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## Cost Implications of Hard Water on Health Hardware in Remote Indigenous Communities in the Central Desert Region of Australia

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## **Abstract**

The provision of services such as power, water, and housing for Indigenous people is seen as essential in the Australian Government's "Closing the Gap" policy. While the cost of providing these services, in particular adequate water supplies, is significantly higher in remote areas, they are key contributors to improving the health of Indigenous peoples. In many remote areas, poor quality groundwater is the only supply available. Hard water results in the deterioration of health hardware, which refers to the facilities considered essential for maintaining health. This study examined the costs associated with water hardness in eight communities in the Northern Territory. Results show a correlation between water hardness and the cost of maintaining health hardware, and illustrates one aspect of additional resourcing required to maintain Indigenous health in remote locations.

## **Keywords**

Indigenous, water, health hardware, hard water

## **Acknowledgments**

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## Cost Implications of Hard Water on Health Hardware in Remote Indigenous Communities in the Central Desert Region of Australia

There is a significant difference in the health of Indigenous and non-Indigenous Australians. The life expectancy of Indigenous Australians is approximately 17 years less than that of the non-Indigenous population. Additionally, infant mortality is high in the Indigenous population with 12.3 deaths per 1,000 live births compared to 4.2 deaths for the non-Indigenous population. Closing the Gap is a federal government policy initiative aimed at improving Indigenous health to achieve morbidity and mortality rates similar to those for non-Indigenous Australians. Various methods for “closing the gap” have been suggested, including improving hygiene education, healthcare facilities, and access to health hardware (Australian Government, 2009a). Health hardware refers to the items and facilities considered essential for maintaining adequate personal health (i.e. showers and toilets). The importance of health hardware to health outcomes was first outlined in relation to nine healthy living practices. Of the nine healthy living practices – bathing, washing clothes, removing waste, improving nutrition, reducing crowding, decreasing the impact of animals and dust, minimizing trauma, improving temperature control – five require access to adequate water supplies (Nganampa Health, 1987).

Effectively functioning water-related health hardware is needed to provide adequate quantities of water for health needs. However, much of the central Australian desert region suffers from highly mineralised groundwater, which, in most cases, is the only source of water available to the communities. Groundwater is characterised by the type of geology it has been in contact with and the retention time within the aquifer (Power and Water Corporation, 2009). Generally, older groundwater (over 10,000 years old), like that found in central Australia, has a “richer” mineral content than relatively young groundwater (less than 10 years old), such as that found in the northern part of Australia (Power and Water Corporation, 2009). Hard water – the focus of this paper – is characterised by high levels of calcium and magnesium ions imparted into the water as “soft” rainwater passes through rock formations (Jones, Kinsela, Collins, & Waite, 2010). Besides the high mineral content, the pH and temperature determine the water hardness and tendency towards scaling (McMellon, 2010). Scaling refers to the build-up of solid encrustations within, and on the outside of, materials where the water has been in contact, which leads to clogging, leaks, and breakages. In terms of nomenclature, a distinction is made between “hard water” and the “hardness” of water. Hard water is a qualitative term used to describe the scaling behaviour of water, while hardness is a quantitative measure of calcium and magnesium ions in water (McMellon, 2010).

Where communities rely on highly mineralised groundwater, particularly when the water is hard, health hardware is impacted by scale build-up, which, if left unchecked, can render the hardware ineffective and potentially impact on health (see Background section below). To overcome these and many other impacts associated with living in the harsh desert environs of these remote communities, more frequent housing and infrastructure maintenance is required than is ordinarily the case in urban or rural areas. While there has been vast government expenditure on the construction of new houses in the remote Indigenous communities, studies have highlighted the need for more funding for internal housing infrastructure maintenance (Pholeros, 2002, 2011; Willis, Pearce, Jenkins, Wurst, & McCarthy, 2004), including water-related health hardware. While there is much anecdotal evidence on the impacts of scaling in communities in central Australia, this paper provides the first quantitative account of the financial impacts of hard water in Indigenous communities in this region.

### Aim of the Study

This study examines the frequency of health hardware replacement and the associated costs of hard water in eight communities in the MacDonnell Shire and the Central Desert Shire (Figure 1) in the Northern Territory of Australia. Water hardness in the 72 remote Indigenous communities was ranked to enable categorisation of the eight communities in the two central Australian Shires (see Methodology section). The research then focused on one in-depth analysis in each category of hardness (high, medium, and low).

