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The Quality of Sydney's Drinking Water: Current Issues

by

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EXECUTIVE SUMMARY

There are four main characteristics of drinking water used to describe its quality. These are: physical; microbiological; chemical; and radiological (page 1). Each of these four areas are very important in their own right. However, in Sydney, lately specific attention has been paid to the microbiological characteristics of drinking water (pages 8-15).

The protozoan parasites Cryptosporidium and Giardia have recently been detected in the distribution system of Sydney Water, leading to boil water alerts in the community (pages 17-24). The ingestion of the cysts of these organisms, which is the environmentally resistant stage of the pathogen, can result in diarrhoea and stomach cramps in affected persons. There is no treatment available for disease caught from Cryptosporidium, the body naturally repels the parasites after a period of time. However, in the immuno-suppressed, the body is less able to do this and death may result (pages 9-14).

Current drinking water guidelines in Australia provide little assistance for water supply authorities in relation to the presence of Cryptosporidium or Giardia in drinking water. Developments overseas, notably the United Kingdom and the United States, have provided some guidelines on international best practice for the presence of these pathogenic organisms in drinking water (pages 27-33).

Outbreaks of disease resulting from Cryptosporidium and Giardia contaminated drinking water have occurred around the world. In Milwaukee in the United States, a contamination event in 1993 resulted in over 400,000 people sick and 104 people died. In Sydney, while these organisms have recently been detected in the water distribution system, no increase in disease has been identified.

Modern water treatment plants like Prospect Treatment Plant should be able to remove 99% of Cryptosporidium oocysts. However, the Sydney Water Inquiry has concluded that this does not appear to be the case, and further disinfection technologies may need to be investigated for the Sydney water supply (pages 19-24). The source of the pathogenic organisms in the Sydney water supply is yet to be finally determined. Overseas, with similar outbreaks it has proved impossible to pinpoint the source of water contamination. In Sydney, considerable work can be done to improve the catchment management of Warragamba Dam, helping to eliminate some potential sources of contamination for the city’s water supply (page 33).

1.0 Introduction

In New South Wales there are about 120 water treatment plants responsible for the supply of safe and palatable drinking water. The Department of Land and Water Conservation manages around 97% of these plants. Dam storages supplying water to treatment plants account for 86% of the raw water supplied. However, when the Sydney metropolitan area plants are excluded, this figure is reduced to 51%. While dams contribute the greatest volume, rivers are the most common source of drinking water in the State.[1]

This paper discusses: the regulatory standards of drinking water; the treatment of drinking water; micro-organisms found in water supplies; analysis of outbreaks of water-borne disease overseas and current problems facing Sydney water supply. Both the United Kingdom and the United States of America are currently reviewing their standards and regulations in regard to pathogenic micro-organisms, and these are reviewed in section 6.

1.1 The Characteristics of Water

A wide range of characteristics are used to describe the quality of water. These include:

- physical
- microbiological
- chemical, including inorganic, organic and pesticides
- radiological

The physical characteristics include colour, turbidity, hardness, total dissolved solids, pH, temperature, taste and odour and dissolved oxygen.

For the purposes of this paper, one of the most important physical characteristics to take note of is turbidity. Turbidity is caused by the presence in water of fine suspended matter such as clay, silt, plankton and other microscopic organisms. High turbidity can result in the water having a muddy or milky appearance. Turbidity is measured in terms of Nephelometric Turbidity Units (NTU), with the detection limit about 0.1 NTU. In major Australian water systems turbidity ranges between 5 NTU and <1.0 NTU where supplies are filtered, and between 1 NTU and 65 NTU where supplies are not filtered.[2]

Consumption of highly turbid water is not necessarily a health hazard in its own right. However, suspended particles may harbour micro-organisms, can interfere with the detection of bacteria and viruses, and protect micro-organisms from disinfection.

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1 Van Anen,M and Dharmappa,H, "A Survey of Water Treatment Plants in New South Wales." in *Water*, Vol 24 No 6 Nov/Dec 1997.

2 National Health and Medical Research Council and Agriculture and Resource Management Council of Australia and New Zealand, *National Water Quality Management Strategy, Australian Drinking Water Guidelines*. 1996.

Section 4.0 of this paper discusses the microbiological characteristics of drinking water.

2.0 The Regulation of Drinking Water

In 1980, for the first time, water supply and health authorities combined together to produce guidelines for drinking water in Australia.[3] In the guidelines it was noted that water quality regulation is the responsibility of the State and Territory health authorities. The guidelines were just that, and to date the responsibility for determining appropriate standards for drinking water rely on the States. Two types of guideline values have been determined. The first is a health related guideline value, which is the measure of a water quality characteristic that, based on present knowledge, does not result in any significant risk to the health of the consumer over the a lifetime of consumption. The second, referred to as an aesthetic value, is the measure of a water quality characteristic that is associated with good quality water.

The guidelines note that the quality of drinking water is determined by three main characteristics: physical, chemical and microbiological. The 1980 guidelines assist authorities by providing the following: basic water quality levels regarded as acceptable under Australian conditions; the long term goal towards which authorities could aim; and an indication of levels above which investigation should be initiated.[4] The guidelines include information on these three levels for the above three determinants of drinking water quality.

In 1987, a revised edition of drinking water guidelines was released.[5] Again, the publication emphasised that the guidelines were not for regulatory purposes and the values given should not be construed as standards. However, the guidelines do state that the achievement of those values will ensure that drinking water is generally aesthetically acceptable and does not carry any significant risk to the public. The guidelines present acceptable levels for the same indicators as the 1980 edition, that is, microbiological, physical, chemical and radiological characteristics. There appears to be a greater recognition in the 1987 guidelines that the microbiological characteristic of water is the most significant of the four in regards to public health.[6]

These guidelines note that microbial pathogens which may be found in water include Giardia. It continues that water supply authorities should give careful consideration to their microbiological monitoring programs. However, in regard to microbiological guidelines, only numerical values for coliforms are provided. This provides an indicator of sewage contamination.

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3 National Health and Medical Research Council and Australian Water Resources Council, *Desirable Quality for Drinking Water in Australia*. 1980.

4 National Health and Medical Research Council and Australian Water Resources Council, *Desirable Quality for Drinking Water in Australia*. 1980, at 1.

5 National Health and Medical Research Council and Australian Water Resources Council, *Guidelines for Drinking Water Quality in Australia*. 1987.

6 The guidelines actually state that the microbiological character of water is important and discuss this characteristic first.

In 1996, the latest edition of drinking water guidelines was released.[7] Again, the guidelines note that they are not mandatory standards but represent a framework for identifying acceptable water quality through community consultation. The guidelines state that the following should be made available to the public:[8]

- a Drinking Water Management Plan, which should provide details of system management, monitoring, performance assessment, reporting, planned improvements, contingency plans and levels of service;
- annual reports;
- contingency plans for emergency situations, including procedures for notification when water quality poses a health risk.

The 1996 Guidelines provide extensive background material on the microbiological quality of drinking water. It is noted that pathogenic organisms may enter water supplies at every stage of the collection and distribution cycle. The guidelines stress that water sources must be protected against faecal contamination. In addition, the following barriers should be used to prevent pathogen transmission:

- the water sources selected should be protected from contamination by human or animal faeces and an active catchment protection program maintained;
- the water should be pre-treated, for example by detention and settling in reservoirs for sufficient time to allow bacteria to die off (3-4 weeks);
- water storages should be protected;
- coagulation, settling, and filtration should be carried out;
- the water should be disinfected before it enters the distribution system. This is of paramount importance;
- an adequate disinfectant residual should be maintained throughout the distribution system;
- the distribution system should be secured against possible re-contamination. This entails ensuring the integrity of the pipe system, vermin proofing water tanks, and

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7 National Health and Medical Research Council and Agriculture and Resource Management Council of Australia and New Zealand, *National Water Quality Management Strategy, Australian Drinking Water Guidelines*. 1996.

8 National Health and Medical Research Council and Agriculture and Resource Management Council of Australia and New Zealand, *National Water Quality Management Strategy, Australian Drinking Water Guidelines*. 1996, at 1-6.

preventing backflow.

2.1 The Regulation of Drinking Water in Sydney

Sydney Water is a State Owned Corporation and was corporatised on 1 January 1995 under the *Water Board Corporatisation Act 1994*. This Act provides for the establishment of the corporation, its objectives and provides the necessary powers for its operation. The *Water Board Corporatisation Act* provides for the separation of the shareholding Ministers, the operating licence Minister and the regulatory Ministers. The operating licence Minister is the Hon Craig Knowles MP, Minister for Urban Affairs and Planning. The regulatory Ministers are the Hon Dr Andrew Refshauge MP, Minister for Health; the Hon Pam Allan MP, Minister for the Environment; and the Hon Richard Amery MP, Minister for Land and Water Conservation.

Sydney Water Corporation is under the control of a Board of Directors, of which there are seven. The Board members are appointed by the voting shareholders, except for the Managing Director who is appointed by the Board.

The *Water Board Corporatisation Act* established four key elements to the regulatory framework. These are: the Operating Licence; the Customer Contract; the Licence Regulator; and Memoranda of Understanding with the regulatory bodies.

The Operating Licence was given in 1994 upon corporatisation of the old Water Board. It sets out the operating and customer standards to be met by the Corporation in running its business. It defines the terms and conditions under which the Corporation can operate, and defines the guiding principles for relationships with its regulators. The Operating Licence requires water supplied for drinking purposes to immediately meet the 1980 Australian drinking water guidelines. It also requires drinking water to meet the 1987 Guidelines according to an agreed timetable to be negotiated in accordance with the Memoranda of Understanding with NSW Health.[9]

The Customer Contract spells out the rights and responsibilities of both customers and Sydney Water. With the exception of certain events (drought, events beyond control, and non-compliance with Contract) if a customer experiences a discontinuity of supply of a water or sewerage service due to a problem in Sydney Water's system, the customer is entitled to an automatic 10% rebate on the water/sewerage service availability charge if the discontinuity lasts more than 1 hour without notice or six hours if notice is given. Where eligible, a customer is entitled to a rebate for each and every incident which is experienced.[10]

The Licence Regulator is an independent statutory body established to advise the Minister and Parliament on the Corporation's licence against the operating standards as set out in its

9 Sydney Water, *Operating Licence*, December 1994.

10 Sydney Water, *Customer Contract*, at 9.

operating licence. The Regulator is responsible for an annual independent audit of the Corporation. The audit is tabled in Parliament.

