and may require experienced personnel. Energy consumption will depend on the concentration of TDS in the water source. Estimates for RO systems desalinating brackish waters are between 0.5 to 2.5kWh/m.\(^3\) However, reverse osmosis is more cost effective than thermal processes (QDNRM, 2003). The energy required for a pump usually comes from either diesel or solar electricity.

### 4.3 Water softeners

Water softeners are an inexpensive method to reduce water hardness. The resin beds have a long life expectancy of approximately 7-20 years depending on water hardness. They also require little maintenance. Bed regeneration needs to occur when they are not able to remove any more hardness ions. Many water softeners now come with the option of automatic or manual regeneration. The addition of an automatic device, which can detect the need for regeneration, increases capital costs but reduces the manual labour required to carry out maintenance. However, this is not a difficult operation and can easily be achieved by householders if they are provided with the appropriate training or knowledge.

These units are made to operate under reliable mains pressure, which is not available on some remote communities, particularly in outstations. An appropriate sized pump may be required

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\(^2\) Ibid.  
\(^3\) Chris Wallace, Business Owner, Suntec. Personal communication 1/2/07
to maintain water pressure in these situations but requires a power source and a level of ongoing service and maintenance commitment.

Their fibreglass construction is vulnerable to vandalism and wind-blown debris. Ion exchange does not treat microbial contaminants in the treatment water. If biologically suspect water is used then filtration devices or chlorination may be considered. An activated carbon filter would be suitable for installation prior to the water softening device. The inclusion of pumps and pre-treatment filters adds to the complexity and costs of any water treatment devices.

4.4 Chemical water treatment

Chemical treatment has been used extensively in industrial applications. It consists of applying a chemical solution to the water supply. It is necessary to construct a plant to administer the correct and regular dosage automatically (Figure 4). Monitoring of plant and the dosage application is required on a regular basis and can be conducted by a trained community member. For major service and maintenance procedures a qualified tradesperson is required. This plant would add to the complexity and costs associated with water treatment.

Polyphosphates such as those in sodium hexametaphosphate are used as ‘builders’ to help soften water by making it more alkaline.\textsuperscript{4} It is also claimed that scale build-up in water distribution pipes is reduced. However a recent study on the effectiveness of the additive in a remote community trial by the Centre for Appropriate Technology was inconclusive (Beard, 2007).

Figure 4: Example of a Calgon\textsuperscript{TM} semi-automated dosing unit installation in a remote community.

\textsuperscript{4} M. Cullen Senior Lecturer, School of Environmental Science, Southern Cross University, Lismore NSW. Personal communication 22/01/07
4.5 Magnetic water treatment

Magnetic treatment is claimed to alter the physical characteristics of the water supply. A study into magnetic fields and their effects on scale formation indicate a significant difference in energy density (~$10^9$ J/m$^3$) is required to bridge the gap between the two forms of CaCO$_3$ – calcite and aragonite (Kobe et al., 2002; 2003). A turbulent flow is required to increase the magnetic field in devices using permanent magnets. A magnetic field can generate the high energy density values within a turbulent flow to prevent scale. However, it is difficult to ascertain the actual amount of energy required to achieve the high values stated. The turbulence should generate considerable velocity fluctuations ($10^3$ m/s) and is a crucial part of the magnetic water treatment theory (Kobe et al., 2003).

The use of magnets themselves is highly contentious but may work if iron oxides (Fe$_2$O$_3$) are in the water supply. Uncertainty prevails as to their effectiveness and ability in removing hardness ions from the water supply. Magnetic treatment is being touted as a relatively cost effective alternative to electricity. This technology has promise in its ecological importance and relative low cost (Kobe et al., 2003).

4.6 Water conditioning

Water conditioning treatments are relatively affordable but doubt exists as to their performance. No qualitative scientific data is available to verify claims of the manufacturers. One manufacturer calls this a ‘catalytic process’; however, it is doubtful if the energy reduction required for catalysis to occur is enough. Unpublished reports indicate a 100% conversion of CaCO$_3$ from its calcite form to aragonite form, but other researchers have not been able to replicate this test as yet. Some anecdotal evidence suggests it does as manufacturers claim. However, this study found many former users of these devices are not convinced of its scale removal ability, and a dearth of data to verify or refute either way limits further analysis.