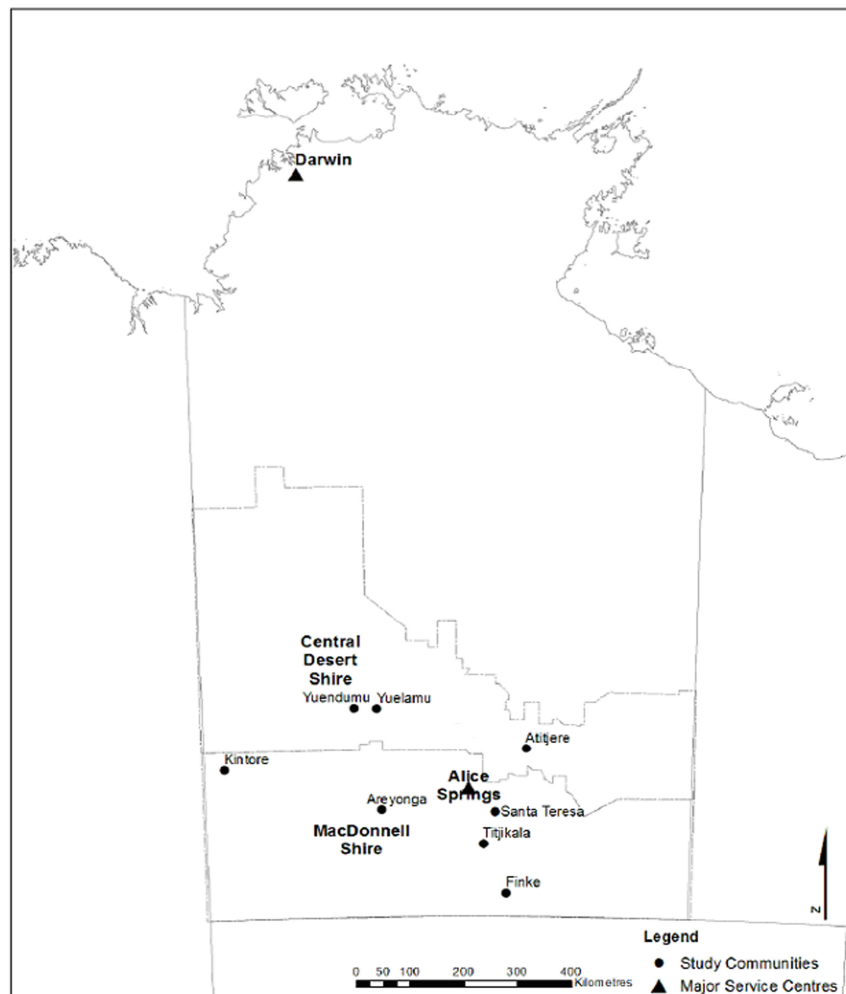


Figure 1: Map of Northern Territory in Australia and the Study Locations.

### **Background: The Importance of Health Hardware in a Context of Indigenous Social Disadvantage**

Substandard fixtures and a lack of maintenance have been identified as potential causes of dysfunctional health hardware, but there are additional factors that can adversely influence its performance. The links between the condition of Indigenous housing – including issues such as crowding, infrastructure, tenure, and homelessness – and health outcomes are evident (Bailie & Wayte, 2006). Further, McDonald, Bailie, Grace, and Brewster (2010) identify dysfunctional health hardware, overcrowding, and lack of effective hygiene education as possible contributors to poor health outcomes. While improvements to hygiene education were considered to have the most sustainable level of impact (McDonald et al., 2010), knowledge of appropriate health practices is meaningless in the absence of items such as soap and running water. It cannot be taken for granted that these will be available in remote Indigenous communities in Australia.

The importance of both the quality and quantity of water for health outcomes has been highlighted in studies by Bailie, Carson, and McDonald (2004) and Bailie and Wayte (2006), respectively. A limited water supply affects all aspects of hygiene – bathing, doing laundry, washing hands, preparing food, and cleaning eating surfaces (Bailie et al., 2004). Thus, apart from the direct health implications of an inadequate quantity and quality of water supply, poor quality water can impact on health indirectly through malfunctioning health

hardware. The impacts of malfunctioning health hardware include reduced water heater efficiency, clogged internal plumbing and water appliances, increased the frequency of fixture replacement, and increased repair and maintenance costs (Downing, 2000). The most costly issue occurs when scale accumulation causes the element in hot water systems to overheat and burn out (Lloyd, 1998).

Problems around household maintenance in remote Indigenous communities are exacerbated by poverty, social inequity, health disparities, and resource inequalities experienced by Indigenous households, compared to most non-Indigenous ones. This gross disadvantage extends across all measurable social determinants of health (Anderson, Baum, & Bentley, 2007; Baum, 2007). Although government agencies provide an allowance for household maintenance in such disadvantaged remote communities, at a personal level, families experience high costs as a result of the impacts of hard water. For example, they have to purchase and use large volumes of particular soaps and other cleaning materials that are capable of lathering in hard water conditions (Downing, 2000; Pearce, Willis, McCarthy, Ryan, & Wadham, 2008). The results of this paper will show that the government housing maintenance allowance is inadequate where water supplies are impacted by hardness.