The *Water Board Corporatisation Act* requires Sydney Water to enter into a separate Memorandum of Understanding with each of its regulators. These include: the Environment Protection Authority, NSW Health and the Water Administration Ministerial Corporation (Dept. Of Land and Water Conservation). The Memoranda with NSW Health is of particular relevance to this paper.

NSW Health has statutory responsibility for protecting public health. It is responsible for regulating Sydney Water in relation to the provision of safe drinking water. Under the *Public Health Act 1991*, the Minister for Health has emergency powers to restrict or prevent the use of water which is unfit for drinking. The Minister's power has been delegated to the Chief Health Officer of NSW. NSW Health also regulates Sydney Water through the Memoranda of Understanding which Sydney Water's operating licence requires it to enter.

The Memoranda of Understanding between Sydney Water and NSW Health, which took two years to complete, was signed on 11 November 1997. The Memoranda committed Sydney Water to meeting the health related criteria of the 1996 Drinking Water Guidelines by mid 1997. The Corporation is also committed to immediately notifying the Department of any water system event or monitoring results which indicate the potential existence of a public health hazard.[11]

Sydney Water also developed a draft Interim Drinking Water Quality Incident Management Plan. The Plan includes a list of contaminants and their concentrations which would trigger a routine, significant or major incident. In raw water, more than one and less than 100 oocysts of Cryptosporidium and Giardia per 100 litres triggers a routine incident; more than this triggers a significant or major incident. In filtered water, 1 oocyst per 100 litres triggers a significant incident and more than this triggers a major incident.[12] NSW Health has recommended the notification of all filtered and raw water incidents involving Cryptosporidium and Giardia.

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11 Memorandum of Understanding Between Sydney Water Corporation and NSW Health. Section 7.7

12 McClellan, P. *Sydney Water Inquiry. Second Interim Report. Management of the Events.* NSW Premier's Department. September 1998, at 23.

3.0 The Treatment of Drinking Water

Water treatment plants can significantly reduce the number of water-borne organisms in drinking water. After initial fine screening water will still contain suspended solids, each particle of which has a negative charge. As like charges repel, the suspended solids tend not to aggregate together and settle out of the water column. Standard practice in a treatment plant is to add a coagulant and flocculant (such as ferric salts), which helps bind particulate matter together, followed by sedimentation and filtration. Filtration may be through sand or a combination of anthracite and sand. There are two types of filter used in water treatment: rapid or slow sand filters. Rapid sand filters contain coarse grades of quartz sand (1mm in diameter) so that the gaps between the grains are comparatively large. This ensures that the water passes rapidly through and at a rate about 50 times that of a slow sand filter. When the filtration rate becomes too slow the filters must be cleaned. This is done by backwashing with clean water. Gray reports that immediately after backwashing there is an increased risk of pathogenic organisms penetrating the filter. It may take up to thirty minutes for the filter to regain optimum efficiency. In addition, Gray notes that the backwashing should not be recycled through the plant.[13] Granular or activated carbon may also be added to remove taste and odour compounds and algal toxins. Water with high sediment loadings requires sedimentation and filtration before disinfection to increase the efficiency of disinfection. The filtration also removes the majority of the large protozoan cysts.[14] Other studies have shown that well operated conventional water treatment processes are capable of achieving better than 99% removal of Cryptosporidium oocysts, which would reduce concentrations in final waters to either non-detectable or barely detectable levels.[15]

Following filtration a disinfectant needs to be added to the water. The 1996 Guidelines state that the ideal disinfectant should:

- effectively remove pathogens over a range of physical and chemical conditions;
- produce a disinfectant residual which is stable and easily measured;
- produce no undesirable by-products
- be easily generated, safe to handle, and suitable for widespread use;
- be cost effective.

The Guidelines note that none of the disinfectants currently available meet all of these requirements. Each of the major disinfectants used around the world are discussed below.

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13 Gray,NF *Drinking Water Quality. Problems and Solutions*. John Wiley and Sons, England, 1994, at 94.

14 National Health and Medical Research Council and Agriculture and Resource Management Council of Australia and New Zealand, *National Water Quality Management Strategy, Australian Drinking Water Guidelines*. 1996, at 5-3.

15 Foundation for Water Research (UK) *Removal of Cryptosporidium oocysts by water treatment processes, Summary*. Report No FR 0457, April 1994. See Internet site: http://www.atlas.co.uk/listons/crypto/fr0457.htm

It is noted that the addition of any disinfection process represents a risk trade-off between eliminating pathogenic organisms and having the presence of any potential disinfection by-products in the drinking water. Section 6.2 of this paper discusses water treatment options further by examining treatment in the United States.

Chlorine

Chlorine was introduced as a water disinfectant early this century and still remains the major chemical used for this purpose around the world. It is a strong disinfectant with excellent bactericidal properties and is effective at short contact times. It is very easy to apply either as a gas or as hypochlorite (which can be in either a powder or liquid form). However, chlorination is not effective against Cryptosporidium oocysts.

In the chlorination process it reacts with naturally occurring organic matter to produce a complex mixture of by-products, the main one being trihalomethanes. A number of epidemiological surveys have suggested an association between water chlorination by-products and various cancers, particularly cancer of the bladder and rectum. The 1996 Guidelines notes that there is insufficient data to determine concentrations at which chlorination by-products might cause an increased risk to human health.[16] However, as discussed in section 6.2, the United States is due to release regulations governing chlorine byproduct concentrations in drinking water by November 1998.

Chloramines

Chloramines are formed when chlorine and ammonia are added to water. There are several types of chloramines including monochloramine and dichloramine. Monochloramine is a weak disinfectant, requiring 25 to 100 times the contact time of free chlorine for equivalent disinfection. However, chloramine persists in distribution systems and continues to disinfect in the extremities of long systems. The increased stability of chloramines can be a disadvantage. Low levels of chloramines are acutely toxic to a variety of aquatic organisms and this must be considered when introducing chloramines to storages and aquariums.

Ozone

Ozone is created at the water treatment plant by passing an electric discharge through clean dry air or oxygen. The resultant ozone is a very strong biocide and oxidising agent and is effective in reducing colour, iron, manganese, taste and odour. It is more expensive than chlorine, has low solubility in water, and is unstable above a pH of 8. Consequently, a residual cannot be maintained in a distribution system. By products of ozonation include formaldehyde and acetaldehyde. Ozone also breaks down the naturally occurring organic matter in water, causing it to become a nutrient source for bacteria. It is possible that the use of ozone, while inactivating Cryptosporidium , could stimulate the growth of bacteria in the distribution system. Some of these bacteria may cause disease, particularly in those

16 National Health and Medical Research Council and Agriculture and Resource Management Council of Australia and New Zealand, *National Water Quality Management Strategy, Australian Drinking Water Guidelines*. 1996, at 3-3.

people with suppressed immune systems.[17]

In Europe, ozone has a long history of use for disinfection and for the control of taste, odour and colour. Interest in ozonation has increased significantly in the United States in recent years since the adoption of stringent limits for trihalomethanes. Ozone has not been used in Australia to date for the disinfection of sizeable potable water supplies.

Ultraviolet Irradiation

Ultraviolet light is generated by low pressure mercury lamps. UV irradiation disrupts the chemical bond of many organic molecules and is a potent disinfectant. Micro-organisms may become viable again in the presence of normal light if UV disinfection is inadequate. The major disadvantage of UV is that it leaves no residual disinfectant. UV irradiation has a minimal effect on the chemical composition or taste of the water, and overdosing presents no danger.

4.0 Micro-organisms in Drinking Water

The 1996 Guidelines for Drinking Water note that there are many different organisms that can contaminate drinking water. The most common and widespread health risk associated with drinking water is contamination, either directly or indirectly, by human or animal excreta, and with the micro-organisms contained in faeces. The following types of micro-organisms have been identified as pathogens:[18]

- Bacterial Pathogens: the human bacterial pathogens are excreted and can be transmitted by consuming contaminated drinking water. Those which present a serious risk of disease include Salmonella species, *Escherichia coli*, *Vibiro cholera* and Campylobacter species. In addition, various bacteria which occur naturally in the environment may cause disease opportunistically. Those most at risk include in the young, old and those with impaired immune systems.

- Viruses: the viruses of most significance in relation to drinking water are those that multiply in the human intestine and are excreted in large numbers in the faeces of infected individuals. Human enteric viruses occur in water largely as a result of contamination with sewage and human excreta. Proper water treatment and disinfection should result in drinking water which is virtually virus free.

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17 San Francisco Public Utilities Commission, Cryptosporidium White Paper. See internet site: http://www.ci.sf.ca.us/puc/html/crypto.htm

18 National Health and Medical Research Council and Agriculture and Resource Management Council of Australia and New Zealand, *National Water Quality Management Strategy, Australian Drinking Water Guidelines*. 1996, at 2-3.

- Protozoa: the great majority of protozoa in fresh water are natural aquatic organisms of no significance to health. They generally feed on other micro-organisms such as bacteria or algae. However, two groups of free-living amoebae have been responsible for serious disease in Australia. Cerebral infection by *Naegleria fowleria* is strictly water-borne, and although rare is usually fatal. Acanthamoeba species cause both cerebral and corneal disease. Enteric protozoa may be found in water following direct or indirect contamination with human or animals faeces. Two enteric protozoa causing severe disruption to the Sydney water system are *Cryptosporidium parvum* and Giardia. Both of these organisms are described in greater detail below.