5 DISCUSSION

Each of the treatment technologies were examined against the following selection criteria. They will be comparatively discussed in detail below with reference to Table 1 (p22). Factors such as treated water quality, capital and maintenance requirements, equipment robustness, and the yield and water wastage were considered important when developing a suitable water treatment system.

5.1 Water quality

Although biological contaminants are important and often the focus of technical intervention technologies for water supplies, the focus of this report was on scale and hardness removal or amelioration. The overall treatment by solar distillation and reverse osmosis are very effective in reducing scale minerals. Both these methods produce very high water quality. Solar distillation also removes all pathogens and biological contaminants, whereas RO

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5 S. Dallas Lecturer Environmental Technology Centre Murdoch University Fremantle WA. Personal communication 17th Jan. 2007

6 L. Scott, PhD candidate School of Civil, Mining and Engineering, University of Wollongong, Wollongong NSW. Personal communication 29th & 31st Jan. 2007
membranes may allow some microscopic pathogens to pass through. The standard of RO membrane capacity is expected to increase to a stage of exceeding the performance of thermal units (Barron, 2006).

Distillation and membranous technology are by far the most effective in terms of contaminant rejection. Chemical treatment, it could be argued is a more targeted approach and can be used to target certain contaminants. This method is also effective in the treatment of numerous chemicals such as uranium (U) and boron (B). Sodium hexametaphosphate ((NaPO$_3$)$_6$) has been used to treat water in Western Australia and the Northern Territory. No assistance is provided to reduce scale build-up in evaporative air conditioners or other areas of cooler water due to its inability to stop calcium precipitating from cold water (Marshall, 1999). This additive keeps the minerals in suspension with eventual ingestion by residents, thus increasing mineral intake. The health effects have not been fully explored (WHO, 2006) with concurrent concerns for renal health and benefits for cardio-vascular patients. WHO (2005; 2006) insist that increased mineral intake is beneficial for cardio-vascular disease, but at high concentrations may increase the risk of renal problems such as kidney stones (Willis et al., 2004). Palatability should not be affected unless over dosing occurs (Marshall, 1999; Downing, 2000).

Water softeners alter the ionic composition of the treatment water by an exchange of ions. The treated water is much softer, which then leads to the possibility of increased corrosive effect in the water distribution network. Therefore, the pH may need to be adjusted to reduce this risk. These devices do not remove biological contaminants, and require a filter such as activated carbon for this purpose.

The use of magnets to treat water aims to influence a change in the physical structure of the mineral ions in the treatment water. Calcite, the harder form of CaCO$_3$, is considered to transform into the softer aragonite, allowing easier removal by the flowing water. The water turbulence is critical in this process. Turbulence also has an impact during the water conditioning process. This method requires no magnets, but a slight electrical charge to reduce internal corrosion.

5.2 Effectiveness

The effectiveness of water treatment methods to reduce or prevent scale build-up has to be measured against the actual water characteristics in remote areas. The water quality conditions experienced in remote Aboriginal communities is often in excess of 400 mg/L hardness and TDS values frequently exceed 1000mg/L. As a result of its efficiency in trapping all but the most microscopic contaminants, reverse osmosis membranes can foul (clog) in hard waters. This would result in frequent servicing requirements with many products estimating replacement every 3-12 months. The cost of filters and membranes are minimal ($80-$250/yr), but affordability will be dependent on replacement frequency. Most of the data on the technologies examined as part of this study indicated that many had never

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7 R. Hutchins, Project Officer, NT Power and Water Authority. Personal communication 16th January 2007
8 Ibid.
been tested under these water quality conditions. Thus effectiveness and cost-effectiveness in treating an ancient arid-zone groundwater can not be adequately discussed.

Because reverse osmosis and solar distillation are very effective in removing most contaminants, this can create a problem in making the water too soft, thus requiring chemical additives to return the water quality to a preferred standard. Solar distillation may also effectively remove all the beneficial minerals from the supply water (Kosisek, 2005). Demineralised water must contain some of the vital minerals important to human health. Remineralisation may be required with reverse osmosis and solar distillation to provide adequate drinking water.