### Measuring Hard Water

There are multiple ways to quantify hard water, and various indicators can be used for different purposes. The classification of water hardness, as per the Australian Drinking Water Guidelines (ADWG), is shown in Table 1. The ADWG recommend that water hardness should be less than 200 mg/L. This guideline is for aesthetic value based on the ability of soap to form lather and the potential for scale build-up, rather than a health guideline. Various indices are available to predict the scaling ability of water (Ryxnar Stability Index, Puckourius Scaling Index, Stiff-Davis Index, Calcium Carbonate Precipitation Potential) (Prisyazhniuk, 2007); however, the most common index and the measure used in this study is the Langelier Saturation Index (LSI).

Table 1: Levels of Hardness that Lead to Corrosion or Scaling

Mg/L Calcium carbonate equivalent	Degree of hardness
<60	Soft, but possibly corrosive
60- 200	Good quality
200-500	Increasing scaling problems
>500	Severe scaling

Source: Australian Government, 2004

The LSI includes measures of water hardness, temperature, and pH to yield a number that predicts the calcium carbonate stability. If the value is positive, it indicates that the water is supersaturated with calcium carbonate and the water will have a tendency to form scale. Conversely, if the value is negative, the water is undersaturated and would dissolve calcium carbonate. At zero, the water is in equilibrium and will neither scale nor dissolve calcium carbonate. In practice, however, water with an LSI value between -0.4 to 0.4 will not display enhanced calcium carbonate dissolving or corroding properties (Prisyazhniuk, 2007).

### Methodology

Water quality data – specifically hardness – were sourced from the Power and Water Corporation, Australia (henceforth referred to as Power and Water), the water and electricity service provider to the Indigenous communities. Two additional sets of data were collected. First, a quantitative data set derived from plumbing audits was analysed to determine the approximate frequency of health hardware replacement and the associated material and labour costs. Secondly, qualitative data, obtained through interviews with key personnel and contract plumbers, complemented the quantitative data. Ethics approval was obtained from the Central Australian Human Resources Ethics Board and the Flinders University Social and Behavioural

Research Ethics Committee. All research was undertaken within the guidelines, and permission was sought for the publication of the work.

### Selecting and Categorising Communities According to Hard Water (Phase 1)

Water quality data (12 parameters) for the period October 2007 to October 2009 were obtained for the 72 Indigenous communities serviced by Power and Water. This study examines two of them, namely water hardness and the Langelier Saturation Index (LSI).

The sampling method was purposive. The MacDonnell Shire and Central Desert Shire (see Figure 1 above) were selected as they contain communities with the highest prevalence of hard water and also communities without hard water problems because they access surface water (included for comparative purposes). This allowed for several factors, such as climate and rainfall, to be kept relatively constant, whilst allowing a range for comparability. Financial, time, and access constraints limited the study to the two shires. It is recommended that future studies extend to other parts of Australia, or elsewhere in the world, where hard water is known to impact on the functioning of infrastructure, but has yet to be quantified in terms of costs.

Data collection went from the initial (phase 1) broad-scale ranking of hardness in the 72 communities as outlined in Table 2 to an in-depth analysis in three communities (one from each category of hardness) as outlined in Figure 2. Selection of the three in-depth study sites was based on the accessibility of the community and key personnel within the community.

Table 2: Hardness Parameters by Which Communities were Categorised

Category	Key defining features	
High hard water	LSI >0.9	Hardness >400 mg/L
Medium hard water	LSI 0.5-0.9	Hardness 200-400 mg/L
Low hard water	LSI <0.5	Hardness <200 mg/L

