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Perceived agricultural runoff impact on drinking water

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Abstract

Agricultural runoff into surface water is a problem in Australia, as it is in arguably all agriculturally active countries. While farm practices and resource management measures are employed to reduce downstream effects, they are often either technically insufficient or practically unsustainable. Therefore, consumers may still be exposed to agrichemicals whenever they turn on the tap. For rural residents surrounded by agriculture, the link between agriculture and water quality is easy to make and thus informed decisions about water consumption are possible. Urban residents, however, are removed from agricultural activity and indeed drinking water sources. Urban and rural residents were interviewed to identify perceptions of agriculture's impact on drinking water. Rural residents thought agriculture could impact their water quality and, in many cases, actively avoided it, often preferring tank to surface water sources. Urban residents generally did not perceive agriculture to pose health risks to their drinking water. Although there are more agricultural contaminants recognised in the latest Australian Drinking Water Guidelines than previously, we argue this is insufficient to enhance consumer protection. Health authorities may better serve the public by improving their proactivity and providing communities and water utilities with the capacity to effectively monitor and address agricultural runoff.

Key words: Chemicals, drinking water, pollution, rural, tank water, water policy

Introduction

Access to high quality, safe drinking water is decreasing globally due to the key contribution of chemical pollutants (UN 2010). The intergovernmental panel on climate change predicted that, in developed countries, the impact of pesticides on water quality would continue to increase as climate change progresses (IPCC 2008). In Australia, as in all agriculturally active countries, contamination threats from agricultural runoff have been a concern for several decades (Paton & Norton 2002; Moss 2008; Bernard, Drechsel, & Konradsen 2008). Government agencies actively work with farmers to improve agricultural practices to reduce runoff through legislation and education campaigns (Paton & Norton 2002). The government's involvement, however, has been biased towards primary producers through safe chemical campaigns and waste drum disposal programs, rather than focusing on companies producing chemicals or chemical intensive crop varieties.

The Australian Government's continued approval of pesticides, considered health hazards and banned in other countries, evidences a bias to shift responsibility towards producers and away from chemical corporations. The latest version of the Australian Drinking Water Guidelines (ADWG) includes 130 more pesticides than the previous version (NHMRC 2011). ADWG's increased number of pesticides indicates not only heightened risk perception, but also increased technical capacity to measure pesticide presence. Noting the possible threat posed by pesticides, Australia's leading medical research authority, the National Health and Medical Research Council (NHMRC), states the following:

> *Although guideline values have been provided for a large number of pesticides, most are unlikely to be present in Australian drinking water supplies. Monitoring should be undertaken for those pesticides that have been detected in the source water, or where local usage suggests that they might be detected. Inlets to storage reservoirs or other water sources should be sampled monthly for relevant pesticide residues* (NHMRC 2011; p. 11).

These strategies may seem to represent a balanced approach to what is considered a low risk issue. Any strategy, however, is only as effective as its application. For example, a study in

southern Australia found local councils were not adjusting their testing regime to match activities in agriculturally dense areas (Amis 2010). Further, there have been several instances in Australia where pesticide levels above those recommended by the World Health Organisation have been discovered in catchments, some connected to treatment plants not equipped to filter out pesticide contamination (Amis 2012; Parris 2011).

The Australian Government's 'no risk but we will test it anyway' views are supported by the Australian Pesticide and Veterinary Medicine Authority (APVMA), which assures consumers that any health risk associated with normal pesticide use and drinking water would be minimal. This is reflected in a response to a consumer's concern on their web site, "While pesticides are unlikely to be in drinking water some are occasionally detected" (APVMA 2010). Although the ADWG meet or exceed many standards recommended by the United Nations related to both the quality of the resource, as well as the practices governing its management and supply, they are still just guidelines. Hence, Australia remains one of the only western nations without legislation governing drinking water quality (Sinclair & Rizak 2004). Some Australian states and territories have sought to bridge this gap through their own legislation, which largely relates back to the ADWG in some capacity. Legislation exists in Victoria (Victoria Safe Drinking Water Act 2003), Queensland (Queensland's Water Supply Safety and Reliability Act 2008), Tasmania (Public Health Act 2008), South Australia, through its 2001 Food Act, and the Northern Territory (Water Services and Sewerage Supply Act).

