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The E. Coli Load In Self-Managed Rural Water In Australia

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Abstract

Access to clean drinking water is taken for granted in most developed nations where many think water quality is a third-world issue. However, for residents of rural Australia water quality is an emerging issue. Our research of drinking water quality, harvesting and management practices of rural NSW residents found that a substantial number of these consumers may be risking their health whenever they turn on their tap. More than half of the tank water sampled failed to meet the Australian Drinking Water Guidelines for safe drinking water. Levels of *E. coli* were up to 230x more than the acceptable levels proposed by the Australian Drinking Water Guidelines. Qualitative research found most consumers were unaware of the risks associated with drinking raw rainwater. Further, few took steps to minimise their risk through accepted water management practices.

Introduction

On the world's driest continent (Shiklomanov, 2000), in an area living through a prolonged drought, discussion of water availability and quantity abound. However, water quality, particularly for human consumption, as opposed to water for crops and grazing, has been largely ignored. A 2008 survey of Australian urban residents from four capitals and one regional city found only 78% of respondents had considered the quality of their drinking water (Crampton and Ragusa, 2008). Australia is particularly vulnerable to threats to both the quality and quantity of drinking water availability because most rainfall evaporates quickly, resulting in twenty percent of the population relying on ground water for drinking supplies which "is extremely difficult to clean up if it becomes polluted" (NHMRC 2004, p.8).

Despite this, Australia remains one of the only western nations without legislation to ensure the quality of its drinking water (Sinclair and Rizak, 2004). The quality of Australian drinking water is managed in accordance with the Australian Drinking Water Guidelines

(ADWG) which provides approved guidelines for management and processing practices as well as acceptable levels of contaminants (NHMRC, 2004). Although the majority of these guidelines are within, or more rigorous than, those advised by the United Nations, they only relate to regulated water (i.e. water controlled by an external body, government and/or industry). Further, the periodicity of water testing to ensure the guidelines are met is dependent on the population served by the water. For example, urban water might be tested weekly for some parameters while rural and regional water might only be tested monthly or bimonthly for the same parameters (NSW Health, 2005). For rural and regional residents in charge of managing their own water supplies, there is no organised testing protocol. Hence, there is no way to ensure rural residents on non-regulated water are consuming water that meets ADWG.

Impurities are expected in all water sources due to the nature of their collection and/or storage. However, it is the nature of the impurities and their effect on waters' organoleptic qualities, or pathogenicity, which is of concern to water providers and consumers. In Australia, as in other countries, the key concern is faecal contamination of the water supply. To monitor for this, the water is screened for the presence of indicator organisms which in themselves may not be pathogenic, but are indicative of the presence of faecal contamination (NHMCR, 2004). The enteric bacterium *Escherichia coli* is the standard indicator used in Australia to test for possible faecal contamination of the water supply (NHMRC, 2004). The ADWG state that *E. coli* should be absent (defined as 0 colony forming units (cfu) per 100ml of water tested (0 cfu/100ml)) from drinking water. Similarly, acceptable water should be free of pathogens such as *Salmonella spp*. and *Camplobacta spp*. (NHMRC, 2004), as both have been the source of tank water based disease outbreaks (Lye, 2002).

While there has been a plethora of studies on 'optional, alternative water sources', namely tank water in urban areas (Yang *et al.,* 2009; Ahmed *et al.,* 2008; Evans *et al.,* 2007; Heyworth *et al.,* 2006), a lack of investigation exists into non-optional, self managed water sources in rural areas. Although conclusions from much of the prior research note the microbial risks faced by consumers of raw tank water, the level of risk and contributing factors, such as tank type and the role of the consumer/manager in enhancing or reducing risk, have not been addressed. This paper presents an investigation of the water quality and harvesting practices of rural residents in a drought stricken region of Australia.