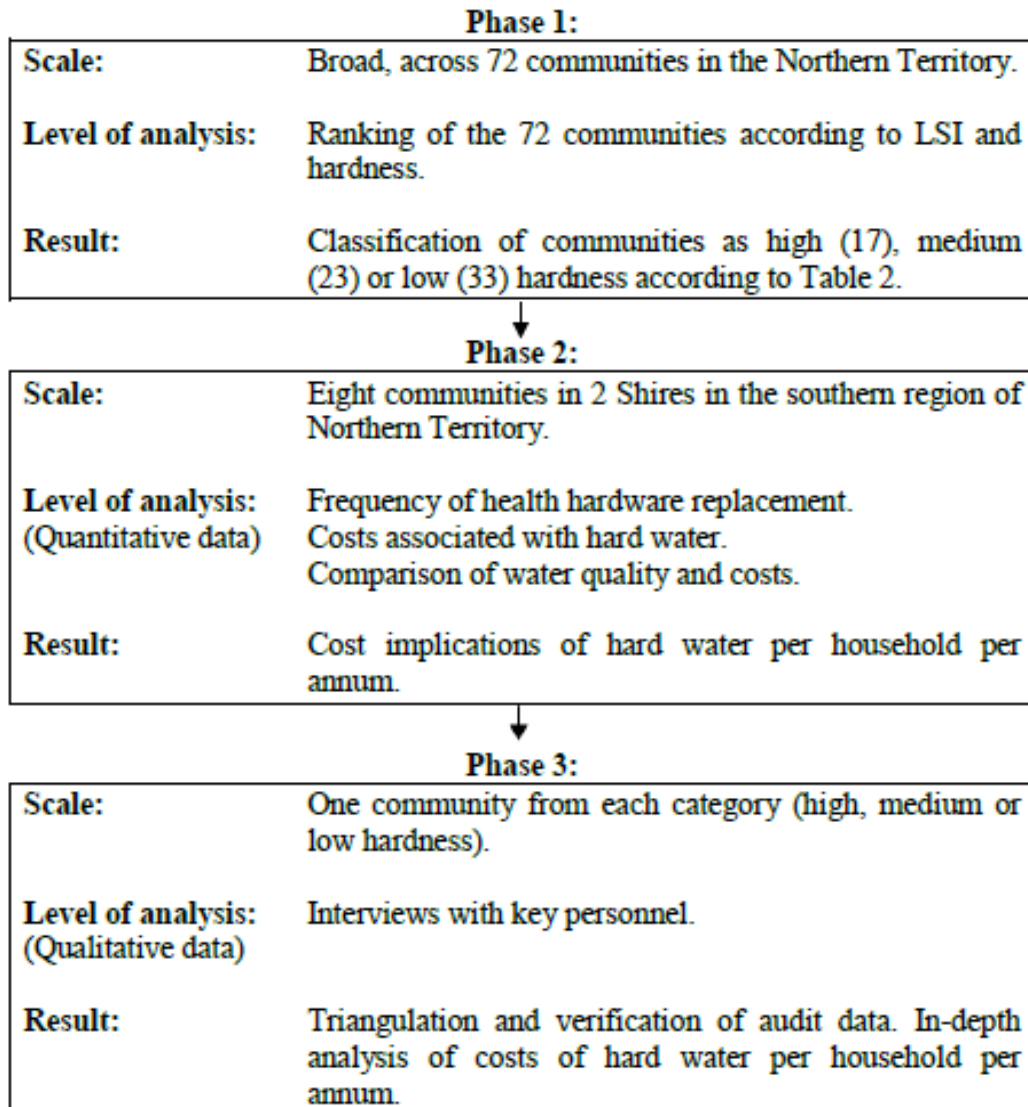


Figure 2: Flow Chart Showing Data Collection Phases and Analysis.

### Quantitative and Qualitative Data Collection

Plumbing audits are conducted twice a year in every house in each community by experienced plumbing contractors. The audit examines and reports on the condition of all water-related components within each house. While the audits are being completed, any issues of public health and safety are addressed, while other tasks are reported to the Shire Councils for further work to be arranged. These quantitative data were analysed as outlined in Figure 2 (phase 2).

Data from the plumbing audits were obtained for a 12-month period from July 2010 to June 2011 from invoices held by the MacDonnell Shire and Central Desert Shire Councils. Properties that did not have data from two audits in the 12-month period were excluded from the analysis. Titjikala, which has medium hard water, was subject to only one audit. However, it was conducted in the latter six months of the study period

(January 2011), so it was assumed that all work required over the whole time period, including incidental works, would be captured in the audit.

Additional incidental work and local maintenance work was included in the dataset, but only for properties that had two completed audits. The incidental work generally occurred as a result of urgent housing maintenance requests. While much of the work was done by external contracted plumbers, some minor work was undertaken by the people within the community, depending on the skills required. All plumbing work is recorded and reported to the Shire Councils who then forward the costs to Territory Housing – the government agency responsible for funding (from a limited budget) housing maintenance in the 72 Indigenous communities.

Qualitative data (phase 3; see Figure 2) were obtained from four interviews conducted with the Shire Services Managers (SSM) and the Essential Service Officers (ESO) in Areyonga, Titjikala, and Yuelamu in July and August 2011. Questions related to the impact of hard water and the frequency of health hardware fixture replacements.

### **Limitations**

Based on the available data, it was not possible to determine whether replacements were preventative to ensure their ongoing function or if they were reactive as a result of reported malfunctions. Furthermore, the data were not detailed enough to determine time lags between reporting of malfunctioning hardware and the subsequent repairs. Due to the remote locations of many communities, where travel to the community can take up to six hours or more, it is possible that tenants could be without access to health hardware for extended periods. During such times neighbours' facilities or community centres might be used, placing an increased strain on those resources.

### **Study Setting**

Australia's Indigenous population makes up 1-2 percent of Australia's total population of 20 million. Twenty five percent of the 510,000 Indigenous Australians live in over 1,100 remote locations, with the concomitant challenges of service delivery (Australian Government, 2009a). Of all the states in Australia, the Northern Territory has the highest proportion of Indigenous residents (28.5%), of which approximately 71 percent live in remote areas (McDonald, Baillie, Brewster, & Morris, 2008). Of these communities, 88 percent rely primarily on groundwater supplies, 8 percent use a combination of ground and surface water, and 4 percent use freshwater springs and dams (Power and Water Corporation, 2009). Such a high reliance on groundwater arises from the arid environment of many locations, which only receive episodic rainfall. Rainfall in central Australia is highly variable and at times oscillates between drought and floods.