While pesticides and petroleum residues may be considered the main risks associated with agricultural runoff (Goss & Barry 1995), microbial contaminants of agricultural origin are also a concern. The ADWG note the importance of maintaining barriers against the inflow of faecal matter alongside microbial water quality tests. The periodicity of this testing and the location (reservoir, inline, tap), however, vary in relation to the population served by the water, with many states adopting their own interpretation of the World Health Organisation guidelines (WHO 2008). Further, indicators of microbial contamination have also been found in rainwater tanks (Crampton & Ragusa 2010), a water source normally considered relatively safe from agricultural contamination and for which there is no routine monitoring

or assessment policy in Australia. Drinking water exposed to agricultural runoff may be contaminated by fertilizers, which can promote algal blooms, negatively impacting organoleptic properties and releasing toxins of unknown affect (EPA 2005). Further, high levels of nitrogen in drinking water have been implemented as causal agents of the potentially fatal condition methemoglobinemia in infants (EPA 2005).

Despite known and potential contaminants scientifically recognised by water authorities and health professionals, little research has investigated whether proximity to potential contaminants, namely agriculture, may mitigate, intensify or prove to be impervious to consumers' perceptions about the safety and quality of their drinking water. Urban Australians espouse satisfaction with the quality of their water (Crampton & Ragusa 2008), but are they adequately aware of what occurs between rainfall and tap to make such judgements? Rural residents who rely on tanks are intimately associated with their water catchment areas, specifically their roofs. They are perhaps, less aware of the internal complexities of the ecosystems operating within their tanks, however, and hence base their water consumption habits on incomplete or erroneous data (Crampton & Ragusa 2010). Further, rural town residents on centralised water are perhaps the most disadvantaged in regards to making informed decisions about their drinking water, given that the quality of their drinking water largely determined by local government water testing practices and decision making. Although rural town water consumers ought to be provided with water that meets the same ADWG standards as urban consumers, the monitoring and testing against these standards happens significantly less frequently in rural locations (National Water Commission 2011).

A random study of Australians and their attitudes and perceptions towards recycled and desalinated water found while consumers were concerned about health risks associated with alternative water sources, they had little factual knowledge to support their concerns and perceptions (Dolnicar & Schafer 2009). This relationship between knowledge and perception, combined with the earlier finding of Turgeon *et al.* (2004) that consumers' satisfaction with their water quality is closely related to their perceptions of associated risks, leads us to question the relationship between perceptions of agricultural activity and water quality.

Methods

This study focuses on water consumers from two major metropolitan cities in Australia, Sydney and Melbourne, and one rural region in southwest New South Wales, the Riverina, including its hub, Wagga Wagga. The rural residents are equi-distant from the two metropolitan areas (~500km) and regularly receive television, radio broadcasts and newspapers from both Sydney and Melbourne. In order to answer the research question, 'What impact does proximity to agriculture have, if any, on how different consumers perceive agriculture may affect drinking water?', the current study includes responses to the survey question, 'What impact do you think agricultural activities could have on the quality of your water?' from urban, rural town and rural tank water samples. Further, tank water consumers were asked, 'What impact do you think agricultural activities would have on the drinking water of people in cities and towns?'. Responses were provided from 142 face to face interviews conducted by the authors in Sydney, Melbourne and Wagga Wagga. Mixed (qualitative and quantitative) research methods informed the construction of the research design and instrument, which consisted of a close-ended survey to permit collection of extensive descriptive data to quantitatively describe and analysis the sample, followed by several open-ended, qualitative interview questions to permit more in-depth investigation of drinking water issues, including awareness or concern about agricultural runoff.

With the exception of the rural tank water users, all interviews were conducted in public places, such as shopping malls and airports. Participant selection was semi-structured to facilitate generation of a demographically diverse sample. Although the sampling framework was purposive, given the exploratory nature of the research about an under-researched population (Neuman, 2011), quota sampling methods informed interviewee selection to achieve a sociologically stratified range of participants on demographic variables of relevance to the research question (Walters 2010). Women were purposely over-sampled for comparative purposes, as articulated by the detailed research design and preliminary gender-specific findings already published (Crampton & Ragusa 2009), and the research aims developed in light of national and international research noting women tend to have more water-issue concerns than men (Hamilton 1985; Park et al., 2001; Mummery, Duncan & Kift 2007; Roseth 2006). Subsequently, the sample is not purely random, whereby every member of the community had an equal chance to participate (Neuman 2011), even though it was not

pre-determined who would appear in a public space at any given time while we were interviewing. In light of this methodology, quantitative findings should be interpreted as illustrative of participants' attitudes and behaviours rather than understood as generalisable to the population at large.