Materials and Methods

Recruitment, Survey Design and Interviews

Participants were recruited via the Holbrook Landcare listserve, university listserves and word of mouth. Potential participants were sent an email outlining the commitment involved, namely collection of water and delivery to designated collection areas and participation in a 20 minute phone interview. Consenting participants were then sent a collection pack consisting of a 4 L sterile plastic jug for each water source to be sampled, a cooler bag with an ice pack, water collection instructions and a survey. The survey contained open and closed ended questions and was designed to ascertain information about participants' water collection devices (i.e. number and type of tanks), residence particulars (i.e. land size and ownership), activities around the collection area (i.e. stock grazing or aerial spraying) and general demographics. Initial collections occurred between April and May 2009 with follow up collections of water from contaminated tanks in September 2009. Test results were sent to participants once they completed a 15-20 minute telephone interview. Interviews consisted of a series of demographic questions, queries about their water collection habits as revealed from the collection survey (i.e. why they did or did not have an inlet screen), attitudes towards water management, agricultural impacts and general perceptions about the quality of their water. The survey and phone interview questions were approved by the School of Biomedical Sciences Ethics in Human Research Committee, protocol number 6/2009/02.

Water Collection

Participants conducted their own water collection and brought their samples to a central location. Collection from the central location was designed to ensure a maximum of four hours between collection and laboratory analysis. Participants were instructed to collect directly from the storage source (tank or bore head) prior to daily use. The participants were given the following collection protocol: 1. Select a tap connected to your regular source of drinking water (tank/bore). 2. Remove any external filters. 3. Clean the tap with a damp cloth 4. Allow the tap to run until it fills a standard bucket. 5. Rinse the collection flask 3 times from the same source as the water to be sampled. 6. Fill the collection flask to the top so that there is minimal air space between the water and lid. 7. Place the collection flask with the ice pack in the insulated bag provided.

Follow up sampling was done in the same manner except that the collection vessels were 2, 200 ml jars per requested sample, as these samples were only tested for levels of *E. Coli* hence less water was needed compared to the initial testing.

Microbial load determination

Laboratory analysis focused on 3 key targets, *E. coli, Campylobacter spp*. and *Salmonella spp*. For each target, 750 ml of water was filtered on to a 0.45µm membrane and cultured under appropriate conditions for each target species. Follow up testing of water sources identified as contaminated during the initial sampling focused only on levels of *E. coli.* For the follow up sampling only 200 ml of water was filtered per sample. *E. coli* detection was achieved by placing the filter membrane onto a Chromocult® nutrient pad (Sartorius Stedim) and following the manufacturer instructions for incubation and detection. Chromocult® media enabled the differentiation between *E. coli* and total coliforms. Potential *Salmonella* isolates were cultured as per the manufacturer's instructions for the Singlepath®*Salmonella* (Merck) detection kit with the filter placed in enrichment media and treated as per the protocol for solid samples. Similarly, potential *Campylobacter* colonies were cultured as per the manufacturer's instructions for the Singlepath® Campylobacter (Merck) detection kit with the filter placed in enrichment media and treated as per the protocol for solid samples.

Data Analysis

Quantitative survey responses and laboratory results were entered into SPSS and descriptive statistics used to generate key information about the relationship between the participants, their water collection activities, their residential environment and incidences of contamination. Correlations were performed to identify if statistically significant relationships existed amongst the variables.

Results

Recruitment yielded 48 participants who supplied 52 water samples (47 rain harvested, 4 bore and 1 spring). Participants were all from within 150km of Wagga Wagga, NSW with 44% from the Holbrook area, 24% from the Wagga Wagga area, 22% from the Albury region and the remaining 10% from Batlow, Tumut, West Wyalong and Cootamundra. Eighty-five percent of participants did not have access to a regulated water supply. The area of land on which the participants resided varied from 0.8 acres to 25000 acres. Sixteen percent lived on less than 10 acres, 9% on 50-100 acres, 27% on 100 - 500 acres, 11% on 500-1000 acres and 38% on more than 1000 acres. Sixty-five percent of participants used their land to run a commercial enterprise, with the grazing of sheep and/or cattle with some cropping being the predominant sources of income. Only 4 participants did not have a livestock-related enterprise.