The Northern Territory is divided into 11 local government areas known as Shires. It is the responsibility of the Shire to appoint and manage on-site Essential Service Officers who are responsible for the communities' power, water, and sewage systems. All contract maintenance work within the Shires is administered centrally. Two of the 11 Shires (MacDonnell and Central Desert) have comparatively more concerns with hard water as the seven communities with the highest LSI values in the Northern Territory are found there. Of all the communities in the Northern Territory, the communities included in this study (with the exception of Yuelamu and Finke) fall within the upper 50 percent of LSI values.

### **MacDonnell Shire**

MacDonnell Shire (land area: 268,887 km<sup>2</sup>) is the southernmost Shire within the Northern Territory (see Figure 1 above) and includes 13 communities (Northern Territory Government, 2011). Five of the communities were included in this research: Areyonga, Titjikala, Finke, Kintore, and Santa Teresa. Alice



Springs and Yulara are enclaves within the MacDonnell Shire Local Government Area. Approximately 7,200 people reside within the remote communities in the Shire (Northern Territory Government, 2011).

### Central Desert Shire

Central Desert Shire is located to the north of Alice Springs and is slightly larger than MacDonnell Shire with a land area of 282,089.76 km<sup>2</sup>, yet it has a smaller population of just 4,782 (Northern Territory Government, 2011). The Shire includes 11 Indigenous communities, three of which were included in this research: Yuelamu, Yuendumu, and Atitjere. A brief overview of each case study community is given below.

### Study Communities

Areyonga is located approximately 220 kilometres west of Alice Springs, approximately a 2.5 hour drive. The community has a transient population of around 300 people and has a school, swimming pool, and arts centre. The water supply at Areyonga is taken from four groundwater bores located a kilometre from the town. They have an output that is sufficient to supply 430 kilolitres per day. While all four bores meet Australian Drinking Water Guidelines, water from Bore 4 has a high mineral content and is only used if breakdowns occur in other infrastructure. The water is disinfected using calcium hypochlorite (Power and Water Corporation, 2007).

Titjikala is situated 130 kilometres south of Alice Springs, a drive of approximately 1.5 hours. The community has a population of 265 and is situated within the boundaries of Maryvale Station – a large cattle station. Titjikala takes water from two bores close to the community. It is pumped to an elevated tank, which stores enough water for at least four days. The water is disinfected using an automatic sodium hypochlorite dosing system (Power and Water Corporation, 2009).

Yuelamu is approximately 290 kilometres northwest of Alice Springs. There is a recorded population of 300, but the population will frequently travel between Yuelamu and Yuendumu. Yuelamu is one of only four remote communities in the Northern Territory that uses surface water. The dam contains good quality water that consistently meets the 29 Australian Drinking Water Guidelines for dam water (Power and Water Corporation, n.d.). An ultra-violet disinfection system, in addition to a chlorine dosing system, is used to treat the water prior to household reticulation. While the water is of good quality, the area experiences low rainfall and a high evaporation rate. Prior to 2007, the dam could provide the community with water, on average, seven out of ten years (Power and Water Corporation, 2007). However, with the AUD\$1 million upgrade to the dam infrastructure to improve the catchment and retention of water, it is now predicted to be a reliable source of water in nine out of every ten years (Power and Water Corporation, 2007). If levels in the dam become too low, groundwater can be accessed to supplement the supply, but the groundwater is of poor quality and not suitable for consumption. During these times, Power and Water has to supply packaged water to the community for consumption.

## Results

### Frequency of Replacement

Seven different items of health hardware were examined. As communities with more houses would be expected to have a higher number of replacements, overall, the data were recorded as a per house measure to ensure comparability between communities. Taps were the most frequently replaced item in all communities (Table 3), with the highest frequency of replacement occurring in Areyonga (LSI=1.34; high hard water) at an average of three taps (2.97/house/year) being replaced in each house every year. Shower roses had a comparatively high frequency of replacement in Yuendumu (LSI=0.72; medium hard water) and Areyonga (LSI=1.34; high hard water) at 0.56/house/year and 0.66/house/year, respectively. Interviews in Areyonga revealed that this is a conservative estimate as staff will often use a hydrochloric acid solution to dissolve the

scale build-up as a repair measure to avoid replacement. Yuelamu (LSI=-0.14; low hard water) appears to be an anomaly with regard to shower roses, and no additional information was gained from the interviews that would explain the high frequency of replacement in a community that has consistently low replacement rates with regard to all other health hardware. Spouts and toilet cisterns showed no clear trends with regards to the frequency of replacement.

