GIARDIA AND GIARDIASIS

IN NEW ZEALAND

A REVIEW

ENVIRONMENTAL HEALTH UNIT

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WELLINGTON

AUGUST 1991

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EXECUTIVE SUMMARY

Giardia, a parasitic protozoa, has been found in a number of New Zealand natural waters and drinking-water supplies. Giardia may enter water as a result of faecal contamination by man or animals. Infection in man occurs as a result of ingesting Giardia cysts. Ingestion may occur via a faecal oral route, ie. ingestion of food contaminated due to poor personal hygiene, or person to person contact, or through consumption of contaminated water.

Research to date would indicate that at present the major route of infection is via the faecal oral route and the consumption of untreated natural waters. A convincing link between contamination of public water supplies and giardiasis has not been established.

Some feral and domestic animals have been shown to carry Giardia species that are infectious to humans. It is likely that the presence of Giardia in New Zealand will become ubiquitous as more animals become infected.

Giardiasis, the disease resulting from Giardia, has been estimated to affect over 3500 New Zealanders per year, and it is likely that this number will increase. The disease is debilitating and generally requires medical intervention to affect a cure. Giardiasis is not a notifiable disease.

Giardia is resistant to disinfection by chlorine at the usual levels used in water treatment. An effective concentration of chlorine followed by a sufficiently long contact time will be effective in killing cysts. However, the concentration of chlorine required to achieve this may result in water with an unpleasant taste. Overseas experience and practice has shown that coagulation plays a key role in assisting filtration to remove Giardia cysts. Many New Zealand water supplies are either unfiltered or rely on rapid filtration without coagulation. Where the water is sourced from rivers, streams, impounding reservoirs, lakes, springs or shallow wells these supplies are at risk of being contaminated by Giardia. The upgrading of treatment systems for these supplies will require considerable financial investment. The World Health Organisation and New Zealand Drinking-Water Standards require a nil presence of Giardia in drinking-water.

RECOMMENDATIONS

Based as reported below, the work conducted on behalf of the Department of Health in reviewing Giardia and giardiasis in New Zealand, the following recommendations are made:

1 That an enhanced level of surveillance be provided for giardiasis to provide a clearer picture of giardiasis in New Zealand.

2 That any future water supply subsidies where appropriate be conditional on steps being taken to prevent Giardia and other protozoan cyst contamination of the reticulated water supply.

3 That area health boards (or their successors) and other authorities continue to promote good hygiene in homes and pre-school centres, with a view to minimising the spread of giardiasis.

4 That future routine inspections of water supplies and national supply gradings include assessments of safeguards against Giardia and other protozoan cysts.

5 That water supply and water treatment systems be progressively upgraded to ensure that they are capable of safeguarding drinking water from contamination by Giardia and other protozoan cysts. Priority should be given to those water supplies or water sources with a high risk of contamination.

6 That the Department of Health continue the support of research at Massey University in the Manawatu/Wanganui area.

7 That the Department of Health produce an advisory circular for area health boards (or their successors) indicating how to assess catchments.

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REFERENCES

ACKNOWLEDGEMENTS

1.0 INTRODUCTION AND OVERVIEW

1.1 Background and overview

Giardiasis, a gastrointestinal disease caused by the protozoan parasite Giardia intestinalis, has probably been in New Zealand for many years. The parasite was first detected in New Zealand among servicemen returning from overseas in the 1940s.

For a long time Giardia was considered a harmless commensal organism until recent years when it was known in North America and Europe to cause intestinal disease among travellers to foreign countries, persons drinking contaminated water, homosexual males and the populations of institutional environments such as schools, prisons and day-care centres. Giardia are intestinal parasites frequently identified in public health laboratories in the USA and the United Kingdom.

The first reported outbreak of water-borne giardiasis occurred in 1965 in Aspen, Colorado, USA. Since that first event, many additional outbreaks have occurred in the United States. Once the presence of Giardia is established, the number of outbreaks of giardiasis has been estimated to double every five years (1).

In New Zealand it is the responsibility of local authorities to provide drinking-water that is "wholesome". This is outlined in the Water Supplies Protection Regulations 1961. Wholesomeness is defined as, "clear water which has been collected from a course or has undergone a process of treatment approved by a Medical Officer of Health and subsequently to such collection or treatment has not been exposed to any danger of contamination" (2).

Since microbiological and biological contamination of a water supply has by far the greatest potential for causing sickness and even death within the community, the microbiological and biological quality of drinking-water is of prime importance. Standards of microbiological and biological quality for drinking water are given in "Drinking-Water Standards for New Zealand" (3) and are based on the World Health Organisation's "Guide-lines for Drinking Water Quality"(4). These standards state that no pathogenic protozoa should be detected in drinking-water.

Recent surveys in New Zealand have identified Giardia in more than 12 water supplies including Oamaru and Kakanui and in the Hutt River and head-waters of Wellington's water supplies.

A limited testing programme has been performed by the Department of Conservation to determine the presence or absence of Giardia at a number of 'high risk' sites throughout the country. The presence of Giardia has been confirmed at nine of the twenty-four sites tested. On the basis of these results the Department of Conservation has concluded that Giardia is widespread in New Zealand and that all waterways should be considered unsafe.

The Department of Conservation has published a 'Giardia fact sheet' which is available to campers, trampers and Conservancy land users (see Appendix I). The sheet provides information about Giardia and giardiasis and outlines methods of treating water when tramping. The Department of Health has also provided technical information to all area health boards about Giardia (see Appendix II) (5).
Giardia cysts cannot be killed using conventional water disinfection such as chlorination that kills enteric bacteria. A proficient filter system as well as chlorination or boiling is required to adequately treat water from at risk supplies.
Since many of New Zealand's water supplies are not filtered the public health implications of this are considerable.

The occurrence of cases of giardiasis in New Zealand is increasing with figures of 60-100 cases per month being reported from Auckland laboratories and two laboratories respectively in Christchurch and Hamilton reporting figures between 200 and 600 per year. Since giardiasis is not a notifiable disease, reliable statistics on the number of cases are not available. It is estimated however that probably over 3,500 cases of giardiasis are tested positive by laboratories annually (6) (see section 3.2). The total number of cases may however be much higher as a large number of cases may be asymptomatic and therefore remain undetected in the population.

1.2 Giardia species

The parasite was discovered by Antony van Leeuwenhoek, the inventor of the microscope, who found it in his own stools in 1681. In his description of Giardia, he noted the size, movement, and morphology of the organism, and associated its presence with the diarrhoeic nature of his stools and his dietary habits. The organism was later described by Lambl, a Czechoslovakian physician in 1859 (7).

Early studies of Giardia suggested that there were at least 40 different species which were highly host specific and that different species infected different hosts. It is now generally agreed, however, that there

are two morphologically distinct species which infect mammals:

- Giardia intestinalis naturally infects humans, beaver, coyote, cattle, cats and dogs and can experimentally infect other mammals. It has also been found in birds in North America;

- Giardia muris infects primarily mice and rats;

- Giardia agilis infects frogs, toads, salamanders and tadpoles.

1.3 Nomenclature

A variety of genus and species names are used in describing these parasitic protozoa. In Western countries Giardia intestinalis is the name usually used for the Giardia causing human infections. In Western Europe these same organisms are commonly called Lamblia intestinalis and the infection that they cause is termed "lambliasis". Other names given are Giardia lamblia and Giardia duodenalis. Throughout this report the organism infecting humans will be referred to as Giardia intestinalis.

1.4 Life cycle of Giardia

The life cycle of Giardia intestinalis includes a trophozoite and a cyst form (see Figure 1):

The **trophozoite** which is the mobile stage of the parasite is microscopically broadly round anteriorly and tapering to a slender tip posteriorly. Its front pairs of flagella provide vigorous mobility. The normal habitat is at the bases of the microvilla of the upper two-thirds of the small intestine and attaches by a central adhesive disk to the mucosa. Reproduction is by binary fission. Gillin and associates in 1983 reported that the trophozoite was rapidly killed by exposure to normal human milk in vitro (12).

In established infections some of the trophozoite detach from the lining of the mucosa for unknown reasons and enter the faecal stream. In the small intestine encystment begins with the trophozoite rounding up to form an immature cyst. Each of the two nuclei in the cyst undergoes a single division so that the mature cyst contains four nuclei. Cysts are ovoid in shape and measure 9 x 12 microns. In the past cysts have been regarded as infective when freshly passed in faeces, however, there is now some doubt on this point. Experiments in which samples from a single batch of purified cysts were exposed to the same excystation conditions suggested that a maturation period ranging from 3 to 7 days may be required (22). It is therefore

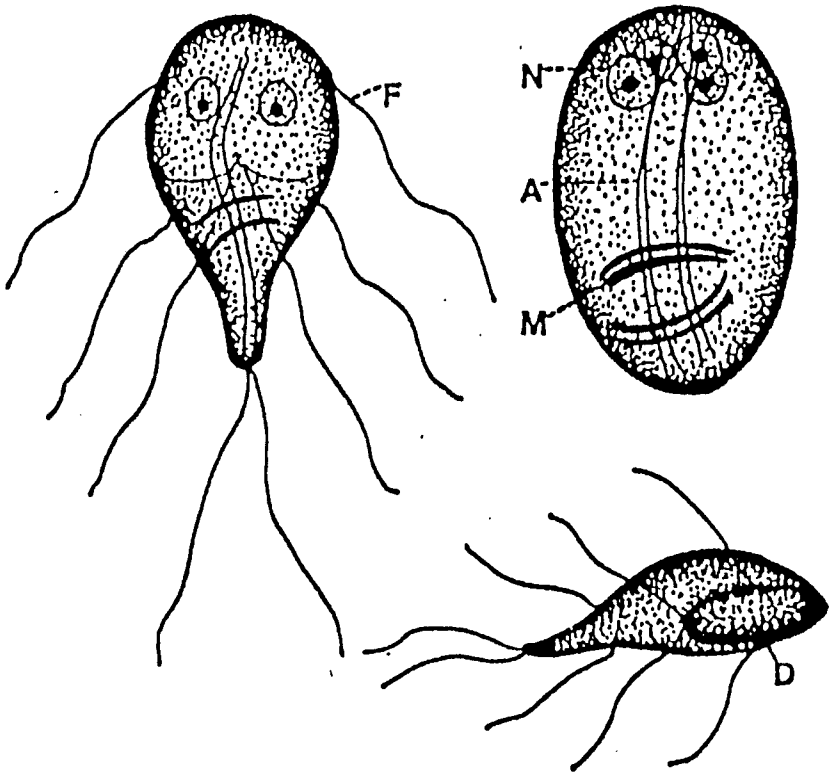

Figure 1 Semi-diagrammatic illustration of *Giardia duodenalis*. Left: dorsal view of trophozoite; upper right: dorsal view of mature cyst; lower right: ventro-lateral view of trophozoite showing suction disk. F, flagella; N, nucleus; A, axostyle; M, median body; D, suction disk. (Original by C.P. Hibler).

possible that cysts in various stages of maturity are present in a single human stool specimen. An infected person may excrete over 900 million cysts per day, so this is unlikely to significantly affect infectivity of faecal material.