4.1 Cryptosporidium

The parasite Cryptosporidium was first discovered in 1907. There are numerous species of Cryptosporidium, but only *Cryptosporidium parvum* (*C.parvum*) is known to infect humans, possibly resulting in the disease Cryptosporidiosis. *C. parvum* infects the small intestine of a wide range of mammals, predominately neonate animals. The one exception is humans, where the host can be infected at any time during their lifespan and only previous exposure to the parasite results in either full or partial immunity to challenge infections.

The life cycle of *C. parvum* begins with the ingestion of the oocyst. Each oocyst contains four infective stages called sporozoites, which are protected from environmental extremes by the thick cell wall of the oocyst. Once ingested, the sporozoites exit the oocyst in the small intestine, and penetrate individual cells that line the intestine. The sporozoites go through a series of reproductive stages, ultimately forming a zygote which is then surrounded by a resistant oocyst wall. This oocyst is then expelled into the environment with the faeces of the host animal or human. Each generation of *C. parvum* can develop and mature in as little as 12-14 hours. Due to the rapidity of the life cycle huge numbers of organisms can colonise the intestinal tract in several days. The interval between infection and the first appearance of oocysts in the faeces is generally four days. Oocysts are generally shed in the faeces for 6 to 10 days in humans with normal immune systems, but may be prolonged in the immune-suppressed. Experiments on calves indicate that a four day old calf infected orally with 25 million oocysts can easily produce 50 billion oocysts within a one week period.[19]

Oocysts of *C. parvum* are widespread in the environment and can be found in lakes and streams. However, oocysts may be unviable due to age, exposure to ultraviolet light, or freezing. The oocysts can remain dormant for months in cool dark conditions in moist soil or for up to one year in clean water.[20]

C. parvum causes the disease Cryptosporidiosis, which is acquired from the ingestion of

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19 "Basic biology of Cryptosporidium", see Internet site: http://www.ksu.edu/parasitology. A site provided by Kansas State University, Manhattan.

20 Department of the Environment, Transport and Regions (UK) *Public Health and Drinking Water: Preventing Cryptosporidium getting into public drinking water supplies*, 1998, at Annex A.

oocysts from either human or mammalian faeces. Modes of transmission include contaminated drinking water or beverages, contaminated food, contact with infected people or animals, exposure to contaminated swimming pools and through other recreational water activities.[21] Recently US researchers have found viable *C. parvum* oocysts in oysters in Chesapeake Bay, Maryland. This is the first report of *C. parvum* oocysts isolated from shellfish in a natural environment. To date there have been no reports of human infection of Cryptosporidiosis from oysters or other shellfish, but as these seafoods are often eaten raw it must now be considered a possibility.[22] Child care centres and swimming pools are also recognised as relatively 'high risk' zones. The NSW Health Department recommends that you wash your hands thoroughly with soap and hot water after touching human or animal faeces; using the toilet; changing nappies; having sex; handling animals; and working in the garden and soil as animals may leave droppings. In addition, do not drink water directly from swimming pools, rivers and lakes or ocean as *C. parvum* is not normally killed by the chlorine.[23]

An indication of the characteristics of Cryptosporidiosis can be obtained from human volunteers and epidemics. Only two human volunteer studies have been reported in the literature. In the first of these studies 29 healthy volunteers without evidence of previous infection were fed between 30 and 1 million oocysts. Of the five volunteers fed 30 oocysts only one became infected (as defined by presence of oocysts in stools) but did not develop any symptoms. Of the remaining 24 people fed between 100 and 1 million oocysts, 17 became infected and 11 became ill. Symptoms most commonly experienced were diarrhoea (which lasted for an average of three days), abdominal pain and nausea.[24] The only way to determine if you have Cryptosporidiosis is to have a stool specimen taken and analysed in a laboratory. Because most people recover from the infection without visiting a doctor, they may never know if *C. parvum* was the cause of their illness.[25] Presently, there is no drug that can cure Cryptosporidiosis. Most people with a healthy immune system will recover on their own within a few days.

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21 Researchers in the Milwaukee Health Department have found that puppies have a very high rate of infection by the protozoa Cryptosporidium and Giardia. A survey of stool samples from 300 apparently healthy dogs from vet clinics, boarding kennels and dog clubs found that 7.3% of the animals had Cryptosporidium, and 11.7% had Giardia. Puppies less than 30 weeks old accounted for 90% of the Cryptosporidium isolates, and 76% of the Giardia isolates.

See: *Health Stream: Program 1 Newsletter* - Issue 10 - June 1998. A publication of the Cooperative Research Centre on Water Quality and Treatment.

22 See: "Cryptosporidium found in oysters" in *Health Stream: Program 1 Newsletter* - Issue 9 - March 1998. A publication of the Cooperative Research Centre on Water Quality and Treatment.

23 See NSW Health Internet site: http://www.healthfax.org.au/cryptofs.htm

24 Robertson, et al "Cryptosporidium and Water: What do we Know?" in *Water*, Vol 25 No 4 August 1998.

25 See NSW Health Internet site: http://www.healthfax.org.au/cryptofs.htm

Cryptosporidiosis is a chronic, severe and disabling condition in those with AIDS and others with suppressed immune systems, such as cancer patients. It is associated with prolonged diarrhoea for a median of at least 60 days, abdominal pain, a median weight loss of 13.6 KG, nausea and vomiting. Diarrhoea is frequently severe and as much as 25 litres a day. Cryptosporidiosis significantly shortens the lifespan of those people with AIDS.

Literature from the United States suggests that in industrialised nations, somewhere around 0.4% of the population appears to be passing oocysts in the faeces at any one time. Of those patients admitted to hospital with diarrhoea, 2 -2.5% are passing oocysts. However, the prevalence of antibodies in the population is much higher. In the United States, it is estimated that 30-35% of the population have antibodies to *C. parvum*. In developing countries up to 60-70% of the population may have antibodies to the pathogen.[26]

Australian studies suggest that the rate of gastroenteritis in the community is estimated at about 0.7 episodes per person per year. A survey of four Melbourne laboratories found that *C. parvum* was detected in 1-2% of faecal specimens. Preliminary findings from another study in Melbourne show a rate of 0.5 episodes of gastroenteritis per person per year. Of 298 faecal specimens collected from those with gastroenteritis, 35 had pathogens of which 1.7% were *C. parvum*. Whilst these figures are estimates only, they indicate that if an average person lived for 100 years, he or she could expect 50 cases of gastroenteritis, of which one would be caused by *C. parvum*. Alternatively, in a city like Melbourne of 3 million people, there would be about 1.5 million cases of gastroenteritis from all causes each year, of which about 25,000 may be due to *C. parvum*.[27]

Although low numbers of *C. parvum* oocysts are commonly detected in surface water supplies, Cryptosporidiosis has not been shown to be caused by drinking water in an Australian capital city. For an individual to become ill they need to ingest adequate numbers of viable *C. parvum* oocysts. As noted above, the lowest dose in volunteer studies that has caused symptoms is 100 oocysts, although in risk assessment studies it is assumed that even one oocyst may cause infection. Concentrations of 100 oocysts in a single glass of water are rarely found, and even if they did many may be either non-viable or of other species of Cryptosporidium. An alternative hypothesis is that drinking water does cause Cryptosporidiosis but that it may be too difficult to detect in the community.[28]

Robertson *et al* conclude that knowing the health implications of a positive water sample for *C. parvum* is difficult given our current level of knowledge. Undoubtably, humans appear to have various degrees of susceptibility to the Cryptosporidium parasite and the effective dose required to produce symptoms will vary between individuals.

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26 "Basic biology of Cryptosporidium", see Internet site: http://www.ksu.edu/parasitology. A site provided by Kansas State University, Manhattan.

27 Robertson, et al "Cryptosporidium and Water: What do we Know?" in *Water*, Vol 25 No 4 August 1998, at 19.

28 Robertson, et al "Cryptosporidium and Water: What do we Know?" in *Water*, Vol 25 No 4 August 1998, at 19.

The latest Australian Drinking Water Guidelines were published in 1996 by the National Health and Medical Research Council and the Agriculture and Resource Management Council of Australia and New Zealand. The Guidelines set no value for *C. parvum* oocysts in drinking water, stating that there is only limited and local evidence of the involvement of drinking water in its transmission in Australia, and the density at which it would be significant for human health is unknown. *C. parvum* oocysts are extremely resistant to disinfection, with a significant percentage apparently surviving extensive chlorination. To add to this problem, the small size of the *C. parvum* oocyst makes some filtration processes vulnerable to penetration. The protection of water catchments from contamination by human wastes and if possible by pasture animals should therefore be a priority. [29]

Feedback from international conferences indicates that *C. parvum* is *the* issue facing water supply authorities, especially in the United States and Northern Europe. In response, the American Water Works Association Research Foundation has put in place a five year US$19 million research program, comprising 67 projects on Cryptosporidium.[30] In Australia, a significant research effort is also underway, with one of the major players being the Cooperative Research Centre on Water Quality and Treatment (CRCWQT). The CRC is conducting research in an attempt to provide guidance on the following questions:

- how to interpret source water monitoring data for microbial pathogens in terms of risk;
- what do consumers and professions perceive as an acceptable level of risk;
- how much are Australians prepared to pay for particular risk decrements;
- what level of treatment gives an acceptable risk without costly over-engineering or excessive disinfection by-product formation.

A risk based analysis of a number of water supply systems was performed for the Department of Primary Industries and Energy and Melbourne Water. The final report "Treatment Requirements for Australian Waters" is not yet available. However, broad conclusions of the study were:

- most of the risk arises from particular events (eg, treatment plant failures, storms, pipe breaks);
- the level of risk varies dramatically from day to day as a result of such events;
- system reliability and integrity is of the utmost importance in minimising risk;
- a number of variabilities and uncertainties lead to predicted risk values having very broad probability distributions and confidence ranges.

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29 National Health and Medical Research Council and the Agriculture and Resource Management Council of Australia and New Zealand, *Australian Drinking Water Guidelines. National Water Quality Management Strategy*, 1996.

