WATER QUALITY AND PUBLIC HEALTH

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I have been asked to speak about progress in health-related water research over the period when Nancy Millis was Chair of the Co-operative Research Centre (CRC) for Water Quality and Treatment. My own background is in microbiology and genetics, and I had heard of Nancy through her work on regulation of recombinant DNA technology, but it was not until the formation of the CRC in 1995 that I became personally acquainted with Nancy and with water quality research. Before that time, tap water was something that I took for granted – you simply turned on the tap and clean, good tasting water came out. As a microbiologist I was, of course, aware of the existence of waterborne diseases but I assumed that nowadays these were only a problem in developing countries, and that supplying safe drinking water in a developed country such as Australia must surely be a fairly simple matter.

However, within a few short months of involvement with the CRC my naïve ideas were corrected and I learned that ensuring the safety of drinking water supplies is certainly not a simple undertaking, but something that needs very careful management. It is now well over a hundred years since contamination of water with faecal microorganisms was recognised as a threat to public health, and we may sometimes be tempted to think that in the intervening time we have learned all there is to know about managing microbial risks. However, when it comes to water quality, new and unexpected issues continue to arise which test our knowledge and our management resources. In the brief time available today I want to outline just one example where a new challenge to public health was recognised, and a coordinated research effort across a range of scientific disciplines was needed in order to understand and manage this issue.

The challenge I am speaking of was the sudden emergence of a new waterborne pathogen called *Cryptosporidium* around the same time that the CRC was formed. This organism is a protozoan parasite, and when excreted in faeces it is contained within a tough outer shell which protects it against adverse environmental conditions. Unfortunately for us, another thing that this shell protects it against is the action of chlorine, the most commonly used disinfectant for water supplies. This means that chlorination, which is effective against most waterborne pathogens, does not provide a barrier against *Cryptosporidium*.

This “bug” was discovered in the early 1900s and subsequently isolated from a range of different animals including mammals, birds and reptiles. Undoubtedly it had been around and causing illness long before we knew of its existence; however, we didn’t even realise it could cause infections in humans until 1976. At first it seemed that *Cryptosporidium* was what we term an “opportunistic pathogen”, meaning it could only infect people with seriously weakened immune systems. However, as diagnostic methods improved, we came to realise that it also caused gastroenteritis in the general population. In the 1980s it was recognised as the cause of a number of waterborne outbreaks in North America and Europe, and in 1993 it was responsible for a massive waterborne outbreak in the city of Milwaukee in the US, which caused gastroenteritis in an estimated 400,000 people out of a population of 1.6 million. This outbreak led to major changes in drinking water regulations in the US.

However, as well as these documented outbreaks, there had also been other occasions when *Cryptosporidium* was detected in water supplies with no evidence of disease outbreaks in the community. Assessing public health risks was very difficult due to limitations in scientific knowledge:

- *Cryptosporidium* cannot be grown on an agar plate or in broth culture in the lab, so this makes it more difficult to study than bacteria which we grow easily in the laboratory.
- as I mentioned before, *Cryptosporidium* was known to occur in many species of animals. Most of these isolates looked identical in appearance down a microscope and molecular analysis methods were at a fairly rudimentary stage in the mid-1990s, so it was difficult to distinguish one isolate from another.
- as a result we were not sure whether all of the animal hosts in water catchments could transmit *Cryptosporidium* infection to humans.
- there were no accredited methods for isolating the organism from water samples, or determining whether it was alive and able to cause infection. A number of laboratories had developed their own methods and quality assurance measures, but there was no independent comparison or validation of these.

In 1995 the level of awareness about *Cryptosporidium* in the Australian water industry was rather variable – some people had heard of the organism and the Milwaukee outbreak and realised that sooner or later this would become an issue for the Australian water industry, while others remained in a state of blissful ignorance. This state of bliss was well and truly shattered in 1998 when *Cryptosporidium*, together with another pathogen called *Giardia*, was detected in the water supply for Sydney. This led to a series of “boil water” alerts over a period of three months, with great disruption and costs to households and businesses. Some of you may recall the newspaper headlines of the time.

Despite the alarm raised over the water contamination, the evidence from an active health surveillance program showed that these events were not accompanied by an outbreak of disease. In hindsight we might say a “boil water” alert was not needed; however, due to the limitations in knowledge, the health authorities in Sydney really had no choice but to assume the worst and issue a “boil water” alert in order to protect public health.

I am glad to say that in the subsequent years scientific knowledge about this organism has improved markedly, and a great deal of that knowledge has been generated here in Australia, under the umbrella of the CRC for Water Quality and Treatment. This has involved studying the molecular biology of the organism and its animal host range, characterising risk factors for human infection, and studying how it is transported through the water supply chain.