Water softening removes hardness ions but its effectiveness is gradually reduced as the resin beds become saturated and cannot absorb any more ions. These units require regular bed regeneration to maintain adequate water quality. Water softeners have a similar effect in softening water too much and may require pH adjustment. Chemical treatment may provide the ability to target certain contaminants in the water supply.

Magnetic treatment and water conditioning methods appear to change the form of calcium compound from calcite to aragonite, thereby reducing its ability to attach to parts of the water distribution system. As a result, it has been observed that scale does accumulate on the outlet pipes such as showerheads and taps. This has also been observed on heater elements in household appliances.

As most of these devices have not been tested under the required groundwater quality conditions, trials should be conducted to determine their efficacy with these water sources.

5.3 **Capital and maintenance costs**

Capital costs can be excessive for large-scale solar desalination and reverse osmosis applications. Technological improvements in RO membranes have reduced their capital and maintenance costs. Under-sink reverse osmosis units appear to be inexpensive (under $1000 capital cost) and may present a better option for smaller communities. Solar power can be coupled to RO units to provide a cheaper energy alternative to conventional diesel electricity. This would improve the operational costs, but considerably add to the capital costs. There were no water quality data for testing under central Australian conditions therefore the earliest shorter maintenance frequency estimates (e.g. 3 monthly) should be considered. This would cause a high maintenance burden on community members.

Large-scale solar desalination applications (e.g. for multiple households) often have expensive capital outlay, and failures are well documented (FRDC, 1994). The addition of on-going maintenance requirements would add to the cost. Mains electrical power or cheaper solar energy is required when running pumps. But this increases the complexity of the system. Remoteness and maintenance-intensive systems offer increased difficulties particularly in securing spare parts.

Water softening is relatively low maintenance and has low capital costs in comparison to solar desalination and reverse osmosis. The automatic regeneration mechanism adds to the capital cost but can reduce the maintenance time. Exchange resins have a long life span depending on water hardness, which can exceed 800mg/L (Willis et al., 2004). In areas where the water supply is biologically unsafe, pre-filtration is needed.
Chemical treatment plants can have a costly initial outlay (> $30 000) although ongoing consumables are relatively cheap. However, regular maintenance and monitoring by trained personnel is necessary and this would increase the costs of operations. Major service issues require specialised technical skills which are not always present in remote area communities. Indications from Northern Territory Power and Water Corporation are that the large initial expense for a chemical treatment plant and on-going chemical costs would be recouped over the long-term through the improvement in water quality, should the technology prove effective.

Magnetic treatment devices have a relatively low cost (Kobe et al., 2003). These and water conditioning units require regular maintenance. This is not labour intensive however, and can be done by easily removing the device from the water pipe and scrubbing with a brush. Electro-magnetic treatment is less maintenance intensive but the operating cost is higher as electricity is used.

5.4  Robustness

Robustness is important due to the harsh climatic conditions experienced in remote arid regions. Robustness here is defined as a resistance to damage from any causes deliberate or accidental (e.g. extremes of temperature, wet and dry, vandalism, misuse, misunderstanding of technology, unskilled repairs). Central Australia often encounters long periods of dry, dusty conditions with occasional heavy periods of rain.

Solar distillation technology has been used in remote areas and the robustness of its parts have been refined and improved over time. Past concerns with the fragility of solar panels have been taken into consideration during the design and construction process and are much improved. It appears that the only risk with these panels is to locate them away from any potential damage from falling or wind-blown objects.

Reverse osmosis membranes and filters are manufactured from fine polymers and fibres and are not usually of strong construction. They will need to remain wet at all times to avoid degradation. If they dry and become brittle, which may occur within 48 hours if not used, they will deteriorate quickly. Larger RO units can be designed for rugged conditions with careful consideration for smaller remote communities to avoid significant breakdowns (AWA, 2006). Small-scale package units appear to be robust for remote locations. However, there are some indications that skills and finances are limiting factors for replacement and maintenance and should be considered in advance of purchasing any such technology.

Since Marshall (1999), no other studies have found any improvement in the robustness of water softeners to withstand the rigours of community life. A supplier in Alice Springs indicates their construction may not withstand acts of vandalism or falling or wind-blown debris. Further studies are required to determine the robustness of these devices through trials in conjunction with a suitable Aboriginal community.