30 "Conference Reports: International Symposium on Waterborne Cryptosporidium. An Overview" in *Health Stream: Program 1 Newsletter* - Issue 6 - June 1997. A publication of the Cooperative Research Centre on Water Quality and Treatment.

Following on from this work a CRCWQT project is aimed at presenting a framework for the interpretation of microbial pathogen monitoring data in terms of consumer risk.[31] The final report is due November 1998 and hopes to provide the best available framework for assessing and managing the public health risk associated with pathogens in drinking water.[32] This should provide some guidance for Sydney Water and the NSW Department of Health as to when to issue alerts to consumers to boil their drinking water.

The Detection of *C. parvum*

Accurate measurement of *C. parvum* is still very difficult. There is no suitable surrogate for the detection of *C. parvum*. Detection involves the concentration of relatively large volumes of water in several stages, staining the material with a fluorescent dye, and examination of the material using an ultraviolet microscope. Oocysts 'glow' with the stain and can then be counted. However, this method cannot determine whether the oocysts are viable or not. Additional tests using another fluorescent dye can then help decide if the Cryptosporidium oocysts are alive.

How often to test for Cryptosporidium and where in a treatment and distribution system to test is still an issue with no definite answers. The 1996 Australian Drinking Water Guidelines states that routine monitoring for Cryptosporidium is not appropriate.[33] This also shows how quickly the science of water quality treatment is developing. Just two years later in 1998, few scientists would agree with such a statement.

Feedback from international conferences suggests that routine monthly monitoring will give a reasonable indication of median levels of *C. parvum* but will give a poor indication of rare or extreme events which could be the cause of a gastro-intestinal outbreak. Monthly sampling usually misses spikes of *C. parvum* and Giardia, producing highly skewed data where the peaks may be ten times the averages.[34] As discussed in section 6.1 of this paper, the United Kingdom authorities are proposing that water treatment plants operate a continuous monitoring program for Cryptosporidium.

4.2 Giardia

Giardia has been known as a human parasite for over 200 years, but has only been seriously

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31 The project is titled: "Development and Evaluation of a Risk Assessment Model to Estimate the Incidence of Cryptosporidiosis and Campylobacteriosis in Drinking Water."

32 "Monitoring data for Cryptosporidium and Campylobacter in drinking water - what does it all mean?" in *Water Quality News, The Quarterly External Newsletter of the CRC for Water Quality and Treatment*, Issue 4 Autumn 1998.

33 National Health and Medical Research Council and the Agriculture and Resource Management Council of Australia and New Zealand, *Australian Drinking Water Guidelines. National Water Quality Management Strategy*, 1996, at FS-31.

34 "Conference Reports: International Symposium on Waterborne Cryptosporidium. An Overview" in *Health Stream: Program 1 Newsletter* - Issue 6 - June 1997. A publication of the Cooperative Research Centre on Water Quality and Treatment.

regarded as a disease since the 1960s. Ingestion of the Giardia cyst may result in Giardiasis, causing diarrhoea and abdominal pains. Giardiasis is the most frequent cause of diarrhoea in North America. It is thought that only one species of Giardia is responsible for Giardiasis in humans (*Giardia lamblia*), but recent genetic evidence suggests a greater diversity.

The Giardia cyst survives longest in waters of low temperatures. Most water borne outbreaks of Giardia in North America have occurred in cooler areas. The infectious cyst is shed in the faeces of animals and humans, with densities of Giardia cysts as high as 400 per litre in raw sewage and five per litre in river water. In North America, aquatic animals such as beavers are generally considered responsible for contamination of water. Hence it is often referred to as 'Beaver fever'.

While the drinking of contaminated water is the most common means of infection, other forms of transmission include direct contact with infected animals such as dogs and cats, and occasionally through contaminated food. NSW Health states that those most at risk of Giardiasis include child care workers; children who are still in nappies and attend child care; international travellers; bushwalkers and others who drink water from contaminated surfaces.[35]

The ingestion of as little as one cyst may cause disease. The active stage of Giardia is known as a flagellate, which attaches to the intestinal wall by an adhesive disc. Giardiasis may involve diarrhoea within one week of ingesting the cyst. Other symptoms include abdominal cramps and nausea. In otherwise healthy persons normally the illness lasts anything from one to six weeks. However, there are chronic cases where infections have lasted from months to years.[36] There are several prescription drugs available to treat Giardia.

Giardia is more frequent in children than in adults, possibly because many people seem to have a lasting immunity after infection. In the United States, Giardia is implicated in one quarter of gastro-intestinal disease, and the overall incidence of infection in the population is estimated to be two percent.[37] In Australia, outbreaks of Giardiasis most often involve close communal groups, and are probably more prevalent in rural than in urban communities. It is particularly common among Aboriginal groups. Animals in Australia known to carry

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35 NSW Health, *Giardiasis - The Facts*.
See Internet Site: http://www.healthfax.org.au/giardfs2.htm

36 US Food and Drug Administration, *Foodborne Pathogenic Microorganisms and Natural Toxins Handbook. Giardia lamblia.*
See Internet Site: http://vm.cfsan.fda.gov/~mow.chap22.htm.

37 US Food and Drug Administration, *Foodborne Pathogenic Microorganisms and Natural Toxins Handbook. Giardia lamblia.*
See Internet Site: http://vm.cfsan.fda.gov/~mow.chap22.htm.

Giardia include dogs, cats, pigs, pasture animals and native rodents and bandicoots.[38]

Giardia cysts are relatively resistant to chlorination. Therefore the protection of water catchments from contamination by human wastes and if possible by domestic animals should be a priority. Comprehensive treatment, including filtration, of surface water is an important element in protecting water supplies from contamination in North America. In Australia there are no national guidelines for the presence of Giardia in drinking water as the evidence of the involvement of drinking water in its transmission in Australia is limited and local, and the density at which the organism would be significant for human health is unknown.[39]

4.3 Anatomy of a Cryptosporidium Drinking Water Outbreak: Milwaukee

In 1993 a widespread outbreak of *C. parvum* occurred in Milwaukee, Wisconsin, USA. The Milwaukee Water Works, which obtains water from Lake Michigan, provides water to a population of 1.6 million people. The city is served by two water treatment plants, south and north of the city, either of which can serve the city as a whole. At the time of the outbreak, both the plants treated water by: adding chlorine and polyaluminium chloride (a coagulant to enhance the formation of larger particulates); rapid mixing; mechanical flocculation (which promotes the aggregation of particulates to form a solid precipitate); sedimentation and rapid sand filtration. After filtration, the water was stored in a large clear well until it was supplied to customers. Filters were cleaned by backwashing them with water, which was then recycled through the treatment plant.

In the Milwaukee outbreak during late March and early April 1993, *C. parvum* oocysts in untreated water entered the southern water treatment plant and were then inadequately removed by the coagulation and filtration process. One major study estimated that 403,000 people in Milwaukee had watery diarrhoea as a result of this outbreak. Cryptosporidiosis was confirmed by laboratory analysis in more than 600 people. More than half of the people who received drinking water predominantly from the southern water treatment plant became ill.[40] In addition, 104 people with suppressed immune systems died as a result of infection.

During the Milwaukee outbreak, laboratory tests showed that drinking water contained between 13.2 and 6.7 oocysts per 100 litres of water. However, visitors to the Milwaukee city who drank less than one cup of water had laboratory confirmed Cryptosporidiosis, indicating that peak concentrations of oocysts far exceeded one oocyst per litre.

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38 National Health and Medical Research Council and the Agriculture and Resource Management Council of Australia and New Zealand, *Australian Drinking Water Guidelines. National Water Quality Management Strategy*, 1996, at FS-33.

39 National Health and Medical Research Council and the Agriculture and Resource Management Council of Australia and New Zealand, *Australian Drinking Water Guidelines. National Water Quality Management Strategy*, 1996, at FS-34.

40 MacKenzie,W et al "A massive outbreak in Milwaukee of Cryptosporidium infection transmitted through the public water supply." in *New England Journal of Medicine*, Vol 331, No 3, 1994.

The source of the oocysts leading into Lake Michigan and the treatment works is still unknown. Possible sources include cattle along two tributaries, abattoirs, human sewage, and rivers swelled by spring rains and snow run-off. More recent research indicates that human wastes in the water from Lake Michigan was the source of the contamination, especially as heavy rains had resulted in numerous sewer overflows.[41] Why the southern treatment plant did not remove all the oocysts is also unclear. Water quality measurements within the plant were within required limits, and the plant had no evident mechanical breakdown of its flocculators or filters. During the outbreak, for unknown reasons the treatment plant failed to maintain treated water at low turbidity levels. The maintenance of low turbidity and removal of particles under 15 micro-metres in diameter have shown to correlate significantly with the detection of *C. parvum* in water. The treatment plant also recycled the filter backwash water, which may increase the concentration of oocysts in water passing through the filters. This practice has now been stopped.[42]

The authors of the above study recommended that until an accurate, rapid and inexpensive method of detecting *C. parvum* oocysts is available, water treatment plant design and treatment should be improved. They recommended continuous monitoring of turbidity, particularly filter effluent and particle size, and that a goal of reducing turbidity to less than or equal to 0.1 NTU should be targeted. In addition, laboratories should routinely test for *C. parvum* in people with watery stools and that Cryptosporidiosis should be a reportable condition.[43]

As a result of the Milwaukee outbreak, the city has had to upgrade its water treatment plant. Part of this upgrade included installing a $100 million ozone treatment process.

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41 "Human sewage implicated as source of 1993 Milwaukee outbreak. Evidence of a *C. parvum* Strain that affects only Humans." in *Cryptosporidium Capsule*, Volume 3 Issue 1. November 1997.

42 MacKenzie,W et al "A massive outbreak in Milwaukee of Cryptosporidium infection transmitted through the public water supply." in *New England Journal of Medicine*, Vol 331, No 3, 1994. At 166.

43 MacKenzie,W et al "A massive outbreak in Milwaukee of Cryptosporidium infection transmitted through the public water supply." in *New England Journal of Medicine*, Vol 331, No 3, 1994.at 177.