In instances where there is rapid intestinal passage there is not sufficient time for cysts to form. Stool specimens from patients with diarrhoea due to giardiasis are likely to contain more trophozoites than cysts. Encystation apparently does not occur outside the host and excreted trophozoites disintegrate.

When mature cysts are ingested the excystation process is induced by the acidic condition in the stomach and completed in the duodenum with the emergence of trophozoites. Infection can only be established if the trophozoites survive, attach, and multiply. They cannot survive the acidity of the stomach for long and may require nutrients in the intestinal fluids to complete the excystation process (21).

1.5 Epidemiology

1.5.1 Distribution :

1.5.1.1 Global: Giardiasis occurs endemically world-wide and its prevalence often depends on the level of community sanitation and the personal habits of the population and the age group surveyed.

While giardiasis may result in malabsorption of fats or of fat-soluble vitamins (8), it has been reported that the condition is well tolerated in children under three years old (9) and healthy day-care children with asymptomatic Giardia infection showed no disadvantage and perhaps an advantage in nutritional status and freedom from other diseases (10). Transmission in most older age groups is usually through contaminated food or water. It is a documented problem in homosexually - active males often as a result of direct faecal - oral contact. More recently AIDS patients have been reported to have severe, protracted diarrhoea due to giardiasis.

Prevalence is higher in areas of poor sanitation and among children. A prevalence rate of 42 per cent has been reported among 2 to 4 year old children in a rural area in Egypt; the rate was 17 per cent among mothers of the children (11). The high rates of infection among the children are partly due to their relative susceptibility, incontinence, poor personal hygiene and lack of discrimination in taking objects to the mouth (7). Day-care centres, kindergartens and junior schools are high risk areas.

Giardiasis has emerged as one of the most significant water-borne infections in the United States. From 1971 to 1979 there were 31 outbreaks causing almost 18,000 cases, more than for any other water-borne disease of known aetiology. These outbreaks have been attributed to the ingestion of surface waters without treatment and do not include non-water related outbreaks (7).

Contamination of a seemingly adequately treated municipal supplies probably led to an outbreak in Bristol, England in 1985 (13).

1.5.1.2 New Zealand: At the national level there is little statistical information on the occurrence of the disease. Little is known about the source(s) of infection in the cases known. Okell et al (14) noted a high incidence of infection in infants and adults of parenting age living in the Eastern Bay of Plenty. He suggested that person to person contact is a more significant mode of transmission since a majority of the cases lived in urban areas with filtered water supplies.

Walker et al (6) carried out a survey of medical laboratories throughout New Zealand to gather information concerning the prevalence of giardiasis. Of the faecal specimens tested over a period of three months, 2.7 per cent were found to be positive for Giardia intestinalis. It was reported that there are at least 3,356 cases of giardiasis per year in New Zealand and suggested that water may not be at present the major route of transmission of giardiasis in New Zealand (see section 3.2).

1.5.2 **Transmission patterns** (see Figure 2):

1.5.2.1 **Water-borne** : Localised outbreaks often occur from drinking non-filtered municipal water supplies. Drinking of unfiltered cold streams contaminated by wild animals is thought to be a common source of outbreaks among campers and trampers. A number of cases of giardiasis have been reported amongst trampers using the Abel Tasman National Park. Contaminated wells have also been implicated (15). Other sources of outbreaks reported are a swimming pool which had been contaminated by faeces (16) and a contaminated water slide (17). Codes of practice for the management and control of swimming pool water quality have been published by the Standards Association of New Zealand (SANZ).

There is increasing evidence to suggest that these activities, camping and tramping are contributing to the spread of the organism into the New Zealand environment. Lack of toilets at rest areas frequently means that travellers have no alternative but to go behind bushes. This may result in the contamination of water and exposure of feral animals to infected faeces. Campers

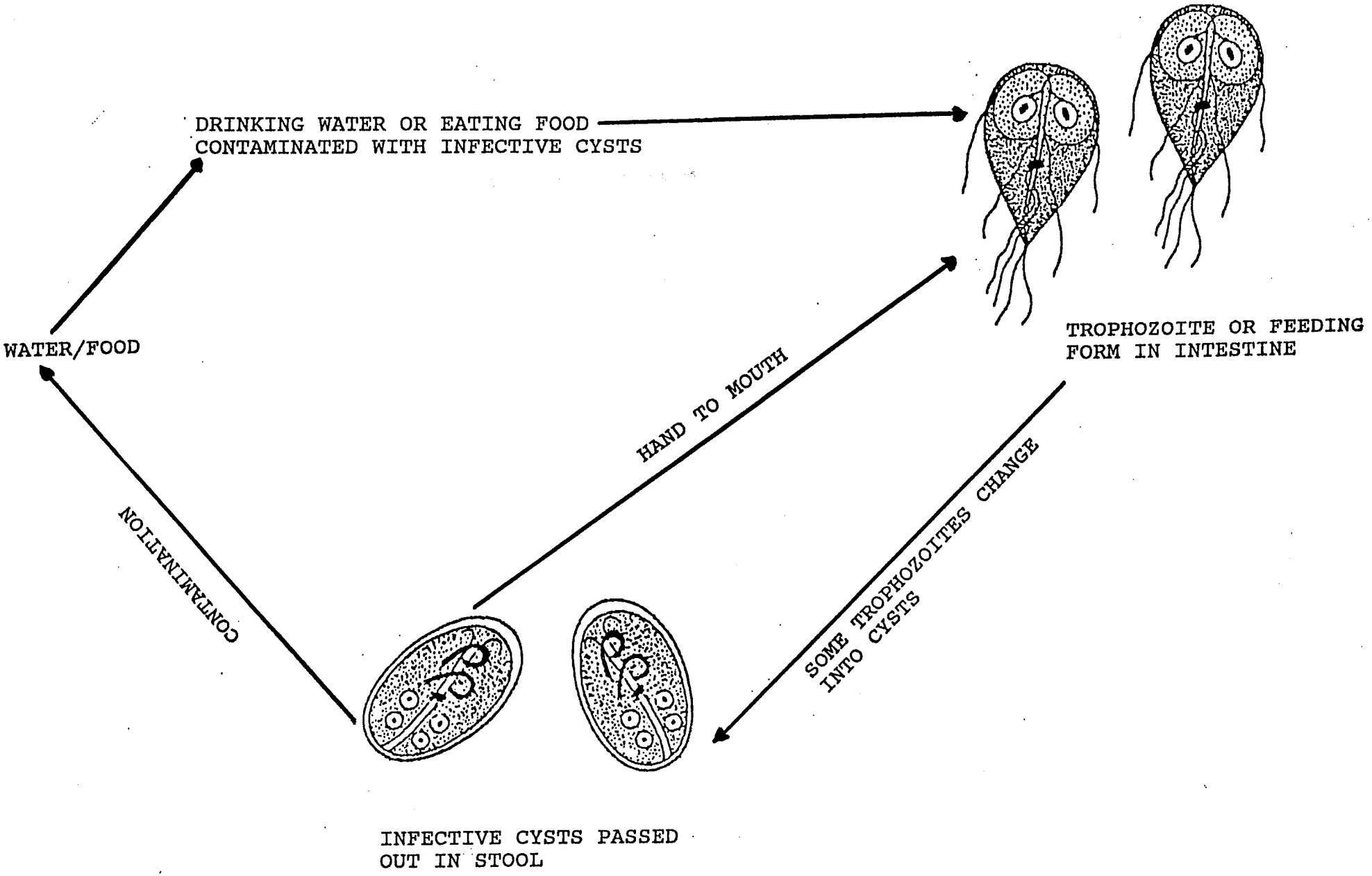

Figure 2 LIFE CYCLE OF GIARDIA

in the USA are thought to have acquired zoonotic infection from water contaminated by wildlife, and beavers in particular.

1.5.2.2 **Food-borne:** Contaminated food is occasionally implicated in localised outbreaks. Giardia cysts have been found on fruit, salad and other food items. An outbreak in the United States in 1981 was attributed to contaminated home prepared salmon (18). Subsequently other food-borne outbreaks have been reported (19,20). Foodhandlers with infected children appeared to be important sources of transmission in these outbreaks.

1.5.2.3 **Person to person :** This form of transmission usually occurs through hand to mouth transfer of cysts from the faeces of an infected individual. It is an important mode of transmission among toddlers and children in play-centres and schools and in communities where sanitary facilities are absent or sub-standard.

1.5.3 Role of animals in transmission of disease:

1.5.3.1 **Domestic pets:** Household dogs and cats have recently been implicated as sources of human infection. A recent survey carried out in Hamilton found infection rates of 25 per cent in dogs and 7 per cent in cats. In Palmerston North the figures were 8 per cent in dogs and 7 per cent in cats. The infection in pets is probably due to their indiscriminate dietary habits and behaviour. (see section 3.1.2)(21).

1.5.3.2 **Wild animals:** Beavers have been implicated in North America. Water-borne outbreaks are common in mountainous communities that use water from streams and rivers without adequate filtration (7). In New Zealand farm animals and wild possums and pigs may be a major source of **Giardia.** Giardia intestinalis has been identified in possums and ships rats in New Zealand.