The average rainfall across the collection area for 2009 was 423mm. The average maximum temperature was 31.5 °C in January and the average minimum 3°C in June. Most participants (78%) relied on rain harvested water as their primary source of drinking water; a further 9% relied on bore water, 2% on spring water and the rest relied on a combination of rain and bore or purchased water. Most tanks were constructed from concrete (53.5%), with PVC the next most popular material (16%). Most of the roofs from which the water was harvested were Zincalume/colourbond (76%). The majority (55%) of participants had only one tank, 18%

had 2 tanks, 21% had 3 tanks and 5% had 4 tanks. The extra tanks were often attached to peripheral buildings, such as shearing sheds. Tank age ranged from 1 to 99 years although most (56%), were less than 20 years old. Only 48% of harvest areas (roof and area between roof and tank) had contamination prevention devices fitted (e.g. leafless gutters, leaf diverter, filter sock) with 27% using a first flush diverter. Contamination reduction devices were fitted to 86%; devices including inlet screens, fines filters, frog flaps, deep tank draw off and in one case an inline filter. Of all the fitted devices, deep tank draw off systems (64%) and inlet screens (50%) were the most predominant. Forty percent of participants had cleaned their tank at least once, yet only 3 participants indicated that it was part of their scheduled maintenance program. Eight participants had tested their water previously, but only 5 due to concerns of quality. All others were for an educational project.

Although numerous non-identified anaerobic colonies were cultured neither *Campylobacter spp*. nor *Salmonella spp.* were detected. The ADWG for acceptable levels of *E. coli* (0 cfu /100ml) were exceeded in 51% of samples and included all three water sources (rain, bore, spring). The highest reading was 229 cfu/100ml from a rain harvested system (see Table 1). Of the 27 samples exceeding the guidelines, 13 (48%) accepted the offer to have their water retested. Re-sampling took place 2-3 months after the initial sampling and followed a period of heavy rain. Seventy one percent of the re-sampled water sources still had levels of *E. coli* contamination above (0 cfu /100ml) and four (29%) samples showed significant increases between the initial and secondary sampling (see Table 2). The *E. coli* levels in 2 of the tanks did decrease between sampling events, however the lower levels were still above ADWG acceptable limit

Statistical analysis of the full data set combining the laboratory results and the survey yielded a correlation between tank type and *E. coli* contamination levels. The metal based tanks (colourbond/zincalume/galvanised) averaged lower levels of contamination than the other tank types, such as concrete and PVC. Although this relationship came from a relatively small sample, it indicates that the relationship between tank type and tank age and *E. coli* contamination is worth further investigation. As seen in Table 2, older tanks were more likely to have excessively high levels of *E. coli* than newer tanks. Tank age may have influenced the correlation between tank type and *E. coli* levels, as 50% of metal tanks were less than 10 years old. In contrast, the majority of non-metal tanks (77%) were more than 10 years old and 40% were more than 20 years old.

Level of *E. coli* CFU/100ml	Number of Tanks
0	18
0.10-0.5	7
0.51-1.0	3
1.1-5.0	11
5.1-10.0	1
10.1-20	3
20.1-50	5
50.1-100	2
>100	2

Table 1: Range of *E.coli* levels and number of tanks with that level of contamination.

Tank	Initial	Secondary
1	**1**	**4**
2	8	8
3	*1*	*0*
4	**3**	**24**
5	*48*	*1*
6	*3*	*2*
7	*17*	*0*
8	*229*	*28*
9	**4**	**40**
10	**23**	**59**
11	*2*	*1*
12	*1*	*0*
13	*40*	*13*

Table 2: Levels of *E. coli* (cfu/100ml) in initial and follow up samplings.

Level of *E. coli* CFU/100ml	< 10 years old (N=12)	10-20 years old (N=15)	> 20 years old (N=19)
0	50	27	32
0.1-0.5	17	7	16
0.51-1	0	13	0
1.1-5	25	20	22
5.1-10.0	0	7	0
10.1-20	8	7	5
20.1-50	0	0	5
50.1-100	0	0	11
>100	0	0	11

Table 3: Percentage of tanks within an age range relative to the level of *E. coli* contamination.