Hot water systems were identified as having costly scaling issues. Servicing is essential to increase hot water systems' longevity and to maintain them at a level where they can be repaired, rather than replaced. There are few electric water heaters in use; solar hot water systems are most often installed. As with other health hardware, hot water systems may need replacing for reasons unrelated to hard water – such as cracked panels or split tanks. Hot water systems were replaced most frequently in Areyonga and Kintore at an annual rate of 0.47 and 0.34 per house, respectively. Yuendumu, Atitjere, Santa Teresa, and Finke had similar rates of replacement ranging between 0.03 and 0.06/house/year. There were no recorded data on hot water system replacements in Yuelamu; however, qualitative data showed that three systems were replaced in the previous year (a rate of 0.08/house/year), but all were a result of split tanks and, thus, not related to hard water. The rates of replacement and the equivalent time frames for Areyonga (with very hard water), Titjikala (with a mid-range water hardness), and Yuelamu (without hard water) are shown in Table 3. In general, items required the most frequent replacement in Areyonga and had the longest life in Yuelamu. In Areyonga, all items, except toilet cisterns, required replacement at least once every 2 years. The replacement times in both Titjikala and Yuelamu ranged from 1 to 33 years.

Table 3: Frequency of Replacement (per house per year) of Health Hardware in Areyonga (high hardness), Titjikala (medium hardness), and Yuelamu (low hardness).

Item	Areyonga (High)	Time (in years)	Titjikala (Medium)	Time (in years)	Yuelamu (Low)	Time (in years)
Yard tap	1.80	0.6	0.44	27	0.21	4.75
Tap	2.97	0.3	1.03	12	0.25	4
Spout	0.53	2	0.09	11	0.04	25
Shower rose	0.57	2	0.22	5	0.32	3
Cistern	0.13	8	0.03	33	0.07	14
Tempering valve	0.50	2	0.34	3	0.00	-
Hot water system	0.47	2	0.13	8	0.00	-

### Costs Associated with Hard Water

For each job, both material and labour costs are incurred, and, due to the remote location of many communities, travel expenses must often be covered as well. Because travel expenses are recorded per community, they were incurred regardless of whether one incidental job was completed or a full community audit was undertaken. The cost of replacing items commonly affected by hard water was calculated using the frequency of replacement and the average cost of both the item and the labour. Costs varied according to the brand and type of item that was installed. Accordingly, an approximated average cost was used based on real cost data from plumbing invoices.

The costs were calculated using only houses covered by the Territory Housing; community establishments, such as council offices or clinics, were not included. Similarly, only the costs for health hardware that falls under the responsibility of Territory Housing and was reviewed twice a year as part of the audit were

calculated. Costs for other health hardware, such as washing machines, that are the tenants' responsibility were not included in the calculations. In determining the frequency of replacement, however, all replacements regardless of the cause were included, since, in many cases, the reasons for replacements were not recorded.

**Material costs.** The replacement of hot water systems was the greatest material expense. The cost of replacing a solar hot water system, the most common type found in the remote communities, was approximately AUD\$5,000. The tempering valve, a component of hot water systems, costs approximately AUD\$200 to replace. Toilet cisterns were also costly at around AUD\$220, but were not replaced frequently.

As expected, the replacement of hot water systems was the greatest expense in Areyonga and Titjikala, followed by the replacement of household tapware with an estimated cost of AUD\$100 per tap. Replacing tapware was the most variable cost measure because the location and brand of taps used caused a large variation in the per item cost identified from the data. Thus, while the cost of tapware appears to be high, the reliability of this estimation is less than that of other health hardware items studied. Of the three case study communities, Areyonga had substantially higher costs than either Yuelamu or Titjikala. The material costs for Yuelamu were just 2 percent of the material costs in Areyonga, and Titjikala fell between the two extremes with costs around 30 percent of the costs in Areyonga.

**Labour costs.** As with the material costs, average labour costs were calculated for each item replaced or repaired. This removed any confusion regarding the number of people working, the time spent on the repair, and the hourly cost of labour. Labour costs varied depending on the complexity of the job; for example, the time required to replace a hot water system depends on the ease with which the old system can be removed and the new system installed. Some of the smaller jobs, such as replacing an external tap, were done during the household audits, for which a one-hour labour cost per house was charged. These expenses would be incurred regardless of whether small replacements were undertaken or not; however, when calculating labour costs, each replacement was treated as though it was a separate job and not part of an audit. This could exaggerate the costs of labour, particularly for garden and household taps.