As a result of this work we now know that:

- the major hosts for *Cryptosporidium* that can infect humans, are humans, cattle and sheep. About two-thirds of infections come from *Cryptosporidium hominis*, a species that only infects humans. *Cryptosporidium* from other mammals, birds and so forth poses a much lower risk for people with a normal immune system.
- the majority of cases in the community have been shown to arise from person-to-person transmission (this is the case for most infectious diseases) and contamination of water in swimming pools from swimmers themselves,
- catchment protection or well operated water filtration provide an effective barrier against transmission through drinking water,
- we have a good understanding of how *Cryptosporidium* behaves in catchments and dams, and how we can optimise its removal by water treatment,
- a National Association of Testing Authorities (Australia)(NATA)-accredited test method for isolating *Cryptosporidium* from water has been developed along with a laboratory proficiency program,
- a number of genotyping methods have been developed which can distinguish those species most likely to infect humans. The CRC organised an international comparative trial of several methods, and a method developed in the Veterinary School at The University of Melbourne proved to be the most highly discriminating methods for separating strains.
- a cell culture technique for assessing human infectivity is also available.

Thanks to this research knowledge, we are now in a much stronger position to assess and manage public health risks from *Cryptosporidium*. Water suppliers are better able to identify sources of *Cryptosporidium* in catchments and understand how to manage risks to their system.

Public health agencies have also benefited from these advances. In fact during the past few years there have been at least two occasions where Australian state health agencies have made a decision not to call "boil water" alerts for major population centres when *Cryptosporidium* was detected in the water supply, because they now had sufficient information and confidence in scientific risk assessments to make a judgement that there was not a risk to human health.

Many innovative techniques were developed in the course of this work on *Cryptosporidium*, but I think perhaps the award for the most novel invention should go to the researchers in the CRC's Catchment Program who are now internationally renowned as the inventors of the "artificial cow pat". All you need to make one of these is 1 kg of gamma-irradiated cow manure, about 10 million *Cryptosporidium* oocysts and a 19 cm spring-form cake tin (Fig. 1).

These cow pats were used to study how rainfall intensity and the slope of the land surface affects the breakdown of manure and the transport of *Cryptosporidium* into water supplies. The research also showed how vegetation (even rather patchy grass cover) can act as an effective barrier to reduce water contamination (Fig. 2).

I hope that this brief summary of the *Cryptosporidium* issue has given you some idea of how new challenges to water quality can arise unexpectedly, and how responding adequately to such issues requires building up a body of scientific knowledge from many research disciplines. The current water shortages in Australia are bringing a range of new challenges for the water industry and health agencies to deal with. As water levels fall in dams and rivers we face deteriorating water quality and increasing risk of blue-green algal blooms in these traditional water sources. In addition we must also deal with potential issues arising from increasing use of alternative water sources in our cities and towns. We are now using sources such as greywater, stormwater, rainwater and recycled water for non-potable purposes to conserve drinking water supplies. All of these sources are of lower microbial and chemical quality than conventional tap water supplies and so careful management is needed to ensure their use does not compromise public health. In supplying these types of water to the public we also need to make allowance for the accidental or deliberate use of the water for unintended purposes. For example a recent survey in the Rouse Hill estate in Sydney (a housing development with recycled water supplied for toilet flushing and outdoor use) showed that 16% of people with swimming pools used the recycled water to fill or top up their pool, even though this is not a recommended use. We also know that children swallow a considerable amount of water while swimming - as much as 150 ml per swim.

A great deal of effort is put into risk management for these dual reticulation housing estates to reduce the chance that pipes will mistakenly be connected the wrong way round (cross-connection) so that recycled water comes out of the drinking water tap. In the Rouse Hill estate all houses are audited to make sure plumbing is correct before permission is given for people to move in. However, even the best efforts cannot completely avoid cross-connections. In a recent incident at Rouse Hill, most houses in a street had already been built and occupied, but one house

Fig. 1. Preparation of artificial cow pats.

Fig. 2. Testing the effect of vegetation cover on release of *Cryptosporidium* from artificial cowpats during rainfall events.

was being built later than the others. Wrongly connected pipes in this house (which had not had its final audit as it was still under construction) resulted in recycled water being supplied from drinking water taps in about 80 surrounding houses. This situation existed for a couple of weeks before people complained about the taste and the problem was discovered. So we must always be aware that even when we supply water for non-drinking purposes, it is inevitable that someday someone will end up drinking it.

Some of the risks from this changing water supply situation can be anticipated and planned for, but as the example of *Cryptosporidium* illustrates, it is likely that completely new and unexpected issues will arise sometimes and we need to have the capacity to respond to these new challenges and rapidly generate the scientific knowledge needed to understand and manage them.

As noted by previous speakers, the CRC for Water Quality and Treatment ended in the middle of 2008, and it has been succeeded by a new organisation called Water Quality Research Australia Limited. We are very glad that Nancy Millis will be involved with WQRA, as a member of its Scientific Advisory Committee, and that we will benefit from her knowledge (and occasional pithy comments) to keep us on track.