Since the rural tank water users (Riverina) could not be obtained using the same sampling framework as for the urban (Melbourne and Sydney) and rural town (Wagga Wagga in the Riverina) consumers, participant recruitment was achieved with the assistance of local land managers (such as the Holbrook Landcare's database), posting of university notices and by word of mouth to take part in a study about the quality of their tank water. The geographically dispersed nature of participants, inherent to locations without access to centralised water sources, made face to face interviews not possible, so the survey and interview for this group were completed by telephone, following the same procedures as for the rest of the research sample.

All interviews lasted a maximum of 20 minutes, were digitally recorded and later transcribed. The School of Biomedical Sciences' Ethics in Human Research Committee approved the questions and sampling procedure (protocol numbers 5/2007/298 and 6/2009/02). Informed consent was provided and obtained by all participants who received no compensation for participation. Quantitative data was entered and analysed using SPSS with correlations, chi squared and ANOVA analyses performed to test for significant relationships. The non-random sampling frame, and hence non-normative distribution of results, precluded the commonly used regression analysis statistic. Qualitative thematic analysis of responses provided to the open-ended questions was independently conducted by the co-authors with common themes first identified to guide reading and analysis of transcripts, then collaboratively to detail major themes and key issues.

Results

Statistical Analyses

The 142 respondents were comprised of 35 rural tank water consumers, 56 rural town consumers from Wagga Wagga, and 51 urban consumers (24 from Sydney and 27 from Melbourne). Collectively, there were 59 men and 83 women ranging in age from 18 to 93.

Highest level of education varied considerably across the sample, from Ph.D. to those with primary (grammar) school education, as detailed in Table 1. The larger proportion of higher educated respondents in the rural samples was likely due to the sampling location being a University town and the use of a University listserve as part of the recruitment strategy.

Table 1:

Respondents' demographic attributes

Attributes	Rural Tank Riverina	Rural Town Wagga Wagga	City of Sydney	City of Melbourne
Age (mean)	57	47	35	41
Sex (%)				
Male	37	43	38	48
Female	63	57	62	52
Highest education (%)				
Postgraduate	23	0	0	0
Undergraduate	34	20	8	4
*TAFE**	31	18	25	30
Trade	0	27	25	26
High school	9	0	4	4
Year 10	3	13	13	7
Primary	3	21	25	30

*Technical And Further Education Institutes (TAFE) are similar to polytechnics or community colleges in other countries

A clear difference emerged regarding perceived agricultural impact on drinking water between rural and urban participants. The majority (63%) of rural tank water drinkers believed agriculture could affect their drinking water, compared with 35% of Melbourne and 17% of Sydney consumers. Interestingly, in contrast with rural tank water consumers, the majority of rural town consumers (62%) did not think agriculture could affect their drinking water, which is a view consistent with their urban counterparts.

Pearson's correlations and Chi-squared analyses produced significant relationships related to perceived agricultural impact on drinking water. Variables which significantly correlated with drinking water perception (*AgCity* - perceived affect of agriculture on water supplied to

cities and *AgTheir* - affect on consumer's own water) were age, education level, residential location, and whether one lived in a rural (town or location requiring tank water) or urban (Sydney or Melbourne) location (Rurality).

The variable *AgCity* was the same as *AgTheir* for Sydney and Melbourne residents because their drinking water is sourced entirely from municipal suppliers, with the exception of purchased bottled water. Only tank water consumers were given the option of providing two perceptions about agricultural impact on water because of their frequent experience with both rural and urban water supplies. Perceptions were provided relative to their own tank water (*AgTheir*) and the drinking water supplied to cities and towns (*AgCity*). Tank water consumers were asked about their perceptions of the potential for agriculture to affect major metropolitan cities, such as Melbourne and Sydney, although no specific city was mentioned in the interview questions.

Pearsons correlation identified five medium strength relationships ($r > 0.3$) that were also shown to be statistically significant by chi squared analysis; *Age* and *AgCity* ($r=-0.484$, $p=0.00$; $X^2(78, N=84) = 104$, $p=0.026$); *Residential location* and *AgTheir* ($r=0.273$, $p=0.001$; $X^2(6, N=140) = 26$, $p=0.00$); *Residential location* and *AgCity* ($r=0.464$, $p=0.00$; $X^2(4, N=84) = 28$, $p=0.00$); *Education level* and *AgCity* ($r=-0.295$, $p=0.006$; $X^2(12, N=84) = 21$, $p=0.047$); *Rurality* and *AgCity* ($r=0.464$, $p=0.00$; $X^2(2, N=84) = 25$, $p=0.00$). As the rural tank sample exhibited higher levels of formal education, the relationship between *Rurality* and *AgCity* may be spurious. Subsequent one-way ANOVA analysis supported the significant relationship ($F(2, 27) = 8.473$, $p=0.000$) between residential location and participants' perceptions of the potential for agriculture to affect their drinking water (*AgTheir*). A Turkey post-hoc test revealed that tank water consumers (1.43± 0.61 min) were statistically more likely to consider that agriculture could impact their drinking water than Wagga Wagga (rural town) (2.11 ± 0.93 min, p= 0.001), Sydney (2.48± .79 min p= 0.000) or Melbourne residents (2.08 ± 0.89 min p= 0.016). There were no statistically significant differences between residential location and the other variables.