4.4 Anatomy of a Cryptosporidium Drinking Water Outbreak: North East of London

On 2 March 1997 680,000 people in the region north east of London were instructed to boil their water due to *C. parvum* contamination of the underground water supply. Public health officials had noticed a threefold increase in Cryptosporidiosis in the previous week.[44] The alert to boil water continued for 17 days until March 19. By the end of the scare, nearly 300 cases of Cryptosporidiosis were confirmed by laboratory tests, and many other people may have been affected without seeking medical attention. The responsible water company, the French owned Three Valley Water Company, refunded affected households ten pounds for the inconvenience. The source of the contamination was traced to a deep bore which had been contaminated by animal waste.[45]

The United Kingdom Drinking Water Inspectorate has investigated 11 outbreaks of suspected drinking water related Cryptosporidiosis between 1990 and 1997. More than 2000 cases of Cryptosporidiosis were reported with these 11 outbreaks, with two of these outbreaks involving over 500 cases of illness within a period of a few weeks. The Inspectorate notes that the majority of outbreaks were associated with predictable water treatment plant deficiencies that could have been avoided.[46]

5.0 The Sydney Water Crisis

5.1 Background - Sydney's Water Supply System [47]

Sydney's water supply is largely drawn from the catchments of four main river systems: the Upper Nepean; the Warragamba; the Shoalhaven; and the Woronora. The Warragamba system supplies the majority of Sydney's population, although water from the Upper Nepean is carried through the Upper Canal to Prospect. The other systems supply water to residents in the Sutherland Shire, Campbelltown, the Blue Mountains and the Illawarra.

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[44] "Cryptosporidium outbreak near London" in *Health Stream: Program 1 Newsletter* - Issue 5 - March 1997. A publication of the Cooperative Research Centre on Water Quality and Treatment.

[45] "London Cryptosporidium outbreak ends" in *Health Stream: Program 1 Newsletter* - Issue 6 - June 1997. A publication of the Cooperative Research Centre on Water Quality and Treatment.

[46] Department of the Environment, Transport and Regions (UK) *Public Health and Drinking Water: Preventing Cryptosporidium getting into public drinking water supplies*, 1998, at Annex D.

[47] This section has been adapted from: McClellan, P. *Sydney Water Inquiry. First Interim Report. Possible Causes of Contamination.* NSW Premier's Department. August 1998.

Sydney's water supply is delivered by pipeline from Warragamba Dam to Prospect Water Filtration Plant. The Prospect Plant supplies about 85% of Sydney's water. Water supplies for the Penrith, Emu Plains and Lower Blue Mountains area are drawn from the Warragamba pipeline before it reaches Prospect and treated at the Orchard Hills Water Filtration Plant.

Historically, Sydney's water supply has been treated through catchment and storage management policies and using chlorine and chloramines as a disinfectant. However, increasing pressures on the quality of the raw water entering storage dams and increasingly stringent water quality guidelines convinced the then Water Board to move towards a filtration plant system. Tenders for the water filtration plants were selected in November 1992 and contracts were finally signed in September 1993.[48] The Joint Select Committee upon the Sydney Water Board extensively discussed the issues facing the Board in relation to drinking water quality. The Committee noted that catchment management of drinking water storages is a crucial part of the water supply system. The minority Government Members report noted that in 1992 the parasites Cryptosporidium and Giardia were discovered in Water Board storages at levels similar to those which caused public emergencies overseas.[49] This was used as an argument to justify the construction of the water filtration plant at Prospect. However, it has been reported that the Water Board did not specify any requirements for the removal of Cryptosporidium or Giardia in the contracts for the new water treatment plants.[50]

Tenders to build, own and operate water treatment plants for 25 years were subsequently let, and the Prospect Water Filtration Plant is owned and operated by Australian Water Services. The Prospect plant opened in November 1996, serves over 80% of Sydney and can filter up to 3 billion litres of water per day. Prospect filters its water using a process of coagulation, flocculation, filtration and disinfection. The filtration involves passing the water which has been coagulated and flocculated through rapid sand filters, of which there are twenty four. The operations contract target for water turbidity levels are 0.3 NTU or less, with a required rolling average of 0.5 NTU or less.[51]

The rapid sand filtration as used at Prospect can remove 99% of particulate matter. The operators of the Prospect Plant claim that their filters remove at least 99.9% of all Cryptosporidium and Giardia organisms.

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48 "Water Board: Tenders for Water Treatment Plants" Hon John Fahey MP Premier of NSW News Release, 18 November 1992.

"Sydney to get largest water filtration plant in southern hemisphere" Hon Robert Webster MP News Release 22 September 1993.

49 Joint Select Committee upon the Sydney Water Board, *Report*, Dr Peter Macdonald MP, Chair, April 1994, at 100.

50 "Six year warning on parasites" in *The Sydney Morning Herald* 1 August 1998.

51 Henderson,G. "Prospect Water Filtration Plant." in *Water*, Vol 24 No 1 January/February 1997.

Water is distributed from Prospect Water Filtration Plant to Pipe Head by tunnels and mains, with some suburbs supplied directly from these mains. From Pipe Head, water for the inner city, suburbs south of Sydney Harbour and inner western suburbs is carried by tunnel and mains to two large service reservoirs at Potts Hill. From there, water is carried in two tunnels (the Pressure Tunnel and City Tunnel) which terminate at Waterloo and Dowling Street pumping stations. Water for the northern suburbs is supplied by two pumping stations, one at Prospect and one at Ryde.

5.2 The Contamination of Sydney Water Supplies: Summary of the First Event [52]

In late July 1998 Sydney Water was faced with a drinking water contamination event. Both Cryptosporidium and Giardia were detected in the distribution system. As part of the Government response to the event, an Inquiry chaired by Peter McClellan QC was established. Below is a timetable of the contamination event as identified by the Inquiry.

Tuesday 21 July 1998
A low level of Giardia (3 Giardia cysts per 100 litres (3G)) was confirmed at the Prospect Distribution Chamber. Low levels of both Giardia (2G) and Cryptosporidium (2 oocysts per 100 litres (2C) were also found at Potts Hill reservoir. These were detected as part of routine water sampling and under existing arrangements Sydney Water informed the NSW Department of Health. The levels did not raise health concerns. More testing was ordered.

Wednesday 22 July 1998
Tests results showed the all clear except one sample from Sydney Hospital (0C/1G).

Thursday 23 July 1998
Results from a retesting of the Sydney Hospital site showed a higher positive result (43C/19G). Surrounding sites showed all clear. More samples taken that night.

Friday 24 July 1998
Test results from previous night showed the all clear for all areas tested except an outlet at Sydney Hospital (1C/0G) and at the Art Gallery (16C/16G), which are both fed off the same main. At this stage it was considered that a localised contamination problem existed.

Saturday 25 July 1998
Tests results from water taken on Friday showed positive levels at the Art Gallery (10C/106G), Macquarie Street (15C/161G) and Crown Street Pumping Station (10C/5G). Tests were then ordered throughout a wider part of the Sydney distribution system. After flushing of most of the affected area, tests of the first flush water from College street showed high readings (104C/461G).

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52 This section is adapted from: McClellan, P. *Sydney Water Inquiry. First Interim Report. Possible Causes of Contamination.* NSW Premier's Department. August 1998, at 11.

Sunday 26 July 1998
Test results from the previous day showed extremely high levels from Macquarie Street (376C/395G), College Street (170C/332G) and the Art Gallery (200C/963G) and lower levels from Crown Street Reservoir (6C/20G). Test results for Prospect plant, Potts Hill, Thornleigh and West Ryde were negative. However, the City Tunnel at Greenacre showed a low positive result (0C/8G), which was the first positive reading received outside the eastern CBD.

Monday 27 July 1998
A public notice was issued warning persons in the affected area of the Eastern CBD not to drink unboiled water. Tests results from Sunday sampling were received and showed the all clear except at the corner of Liverpool and Crown streets (1C/16G).

Tuesday 28 July 1998
From testing the previous day some further low positive results were received, including Macquarie street (2C/1G), College street (4C/6G) and Crown Street Reservoir (0C/14G). Other Eastern Suburb sites tested negative. A site at Rhodes tested positive (0C/4G).

Wednesday 29 July 1998
Three samples from Potts Hill Reservoir showed two clear and one with a low count (5C/2G). Results from the CBD showed five sites clear and low counts at the Art Gallery (4C/0G), College Street (2C/0G), Macquarie Street (1C/0G) and Crown Street (1C/0G). Llwewllyn street also tested positive (0C/4G).

In the late afternoon, a result from the sediment at Prospect Water Filtration Plant clear water tank No 1, which was offline, showed a high positive reading (96C/42G per four grams of sediment). In the evening, high positive results were received at Potts Hill Reservoir (10C/48G), the City Tunnel (24C/27G) and the Pressure Tunnel at Enfield (12C/136G). Another low count at Rhodes was also received (1C/1G).

In light of these positive readings at sites beyond the Eastern CBD, a public alert to boil all drinking water was issued for people serviced by the Potts Hill system, defined as "an area east of Bankstown - Silverwater; south of the Harbour and north of the Georges River".

Thursday 30 July 1998
A high positive result was received from Palm Beach (365C/151G). A precautionary boil water advice was issued to apply to the whole Prospect system. A high result was also received from at Warragamba Pipeline Number 2 (409C/70G) which was immediately closed. Three positive readings were received at Potts Hill, the highest of which was 273C/109G. A sample at Prospect distribution chamber also tested positive (2C/1G).

Friday 30 July
The Minister for Urban Affairs and Planning Hon Craig Knowles announced the formation of an expert panel to advise on when the water supply was safe.

Sunday 2 August to Tuesday 4 August 1998
Periodic announcements were made lifting the boil water advice for selected postcodes. On 4 August the boil notice was lifted for all areas.

5.3 Possible Causes of Contamination [53]

In relation to the first incident the Sydney Water Inquiry identified five possible causes of contamination. These were:

- A localised contamination event in the eastern CBD. The Commissioner rejected this theory and identified seven reasons for doing so. It was noted that events and testing supported a wider system problem.