1.6 Pathogenesis

It has been suggested that individuals may differ in their susceptibility to infection and that strains of Giardia intestinalis differ in virulence. Immune-compromised persons (eg. people suffering from cancer, HIV/AIDS or taking high-dose corticosteroids) are likely to develop long-lasting infection. It has been shown that as few as 10 viable cysts can infect humans and one cyst can infect the mouse (23). Persons with achlorhydria (absence of hydrochloric acid from the gastric juice found in cases of pernicious anaemia, chronic gastritis and carcinoma) may be more susceptible to infection.

Many unproven theories of the pathogenicity of Giardia have been suggested. These include the following:

1.6.1 Mechanical

(i) Mechanical irritation of the mucosa by the organism.

(ii) Mechanical blockage of the surface of the intestine by numerous trophozoites.

1.6.2 Chemical

(i) Production of toxic substances by the trophozoite.

(ii) Production of abnormal bile salt.

(iii) It has been suggested that immune response occurs following penetration of trophozoites through breaks in the mucosa or by actual invasion of trophozoites into the intestinal lymphoid tissue. The severity of morphological changes depends on the clinical severity of the disease in some patients. Abnormalities may include increased epithelial cell tumour incidence, local acute inflammation, round cell infiltration and hyperplasia of lymphoid nodules (24).

1.7 Susceptibility

Giardia cyst are known to be resistant to destruction by hypotonic solutions such as water. The cysts are known to survive for more than two months at 8C, one month at 21C and four days at 37C. It has been reported that cysts suspended in lake or river water were viable for 56 to 84 days in winter, but only up to 14 days in tap untreated water (25).

Boiling immediately makes cysts incapable of excystation and the process of freezing and thawing makes more than 99 per cent of cysts incapable of excystation (21). Cysts are quickly killed by drying and hot temperatures but survive chlorination at standard concentration levels (0.5ppm residual chlorine).

1.8 Clinical presentation

There is a variable incubation period ranging from one to three weeks with a median of 7-10 days and a mean of 9.1 days. Clinical manifestation ranges from mild transient intestinal complaints that resolve spontaneously to severe long-standing disease with malabsorption and debilitation.

1.8.1 Acute Infection

There is a sudden onset of watery diarrhoea with frequent bowel actions passing yellowish watery offensive, frothy, foul-smelling stools along with abdominal discomfort and foul-smelling flatus. Anorexia, nausea, lethargy and weight loss are common symptoms. Occasionally fever has been reported. In most acute cases there is a tendency for spontaneous improvement within two to three weeks.

Some patients may have a persistent lactase deficiency after treatment and symptoms of this could be confused with recurrence of infection.

1.8.2 Subacute infection

This is characterised by mild or moderate symptoms often without a history of more severe acute infection and may last for months. There are episodes of mushy foul-smelling stools with mid-epigastric pain, substernal burning, increased distension, foul-smelling flatulence and belching. Anorexia, weight loss, fatigue and general unwell feeling occurs.

1.8.3 Chronic Infection

The infection is characterised by periodic episodes of mushy foul-smelling stools with increased flatulence and abdominal distension. Cramps are common. Anorexia is sometimes noted. Chronic infection may or may not be preceded by acute or subacute infection. Children are occasionally brought to medical attention because of failure to thrive.

Subacute and chronic infection could be confused with peptic ulcer, gall bladder disease, or hiatus hernia.

1.8.4 Asymptomatic infection

People who have asymptomatic infections are less likely to be diagnosed and treated and are therefore important in transmission of the disease as healthy carriers. Excretion of cysts by carriers may last months or years.

1.9 Diagnosis

(i) Examination of diarrhoea and formed stool specimens for cysts or trophozoites is the routine method of diagnosis. Stool specimens may, however, be negative in the early stages of the disease and also in patients who shed the organism in a cyclic pattern. The recommendation therefore is to examine at least three different stool samples collected over one week. Specimens may be examined within 24 hours or placed in fixatives. Diarrhoeic specimens should, however, be examined within one hour or placed in fixatives.

(ii) When Giardia infection is suspected but no cysts are found in routine examinations, trophozoites can be examined in specimens obtained by intestinal aspiration or biopsy. (26). The specimens should be taken to the laboratory promptly. It is advisable to inform the laboratory prior to submitting the specimen and also to obtain the specimen during regular working hours.

(iii) Antibodies can be demonstrated in some persons infected with Giardia and the T-cell system appears to be important in the pathogenesis of mucosal lesions. Birkhead et al (27) in 1989 reported that convalescent cases showed a significant increase in IgG and IgA but not IgM levels. It was recommended that serum IgA will be helpful in detecting exposure to water contaminated with Giardia intestinalis or detecting illness during an outbreak.

(iv) Giardia antigens have been detected in stool samples by means of semi-quantitative enzyme immunoassay test. Filtration reduced the efficacy of the diagnostic method (27).

1.10 Treatment

Metronidazole is routinely prescribed. Cure rates are in the order of 86 per cent, which is less than that with quinacrine, but tolerance to metronidazole is generally better than with quinacrine. Common side effects of metronidazole include metallic taste, dark discolouration of urine, nausea, and headache. There is a disulfuram-like reaction when taken with alcohol. Combined treatment with both quinacrine and metronidazole are effective when either of them have failed (23).

Tinidazole, a nitroimidazole related to metronidazole, has also been found useful.

Quinacrine hydrochloride and furazolidine have been used overseas but are not routinely available in New Zealand.

None of these drugs has been proven safe in pregnancy. They should therefore be used in pregnancy only when severe symptoms are definitely attributed to giardiasis and benefits outweigh potential risks.

Pregnant women who received metronidazole at 200mg thrice daily for 14 days for trichomoniasis at various stages of pregnancy did not have excess of fetal loss, premature labour, perinatal mortality or foetal abnormality (28).

Treatment of asymptomatic giardiasis should be considered for prevention of transmission of the disease and later appearance of symptoms.

1.11 Prevention and control

As Giardia cysts withstand chlorine concentrations that kill enteric bacteria, a proficient treatment system to back-up chlorination is required for safe drinking water taken from natural sources of surface water.

Water heated to boiling for three minutes is safe. Heating water to at least 70C for 10 minutes has been suggested as an alternative to water treatment in back-country sites (28).

Iodine in aqueous solution made from crystals, tincture, or commercial preparation is highly effective as a disinfectant for small quantities of drinking water. (Ten drops (0.5ml) of 2 per cent tincture of iodine per litre, see Appendix II).

It is important to note however that the use of iodine for regular disinfection of water is not appropriate. Long term ingestion of iodide can cause a mild chronic syndrome called "iodism", with coryza-like symptoms (nasal discharge), parotitis (inflammation of the parotid gland) and skin rash.
Goitres can also develop in susceptible people after long term (for a year or more) consumption of iodine. Neonatal hypothyroidism has also been recorded.

Commercial disinfectants giving high chlorine residues are also effective (Jarrol et al, 1980). (2-4 drops (0.1-0.2ml) of household bleach per litre, see Appendix II).

In endemic areas, water for drinking or for making ice should be boiled for at least 3 minutes or treated with iodine. Uncooked or unpeeled fruit and vegetables should be avoided. Hot cooked food should be preferred to cold foods and salads.

There is the need for regular testing of residual chlorine and proper maintenance of dosing equipment and filtration systems of swimming pools. Contingency plans for direct contamination by faeces should be in place.

As already discussed in sections 1.5.2 and 1.5.3 the transmission of Giardia may occur through person to person contact, contact with infected animals and poor standards of personal hygiene. It is important that in areas of higher risk such as play-centres and schools a high standard of hygiene is maintained. A health guidelines and health report for early childhood centres has been published by the Ministry of Education (32).

2.0 RESPONSE OF THE DEPARTMENT OF HEALTH TO *GIARDIA*

The isolation of *Giardia* in some water supplies and waterways and recorded cases of giardiasis has generated considerable media interest and some public anxiety. In response to the public health issues concerning *Giardia* and because of the paucity of information on the ecology of *Giardia* in New Zealand, the Department of Health has engaged consultants to provide detailed reports on the presence and effects of *Giardia intestinalis* within the environment.

During 1990/91 the Department of Health provided funding for four projects investigating aspects of *Giardia* in New Zealand, as follows:

2.1 Massey University:

(i) determine the sensitivity of the standard isolation method used to isolate *Giardia* from water and sewage;

(ii) determine prevalence and distribution of *Giardia* in suspect New Zealand waterways.

2.2 New Zealand Communicable Diseases Centre:

(i) develop national strategy for the isolation and identification of *Giardia intestinalis* from suspect drinking water supplies.

(ii) determine the demographics of giardiasis in New Zealand.

2.3 DSIR (Land Resources):

(i) determine whether any wild mammals or birds carry *Giardia* in or near town water supplies, starting with rodents;

(ii) measure the geographic distribution and prevalence of *Giardia* in the host species, and

(iii) measure the relative abundance of Norway rats, ship rats and mice along some waterways supplying cities and towns.

2.4 **Works Consultancy Services:**

(i) Provide useful, practicable information for local authorities to either modify or improve water treatment facilities to effectively remove Giardia cysts.

(ii) Carry out a literature search of treatment options for removal of Giardia cysts in water treatment plants.

(iii) Treatment options to include:

a) conventional treatment processes for urban supplies;

b) rural treatment where electrical power is not available;

c) point of use treatment; and

d) recommended changes to treatment plants.

3.0 PROJECT EVALUATION

3.1 Massey University Giardia Research Group

This work has been performed in close collaboration with DSIR Land Resources and the New Zealand Communicable Disease Centre (NZCDC).

The main outcomes of this work are as follows:

3.1.1 The Physiology and culture of Giardia intestinalis

(i) A method for the in vitro production of Giardia cysts has been developed. This has been a major advance as cysts had not previously been cultured from the environment. The success of this was essential for further research.
The laboratory conditions to grow and maintain Giardia intestinalis have been established. The Research Group now has eleven strains of human isolates of Giardia intestinalis in permanent culture. This provides a supply of Giardia as a basis for all laboratory, experimental and field work. The in vitro production of Giardia cysts is now routine at Massey University. Cysts are essential for testing the methods and techniques used in water testing.