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9 R. Hutchins - Ibid
10 Employee – Taps, Tubs and Tiles, Alice Springs NT. Personal communication 15/2/07
If vandalism or wind are found to be a significant risk to uptake of the technology, one option may be to build a suitable structure around the water softening device aimed at avoiding external damage.

All of the magnetic water treatment devices and water conditioning devices examined for this study are small, robust units with few moving parts. Although the processes they use are different, they are made of similar material. In water conditioners alloy is preferred for the internal diameter with brass often used externally. The main physical difference is the use of magnets or electrical pulses (magnetic treatment) as opposed to an inner metallic core that increases water turbulence (water conditioners).

5.5 Yield and wastage

Reverse osmosis has a reputation for water wastage with a ratio of up to 6:1 water wasted against water produced. The average for the range of products tends to be around 3:1 and should be considered when making a purchase. If wastage reaches 1:1 indicating more treatment water entering the membrane, it will be necessary to replace the membrane more frequently.¹¹

The water yield of a conventional solar still is approximately 3L/m² of collecting surface (Genders, 1997). This quantity is relatively slow but should be weighed against the quality of water produced.

Water softeners require a certain amount of water (‘backwash’ water) to regenerate the ion exchange beds. The frequency and amount of waste water will depend to a large extent on water hardness. Automatic regeneration devices may reduce the amount of waste water.

Magnetic field devices and water conditioning methods are placed in-line with the water supply. This prevents wastage and does not affect the ordinary pipe yield.

5.6 The selection criterion

Each of the selection criterion was given a simple six point rank-scale score as per Table 1. The treatments were scored from 6 to 1 according to their ability to meet the selection criteria, with 6 being more appropriate and 1 being less appropriate. Water quality and robustness are both highly regarded in remote locations and are given a weighting of 1. The ability to withstand the rigours of remote locations has high importance and the robustness weighting of 1 is indicative of this. The water used to test most of the technologies was often of higher standard to that found in central Australia. A weighting of 0.9 is given for effectiveness of the technology to treat the varying standards in water quality; however, given the available information this is difficult to determine. Capital and maintenance costs have a weighting of 0.6 with slightly more importance given to the maintenance regime. This has a weighting of 0.8 and considers technical knowledge, labour time and potential delays caused by isolation. The water yield and wastage were not considered as a high priority for this report and are weighted as 0.3 and 0.4 respectively. Obtaining a higher degree of water quality was considered more valuable.

¹¹ PSI Filters – op cit
The following Table is a measure of the treatment technologies against the selection criteria. It is important to note the data in Table 1 and the results and recommendations of this report should be considered in light of the lack of information relevant to Central Australian conditions provided on each of the respective technologies.

Using this scoring and weighting system to rate technologies against the selection criteria, the most promising technology was water conditioners and (not far behind them) magnetic treatment options. This is because of the combination of the high importance placed on costs, robustness, maintenance, yield and wastage in remote areas. Their low score for effectiveness reflects the lack of information available to adequately assess this parameter. Further trials that could determine their efficacy would help to inform exclusion or decision-making on these technology options.

The next best-performing technologies were the under-sink reverse osmosis units and thermal desalination processes. However, both of these scored low under yield and wastage criteria. Further, the effectiveness score is high based on knowledge of the effectiveness of the process and not field test data under hard water conditions. These technologies also have limited ability to scale up to whole of house scenarios.