Discussion

In Australia, the USA and EU, the detection of *E. coli* is used as the key indicator of faecal contamination of a water source (Australian Government, 2004; Barrell *et al.,* 2000). If the *E. coli* levels seen in the majority of tanks sampled in this study (up to 230x the recommended guidelines) had been isolated from a regulated water source, then the providing water utility would have had to notify the public health unit, retest the water and increase decontamination action. Further, if the retest was positive for *E. coli* then the NSW chief health officer would have had to issue a boiled water alert for consumers (NSW Health, 2005), a course of action, leading to consumer notification, covered by the Public Health Act of 1991. However, as the ADWG are just guidelines, there are no means by which a utility can be legally forced to provide water that meets said guidelines (NHMRC, 2004). Hence, utilities could continue providing contaminated water so long as the boiled water alert is supplied. In the UK, the supply of such water would be deemed a criminal offence (Barrell *et al.,* 2000) and appropriate legal action would be taken against the utility. However, at this high level, some several hundred times greater than allowed by ADWG, the self-managed sources were under no obligation to monitor water quality, nor had they the resources to do so. Therefore, such high levels would normally go unnoticed and continue to pose potential health risks to naïve consumers. Yet, whilst the UK considers *E. coli* in the regulated system to have the potential to result in a criminal charge to the supplier, it does not specify minimal microbial standards or testing frequencies for single dwelling supplies (Barrell *et al.*, 2000). In Australia, only tank water used for commercial purposes, such as the preparation of food for sale, provision of water in tourist parks or bed and breakfast lodgings, must be tested and meet ADWG (Australian Government, 2004). The NSW guidelines for such commercial uses of private water supplies indicate that if the water is contaminated it must be boiled before use or non-contaminate supplies provided (i.e. bottled water). If the water is not tested (monthly for *E. coli* and annually for chemical contaminants), or is contaminated and treatment or alternatives are not supplied, then consumers must be warned of the risks, preferably via signage at the outlet (NSW Health, n.d). For the participants in this study, these responsibilities, as they are termed in the absence of any legislation to enforce the guidelines, may be irrelevant in the course of their day to day existence. However, if they were to invite people onto their land for a field-day or sale event such as an annual ram sale, then in accordance with the NSW guidelines they would need to label water as unsuitable for drinking and provide an alternative water source. While the underlying principles of the guidelines promote self-responsibility for managing risk, they make it irresponsible to expose others to the same risk without notification. Consequently, they fail to address fundamental issues of prior knowledge and access to resources. It is clear from this study that a significant proportion of rural tanks may not meet ADWG for safe drinking water, yet consumers do not know their level of water safety. Thus, consumers cannot advise others of potential risks.

The risk of microbial contamination in tanks can be reduced by several well known practices. These include the installation of first flush devices, cleaning gutters, both of which are designed to reduce the build up of potential contaminants and the use of filtration to remove potential contaminants before use (NHMRC, 2004b). Indeed, NSW Health, the key health authority figure for the participants in this study, has stated, “providing systems are well maintained the risk of harmful organisms being present is low” and in the same document they are cautious in their descriptions of risk noting, “a well maintained water catchment system is probably safe and unlikely to cause illness for most users” (NSW Health, n.d.). This echoes the findings of numerous studies which have shown that while most rain water is pure once it reaches the catchment surface, such as roof top or tank, its purity is affected by a myriad of factors including the degree to which the catchment system has been maintained (Richardson *et al.*, 2009; Abbott *et al.*, 2007; Australian Government, 2004; Lye, 1992). However, the results of this study indicate that this level of low risk is not being achieved and that consumers are being exposed to higher than acceptable levels of microbial contamination.

Periodicity and intensity of rainfall have been shown to impact level of microbial contaminant entering tanks, and the more time between events, the more contaminants accumulate and are washed into the tank (Abbott *et al.*, 2006). For sites sampled twice, changes in contamination levels between sampling events may have been due to recent rainfall events washing more contaminants and sources of nutrients into the tank and/or increased temperature providing an environment more conducive to microbial growth. The two tanks where levels decreased may not have had a major rainfall event. Alternatively, the original testing may have occurred after a recent rainfall event following a prolonged dry spell, thereby reflecting only a short term increase in microbial contamination levels. Thus, results highlight the need for further investigation of the periodicity and nature of contaminant survival and growth in association with temperature, rainfall and maintenance activities. Such information will enable development of appropriate control strategies that address key risk indicators and determine the most appropriate timing and style of intervention(s). Similarly, more research is needed on the effect of tank type and age. Level of maintenance may impact the influence of tank age as never-cleaned older tanks, as in one case not cleaned for 30 years, are more likely to harbour a significant level of sludge that may act as a nutrient bank enabling contaminants to persist in the tank environment.