Discussion

Our results indicate rural residents were more concerned about the impact of agriculture on the quality of their drinking water (63%) than were urban residents (32%). Interestingly, tank water consumers, all of whom were rural, voiced greater concern about the impact of agricultural runoff on water supplied to cities and towns than its potential to contaminate their own drinking water. A key reason identified for this difference were the collection and storage methods utilised for their drinking water. Specifically, self-managed drinking water was primarily stored above ground in tanks and, thus, not considered exposed to surface-based agricultural runoff. The only contamination concerns expressed by tank water consumers was occasional mention of aerial spraying and contaminated dust.

Level of urbanisation affected consumer perceptions about whether drinking water could be impacted by agricultural runoff. The manifestation of an urban/rural divide recognising potential environmental impacts on drinking water is similar in kind to wind turbine issue awareness. Coleby et al. (2009) found while the generation of electricity by wind turbines benefited both urban and rural consumers, only the rural consumers, close to wind turbines, expressed any awareness or concern of potential environmental impacts.

Environmental and/or personal impact concerns relating to farming and agriculture are often presented as NIMBY, or 'not in my backyard', issues by urbanites (Devine-Wright 2005). Our research, however, indicates that when exploring perceived agricultural impact on drinking water quality, the issue could be described as 'it's in my backyard so I should know', or, in some cases, 'it is my runoff and I don't drink it'. Such was the key theme evidenced by rural consumers in qualitative responses to the question, 'What impact do you think agricultural activities may have on the drinking water of people in cities and towns?'

> *Definitely* [it has an impact]. *It is the current way of farming orientated around artificial fertilizers and chemicals that is has got to affect our waters supplies with runoff as well as rainfall and the direct impact of chemicals on the roof of a house and running into your water system* (Tank 25).
>
> *Well it has to. They get the dust storms as well and it ends up in the reservoirs and all the other things that farming practices do, especially in drought times, that is the immediate fall out. Otherwise, I suppose you are not looking at rivers and those sort*

> *of things from rural areas running into domestic storages*, [into] *urban storages*. (Tank 22).

In comparison, few urbanites thought agricultural activities could impact their drinking water: *Pretty unlikely in Sydney for the agriculture* (Sydney 64); *Don't really think so because I think the farming areas* [are] *not around here* (Melbourne 103); *Agricultural runoff can contaminate the water supply, but I don't think that's a big issue in Australia* (Melbourne, 108).

Both our water study and the wind turbine examples are consistent with the notion that geographical distance from risk inducing activities affects consumers' ability to gain direct sensory perception about local environments, resources and practices. Such distance may thus hinder concern and/or understanding of potential environmental or health impacts (Takacs-Santa 2007). Notions of responsibility and affectedness have also been linked to development of environment-related concerns and may have impacted participants' responses. For example, rural residents drinking tank water were responsible for managing their water supplies. In contrast, urban residents devolved that responsibility to another whom they expected and/or trusted to provide them with safe water, as noted in other studies (Gooch & Rigano 2010). Lack of direct responsibility may have also impacted urban consumers' consideration or concern for environmental factors that could affect their drinking water. The following quotes provided in response to the question about who should manage respondents' water supply typify the general difference in perceived responsibility between many tank and urban water consumers:

> *I think it just can't be the normal person because we don't know that much about it. If it's the government, and/or equally if it's corporations, they might do a better job, but they're also influenced by politics and priorities and commercial factors. I think it should be up to scientific organizations like CSIRO* (Melbourne 107).

> *Well I think if you choose to live in rural areas then you should look after yourself as far as supply is concerned. It is up to the individual. It shouldn't be driven by the government to do that* (Tank 22).

> *I expect them* [government] *to give me quality water if there was a problem, unless it was their fault. In filtration, or whatever, there is the chance of infection getting in there and it can't be helped* (Sydney 59).