(ii) Counting methods have been refined.

(iii) New Zealand Giardia isolates have been grown over a range of temperatures and dissolved oxygen levels. The relationship between temperature and oxygen sensitivity has been established.

3.1.2 Giardia in reservoir hosts

(i) Giardia cysts in some dogs and cats were examined. Up to 25 per cent of dogs and 7 per cent of cats were found to be positive. Infectivity toward humans needs to be evaluated (21).

(ii) DSIR Land Resources have been trapping possums and transferring duodenal contents and faeces to Massey University, where assessment of the presence of Giardia has been made. Infection has been found in 25 per cent of ship rats in the Orongorongo and Hutt Valleys and 10 per cent of possums from the Orongorongo Valley and farmland near Havalock North. The positive isolations have all been

the human strain,ie.Giardia intestinalis though mice from Wellington and the Manawatu have proved negative for the human strain.

The distribution of rats (rattus rattus) in New Zealand is estimated to be about one per hectare, though under certain conditions numbers may be much higher. Possum distribution is estimated to be about five per hectare. Infected rats and possums from remote forest areas in the Rimutaka Ranges have been caught, it would seem unlikely that animals in these area have come into regular or close contact with humans and that infection is circulating within the species. Giardia was not detected amongst a small sample population of possums caught in the Auckland region, this may however be indicative of the small sample size. DSIR was unable to catch any Norway rats.

In conjunction with a wider study programme based in the Manawatu/Wanganui region, work has begun to examine the distribution of Giardia in wild and rural animals. Results obtained to date are as follows:

Possums	3 out of 48	=	6.25%
Rats	69 out of 100	=	69%
Mice	5 out of 17	=	29.4%
Sheep	10 out of 25	=	40%
Cows	1 out of 9	=	11%
Hens	4 out of 13	=	31%

These results are preliminary and insufficient to be statistically reliable. This work will be expanded with the involvement of DSIR Land Resources.

3.1.3 Validation of water testing methods

A modified standard method of the USEPA has been developed and is routinely used. The method has been validated both using in vitro cysts from the laboratory and cysts from the wild. Testing provides results that are not only positive or negative, but are also quantitative within the limits of current technology.

3.1.4 Water testing methods and sensitivity

The use of a tangential filter to speed up testing is been examined. The lowest level of sensitivity in a range of waters has been assessed to be of the order of 100 cysts per 100 litres of water.

3.1.5 Distribution of *Giardia* in New Zealand waterways

In cooperation with the Department of Conservation (DOC) and Local Authorities, Massey University has examined water samples from across the country. There is a patchy, but increasing, prevalence of *Giardia* in New Zealand waterways. Of 267 samples tested, 28 per cent were positive. A negative test cannot be regarded as an absolute negative but indicates that *Giardia* was not present at the time of sampling. The distribution is arbitrary as samples were taken at the behest of local bodies, DOC and other similar organisations. The distribution of *Giardia* in the New Zealand waters tested is shown in Figure 3.

3.1.6 *Giardia* antibodies

The Enzyme Immune Assay (EIA) to detect antibodies to cysts and trophozoite blood samples has been undergoing development at Massey University. If this test is established, it will obviate the necessity for using faecal tests to determine a past *Giardia* infection. It is also hoped to determine antigenic differences between trophozoites and cysts. A clear cut system however has not yet been established. The difficulty of getting blood samples has limited this work at this stage.

3.2 New Zealand Communicable Disease Centre

A nation wide survey of medical laboratories was carried out in order to gather information concerning the prevalence of giardiasis and laboratory testing methodologies (6). Testing of faecal specimens for *Giardia intestinalis* was routinely performed in 46 per cent of laboratories and performed only at the request of a practitioner in 54 per cent. Specimen concentration was routinely performed in 67 per cent of laboratories. The most common method of testing faecal specimens for *Giardia intestinalis* was a direct wet film preparation with subsequent staining using iodine or trichrome (44 per cent). Immunofluoresent Assays (IFAs) are not widely used for testing.

Over a period of three months testing, 2.7 per cent of faecal specimens were found to be positive for *Giardia intestinalis*. This would suggest over 3,300 cases of giardiasis in New Zealand per year. Insufficient data was available to identify an unequivocal link between cases of giardiasis and the type of water supply. It is hoped that future work will give a clearer indication of any link (see section 6.0).

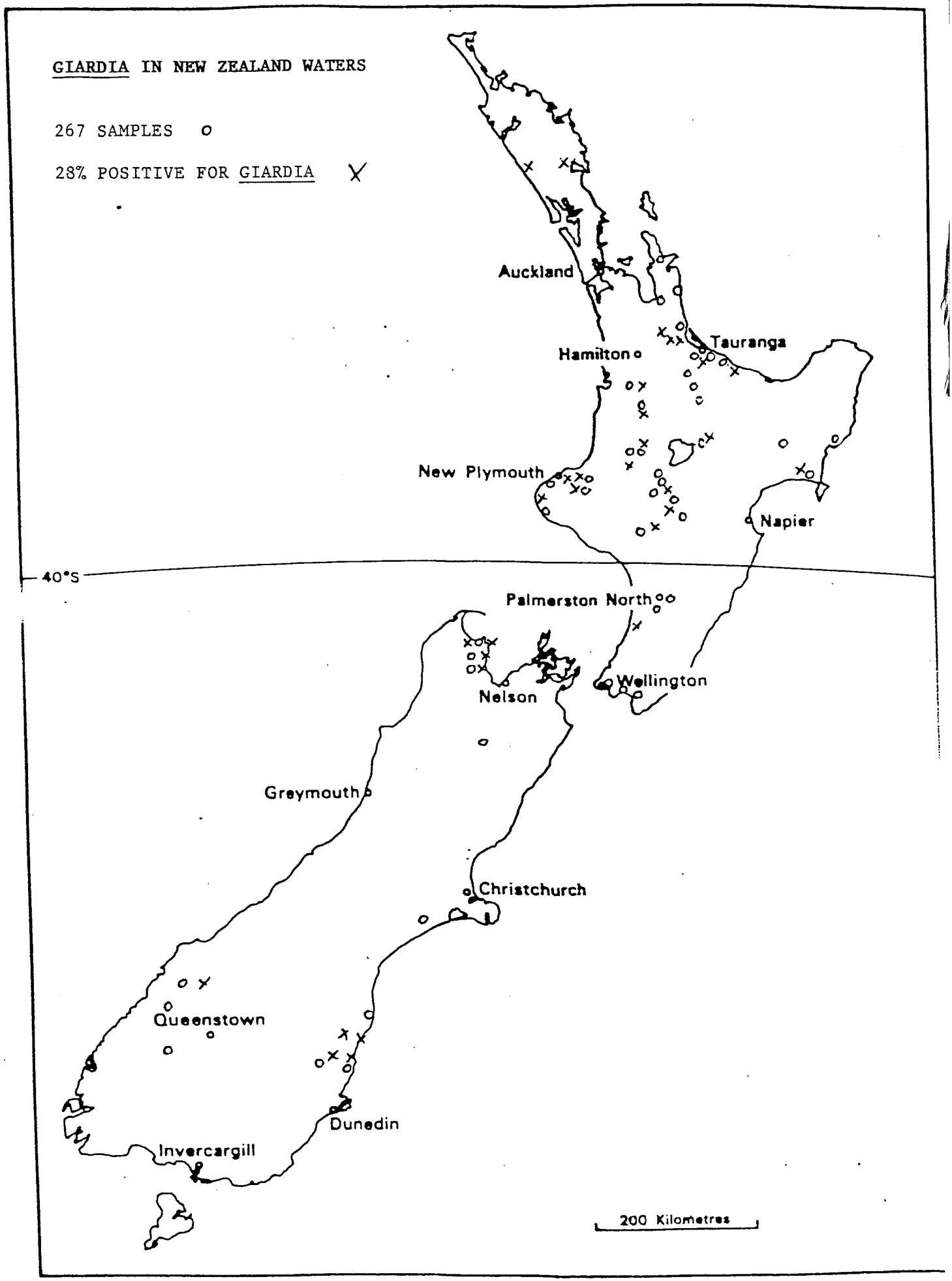

Figure 3

Note: Positive findings relate only to sites tested and are not representative of national coverage

3.3 DSIR Land Resources

This work has been performed in close association with Massey University. Initial results indicate that the human strain of Giardia is present in some mammals though not all (see section 3.1.2). Animals have only been caught on the North Island. Though the amount of data is limited, an indication of the positive instances of identification of Giardia in animals is shown in Figure 4.

3.4 Works Consultancy Services

An evaluation of the different drinking water treatment technologies for Giardia removal has been completed by Works Consultancy Services(30).

The main conclusions drawn from the report are:

(i) Many New Zealand water supplies do not receive treatment which would effectively remove Giardia cysts. Many supplies rely on only chlorination of the source water while some supplies receive no treatment at all. Both these supplies are of particular risk if source waters are contaminated with Giardia. Since Giardia does not breed in water, microbiological testing of supplies does not provide any assurance that Giardia has not been or will not be present in the future.

(ii) Chemical disinfection treatment technologies are not effective in killing Giardia cysts unless stringent conditions apply. These depend on source water quality, supply system control and the ability to maintain adequate chemical concentrations and contact time. A major disadvantage in the use of chemical disinfection comes from unpleasant tastes and the possible formation of trihalomethane compounds (see Appendix III).

(iii) Ultra violet light disinfection is not effective.

(iv) Water treatment upgrading is likely to be expensive. Since many water supplies in New Zealand are not treated using filtration, upgrading of facilities would seem essential. Overseas experience has shown that where Giardia and other protozoan organisms such as Cryptosporidium have been found, chemical coagulation and filtration have been the principal treatment.