Table 1: Scoring of water treatment methods against the selection criteria.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Weighting</th>
<th>RO</th>
<th>Rating</th>
<th>Score*</th>
<th>WS</th>
<th>Rating</th>
<th>Score*</th>
<th>TD</th>
<th>Rating</th>
<th>Score*</th>
<th>CT</th>
<th>Rating</th>
<th>Score*</th>
<th>MT</th>
<th>Rating</th>
<th>Score*</th>
<th>WC</th>
<th>Rating</th>
<th>Score*</th>
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<tbody>
<tr>
<td>Water quality</td>
<td>1.0</td>
<td>5</td>
<td>5.0</td>
<td>4</td>
<td>4.0</td>
<td>6</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effectiveness</td>
<td>0.9</td>
<td>6</td>
<td>5.4</td>
<td>4</td>
<td>3.6</td>
<td>6</td>
<td>5.4</td>
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<td>4.5</td>
<td>1</td>
<td>0.9</td>
<td>1</td>
<td>0.9</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Capital costs</td>
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<td>3.0</td>
<td>4</td>
<td>2.4</td>
<td>2</td>
<td>1.2</td>
<td>2</td>
<td>1.2</td>
<td>6</td>
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<td></td>
<td></td>
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<tr>
<td>Maint costs</td>
<td>0.7</td>
<td>4</td>
<td>2.8</td>
<td>5</td>
<td>3.5</td>
<td>3</td>
<td>2.1</td>
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<td>2.1</td>
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<td>4.2</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Maint regime</td>
<td>0.8</td>
<td>4</td>
<td>3.2</td>
<td>5</td>
<td>4.0</td>
<td>2</td>
<td>1.6</td>
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<td>1.6</td>
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<td>4.8</td>
<td>6</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Robustness</td>
<td>1</td>
<td>3</td>
<td>3.0</td>
<td>3</td>
<td>3.0</td>
<td>4</td>
<td>4.0</td>
<td>4</td>
<td>4.0</td>
<td>5</td>
<td>5.0</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield</td>
<td>0.4</td>
<td>3</td>
<td>1.2</td>
<td>4</td>
<td>1.6</td>
<td>5</td>
<td>2.0</td>
<td>5</td>
<td>2.0</td>
<td>6</td>
<td>2.4</td>
<td>6</td>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wastage</td>
<td>0.3</td>
<td>3</td>
<td>0.9</td>
<td>4</td>
<td>1.2</td>
<td>5</td>
<td>1.5</td>
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<td>6</td>
<td>1.8</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sum total</td>
<td>-</td>
<td>33</td>
<td>24.5</td>
<td>33</td>
<td>23.3</td>
<td>33</td>
<td>23.8</td>
<td>29</td>
<td>20.9</td>
<td>37</td>
<td>23.7</td>
<td>38</td>
<td>24.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+ RO = reverse osmosis; WS = water softeners; TD = solar desalination; CT = chemical treatment; MT = magnetic treatment; WC = water conditioners

* Scores = weighting x specific tech rating (RO, WS, TD...etc)

Reverse osmosis systems theoretically provide excellent water quality. Inexpensive under-sink and wall-mounted units appear good value but don’t treat whole-house situations. The purchase of more than one unit may be required if treating multiple access points (e.g.
kitchen, laundry etc). This may not be practical or financially viable, and is dependent on results of trials examining the life of the membranes under central Australian water quality conditions. It is expected that the ongoing maintenance requirements would increase considerably. Large-scale units can be designed to suit whole communities or outstations; however, these have been vastly unsuccessful in the past and capital and maintenance costs for these may be excessive. Consideration may be given to small-scale units if the goal is to obtain small volumes of high quality drinking water and possibly foregoing treatment of other areas of the house. Consideration should also be given to the amount of wastewater generated versus the water produced for consumption.

Water softeners required low capital and maintenance costs and low maintenance regimes but did not score well for robustness. Water softeners produce good water quality, are inexpensive and will treat whole-house situations. However, their fibreglass construction makes them vulnerable to vandalism and damage from wind-blown debris. Should this prove to be a significant limitation, a suitable structure could be erected to house the water softener to avoid damage. The other concern is the ability of the resin beds to effectively remove hardness ions in very hard waters and the regeneration time required.

6 CONCLUSIONS

The use of appropriate technology in remote locations for reducing water hardness may improve living conditions. This review found that none of the available treatment methods were completely appropriate for resolving the scale issues in remote Aboriginal communities. The problem is difficult to address and there is currently no ‘silver bullet’. Each of the reviewed technologies fails on one or more of the selection criteria. Under the current technology options available, it will be necessary for community councils, resource agencies, asset funding agencies and possibly service providers in discussion with these management agencies to rationalise what water gets treated, based on community identified priorities. For example, it is necessary to determine if the desired outcome is water quality for consumption purposes or for systemic scale prevention and reduction. Appropriate problem definition, and understanding of the trade-offs in decision-making about water quality, will aid in the selection of the most suitable technology option for addressing the particular water quality goals in a community. This approach should result in the most efficient allocation of resources to meet identified community needs and should avoid costly treatments that don’t deliver the necessary outcomes.