- Contamination at Potts Hill Reservoir. This is a major reservoir which is uncovered. The Commissioner concluded that it was unlikely that the reservoir was the source of the contamination. It was noted that there were quite high positive readings above the reservoir.

- Catchment area impacts on the inflow to the Prospect Plant. These impacts included raw water turbidity events associated with rainfall; septic systems in an urban area known as The Oaks draining into the Warragamba Dam; scouring of the Upper Canal during an environmental flow test; dead dogs and foxes found in the Upper Canal; and extraction of water from lower levels of Warragamba Dam that have demonstrated high levels of organisms. The Commissioner concluded that any one or combination of these factors is a likely source of a continuing contamination of the water feeding the Prospect plant. However, the Commissioner doubted whether an event of sufficient significance occurred to cause a large concentration of contaminants to enter the plant and overload the system.

- Contamination at the Prospect Plant. Possible causes in the Plant include: the release of sediment deposits from the inlet chamber during flow surges; loss of dilution water; reducing the effectiveness of the coagulation process; problems in the backwash procedure; and the cleaning of the clear water tanks and the use of a bypass channel. At the time of writing his report, the Commissioner was not persuaded that the plant was the source of the contamination. However, he noted that the plant operated at various times during the event in other than its normal manner, and filtration was at times less than optimum. A fuller understanding of the contamination of the clear water tanks will also need to reached, and the views of the plant operator and Sydney Water considered further before reaching a definite conclusion.

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[53] This section is adapted from: McClellan, P. *Sydney Water Inquiry. First Interim Report. Possible Causes of Contamination.* NSW Premier's Department. August 1998

- Potential impacts downstream from the Prospect Plant. As water leaves the plant it enters the Sydney water system and is carried in two pipelines through a junction chamber. The two pipelines are underground. Whether they are in good condition or whether they could allow inflow is unknown. If they do allow inflow, contamination is possible.

  At the Junction Chamber there is a pipeline leading from the Prospect Reservoir. The pipe has barriers at the Reservoir and a steel separator within the junction chamber. It does not appear to be a secure system. There is evidence of an infestation of bats in the pipeline which could be a source of both Cryptosporidium and Giardia. Water was found in the pipes, and AWS tests indicate the presence of fluoride and chlorine which suggests flows between it and the distribution system. It has been proposed that water from the pipe which contains the droppings could have penetrated the junction chamber.

  In addition, separate tests by Sydney Water have shown that surface water near the pipeline downstream of the Plant may be heavily contaminated. With recent rain the groundwater level has increased. At the same time, with maintenance occurring in the Plant, the pressure in the mains would probably have been reduced. The consequence is that the changes in pressure may allow groundwater to inflow into the water main.

  The Commissioner has ordered further work on the above two possible causes.

5.4 A Second Contamination Event

Not long after the all clear been given by the expert panel for the so called first contamination event, another boil water alert was issued. On 25 August further significant contamination of the water supply was found, and a 'second event' was declared. Mr McClellan QC of the Sydney Water Inquiry noted that this time, the Prospect water treatment plant was operating at optimum performance. Nonetheless, extremely high levels of organisms passed through the plant and were measured in the supply system. The Inquiry noted that in the days preceding the second event, Warragamba Dam received heavy rainfall and the Dam filled from approximately 60% to overflowing within a period of about ten days. With drought like conditions before this down pour, the Inquiry accepted that significant amounts of faecal pollution entered the Dam. In addition, the introduction of water of this volume would have scoured the bottom of the Dam and caused much of the settled material, including oocysts, to enter into suspension.[54]

The Inquiry also noted that the Wollondilly and Cox's Rivers flow into Warragamba Dam and comprise in excess of 60% of the inflow. With heavy rains in the upper catchment, sewage treatment plants at Goulburn, Bowral, Mittagong, Bundanoon and Berrima were all overloaded, and significant volumes of poorly treated sewage were allowed to enter the

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54 McClellan, P. *Sydney Water Inquiry. Second Interim Report. Management of the Events.* NSW Premier's Department. September 1998, at 83.

Wollondilly River. In addition, faecal material was evident in the Cox's River. The heavy rainfall event led to the contamination of Warragamba Dam waters.

Upon release of the Second Interim Report of the Inquiry, the Commissioner concluded that it was unlikely that the first event contamination was significantly contributed to by the introduction of organisms into the network immediately downstream of the Prospect plant. Inspections of the various chambers indicates that any contamination from this source was unlikely to have caused the levels of contamination which were found throughout the system. The Commissioner noted that prior to the first event there was no identifiable rain event which would have caused run-off to bring faecal contamination in sufficient quantities into the raw water supply. A source of contamination is therefore more likely to be the scouring of the Upper Canal, or some other event apparently not associated with other faecal indicators.[55]

The Commissioner concludes that for reasons presently not known, even when the Prospect Plant is operating at optimum levels, it is not able to remove all Cryptosporidium and Giardia oocysts which are introduced in the raw water supply. While the Commissioner accepts that the plant was never designed to achieve total removal of particles, it was believed that it would take out a greater proportion than appears to have occurred during the Second Event. To date, the operators of the plant, Australian Water Services, have not commented publicly on such a conclusion.

No sooner were parts of Sydney given the all clear to drink their water on September 2 1998, than by 6 September a third alert was issued to boil drinking water until September 19. By the week beginning Sunday 20 September, Sydney Water was advising the public that the water was safe to drink without boiling except for the immuno-suppressed, in which case it advised continued boiling of drinking water.

5.5 The Health Effects of the Sydney Water Incident

The Sydney Water Inquiry reports that the level of contamination in the water supply found during the above events were sufficiently high to cause concern that they may have endangered the health of the public. The levels found in the water were at a level which would have resulted in an average consumption of up to ten Cryptosporidium oocysts per person per day.

However, even after intensive investigation by the Health Department no increase in infection with *Cryptosporidium parvum* has been identified. A small increase in the level of Giardia infection has been demonstrated but it is not clear if this is due to the consumption of contaminated water or increased detection of the disease due to increased testing.[56]

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55 McClellan, P. *Sydney Water Inquiry. Second Interim Report. Management of the Events.* NSW Premier's Department. September 1998, at 81.

56 McClellan, P. *Sydney Water Inquiry. First Interim Report. Possible Causes of Contamination.* NSW Premier's Department. August 1998, at 8.

In an attempt to explain the lack of Cryptosporidiosis in people across Sydney, it was reported that health officials considered that the parasites infecting Sydney's water may be a rare strain that was harmless to humans.[57]

5.6 Institutional Response to the Sydney Water Incident

As part of the Sydney Water Inquiry Commissioner McClellan looked at the management of the contamination events by both Sydney Water and NSW Health. He provided both some conclusions on the deficiencies that manifested themselves during the management of the events and some future directions to help ensure that they do not recur.[58]

In particular, Mr McClellan noted that the actions of Sydney Water on the night of the initial contamination event caused confusion and delay in the issue of a confirmed warning for the whole of the Prospect supply system. The Commissioner noted that the level of contamination in the supply system could be life threatening to immune deficient people, and notification was warranted immediately. The actions by Sydney Water to try and limit the alert as issued by NSW Health were influenced by concerns as to the reputation of the Corporation.[59] It could be easily argued that the reputation of the Corporation would have been more damaged had people died from the contaminated water after Sydney Water had tried to retract warnings.

The Commissioner noted that the Memoranda of Understanding between Sydney Water and NSW Health during crucial moments of the event had failed and there was no effective framework for decision making to guide the actions of the two organisations. At the time of the event there was no protocol in place for the issue of a boil water alert. The MoU contains a general definition of what constitutes a contamination event, but a detailed definition had been resisted by both parties. The Commissioner supports proposals to more clearly define what is a contamination incident.

Whilst both Sydney Water and NSW Health had incident management plans in place, in the opinion of Mr McClellan Sydney Water was not prepared for an event of the magnitude of that which was experienced. He concluded that the incident management documents did not serve as an effective guide to the management of the event. Mr McClellan identified the following management difficulties in both NSW Health and Sydney Water:

- the incident reporting chain in both organisations appears to have failed to provide swift notification to an appropriate decision maker .

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57 "Water bug was never a danger" in *The Sun-Herald* 20 September 1998.

58 McClellan, P. *Sydney Water Inquiry. Second Interim Report. Management of the Events.* NSW Premier's Department. September 1998, at 65.

59 McClellan, P. *Sydney Water Inquiry. Second Interim Report. Management of the Events.* NSW Premier's Department. September 1998, at 66.

- NSW Health does not currently possess the expertise necessary for a fully informed decision about the impact of a potential contaminant in the water supply system on the Sydney population. The department is dependent on Sydney Water to define the area at risk. Sydney Water is required to balance its commercial imperatives with broader public health concerns, which has the potential to compromise the decision. This is not appropriate.

- NSW Health has limited statutory powers in relation to the regulation of drinking water.

- The views of the technical and operational staff within Sydney Water who fully understood the operation of the system and the likely dispersion of any possible contaminants do not appear to have been adequately reflected in the decision of 29 July. Any impact on the reputation of the Corporation should not be a consideration when making decisions about issuing boil water alert notices.

- Contrary to the Draft Incident Management Plan, there appears to have been poor communication between Sydney Water's operational team and its media team.

The Commissioner also made the following points:[60]

- Sydney Water's structure requires it to give equal consideration to its business objectives, protection of the environment and the protection of public health. These objectives may not always be compatible.

- the split in responsibility between the two organisations resulted in undue delays in the issue of media releases to warn the public to boil their drinking water.

- the Managing Director of Sydney Water poorly informed the Board and Minister Knowles on the lead up to the incident. It was essential for the Premier and Minister to establish an Expert Panel and the Minister's Office to take over media liaison.

- the ability of Minister Knowles to provide effective and accurate advice to the public was seriously compromised by the inaccurate advice from Sydney Water.