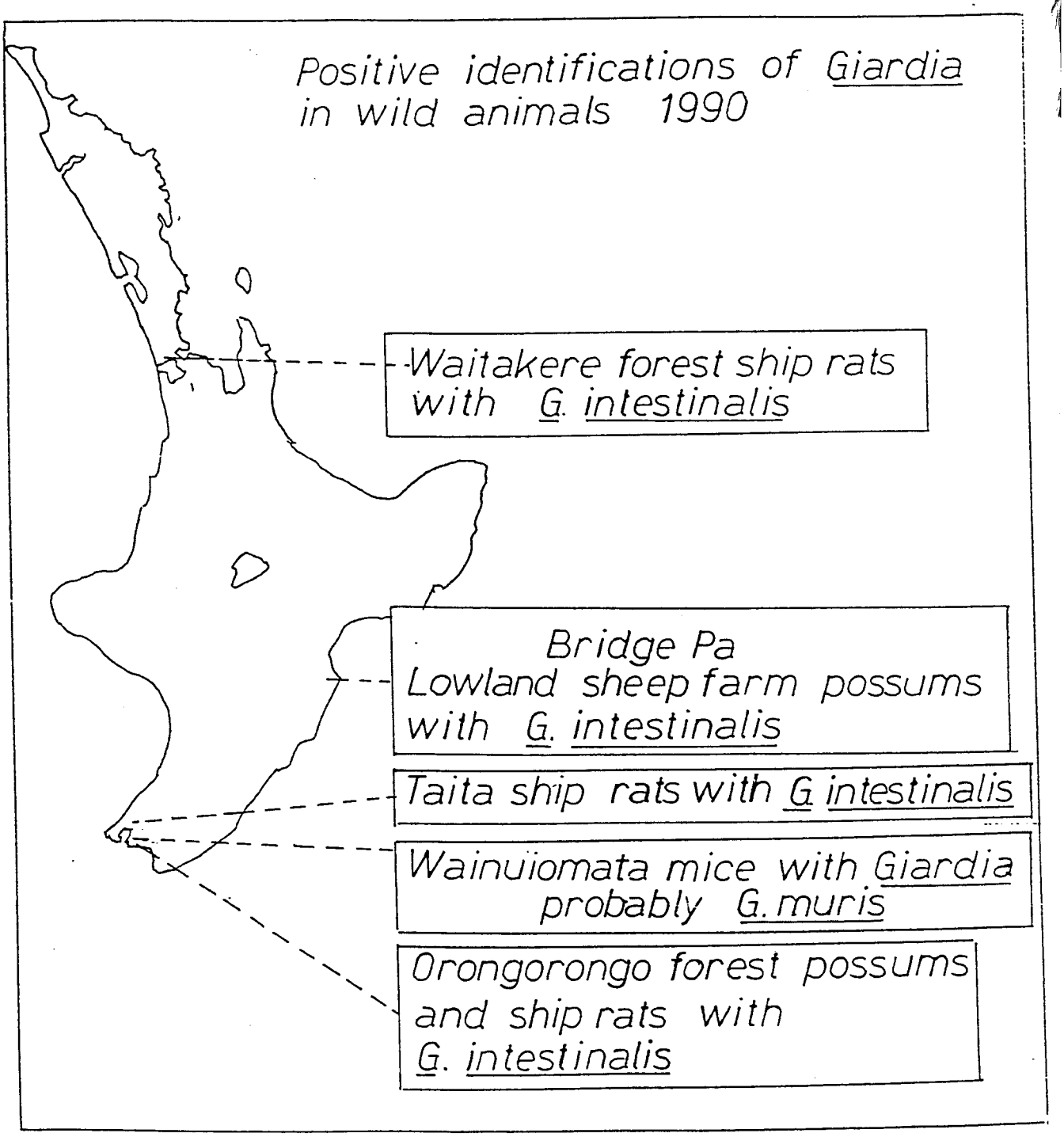
Positive identifications of Giardia in wild animals 1990
Waitakere forest ship rats with G. intestinalis
Bridge Pa
Lowland sheep farm possums with G. intestinalis
Taita ship rats with G intestinalis
Wainuiomata mice with Giardia probably G. muris
Orongorongo forest possums and ship rats with G. intestinalis

Figure 4

4.0 *GIARDIA* REMOVAL - IMPLICATIONS FOR WATER TREATMENT

4.1 Water Treatment Requirements

4.1.1 The "Multi-barrier" Approach

Giardia is of concern where upland shallow well and spring water sources are used for public water supply and where water treatment systems are inadequate to remove or inactivate *Giardia* cysts.

A "multi-barrier" approach is used to safeguard water supplies from microbiological contamination. Traditionally, this took the form of catchment control (often catchment closure), sometimes with long term water storage and often with chlorination or other chemical disinfection of water. This approach helped to dramatically reduce the incidence of water-borne gastro-enteric infections. Studies conducted by Massey University in conjunction with DSIR (Land Resources) indicate that *Giardia*, however, is carried by animals which are commonly found wild in catchment areas. Catchment control, without other measures, is of limited use for the control of contamination of water by *Giardia* cysts.

The adoption of more sophisticated treatment techniques enabled a "barrier" system to be incorporated into the treatment plant itself. For many turbid and discoloured surface waters, a "conventional" treatment train comprising chemical coagulation, sedimentation, rapid sand filtration and disinfection by chlorination evolved. Each of these processes forms a barrier against harmful micro-organisms. The "conventional" treatment train provides a multi-barrier system.

4.1.2 Chemical Coagulation

For the removal of *Giardia* cysts, the most effective barrier in the "conventional" treatment train is chemical coagulation.

Treatment processes incorporating chemical coagulation have been demonstrated to remove more than 99.9 per cent of *Giardia* cysts from contaminated water. Without chemical coagulation, rapid sand filtration has limited effect in removing *Giardia* cysts. Chlorination procedures as normally practiced in New Zealand also have limited effect.

Where the source water is relatively clear, however, coagulation may not be needed for turbidity removal. *Giardia* cysts survive in clear, cold "pure" looking waters. The "conventional" water treatment train has limited capability to remove *Giardia* cysts if chemical

coagulation is omitted or is improperly controlled. Outbreaks of giardiasis in the USA have been clearly demonstrated in association with water supplies which do not incorporate coagulation as a treatment step.

Several community water supplies in New Zealand either do not incorporate chemical coagulation, rely on chlorination alone, or rely purely on catchment control or catchment closure. Such systems must be regarded as inadequate for removal of Giardia cysts.

4.1.3 Slow Sand Filters

Other forms of water treatment have been found to be effective for removing Giardia cysts. These processes include slow sand filters and diatomaceous earth filters, whose straining properties are effective for cyst removal.

The ability of slow sand filters to reduce contamination of water have long been known, even though a full microbiological understanding took time to develop. Slow sand filters were one of the first processes to be used for the treatment of city water supplies in Britain, Europe and the USA. They are used as a part of water treatment systems at several large cities overseas.

In slow sand filters the straining action of the relatively fine filter sand is enhanced by the natural growth of a biological layer on the filter surface (a maturation period is important after filter cleaning). Recent studies in the USA have shown that slow sand filters are very effective at removing Giardia cysts.

Slow sand filters require relatively large areas of land. They also require large inputs of manpower or plant for periodic cleaning. They were never adopted to any extent in New Zealand - coagulation and rapid gravity filter technology had become standard practice by the time the majority of water treatment systems were developed. New Zealand's relatively turbid river waters would have presented problems, although simple and effective pre-treatment systems for slow sand filters have now been developed and are being used overseas.

4.1.4 Diatomaceous Earth Filters

Diatomaceous earth filters for water supplies came to prominence during the Second World War. The United States Army needed robust and portable water treatment plants capable of removing amoeba cysts. Amoebic dysentery had become a problem for troops serving in the Pacific and South East Asian theatres of war.

Diatomaceous earth filtration, along with chlorination, was found to be suitable for the purpose. Portable water treatment plants were developed for use in the field and are used by the New Zealand defence forces. More recently, diatomaceous earth filtration has been found to be extremely effective for the removal of Giardia cysts. The diatomaceous earth filter medium and filter pre-coat provides a very good straining "matrix".

In New Zealand, diatomaceous earth filters are used to improve water clarity at a number of swimming pools. They are used for a similar purpose in some industries. Their use for treating community water supplies has, however, been limited to one or two installations. They require careful maintenance of pumps and other mechanical equipment and careful control of pre-coat and filter medium dosing.

4.1.5 Chlorination

As mentioned in 4.1.2, chlorination procedures as generally practised in New Zealand water treatment have, on their own, limited effect on the inactivation of Giardia cysts. Chlorination can, however, be adapted to be extremely effective for this purpose. It requires higher chlorine doses and longer contact periods than are normal practice at present.

Several researchers have pointed out the need to assess the "C.T." criteria of chlorination systems. Here, "C" refers to the concentration of free chlorine in water after a contact time of "T" minutes. The required "C.T." to inactivate Giardia cysts depends on several factors, including the level of the chlorine residual itself (that is, the level of "C"), the pH of the water and the temperature of the water. The United States Environmental Protection Agency (USEPA) has published tables of the required "C.T." levels to give 99.9 per cent inactivation of Giardia cysts, taking these factors into account (See Appendix III).

Many natural factors interfere with chlorination. For chlorination to be the sole means of treatment of water supplies in the USA, the USEPA has set down rigourous limits for the maximum values of turbidity, total and faecal coliform numbers in source waters. In addition, the USEPA has set down stringent criteria for other factors. These criteria adapted for use in New Zealand, are presented in Appendix III.

4.1.6 Other Methods of Disinfection

Long-term water storage, ultraviolet light and ozonation are used as alternatives to chlorination for some New Zealand water supplies. Just as with chlorine, however, Giardia cysts have relatively high resistance to other disinfectants.

Storage in itself may have little effect. Giardia cysts settle out of water much more slowly than particulate matter. At the ambient temperatures of most New Zealand water storage lakes, long survival periods can be expected. Impounding reservoirs are themselves open to contamination by animal carriers of Giardia.

Ultraviolet light has been variously reported by researchers to be effective and ineffective for the inactivation of Giardia cysts. It seems that the clarity of the water is very important. If the water does not have very low turbidity, inactivation by ultraviolet light can be expected to be poor.

For chlorine dioxide and ozone, the USEPA has tabulated "C.T." values for 99.9 per cent inactivation of Giardia cysts (in this case, "C" is the concentration of residual ozone after contact time "T"). These values are temperature dependent.