7 RECOMMENDATIONS

1. Field trials on available technologies. Research field trials should be conducted by CAT on the following identified available off-the-shelf treatment technologies where adequate data was not available:

- magnetic water treatment technologies
- water conditioning devices
- under-sink reverse osmosis units
- small package-plant water softeners
- Such trials should be conducted under variable water quality conditions and involve robust controls. The robustness of water softeners and effectiveness of the other abovementioned technologies is questionable and need to be investigated further through field trials.
2. **Promote dialogue with Environmental Health agencies.** Scale issues in remote communities have been found to have an indirect impact on Indigenous environmental health through the malfunctioning of basic health hardware such as hot water systems, etc. There appears to be little environmental health agency engagement in the NT on the issues around water supply provision to remote communities. Environmental health agencies may provide another source of funding, information and resources for addressing this important issue.

3. **Further development of technical scale research.** The CRCWQT or other water quality research entities should further research and develop technologies that are appropriate, simple and robust to address hard water issues in groundwater-dependent settlements for regional and remote areas of Australia. There are some indications that nanofiltration may present some promise but the technology is not currently available ‘off the shelf’. There is little scientific data on the use of chemical anti-scalants, water softeners and other innovations in very hard waters. Drinking water research in this area appears to be dominated by other affluent nations such as the US and UK who do not appear to have hard water issues to the same extreme as regional Australia. There is a substantial body of information to indicate that improvement of available and development of new, simpler technologies would be useful to other arid nations dependent on hard groundwaters.

4. **Aboriginal community evaluations of technologies.** Any future field trials of technologies or management regimes to address hard water issues should be executed in conjunction with willing remote Aboriginal communities who have identified a problem with very hard water and scale accumulation. Analysis should engage householders in evaluating the use, maintenance and operational burdens of the technologies. Findings from this work would then incorporate an evaluation of technology effectiveness under the actual use regimes of communities or individual houses.

5. **Technical advisory service expansion.** The independent technical advisory role funded at CAT by the CRCWQT and accessed by Aboriginal communities for water supply issues should continue to be supported. This free service provides a means of helping communities to better utilise their scarce resources on community water supply technology. There is scope for this service to be expanded to further facilitate informed decision-making by remote community stakeholders (service providers, funders, community councils, residents) around water supply technology and management.
REFERENCES


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Rowling, J. 2004. *Cave aragonites in New South Wales*. Faculty of Sciences, School of Geosciences, University of Sydney, Sydney.


## APPENDIX 1

<table>
<thead>
<tr>
<th>Brand</th>
<th>Technology</th>
<th>Capital costs (A$)</th>
<th>Maintenance costs (A$)</th>
<th>Life expectancy</th>
<th>Yield (L/Day)</th>
<th>Energy requirement</th>
<th>Water wastage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puralife</td>
<td>Column filtration.</td>
<td>$799 incl. full installation kit. Handyperson or plumber can install.</td>
<td>Pre-filters (x2) $89; post-filter $40; membranes $154.</td>
<td>Pre-filters (x2) 6-12 months; post-filter every second service; membranes 4-6 years. Replace earlier if water exceeds 200ppm or high Fe concentrations.</td>
<td>240L/day</td>
<td>No power required. Fit into existing pipe work. Mains pressure not required if treating small community drinking water only.</td>
<td>3:1 waste: pure water.</td>
</tr>
<tr>
<td>PSI Filters</td>
<td>Wall-mounted or under-sink systems.</td>
<td>$450-$950 depending on membrane used. Easy to install.</td>
<td>&lt;$100 for replacement filters.</td>
<td>Up to 10 year warranty.</td>
<td>140 - 400L/day</td>
<td>Not required as it fits into the water supply line. Mains pressure is not required if treating small community drinking water only.</td>
<td>3:1 or 1:1 waste: pure water.</td>
</tr>
</tbody>
</table>

**REVERSE OSMOSIS.** Reverse osmosis membranes with different size pores remove 99% of contaminants incl. most salts and inorganic materials and some organic compounds. Very high water quality but some viral organisms can't be detected. Activated carbon filters should be used where water is biologically unsafe. Use pre-filtering to ensure system longevity. Iron (Fe) content should not exceed 2ppm. Optimum temp. 0-45°C and pH 4-13. Membrane/filters dry out if unused for 1-2 days; shut-off valve may be required to prevent this. More servicing required in extremely hard water areas. No specialised technical knowledge required. No running costs.