- it is essential that the Government reviews the arrangements relating to corporate control to ensure that the Government has sufficient power to obtain information from the Corporation and, if circumstances require, give a direction to the Corporation which is necessary in the public interest.

- there was significant difficulty in the communications between Sydney Water and the operators of the Prospect Treatment Plant, Australian Water Services, probably as a result of their competing commercial objectives. However, an inability for free and

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60 McClellan, P. *Sydney Water Inquiry. Second Interim Report. Management of the Events.* NSW Premier's Department. September 1998, from pages 70-77.

effective communication between the operators of the different parts of a water supply system cannot be accepted.

Mr McClellan noted that having investigated the management of the incident, several areas need to be addressed. These include:

- **Strengthening of public health powers and regulatory controls.**
  The statutory powers of NSW Health may need to be strengthened to enable it to: require tests and other quality assurance processes to be undertaken by water suppliers; to require water suppliers to disclose a range of information necessary for the proper evaluation of drinking water safety; to declare public health alerts in relation to drinking water supplied by any authority; and it will be necessary to consider whether NSW Health is appropriately resourced to accept a role as an efficient regulator of water safety.

- **Public Health Alerts**
  A committee of experts should be constituted to support NSW Health in its statutory role in respect of public health alerts. A public health education program should be developed which provides the community with an informed understanding of the health risks associated with various water quality indicators. The MoU between Sydney Water and NSW Health should be reviewed. An interim protocol which identifies triggers required between the two organisations to institute action in response to positive findings of Cryptosporidium and Giardia and the circumstances leading to boil water alerts and their lifting should be developed. This protocol must be completed by the time of the Commissioner's Final Report and remain in place until such time as the NHMRC finalises the development of national guidelines.

- **Water Quality Data**
  There should be greater coordination within Government of the collection of data on water quality for use by all relevant agencies. Greater public transparency should be introduced in the reporting of water quality data to restore public confidence in Sydney Water.

- **Incident Management**
  Contingency and emergency plans between NSW Health and Sydney Water should be finalised as a matter of urgency.

- **Water Catchment Protection**
  The current structure of Sydney Water should be reviewed to determine whether current environmental and health considerations are given sufficient priority, and if not to determine the appropriate future structure.

- **Ministerial Control over Sydney Water**
  The arrangements relating to the management of Sydney Water as a State Owned Corporation should be reviewed to ensure that the Minister has sufficient power to obtain information from the corporation and if circumstances require, give directions which are necessary in the public interest.

6.0 International Responses to the threat of Cryptosporidium in Drinking Water

6.1 The United Kingdom Regulatory Response to Cryptosporidium[61]

Water supply in the United Kingdom was given a thorough shake up with the privatisation of the many water public utilities when Margaret Thatcher was Prime Minister. The private water companies are now regulated and policed by what is known as the Drinking Water Inspectorate.

The United Kingdom has undertaken several major inquiries into Cryptosporidium.[62] The Drinking Water Inspectorate is now of the opinion that water treatment plants should still provide satisfactory protection against Cryptosporidium even if a water source exceptionally becomes heavily contaminated with the parasite. Exceptional events may include accidental agricultural pollution or heavy rainfall and the resultant run-off from agricultural land or the discharge of sewage effluent.

The Inspectorate is of the view that water borne outbreaks of Cryptosporidiosis have been associated with failures or inadequacies in the water treatment process or its operation. The majority of outbreaks occurred in situations where the integrity of treatment had been compromised, or where the treatment provided was inadequate. Outbreaks have occurred in situations where filters were overloaded or badly maintained, or where inadequate pre-treatment had been provided, or where treatment processes have been by-passed.

In a water borne outbreak, it is believed that a 'pulse' of Cryptosporidium oocysts passes through the treatment works. Such 'pulses' are believed to be associated with a break through of turbid water. The oocysts may be clumped, in that they are loosely attached to

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61 This section is adapted from the following discussion paper:

Department of Environment, Transport and the Regions, *Public Health and Drinking Water: Preventing Cryptosporidium getting into public drinking water supplies*, 1998.

62 For example, major inquiries were undertaken in 1990, a follow up in 1995, and one currently underway due to report by the end of 1998. See:

Cryptosporidium in Water Supplies. Report of the Group of Experts, Chairman Sir John Badenock. HMSO, London 1990.

Cryptosporidium in Water Supplies. The Second Report of the Group of Experts, Chairman HMSO, London 1995.

one another rather than evenly spread through the water. The oocysts pass into the distribution system, and into the water that is drunk by consumers. By the time any diagnosis of Cryptosporidiosis is made in the community most of if not all oocysts in the 'pulse' will have been flushed out of the distribution system. Presently, there is already sampling for Cryptosporidium at treatment works believed to be particularly at risk. However, the method used is to take a 'spot' sample, ie, a single sample taken at a particular time. This would only detect the 'pulse' of oocysts if the sample collection time coincided with the passing of the 'pulse'. As increased sampling often only happens after an increase in reporting of Cryptosporidiosis in the community, as noted above the oocysts are no longer likely to be found in the distribution system. It is therefore difficult to establish from indirect information, especially if a criminal case is mounted against a water company, that the outbreak is due to a failure at a particular water treatment plant.

In the UK a legislative framework for the supply of drinking water is found in the *Water Industry Act 1991*, and drinking water standards are set by the *Water Supply (Water Quality) Regulations 1989*, as amended.

Presently the Regulations set standards for some microbiological and chemical parameters, but there is no specific standard for Cryptosporidium. However, there is a general requirement that drinking water: "does not contain any element, organism or substance... at a concentration or value which would be detrimental to human health." Water that contained sufficient Cryptosporidium oocysts to cause illness would breach this requirement and would be unwholesome. The supply of water unfit for human consumption is an offence under the *Water Industry Act 1991*. An unlimited fine could be imposed by the Crown Court on a water supplier convicted of this offence.

The Drinking Water Inspectorate has generally brought prosecutions under this power in response to incidents where water quality has fallen below that required. Several successful prosecutions have been brought when the appearance, taste or odour of water was so bad that consumers would not drink it. The Inspectorate has bought one prosecution following investigation of an incident believed to have arisen from water borne infection by Cryptosporidium. In that case an epidemiological study linking the outbreak to the water supply was ruled inadmissible as evidence, and the water company was acquitted.

In response to this failed prosecution and the rising importance of Cryptosporidium to the community, new regulations are proposed.

The proposal in the United Kingdom is to establish a standard for Cryptosporidium that the water supply companies must achieve. The Regulations would require water companies to treat their water supplies in such a way as to meet the standard that the water entering the supply must contain less than the average of 1 Cryptosporidium oocyst in 10 litres of water. The Regulations would establish a new offence of allowing the presence of excessive numbers of Cryptosporidium oocysts in the output water from a treatment plant. The Drinking Water Inspectorate would prosecute for this offence, either in a Magistrate's or a Crown Court. If convicted in the Crown Court, there would be no limit on the size of any fine imposed.

The new Regulation will require continuous monitoring of Cryptosporidium at those treatment plants where the source water might contain sufficient numbers of oocysts. A water sample of at least 1000 litres, taken throughout each day must be taken and filtered and analysed for Cryptosporidium. The process of changing the filter, its transport and analysis, is to be by a person not under the control of the water company. Similarly, the laboratory carrying out the analysis must not be under the control of the any water company. The Regulation specifies that water analysis must be by approved methods.

The results of the sampling must normally be reported within three days of the sampling process being completed. If the water company has detected a significant increase in turbidity of the water at the treatment plant, the analysis must be completed within one day. Notification to the appropriate authorities of all problems that may give rise to risks to public health is required. This would typically involve informing local health authorities, local environmental health officers and the Drinking Water Inspectorate. The water company is also required to place the results of the sampling and analysis for Cryptosporidium on the public record.

6.2 The United States Response

In the United States the primary statute protecting drinking water supplies is the *Safe Drinking Water Act 1974*. Major amendments to the act were introduced in 1996, which refocused the Act to a risk based priority approach. This means that the United States Environment Protection Authority (EPA) can decide which contaminants to regulate based on data about the adverse health effects of the contaminant, its occurrence in public water systems and the projected risk reduction. The amendments increased the requirements for research and provided greater flexibility for the States to implement the Act according to their specific needs.[63]

Under the direction of the Safe Drinking Water Act, the EPA is developing a series of regulations to control microbial pathogens and disinfection byproducts in drinking water. These regulations are known as rules, and there are three main rules that are relevant to this paper. These are:

- Information Collection Rule
- Microbial pathogen and disinfection byproducts rule
- Interim enhanced surface water treatment rule.

The Information Collection Rule

The Information Collection Rule was first proposed in 1994 and was finally published in the *Federal Register* on May 14 1996. One of the causes of delay was the difficulty in developing protocols for the analysis of water samples for Cryptosporidium and Giardia.

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[63] United States Environment Protection Agency, *The Safe Drinking Water Act - One Year Later*. September 1997.

The Information Collection Rule requires public water systems serving over 100,000 people to collect information on the presence and levels of microbial contamination and disinfection byproducts, as well as the effectiveness of various treatment technologies to reduce those levels. The water systems are to monitor representative bacteria, viruses and protozoa over an 18 month period, beginning in early 1997. About 350 supply authorities operating 500 treatment plants are involved in the data collection effort for a total cost of around US$130 million. In addition, some systems serving more than 100,000 people must complete pilot scale studies on the removal of precursor disinfection byproducts by the use of activated carbon or membrane technologies. The EPA is also supplementing the efforts of the larger utilities by doing their own surveys on medium and small sized water supply systems. These surveys are designed to help understand the differences affecting the smaller supply systems.

The information collected by this rule will be used, in conjunction with other health related research, to help develop the interim enhanced surface treatment rule and the disinfection byproducts rule.