Of all the work done, the labour costs associated with hot water systems were the highest at approximately AUD\$800 per installation. Labour costs associated with hot water systems in Areyonga and Titjikala were AUD\$376 and AUD\$104/house/year, respectively. In all three communities, a high proportion of labour costs were incurred replacing and repairing taps – between 38 and 42 percent of the total labour costs. As previously noted, this cost could be inflated as some of the replacements could occur within the allocated audit time. The labour costs associated with some items, such as yard taps (AUD\$60 labour/tap), were greater than the cost of materials (AUD\$10 tap). This was also the case for spouts and shower roses. The labour costs associated with household taps, cisterns, and tempering valves were slightly lower than the material costs – a difference of less than AUD\$100. Hot water systems were the exception with very high material expenses (AUD\$5,000) and comparatively high labour expenses (AUD\$800).

**Proportion of costs spent on labour, materials, and travel.** Given the vast distances between urban or rural centres and remote communities, travel and overnight accommodation costs tend to be high in Australia. There is a fair degree of variability in the amounts charged by different contractors, so they are not included in the costs/house. For example, rates will vary according to the duration of the visit, meal expenses, and whether the roads to the community are sealed or unsealed.

Overall the three cost components – labour, materials, and travel – contribute differently to the total plumbing expenses associated with hard water in a community. In seven of the eight communities, the material costs constituted the largest proportion of the costs (40.0-68.5%), as seen in Table 4. Yuelamu was the exception with travel expenses representing the largest component (52.6%). This is despite having only the minimum of two annual trips in the 12-month period (July 2010 to June 2011).

Table 4: Proportion of Total Costs Calculated Spent on Labour, Materials, and Travel.

Community	Hardness	Percentage (%) of total costs		
		Labour	Materials	Travel
Areyonga	High	21.6	68.0	10.4
Kintore	High	15.3	68.5	16.2
Yuendumu	Medium	31.0	50.2	18.8
Titjikala	Medium	20.8	62.0	17.3
Atitjere	Medium	21.2	47.1	31.7
Santa Teresa	Medium	27.8	58.3	13.8
Finke	Low	25.5	40.0	34.5
Yuelamu	Low	26.6	20.8	52.6

*Note:* Hardness is categorised as high, medium, or low as defined in Table 2.

**Personal costs of hard water.** While some of the direct costs (labour, materials, and travel) were quantified through the audit data, there are other indirect costs borne by community residents associated with hard water. Scale build-up not only reduces the longevity of appliances, but also causes appliances to draw more energy to function. This can result in higher energy bills and a smaller quantity of hot water available, which is an additional burden on low-income Indigenous families. According to one plumbing contractor interviewed, a 50 litre tank, if not serviced, could be expected to halve in volume within five years due to calcium build-up. The concomitant reduction in the quantity of hot water delivered can hinder healthy living practices, such as bathing and washing clothes, particularly if there are many people living in the house, which is often the case in Indigenous households. Overcrowding occurs in almost 20 percent of Indigenous homes located in remote areas (Baillie & Wayte, 2006). At the time of the study the average income for Indigenous people in remote and very remote locations was AUD\$267 and AUD\$356 per week, respectively, compared to AUD\$579 and AUD\$622 per week for non-Indigenous people, who are usually in some form of employment, in these communities (Australian Bureau of Statistics, 2012). Without the government funding assistance for housing, many Indigenous people could not afford the housing maintenance that has been outlined in this paper.

While the personal costs were largely anecdotal in this study, other studies have quantified the costs of health consumables (such as soap and shampoo) in communities with hard water. For example, Pearce et al. (2008) found that residents in a remote Indigenous community with hard water in South Australia spent, on average, 18.7 percent more per week (8.8% of their income) on health consumables, compared to residents in the metropolitan city of Adelaide where hard water is not a concern. Extrapolating these results to Areyonga, a high hard water community, would mean that Indigenous residents with an average “very remote” income would need to spend 27 percent of their income on water-related health hardware annually.

Tenants need to understand the importance of reporting malfunctions to the Shire Services Manager. Those who fail to do so may be without access to adequate quantities of hot or running water or properly flushing toilets because any non-operational fittings will only be discovered during household audits, which occur every six months.

### Implications of the Costs of Hard Water

As seen in Figure 3, the LSI of the eight communities shows a similar trend to that of house/year cost of health hardware (excluding travel costs). Communities in the mid-range of hardness (Yuendumu, Titjikala, Atitjere, and Santa Teresa) had similar LSI values with the costs/house/year within the range of AUD\$589 to AUD\$1,134; Areyonga and Kintore had elevated LSI levels and costs of AUD\$2,219 and AUD\$3,749, respectively; while Yuelamu had the lowest LSI and noticeably lower costs of AUD\$141.