> *I really don't want any government body coming out here saying that you got to do this and you got to do that. I think it should be an individual decision. Again if you live on a farm and you are from a farming background, a lot of the government people that would come out would not be from a farming background and so that would cause a lot of unrest if they started telling farming people how to look after their water systems. If they policed that, it would cause a lot of unrest and a lot of problems* (Tank 11).

While studies of consumer perceptions and acceptance of decentralised water sources are on the rise (Mankad & Tapsuwan 2011; Ferguson et al. 2013), seemingly to help communities prepare for anticipated future inadequacies of centralised systems, none have looked at consumers' perceptions of risks associated with centralised water sources. Further, some postulate increasing public awareness and encouraging community participation in decision-making would improve the trust and acceptance of decentralised water sources (Radcliffe 2006; Marks et al. 2008). Still, there remains no investigation into the level of public awareness of issues related to the current, mostly centralised, sources of drinking water for urban or rural Australians. In an historical investigation governance and management of Melbourne's water supply, Ferguson et. al. (2013) noted several instances where consultations failed to include members of the general public. The more 'political' and/or rushed decisions were, such as the construction of a desalination plant, the greater amount of public outcry they received (Ferguson et. al. 2013). Subsequently, it was recommended that future planning processes and changes include community members as well as political lobbyists, water practitioners and policy makers.

A crucial, albeit yet to be identified, issue is how much lack of concern is related to lack of knowledge of risk perception. Sydney consumers vocalised their drinking water concerns by forming local community groups to protest the introduction of desalination plants and

recycled water (Dolnicar et al. 2010). Risk awareness may not necessarily translate into increased participation in relevant discourse. As Penn (2003) noted, education alone may be insufficient for resolving environmental problems. Individuals often need an incentive to become more environmentally active even when it directly affects their well-being (Penn 2003). We, therefore, suggest a key strategy to overcome perceived and actual risk associated with consuming drinking water in Australia is to improve the transparency between knowledge and individual action. With improved policy initiatives and health campaigns that remedy misperceptions and provide concrete steps, individual consumers could take steps to minimise potential exposure to environmental risks, such as agricultural runoff contaminating drinking water supplies. Thus, the gap between environmental risk and health literacy may be reduced. Nevertheless, while enhanced public education and awareness may empower some individuals to make healthier choices, just as campaigns targeting water conservation led some to install tanks and grey water systems (Ferguson et al 2013), a systemic approach may be simultaneously required to facilitate active engagement.

To improve adoption of decentralised water systems, like tanks, education campaigns need to address anticipation related emotions related to perceived risks and further education should occur early in the process, before mandatory adoption of a system (Mankad 2012). For instance, as Mankad's (2012) example of an education campaign including guided tours of recycled water plants in Singapore revealed, there is value to increasing the public's sense of ownership of new initiatives, such as recycled water technology. Sense of ownership may be enhanced in the general public through the creation of incentives that encourage individuals and groups to actively engage with initiatives. Thus, we recommend one way to improve the public's 'sense of ownership' for their water-related health literacy is for water providers to highlight the activities and technological advances made possible in their industry with the changes and/or initiatives undertaken by their customers. Through 'attribute framing' of promotions, the sense of ownership created and conveyed by notable, pioneering consumers may serve as an incentive to others, thereby encouraging them to play a more active role in discussing and safe-guarding individual and collective water supplies.

Conclusions

We have shown that proximity to agricultural activities affects an individual's capacity to perceive the potential impact of those activities on drinking water. Those geographically closer to agricultural activities were more aware of the potential for pesticide and animal

effluent runoff to contaminate drinking water supplies than their distal urban counterparts. We suggest consumer perceptions are largely shaped by inadequate knowledge, due to a dearth of relevant information, which is needed to make an informed decision about their drinking water consumption practices. Our findings indicate that authorities in other regions may wish to evaluate their water quality information strategies to ensure that consumers located away from potential contaminating sources (e.g. farms, industrial areas and mines) are adequately aware of potential impacts on their drinking water quality. Further research is needed to determine the most appropriate strategies for a given issue in a given area as the most appropriate strategy will need to consider the nature of the contaminant (risk) and the intended audience, in a culturally and proximity relevant manner. In conclusion, for Australians, while the additions to the ADWG are a good step towards enhancing the management of centralised water supplies, they provide inadequate guidance or impetus for government agencies and/or suppliers to engage with communities on matters that affect both self-managed as well as centralised water supplies. Finally, we note that without such knowledge transparency, consumers will not be able to enhance their health literacy as it relates to this most essential of resources, drinking water.

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