4.1.7 Point of Use Treatment

"Point of use" treatment devices, which are fitted to domestic taps or into domestic plumbing systems, are increasingly being adopted in New Zealand. Many of these are designed purely for the improvement of taste and odour of water. The filter media used in some devices is not suitable to strain out Giardia cysts. Granular activated carbon, for instance, is too coarse. Devices which use powdered activated carbon or diatomaceous earth may, however, be effective. For the removal of Giardia and Cryptosporidium cysts, the media must be capable of removing particulates less than 3 microns in size.

4.2 Water Treatment in New Zealand

4.2.1 Urban Water Treatment Practices

Full "conventional" water treatment as described in 4.1.2 is used at a number of towns and cities in New Zealand. Large scale examples are to be found on the Auckland regional water supply system, at the Te Marua plant on the Wellington supply system, on the Waikato River supply to Hamilton and at the Mount Grande plant at Dunedin. There are similar plants at Palmerston North, New Plymouth, Invercargill and elsewhere. There are many smaller scale plants serving smaller towns and

rural communities. Provided that the coagulation process is properly controlled these plants provide good protection against Giardia contamination.

Some large cities - such as Christchurch, Napier and Hastings - and many smaller communities draw their water supplies from deep boreholes. Water treatment, in most of these cases, is aimed primarily at removing iron, manganese, hardness, taste and odours from the water. In some cases only chlorination - or perhaps no treatment at all - is practised. Water drawn from deep bores is not contaminated by Giardia except where contamination occurs in the storage and distribution system. Thus deep bore supplies give good protection from Giardia infections except where the water passes through open tanks or open impounding reservoirs.

There are, however, several supplies where water is taken from streams, rivers, lakes and open impounding reservoirs and where treatment is more limited. Treatment is by chlorination alone, or by rapid gravity sand filtration or microstraining in association with chlorination. Some supplies rely solely on catchment control or closure, or catchment control in association with chlorination. At least two cities have subsidiary supplies, in addition to their "conventionally" treated main supplies, which rely on such forms of control and treatment.

Several other supplies draw water "indirectly" from rivers, streams and lakes through infiltration galleries or shallow wells. Water travel pathways may be too short, and soil interstices too coarse, to provide effective removal of Giardia cysts. The same can be said of spring supplies. Careful investigation of the source water (with sanitary surveys where appropriate), together with water quality monitoring, must be carried out before such systems can be excluded as a risk of Giardia infections.

As noted in 4.1.1 and 4.1.5, if the source water quality does not meet stringent levels and if chlorination practices - and other procedures - are inadequate, these supplies are at risk of spreading Giardia infections. In any event, there are less "barriers" to Giardia than in "conventional" treatment systems. These supplies should be regarded as Giardia risks until they, and their operation, have been carefully assessed.

4.2.2 Water Treatment Practices for Rural Communities

Small rural communities often rely on simple rapid gravity filtration systems in association with chlorination, or on chlorination alone. A few use ultraviolet light disinfection instead of chlorination.

Some rely purely on catchment control or the "natural goodness" of the water itself. All these systems must be taken as being potential sources of Giardia infections.

There are one or two slow sand filtration systems on small community water supplies. Such systems must be properly designed and operated to be effective for the removal of Giardia cysts.

Some small community water supplies use coagulation with rapid gravity sand filters or use a full "conventional" treatment train. Provided these systems are properly operated, they will give good removal of Giardia cysts.

4.3 Methods of Improving Water Supplies

4.3.1 Population Numbers at Risk

The population "at risk" has been roughly estimated from examination of 1982 Ministry of Works and Development Local Authority Water Supply Statistics, with some modifications to allow for water treatment improvements since that time.

The examination roughly sorted those supplies which;

- utilise upland sources, impounding reservoirs, springs, infiltration wells and shallow wells;

- do not incorporate coagulation in their water treatment systems.

This gives a "high" estimate of the population at risk. Not all spring and shallow well supplies are susceptible to Giardia contamination. Some cities, notably Wellington, which use "chlorination only" at some water sources may be adequately treating their water - nevertheless an estimate of the populations served by such "chlorination only" sources has been included.

On the other hand, data for many small communities are incomplete and many have not been included.

This "rough estimate" gives a "population at risk" figure of approximately 500,000 people.

4.3.2 Chlorination Practices

Where source water quality and factors relating to:

- disinfection capability

- watershed control

- on-site inspection

- absence of water-borne disease outbreaks

- total coliforms in the supplied water

- levels of trihalomethanes

meet the criteria set in Appendix III. Under some circumstances super chlorination may form an effective barrier. These criteria may have major implications for the management of the water supply system.

4.3.3 Improved treatment methods

Communities whose water sources do not meet the stringent quality levels required for "chlorination only", and which cannot meet the other criteria, will have to install a form of treatment capable of removing Giardia (and Cryptosporidium) cysts. This is most likely to be in the form of the "conventional" treatment train briefly described in 4.1.1. Coagulation, rapid sand filtration and chlorination are important steps. Sedimentation, after coagulation, may or may not be required depending on the turbidity of the source water. The adoption of this approach will incur significant capital and operating costs.

Urban communities which already utilise rapid sand filters may be able to effect improvements by incorporating coagulant dosing, with or without sedimentation. This approach will significantly increase the operational requirements of the plants.

Small communities will be able to adopt simpler plants incorporating coagulation, rapid sand filters (in the form of pressure filters) and chlorination.

For some small supplies, treatment by slow sand filters may be possible. These may require pre-treatment systems incorporating plain sedimentation and roughing filters. They should be backed by chlorination. Whilst these systems require knowledgeable operation, and some manpower input for regular filter cleaning, operational procedures for small plants are much simpler than for "conventional" treatment. Capital costs may, however, be significant.

The installation of diatomaceous earth filters is a further alternative. These may require the incorporation of coagulation if the source water is turbid. Capital costs may again be significant and operational input will be significant.

For rural water supplies, where a significant proportion of the water is supplied for stock watering or other agricultural purposes, "point of use" filters may be the

most practicable process. These should, however, be of a type which is capable of straining out Giardia and Cryptosporidium cysts (4.1.7).

4.3.4 Summary of Appropriate Treatment Processes

The following water treatment processes are appropriate for the removal of Giardia and Cryptosporidium cysts where surface water, and groundwater subject to direct influence of surface water sources are used:

- Where source water meets the required turbidity and coliform standards and where catchment control, system control, inspections, absence of water-borne disease, total coliforms and trihalomethanes are as set out in Appendix III:

  chlorination to appropriate "C.T." level.

- Where source water does not meet required criteria for "chlorination only":

  either

  coagulation, sedimentation, rapid sand filtration (gravity or pressure filters) and chlorination

  or

  coagulation, rapid sand filtration (gravity or pressure filters) and chlorination (where source water turbidity permits)

  or

  slow sand filters and chlorination (with pre-treatment by sedimentation and roughing filters if the source water is turbid)

  or

  diatomaceous earth filters and chlorination (with coarse sedimentation and coagulation if the source water is turbid)

- For rural water supplies:

  "point of use" filters of a type capable of straining out Giardia and Cryptosporidium cysts.

4.3.5 The Cost of Improvements

Water treatment plants that require upgrading to be able to remove Giardia cysts vary widely in size. They range from very small units, serving less than 100 people, to very large units serving cities.

Water treatment plant costs are related to the size of the plant. A full "conventional" plant treating 450 cubic metres of water per day might cost around $270,000. A plant treating 90,000 cubic metres of water per day might cost around $27 million. When viewed from the basis of "cost per cubic metre of water treated", however, there are significant economies of scale.

Some plants need only limited upgrading. In some cases the system might meet the criteria that permit treatment by "chlorination only". In other cases improvements might be economically retro-fitted.

A rough assessment, which uses average costs and makes some allowance for possible economies of retro-fitting, shows that the cost of upgrading water treatment plants nationally might lie between $50 million and $100 million.

5.0 MAIN OUTCOMES

The work performed by Massey University in conjunction with DSIR Land Resources and NZCDC indicates that the presence of Giardia and outbreaks of giardiasis in New Zealand is increasing.

In the Auckland region alone nearly 400 cases of giardiasis were recorded during the first quarter of 1990 (31). On a national basis this would suggest as many as 5000 cases of giardiasis are occurring annually. This number corresponds only to those cases of giardiasis that receive medical attention and diagnosis. Since giardiasis is not a notifiable disease this would suggest that the actual number of cases of giardiasis may be much higher.

It is interesting to note, however, that outbreaks of giardiasis have occurred in many areas that receive 'complete' water treatment, ie. filtration and disinfection. This suggests that the major route of giardiasis transmission in these areas is through faecal-oral infection and not drinking-water (see section 3.2) (6).

In terms of public 'peace of mind' it is important that accurate information about Giardia is available. The Department of Health and numerous area health boards and local authorities have been approached by members of the public who have been told by their doctor that their giardiasis is due to drinking the local water. In many cases this has been highly unlikely due to supplies receiving 'complete' treatment. It is feasible however that should a treatment process fail, Giardia cysts could enter the supply. The statement that water supplies are Giardia free is equally erroneous. Since Giardia does not breed in water, testing only shows that no Giardia cysts were present in that particular sample.

The Canterbury, Wellington and Manawatu/Wanganui area health boards have undertaken voluntary reporting schemes to assess the number people infected by Giardia in their areas. This will provide invaluable information on the extent of giardiasis in these communities and the probable routes of infection. To date however insufficient data has been gathered to evaluate the mechanism by which giardiasis is transmitted in these communities.

Area health boards have been encouraged by the Department of Health to undertake a voluntary reporting scheme with local medical practitioners. An example of the 'Giardia Questionnaire' used by the Canterbury area health board is shown in Appendix IV.

The efficacy of water treatment facilities to remove Giardia from New Zealand water supplies is in certain situations under considerable doubt. Some local authorities are addressing Giardia control by increasing levels of disinfection by chlorination. While this may be effective in killing Giardia cysts, 'side effects' in previously unchlorinated supplies, such as the formation of chlorinated organics (eg. trihalomethanes) in water with high natural organics, and undesirable taste and odour may occur.