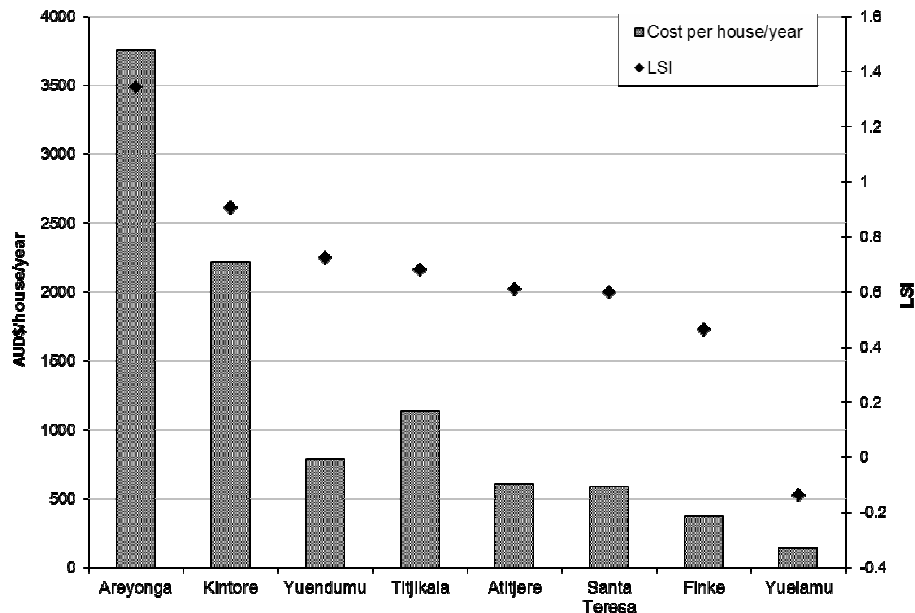


Figure 3: A Comparison between the LSI in Eight Remote Indigenous Communities and the Annual Cost/House/Year for Water-Related Health Hardware Replacements and Maintenance.

Indigenous Housing Authority Northern Territory allocates AUD\$1,700 per house annually for health and safety repairs and maintenance. Comparing this amount with the findings of this study (Figure 3), those living in Areyonga would have a deficit of approximately AUD\$2,000 per house, or 117 percent, thus indicating that not all repairs could be undertaken. This could lead to a lack of access to running water and water-related health hardware, such as toilets. In Tiijikala, two thirds of the allocated AUD\$1,700 would be spent on water-related health hardware. In contrast, Yuelamu would only use 8 percent of the allocation. This shows that, for communities in the high and medium hard water categories, a disproportionate amount of housing maintenance funds need to be spent on water-related repairs, compared to communities without hard water.

Browett (2011) modelled the cost of hard water against the LSI to provide a predictive indication of the cost/house/unit increase in hard water. Length constraints preclude the details from being included here, but a brief summary of the key findings is given. Based on a linear relationship between the LSI of a community and the predicted annual cost/house, results show that, for every 0.1 unit of change in LSI, a change of around AUD\$250/house could be expected. Within limits, the results can be scaled; for example, a 0.2 reduction in LSI would save AUD\$500/house/year and a 0.3 reduction AUD\$750/house/year. The policy implications of these findings are discussed below.

### Discussion and Conclusion

The aim of this study is to examine the cost implications of hard water in remote Indigenous communities in the Northern Territory of Australia. Data were analysed to determine the relationship between the degree of water hardness and the maintenance and repair costs incurred. The results show that communities with hard water require more frequent replacements of health hardware items (such as taps, spouts, shower roses, and hot water systems) and have higher maintenance costs, compared to communities without hard water. This has implications for policy.

Currently, a ten-year agreement, entitled the National Partnership Agreement on Remote Indigenous Housing, is in place. This agreement aims to address the issues of overcrowding, homelessness, and poor housing conditions in remote communities. Funding of AUD\$5.5 billion has been allocated over ten years to provide 4,200 new houses in remote communities and upgrades to a further 4,800 houses (Australian Government, 2009b). In the Northern Territory, the Australian and Northern Territory governments are working in partnership with the communities to deliver improved housing services. At a local level, the Shires serve as agents for Territory Housing and manage some aspects of housing maintenance; however, funding for housing maintenance is allocated on an annual basis and is largely aggregated for the state or territory. Furthermore, while the maintenance allowance may be appropriate for communities with “regular” water supplies, this study has shown that, where communities are highly impacted by water hardness, the allowance is inadequate. In such cases, if the water-related repairs are undertaken, they may be done at the expense of other repairs, which may be just as pressing (i.e., power-related needs), or some communities may be overlooked while the funding is spent where it is needed most. These findings are particularly pertinent given that 59 percent of communities in the Northern Territory have water supplies in the medium to high hardness category (Power and Water Corporation, 2011). In other parts of central Australia, hard water is also prevalent.

The figures presented here are estimates based on the best data available; nonetheless, they provide a valuable base from which policy changes can be established. To date, maintaining and repairing systems is deemed as being preferable to installing water softening plants or other water treatment systems in the impacted communities. The results of this study will help agencies calculate monetary benefits and repayment periods as they choose appropriate mitigation measures and build business cases for the implementation of water quality improvement programs in remote communities.

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