The Interim enhanced surface water treatment rule[64]

The first surface water treatment rule, promulgated in 1989, applies to all public water systems using surface water (or ground water which is influenced by surface water) as a drinking water supply. The rule established maximum contaminant levels for a variety of viruses and bacteria, as well as Giardia (99.9% removal). Cryptosporidium was not regulated under this rule. The rule also contained treatment technique requirements for filtered and unfiltered systems that were specifically designed to protect against microbial pathogens.

Under the *Safe Water Drinking Act*, an enhanced interim surface water treatment rule is due to be promulgated by November 1998. A draft rule was first proposed in 1994, and applies only to those systems supplying more than 10,000 people.

The rule as proposed in 1994 set the maximum contaminant level goal for Cryptosporidium at zero. According to the EPA, most commentators in the industry supported this level. Reasons for support include the probability that one oocyst can infect and the data does not support a threshold dose below which an outbreak or disease will occur. A Federal Advisory Committee, established to review the interim rule, also supported the goal of zero. However, a key issue to emerge from the Committee was whether the goal should be for Cryptosporidium species in general, or for *C. parvum* only. The 1994 draft rule proposed classification at the genus level. The USEPA has yet to decide which is the more appropriate.

The Federal Advisory Committee, established to advise the EPA in preparing the Interim Rule, concluded that surface water systems supplying more than 10,000 people and which

64 Information for this section is from: United States Environmental Protection Agency. *National Primary Drinking Water Regulation: Interim Enhanced Surface Water Treatment Rule Notice of Data Availability*, Federal Register Document, November 3 1997, Volume 62 No. 212.

are required to filter their water must achieve at least a 99% removal of Cryptosporidium. It was noted that requiring a 99.9% removal (as for Giardia) is not economically or technologically feasible at this stage.

The Interim Rule presented a considerable amount of data and information on the removal of Cryptosporidium by filtration. It concluded by stating that rapid granular (ie sand) filtration, when operated under appropriate coagulation conditions and optimized to achieve a filtered water turbidity level of less than 0.3 NTU, should achieve at least a 99% level of Cryptosporidium removal. Members of the Federal Advisory Committee noted that tighter turbidity performance criteria would increase the likelihood of systems achieving higher oocyst removal rates. As a general principle, the Committee indicated that if a utility were required to achieve less than 0.3 NTU 95% of the time, the utility would target substantially lower turbidity levels in order to have confidence that it will not exceed the 0.3 level. The Committee subsequently endorsed this turbidity goal, together with the requirement that the turbidity level of a plants' filtered water must at no time exceed 1 NTU. It is stated that plants which achieve these turbidity goals are assumed to remove 99% of Cryptosporidium oocysts.

The combined water from a plant is to be tested for turbidity every four hours, and each individual filter in a plant is to be continuously monitored. The plant operator shall provide what is referred to as an 'exceptions report' to the State on a monthly basis. Exceptions reports include: those events where any individual filter had a turbidity reading greater than 1.0 NTU on two consecutive readings fifteen minutes apart; or any individual filter with a turbidity level greater than 0.5 NTU at the end of the first four hours of filter operation based on two consecutive readings 15 minutes apart.

The Interim Rule notes that it may not be appropriate to rely solely on the physical removal to control Cryptosporidium in drinking water supplies, and that additional inactivation may also be required. As part of the Interim Rule the EPA hoped to be able to map out the inactivation efficiencies of different technologies, such as ozone treatment. However, lack of data and lack of uniform experiment protocols made this very difficult. A summary of the EPA information is as follows:

- the ineffectiveness of free chlorine alone is confirmed;
- sequential disinfection with free chlorine followed by monochloramine can achieve a much greater degree of inactivation than chlorine alone;
- sequential disinfection such as ozone or chlorine dioxide followed by one of the chlorine species appears more powerful than either disinfectant alone;
- the literature on inactivation with ultra violet light is confusing due to different experimental protocols. Some researchers have found it very effective, others ineffective;
- results from ozone treatment vary dramatically according to the experimental protocol used. However, it is noted that the use of ozone cannot be expected to significantly inactivate Cryptosporidium at the concentration and contact times employed in inactivating Giardia;
- the use of chlorine dioxide may be limited for inactivation due to byproduct

residuals;
- the effect of multiple disinfectant treatments is synergistic and may greatly improve inactivation. However, the combination of chlorine species with other disinfectants may produce toxic disinfectant byproducts.

The Interim Rule refers to a 'multiple barrier approach' to ensure that Cryptosporidium does not enter a drinking water distribution system. This includes source water protection, physical removal, inactivation and so forth. It is noted in the rule that the value of protecting the source water cannot be overstated. It appears that unfiltered water systems that comply with the US source water requirements of the original 1989 surface water ruling, may have a risk of Cryptosporidiosis equivalent to that of a water system with a well operated filter plant using a water source of average quality.

The Interim Rule proposes that a system of Sanitary Surveys be conducted for all public water systems that use surface water, regardless of whether they filter or not. A sanitary survey is defined as an onsite review of the water source (identifying sources of contamination), facilities, equipment, operation, maintenance, and monitoring compliance of a system to evaluate its adequacy as a system as a whole and its components. A survey, conducted by the State, would be held no less than every three years.

Consumer Confidence Reports

The USEPA is requiring water suppliers to publish and deliver annual drinking water quality reports to each of their customers. In the US, consumers will receive their first report in 1999 and by July 1 for each year thereafter. Each report must provide consumers with the following fundamental information about their drinking water:

- the source of the drinking water
- a brief summary of the susceptibility to contamination of the local drinking water source, based on source water assessments which are currently being completed
- how to get a copy of the water system's complete source water assessment
- the level (or range of levels) of any contaminant found in local drinking water, as well as the EPA's health based standard for comparison
- the likely source of that contaminant in the local drinking water supply
- the potential health effects of any contaminant detected in violation of an EPA health standard, and an accounting of the system's actions to restore safe drinking water
- the water system's compliance with other drinking water related rules
- an educational statement for vulnerable populations about avoiding Cryptosporidium;
- educational information on nitrate, arsenic or lead in areas where these contaminants are detected above 50% EPA's standard
- phone numbers of additional sources of information.

The annual report is not the primary notification for health risks posed by drinking water, but will provide customers with a snapshot of their drinking water supply.

7.0 Conclusion

The recent outbreak of pathogenic organisms in Sydney's drinking water encapsulates the problems of emerging technology and frontier science. It is on the public record that Cryptosporidium oocysts have been recorded in the raw water of Warragamba Dam since the early 1990s. Without a doubt, if the oocysts were in the water in the dam then, the water treatment technology used in the early 1990s would certainly have not eliminated them from the drinking water distribution system. In other words, it is highly likely that Sydney-siders have been drinking water contaminated with Cryptosporidium and Giardia for some time.

For Sydney, the crux of the problem appears to be twofold; the catchment and the water treatment plant. International best practice suggests that a treatment plant like Prospect should be able to remove 99% of Cryptosporidium oocysts from raw water. In the United States this is assumed to be automatic given compliance with certain operating conditions. In the United Kingdom, outbreaks of Cryptosporidiosis are invariably linked to a breakdown in the water treatment plant, meaning that when a plant is operating properly then Cryptosporidium oocysts are removed from the water supply.

If it can be demonstrated that the Prospect Water Treatment Plant was operating at international best practice, then water authorities around the world may have to reconsider their assumptions of how effective a rapid sand filtration plant is at removing pathogenic protozoa. If this is the case, then water supply authorities are going to have to consider disinfection options. However, some of these technologies are yet to be tried on a commercial basis. The United States Environment Protection Authority has yet to be able to demonstrate the relative efficiencies of the various disinfection technologies to eliminate Cryptosporidium. The Sydney media has consistently run stories on how Milwaukee added an ozone treatment system to their water treatment plants after their Cryptosporidiosis outbreak in 1993.

It could be argued that the catchment of the Sydney water supply is not as 'clean' as it should be. It seems inappropriate that septic and overflowing sewage systems drain into Sydney's main water supply. Already the NSW Government has indicated that it will investigate establishing a catchment commission to manage the catchment areas. The Board of Sydney Water has stated that the Corporation will fast track sewering the urban areas within Warragamba catchment that are still on the old septic system.

It is pertinent to note the difficulties and conflicts that have arisen when only one part of major infrastructure is a private corporation. Commissioner McClellan noted the lack of effective communication and other difficulties that arose in relation to Sydney Water and the privately operated Prospect Water Treatment Plant. Before the Inquiry both organisations were explaining how the other was responsible for the contamination of the water supply. In the United Kingdom the Drinking Water Inspectorate regulates the privately operated water supply system and lessons may be learnt from their operations on how to effectively communicate with and regulate the water industry. The Premier Hon Bob Carr MP has also foreshadowed legislative changes to enable Ministers to have wider powers to intervene in the day to day operations of major public utilities such as Sydney Water.[65]

Presently the NSW Government has stated that it will await the final recommendations of the Sydney Water Inquiry before making any major decisions arising from the recent water contamination. The Leader of the Opposition Hon Peter Collins MP has said that he will introduce a Private Members Bill to remove the need for development assessment procedures for any disinfection treatment additions to the Prospect plant. The aim of this Bill is to reduce the time taken to bring the new treatment on-line.[66] On 8 September 1998 the Hon Peter Collins MP gave notice of motion to introduce a bill to require Sydney Water and Hunter Water to provide periodic reports on the quality of drinking water and to require compensation payments to customers if the water is unsafe to drink.

Sydney Water has a large public information campaign ahead of it to explain the problems of pathogenic protozoa in the water supply system. Annual water quality reports similar to those required from water suppliers in the United States may be an effective tool by which the Corporation can explain its actions to its consumers.

Finally, as Mr McClellan hints at, the NSW public will have to decide if wants a water supply authority which has equal objectives as a business, to protect the environment and to protect public health. Mr McClellan notes that these three objectives are not necessarily compatible. If Sydney Water is to be run as a business, the community may want a stronger regulator than what is currently in place.

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65 "Carr tightens control on Sydney Water" in *The Sydney Morning Herald*, 3 September 1998.

66 "City needs $800 million water plant: Libs." in *The Australian Financial Review*, 16 September 1998.