The impact of Giardia on community health in New Zealand is at this stage unknown. Giardiasis may play an important part in reducing the standard of the national health in terms of quality of life. Economic costs may also arise due to absence from work due to illness.

6.0 FUTURE WORK

The Department of Health is providing financial support to Massey University's Department of Microbiology and Genetics for research into Giardia and giardiasis in the Manawatu/Wanganui Health District. The three year project will seek to achieve the following:

1 Quantitative monitoring of selected waterways and supplies in the Manawatu/Wanganui Health District.

2 Monitoring of farm and domestic animals for the presence of Giardia cysts.

3 Monitoring of wild animals for the presence of Giardia cysts.

4 Attempted establishment of laboratory cultures from human/animal/environment sources.

5 Develop molecular techniques of strain definition.

6 Determine which strains are carried in which host.

7 Estimate of cyst viability and the proportion of cysts normally viable.

8 Streamlining and development of sampling and testing methods.

9 To develop a serological test which will allow the distinction to be made between humans never infected with Giardia, humans who have been infected and humans with a current infection.

10 Survey a target human population to gain information on the prevalence of Giardia infections.

11 Examine the relationship between known Giardia cases and the presence of Giardia in local waters and/or presence of Giardia in animals.

12 Attempt to model the relationship of the factors affecting the incidence and prevalence of Giardia and giardiasis in the region.

On-going work within area health boards is also expected to provide a more comprehensive picture of how giardiasis is distributed and transmitted in New Zealand.

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ACKNOWLEDGEMENTS

The authors would like to thank the following for providing information, useful comment and criticism during the compilation of this report.

Dr Mel Briesman (Medical Officer of Health, Canterbury Area Health Board), Dr Bob Brockie (DSIR Land Resources), Associate Professor Dr Tim Brown (Head of Department, Department of Microbiology and Genetics, Massey University), Mr Jonathan Fletcher (Unit Manager, Environmental Health Policy Group, Department of Health), Mr David Kettell (Principal Consultant, Environmental Engineering, Works Consultancy Services), Mr Desmond Till (Chief Bacteriologist, New Zealand Communicable Disease Centre), Mr Jim Waters (Toxicologist, Department of Health) and Te Wahanga Hauora Maori (Maori Health Unit, Department of Health).

APPENDIX I

Department of Conservation *Giardia* Fact Sheet

Giardia Fact Sheet

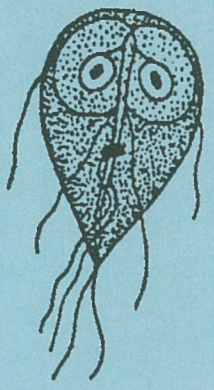
There is a new problem in New Zealand that you need to be aware of. A parasite called *Giardia* may be in your drinking water. This information will help you to avoid *Giardia* in the outdoors.

WHAT IS IT?

Giardia is a parasite that lives in the intestine. It cannot be seen by the naked eye but can cause a serious stomach illness.

The *Giardia* life cycle has two stages. The swimming (feeding) stage, and the cyst (resting) stage. The cyst is the infective stage. Cysts infect a person's intestine and begin the feeding stage.

Magnified view of *Giardia*



Feeding (swimming) stage

HOW IS IT SPREAD?

Giardia is spread by cysts being passed in the faeces and entering a new host through the mouth. Poor toilet waste disposal can result in cysts entering water systems such as streams and lakes. *Giardia* cysts can survive in very cold water.

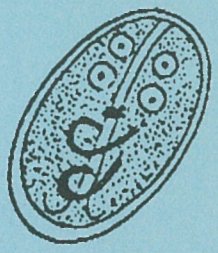
When contaminated water is drunk *Giardia* enters the intestine where it feeds and produces more cysts which are in turn passed out in the faeces.

HOW TO STOP IT

Where toilet facilities are provided, use them.

Where no facilities exist, bury toilet waste. Select a place more than 50 metres away from water sources and busy areas. Dig a shallow hole within the organic layer of the soil and bury toilet waste and paper.

Washing hands after going to the toilet and before handling food is important. DO NOT wash hands directly in a water source. Take water well away and drain it into the ground after use.



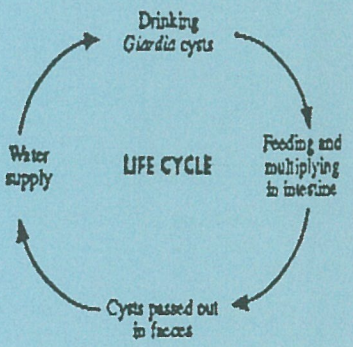
Cyst (resting) stage

TREATING WATER

If you suspect that water may be contaminated with *Giardia* there are three ways to make it safe to drink.

1. **Boiling water**
   Bring water to a fast boil for more than 3 minutes to kill the cysts.
2. **Chemical purification**
   Adding chemicals is a convenient means of killing the cysts. Iodine solution and chlorine purification tablets are available from chemist shops and outdoor equipment retailers. Effectiveness depends upon the clarity of the water, the strength of the chemical, and the length of treatment time before drinking.

   Ten drops of tincture of iodine per litre of water or 2–4 drops of household bleach per litre will kill the cysts after 20 minutes.
3. **Filtration**
   Portable filtering mechanisms are now available from some outdoor equipment retailers. Water filtered through *Giardia* rated filters need not be boiled and is pleasant to drink.



IF YOU'VE GOT IT

The signs and symptoms of *Giardia* are: explosive foul smelling diarrhoea, stomach cramps, bloating, dehydration, nausea, and weight loss. It may take 3 weeks for symptoms to occur after cysts have been swallowed.

Unlike other causes of diarrhoea *Giardia* may last for months. As a carrier you risk spreading the parasite to other people.

Treatment is simple and quick acting with prescribed drugs. If you suspect that you have *Giardia* see your doctor as soon as practical.

Help keep your environment free of Giardia. Avoid spreading the parasite.

CONSERVATION
TE PAPA ATAWHAI

Department of Conservation,
PO Box 10-420, Wellington

July 1990

APPENDIX II

Area Health Board Communication, Technical, Giardia Fact Sheet T7/91 Department of Health

Area Health Board Communication
Technical
From the Department of Health
T7/91. 12 March 1991

GIARDIA FACT SHEET

Dear General Manager

ATTENTION: ALL HEALTH PROTECTION OFFICERS

Why are we interested?

Over the past months considerable public interest has been shown in the presence of *Giardia* in some of New Zealand's natural waters. Tests performed for the Department of Conservation (DOC) by Massey University have indicated that *Giardia* is present in many streams, lakes and rivers in National Parks.

DOC has published a "*Giardia* Fact Sheet" which is available from DOC information centres. Many tramping clubs and associations have also published information material.

Projects funded through the Department of Health indicate that *Giardia* is likely to spread as more of the feral animal population becomes infected. This 'update' is to provide background information about *Giardia*.

What is it?

Giardiasis, a gastrointestinal disease caused by the parasite *Giardia lamblia*, has probably been in New Zealand for many years. The parasite was first detected in New Zealand among servicemen returning from overseas in the 1940s. Recent surveys have identified the organism in some water supplies in New Zealand.

Giardia is one of the most frequently identified parasite in public health laboratories in the USA and the United Kingdom.

It is now generally agreed that there are two morphologically distinct species which infect mammals:

- *Giardia **lamblia*** naturally infects humans, beaver, coyote, cattle, cats and dogs and can experimentally infect other mammals. It has also been found in birds in North America;

- *Giardia **muris*** primarily infects mice and rats.

How is it spread?

Global : Giardiasis occurs endemically world-wide and its prevalence often depends on the level of community sanitation and the personal habits of the people. Prevalence is higher in areas of poor sanitation and among children. The high rates of infection in children are partly due to their relative susceptibility, incontinence, indifference to faeces and lack of discrimination in taking objects to the mouth. Child care centres, kindergartens and primary schools are high risk areas.

If you've got it

There is a variable incubation period ranging from one to three weeks with a median of 7-10 days. Clinical manifestation range from mild transient intestinal complaint that resolve spontaneously to severe long-standing disease with malabsorption and debilitation.

1 **Acute Infection**
There is a sudden onset of watery diarrhoea with frequent bowel actions passing yellowish watery offensive, frothy, foul-smelling stools along with foul-smelling flatus. Anorexia, nausea, lethargy and weight loss are common symptoms. Occasionally fever has been reported. In most acute cases there is a tendency for spontaneous improvement within two to three weeks.

2 **Chronic Infection**
The infection is characterised by periodic episodes of mushy foul-smelling stools with increased flatulence and abdominal distension. Cramps are common. Anorexia is sometimes noted. Chronic infection may or may not be preceded by acute or subacute infection. Children are occasionally brought to medical attention because of failure to thrive.

3 **Asymptomatic infection**
People who have asymptomatic infections are less likely to be diagnosed and treated and are therefore important in the transmission of the disease as healthy carriers. Excretion of cysts by carriers may last months or years.

Diagnosis and treatment

Microscopic identification of distinctive *Giardia* cysts in formed stools or cysts and trophozoites in loose stools is definitive.

Mertronidazole is the drug of choice in New Zealand, although other nitro-imidazoles are effective. Rarely, when appropriate nitro-imidazole regimens have been proven to fail, quinacrine hydrochloride may be used.

People who suspect that they have *giardia* infection should be advised to see their doctor for diagnosis and treatment.

How to prevent *giardia* infection

Personal hygiene

Toilet facilities should be used if provided.

Toilet waste and paper should be buried if no toilet facility is provided. The place should be more than 50 metres away from water sources or busy areas. A shallow hole (300mm) should be dug within the organic layer of the soil.

Washing hands after going to the toilet and before handling food is important. Waste water from handwashing should not pollute water source.

Transmission in most older age groups is usually through contaminated food or water. It is a documented problem in homosexually-active males often as a result of direct faecal - oral contact. More recently AIDS patients have been reported to have severe, protracted diarrhoea due to Giardiasis.

Person to person transmission is usually by hand to mouth transfer of cysts from the faeces of an infected individual. Unfiltered stream or lake waters that are open to contamination by human and animal faeces are a source of infection.