**ION EXCHANGE** (next page). A tank containing a resin bed saturated with Sodium [Na] ions. These Na ions are replaced (exchanged) by hardness ions Calcium (Ca) and Magnesium (Mg) as the water flows through the tank. To regenerate the resin beds, clean water or concentrated Na brine is used to remove the Ca and Mg ions. Minimal time required to regenerate resin bed; frequency depends on water hardness. Resin beds can generate particles and culture bacteria. Activated carbon filter may be needed. Removes Fe, heavy metals, inorganic and organic chemicals.
<table>
<thead>
<tr>
<th>Brand</th>
<th>Technology</th>
<th>Capital costs (A$)</th>
<th>Maintenance costs (A$)</th>
<th>Life expectancy</th>
<th>Yield (L/Day)</th>
<th>Energy requirement</th>
<th>Water wastage</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSI Filters</td>
<td>Column filtration using resin beds.</td>
<td>$400-$1000.</td>
<td>Cost of resin beds.</td>
<td>Estimates of between 7-20 years for resin beds dependent on water hardness.</td>
<td>Fits into the water pipe.</td>
<td>If an automatic device is used it will require power to operate the auto switch to back flush the tank.</td>
<td>Minimal waste water used to back flush the system.</td>
</tr>
<tr>
<td>Crystalline</td>
<td>Mixed bed column filtration</td>
<td>Up to $1000</td>
<td>Cost of resin beds</td>
<td>Estimates of between 7-20 years for resin beds dependent on water hardness.</td>
<td>Fits into the water pipe.</td>
<td>Automatic device will require power to operate the auto switch to back flush the tank.</td>
<td>Minimal waste water used to back flush the system.</td>
</tr>
<tr>
<td>Solar Water Purifier</td>
<td>Solar panels - cascading trays</td>
<td>Not known at this stage.</td>
<td>Simple to use with no moving parts; minimal maintenance and operating costs</td>
<td>Up to 20 years.</td>
<td>Small unit produces ~3.5 - 6L/day; medium unit 11 - 25L/day; large unit 35 - 60L/day but all figures are dependent on ambient temperature.</td>
<td>Uses solar energy.</td>
<td>It has a cut-off valve to prevent any wastage once the storage tank is filled.</td>
</tr>
</tbody>
</table>

SOLAR DESALINATION. This process uses heat to remove vapour from a water supply, which then drips into a storage tank. Solar energy is cheaper than electricity and more readily available in remote areas. Produces high quality water, removes nitrates, chloride and other salts and pathogens. Technical problems may result in reduced efficiency with individual units subject to glass breakage by vandals and storm damage. Concentrated salts will need to be removed. Local materials and labour may reduce costs. Reticulated systems may need pumping of water. Basin temperature should be high to increase the ratio of heat transfer by evaporation-condensation. Minimise growth of algae/microfauna to maintain heat transfer.
## MAGNETIC WATER TREATMENT

Permanent or electromagnetic water treatment has no moving parts, no filtration, appears to be robust. Effectiveness relies on i) proper sizing and placement of units within household plumbing, ii) water characteristics at the location of use, iii) extent of maintenance conducted. Some units don’t require a power supply to operate. Further scientific research is required into their effectiveness. Where scale is not removed entirely a surface coating will reduce its scale prevention ability over time. Regular maintenance required. Magnetic SPDs not effective if excessive (>0.5mg/L) Fe concentrations. Reportedly reduces calcite with increase in aragonite form.

### Solco

- **Brand**: Solco
- **Technology**: Solar panels
- **Capital costs (A$)**: $25 500 for a complete system. Designed to suit needs.
- **Maintenance costs (A$)**: Low operation and maintenance costs. Independent solar units can be costly if damaged. Maintenance schedule can be time consuming.
- **Life expectancy**: Not known but usually such units will last about 20 years.
- **Yield (L/Day)**: Produces up to 4500L of non-potable water and up to 400L/day of potable water and can be designed to meet requirements.
- **Energy requirement**: No electrical energy required. Uses low-voltage photovoltaic panels.
- **Water wastage**: No expected water wastage.