Inadequate maintenance, the common status for self-managed systems (Abbott *et al.*, 2007; Lye, 1992) and a noted characteristic of systems in this study, increases the level of organic matter (i.e. leaves) that enters water tanks facilitating the build up of nutrients available to microbial contaminants. The survival of enteric bacteria, like *Salmonella spp.* and *E. coli,* within the tank environment is influenced by temperature and the presence of nutrients (Leclerc *et al.,* 2002). While leaves are a common source of organic matter, dust, especially during times of drought when particles of ground-based organic and inorganic matter can be carried for hundreds of kilometres during dust storms (Goudie, 2009), is another source. Evans *et al.,* (2007) demonstrated that airborne pathogens from surrounding soils, including *E. coli*, are significant contributors to the microbial contamination of tanks. Therefore, in addition to the commonly attributed sources of microbial contaminants, birds, possums or rodents defecating or dying in tanks (Australian Government, 2000), rural participants who graze sheep and cattle, may be exposed to microbial contaminates from higher order-mammals. Exposure to microbial contaminants from higher-order mammals brings with it an increased health risk due to the greater zoonotic potential of such microorganisms. The Australian Government in its guidance on use of rainwater tanks (Australian Government, 2004) identifies livestock waste as a health hazard only for underground tanks and aerosol waste appears unconsidered. This partitioning of risk, between in-ground and above-ground tanks needs to be reconsidered in light of the work of Evans *et al.,* (2007), current drought and dust conditions and the increased incidence of livestock related zoonotic disease (i.e. H1N1, swine flu).

Increasing outbreaks (Callaway *et al.,* 2009; Goode *et al.,* 2009) of gastrointestinal illness from livestock-derived *E. coli* indicates it is perhaps time to rethink the significance of the presence of *E. coli* in tanks, particularly in rural areas with livestock. In 2006, the most notorious strain of *E. coli,* STEC O157, was responsible for a waterborne-related outbreak that affected more than 100 people across America and caused at least one death when bacteria transferred from a contaminated water source to a spinach crop that was then packaged and widely distributed (Bettelheim 2007).

In addition to bacterial-related health risks, faecal contamination carries the increased risk of viral contamination of the water source. Although viruses cannot multiply in water, some may remain static (Leclerc *et al.,* 2002) and, when combined with their low infective dose, may pose a health risk to consumers. This health risk is elevated in treated water (i.e.

chlorinated tanks) where the faecal indicators may be absent, but the viral load is still elevated due to their resistance to disinfection agents (Payment, 1993). Viruses, such as rotoviruses and caliciviruses, have been identified as key etiological agents in outbreaks of drinking water derived gastrointestinal illness in the United States and Netherlands (Leclerc *et al.*, 2002).

While the true risk to regular consumers of tank water is debatable due to issues of acquired immunity (Heyworth, 2006) and lack of identification of distinct pathogens rather than indicators, the widespread incidence of high levels of contamination, as well as the probability that these levels underestimate exposure, highlights the need for further investigation of the quality of water available to rural residents. As Sydney Water (2003) informed consumers,

"People with special health needs such as those with a severely weakened immune systems (including some people with HIV and AIDS, transplant recipients, dialysis patients and cancer patients) should talk with their doctor about taking special care by using only boiled, bottled or microfiltered water."

So, too, should rural residents be advised to take the same precautions with their water, especially in relation to 'at risk' visitors including the very young, elderly and immune compromised. This concern was also expressed by NSW Health in their rainwater tanks pamphlet, " the very young or very old, may wish to take extra care by using only boiled, bottled or micro-filtered water and avoiding foods and beverages that may contain rainwater" (NSW Health, n.d.).

This study has shown consumption of raw tank water by rural residents in NSW, Australia, unknowingly exposed them to a level of risk not encountered by urban residents. Further, our research has shown rural consumers are ill informed about risks and correct actions to take to ensure better safety of tank-water consumption. Rural residents are regularly bombarded with a deluge of information on land management, drought relief and factors related to surviving on the land. Our research advocates greater attention must be paid to the water residents are drinking, in addition to the water used for other interests.

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