### Aqua Treat

- **Technology**: Electro-magnetic type
- **Capital costs (A$)**: $280 for 20mm pipe diameter. Relatively easy to install.
- **Maintenance costs (A$)**: Virtually maintenance free with low running costs.
- **Life expectancy**: Strong construction.
- **Yield (L/Day)**: Yield is not restricted.
- **Energy requirement**: Power supply plus turbulence provided by water flow required to create a magnetic field. Electricity costs are claimed to be minimal due to low wattage power use.
- **Water wastage**: No wastage.

### Ecovortek

- **Technology**: Magnetic treatment
- **Capital costs (A$)**: ~ $470-$900/unit. Standard unit $795.
- **Maintenance costs (A$)**: No maintenance or upkeep required.
- **Life expectancy**: Estimates >10 years.
- **Yield (L/Day)**: Will fit into existing water pipe. Pressure >150L/min will require a larger pump due to head loss.
- **Energy requirement**: No energy required.
- **Water wastage**: No waste.
### ELECTRICAL AND ELECTROSTATIC WATER TREATMENT

Often uses computer generated resonance frequencies to disrupt electron polarity in the water supply. No chemicals so the chemistry of the water does not change. Further research is required into its effectiveness as no reliable information exists to endorse the benefits of this technology.

<table>
<thead>
<tr>
<th>Brand</th>
<th>Technology</th>
<th>Capital costs (A$)</th>
<th>Maintenance costs (A$)</th>
<th>Life expectancy</th>
<th>Yield (L/Day)</th>
<th>Energy requirement</th>
<th>Water wastage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian Electronic Water Conditioner (AEWC) Pty Ltd.</td>
<td>Electrostatic water treatment</td>
<td>Unknown</td>
<td>Relatively easy maintenance.</td>
<td>May be prone to dust and water.</td>
<td>Unit is connected to the external diameter of the pipe so water supply is not restricted.</td>
<td>Uses electrical energy to create a complex frequency modulated waveform to induce an electro-magnetic field inside the pipe.</td>
<td>Not applicable.</td>
</tr>
</tbody>
</table>

| Hydrosmart (formerly Calclear)                          | Computer assisted water treatment | $1995 for a 20mm pipe. Easy installation with computer pulsation box and 3 wire antennae around existing pipe work; increase magnetic field within the pipe. | Virtually maintenance free. | Long life expectancy dependent on exposure to dust and water. | Yield is not restricted as the unit is connected onto the water pipe. | Mains power with outlet for plug in transformer, or 12v DC. Can be connected to battery or solar power. It uses 200milliamps. | Not applicable. |

WATER CONDITIONING (next page). Involves a chemical reaction between ions within the water supply. However, appropriate metals are required in the construction of these devices for the reaction to occur. Calcium (Ca) and Magnesium (Mg) cations within the water flow require additional electrons to alter their chemical composition to allow them to be expelled as stable substances. The anions released to the water supply are called catalysts, which assist the reaction but are neither reactants nor products of the reaction. Generally catalysts are substances, which change the mechanism of a reaction to increase the speed of that reaction.
<table>
<thead>
<tr>
<th>Brand</th>
<th>Technology</th>
<th>Capital costs (A$) for 15mm pipe diameter.</th>
<th>Maintenance costs (A$)</th>
<th>Life expectancy</th>
<th>Yield (L/Day)</th>
<th>Energy requirement</th>
<th>Water wastage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carefree Water Conditioner</td>
<td>Water conditioner</td>
<td>&gt;$363 (1999)</td>
<td>Minimal costs with bi-annual dismantling of device and scrubbing with wire brush; dilute acid (if used) will add to cost. It requires a good earth connection to operate effectively.</td>
<td>10 year warranty against faulty workmanship or manufacturing defects.</td>
<td>Water flows through the device, which is fitted into the pipe work.</td>
<td>No energy requirement; soil around earth rod must be moist to assist in electrical energy.</td>
<td>No waste water.</td>
</tr>
</tbody>
</table>