Outbreaks of the disease can often start from drinking faecally contaminated water supplies. Other sources of outbreaks reported are swimming pools. Contaminated food is occasionally implicated in localised outbreaks. Drinking from cold streams contaminated by wild animals is thought to be a common source of outbreaks.

In New Zealand, work conducted to date by Massey University and the New Zealand Communicable Disease Centre do not support the hypothesis that water is a major route of transmission of giardiasis in New Zealand.

Asymptomatic individuals are probably more important in transmission than those with diarrhoea. Carrier rate is high.

New Zealand: Little is known about the transmission patterns in New Zealand. At the national level, there is little statistical information on the occurrence of the disease. Data available suggests that probably over 1,000 cases are tested positive by laboratories annually. Comprehensive statistics are not available as the disease is not notifiable. Little is known about the source(s) of infection in these cases. Research is in progress to determine the role of wild animals and birds.

People involved in camping and tramping may have a higher risk of infection. There is increasing evidence to suggest that these activities are responsible for the spread of the disease from overseas into the New Zealand environment. Lack of toilets at laybys and rest areas frequently means that travellers have no other alternatives but to use the bush.

Life cycle

The life cycle of *Giardia lamblia* includes a trophozoite and a cyst form:

The **trophozoite** which is the mobile stage of the parasite is microscopically broadly round anteriorly and tapering to a slender tip posteriorly. Its front pairs of flagella provide vigours mobility.

In established infections some of the trophozoite detach from the lining of the mucosa for unknown reasons and enter the faecal stream where in the small intestine encystment begins with the trophozoite rounding up to form a **cyst**. Each of the two nuclei in the cyst undergo a single division so that the mature cyst contain four nuclei. Cysts are ovoid in shape and measure 9_x_12_microns.

Giardia cyst are known to be resistant to destruction by hypotonic solutions such as water. The cysts are known to survive for more than two months at 8 C, one month at 21 C and four days at 37 C. It has been reported that the cyst suspended in lake or river water were viable for 56 to 84 days in winter. Boiling kills cysts immediately.

Water treatment

Suspect water may be treated in the following ways:

1 Boiling

Boiling water for more than 3 minutes will kill the cysts.

2 Chemical disinfection

Iodine solution and chlorine purification tablets may be used in treating small quantities of drinking water. Effectiveness will depend on the turbidity of the water, the strength of the chemical and the duration of treatment.

Ten drops (0.5ml) of 2 percent tincture of iodine per litre of water or 2-4 drops (0.1-0.2ml) of household bleach per litre may kill the cysts after 20 minutes depending on the quantity of organic matter that may also be present in the water. A longer contact period of say 30 minutes should be allowed if the water is cold.

3 Filtration

Portable filters for *giardia* cysts may be used to treat smaller quantities of drinking water. It must be emphasised however that filters may not be effective in removing other pathogens such as bacteria and viruses.

For municipal water supplies slow sand filtration or chemical coagulation followed by filtration as well as chlorination is required for safe drinking water taken from suspect surface water. *Giardia* cyst withstand chlorine concentrations that would normally kill enteric bacteria.

Swimming pools

There is the need for regular testing of chlorine and proper maintenance of dosing equipment and filtration system of swimming pools. Contingency plans for faecal accidents should be in place. (See Standards Association of New Zealand : NZS5826 Parts 1 & 2)

Surveillance

There is no surveillance of the disease at the national level. A voluntary notification scheme has been developed by some area health board. An example questionnaire produced by the Canterbury Area Health Board is enclosed for your information.

Each area health board is advised to put in place a local voluntary reporting system. Such a system will be of value in assessing the transmission patterns of the disease in the area. A reporting system will be helpful in developing short and long term policies for the control of the infection in the area.

Public awareness

People need to be aware of the risks associated with drinking untreated water. All natural waters have the potential to be infected with pathogenic organisms and should therefore be sterilised before being consumed.

T7/91

Department of Health funded projects

The Department of Health has provided funding support for four projects investigating *Giardia* and giardiasis in New Zealand.

1) "Water treatment for the removal of *Giardia* Cysts".
   A report prepared by Works Consultancy Services evaluating different drinking water treatment technologies for *Giardia* removal.

2) "Giardiasis in New Zealand, Results of a laboratory based survey". A survey conducted by the New Zealand Communicable Disease Centre of medical laboratories throughout New Zealand to accumulate information on prevalence of giardiasis and laboratory testing methodologies.

3/4) Massey University has undertaken research in the methods used to isolate *Giardia*. In conjunction with DSIR Land Resources a study to determine the prevalence of *Giardia* in domestic and feral animals and suspect New Zealand waterways is being undertaken.

Officers for enquiries: Dr Emmanuel Ampofo, (04) 496-2323
Christopher Shaw, (04) 496-2227

Yours sincerely

Steve Anderson
General Manager
Review

APPENDIX III

Criteria for "Chlorination Only" treatment and "C.T." values for chlorine disinfection

(adapted from USEPA Federal Register 1989)

CRITERIA FOR "CHLORINATION ONLY" TREATMENT

General

The following criteria relate to "chlorination only" water treatment and are based on those of the United States Environmental Protection Agency, as published in Federal Register Volume 54, Number 124 of 29 June 1989. The criteria set out below are for use in New Zealand.

These criteria are applicable where surface water, and groundwater subject to direct influence of surface water sources are used, or where there are open storage reservoirs.

If these criteria cannot be met, appropriate water treatment systems must be installed and efficiently operated.

Source Water Quality

The faecal coliform concentration in the water prior to chlorination must be less than 20 per 100 ml in at least 90 per cent of samples. Coliform monitoring is an on-going requirement. The frequency of sampling should relate to the size of the supply. As a minimum, samples should be taken once each week and must be evaluated every month for the preceding six months.

The turbidity of the water prior to chlorination must be less than 1 NTU based on grab samples taken every four hours that the system is in operation.

Chlorination Systems

Chlorinators must be supported by back-up units with auxiliary power supply and automatic start-up and alarm. Alternatively, the system may incorporate automatic shut-down of the water supply when the chlorine residual is less than 0.2 mg/l in the water. In the latter case an alternative fully treated water source must be available (i.e. this alternative applies only to "multiple source" systems).

The free chlorine residual entering the water supply system must not be less than 0.2 mg/l for more than four hours. Systems are expected to incorporate continuous monitoring, although supplies serving

- fewer than 3,000 people may substitute a programme of at least three grab samples each day at least three hours apart.

- fewer than 2,000 people may substitute a programme of at least two grab samples each day at least four hours apart.

- fewer than 500 people may substitute a programme of at least one grab sample each day.

The chlorine residual must be measured at, or above, the first consumer in the system.

The appropriate "C.T." criterion as tabulated in this Appendix must be met at all times. Daily calculations of "C.T." must be made for a point at or above the first consumer and must relate to the contact time and chlorine residual during the peak hourly flow.

Where,

CT = Residual chlorine (g/m3) x Contact time (minutes)

A free chlorine residual is expected to be achieved at all times in the distribution system. The residual must not be undetectable in more than five per cent of samples in a month for any two consecutive months.

Catchment Control

An effective watershed control programme to minimise Giardia contamination must be maintained. This programme must, as a minimum:

- characterise the catchment hydrology and land ownership;

- identify characteristics (including livestock and wildlife) and activities which may have an adverse effect on source water quality;

- monitor the occurrence of activities which may have an adverse effect on source water quality;

- carry out any necessary livestock and wildlife control and activity control.

On-site Inspections

Routine inspections of the system must be carried out to demonstrate that the catchment control programme is being maintained, that the chlorination procedures are reliable and that potential health hazards are identified. A comprehensive inspection must be carried out at least once per year. This must include:

- a review of the effectiveness of the watershed control programme;

- a review of the physical condition of the source intake and how well it is protected;

- a review of the system's maintenance programme to ensure that there is a low probability of failure of the chlorination process;

- a review of operating procedures;

- a review of data records, particularly to ensure that all required tests are being carried out;

- identification of any improvements necessary.

Full reports of such inspections must be made available to the area health board on request.

Water-borne Disease Outbreaks

The system must not have been a source of a significant occurrence of acute infectious illness. If it has been identified as such a source, it must have been modified so as to prevent another occurrence.

Coliform Levels

The system must comply with the levels of faecal coliforms and coliform organisms set out in the Drinking-Water Standards for New Zealand (Board of Health, Wellington, 1984) for treated water entering the distribution system and for water in the distribution system.

Trihalomethanes

Where a source water contains significant amounts of organic matter it is unsuitable for "chlorination only" treatment.

The Drinking-Water Standards for New Zealand do not currently set standards for total trihalomethanes. The Standards do, however, draw attention to the role of organic precursors and the desirability of their removal by water treatment prior to chlorination. The maximum value for chloroform (30mg/m3) set in the Drinking-Water Standards for New Zealand should be used as a guide-line.

C.T values for 99.9% inactivation of Giardia lamblia by free chlorine at 0.5C or lower.

Residual Chlorine (g/m3)	pH <6.0	6.5	7.0	7.5	8.0	8.5	<9.5
<0.4	137	163	195	237	277	329	390
0.6	141	168	200	239	286	342	407
0.8	145	172	205	246	295	354	422
1.0	148	176	210	253	304	365	437
1.2	152	180	215	259	313	376	451
1.4	155	184	221	266	321	387	464
1.6	157	189	226	273	329	397	477
1.8	162	193	231	279	338	407	489
2.0	165	197	236	286	346	417	500
2.2	169	201	242	297	353	426	511
2.4	172	205	247	298	361	435	522
2.6	175	209	252	304	368	444	533
2.8	178	213	257	310	375	452	543
3.0	181	217	261	316	382	460	552

C.T values for 99.9% inactivation of Giardia lamblia by free chlorine at 5.0C.

Residual Chlorine (g/m3)	pH <6.0	6.5	7.0	7.5	8.0	8.5	<9.5
<0.4	97	117	139	166	198	236	279
0.6	100	120	143	171	204	244	291
0.8	103	122	146	175	210	252	301
1.0	105	125	149	179	216	260	312
1.2	107	127	152	183	221	267	320
1.4	109	130	155	187	227	274	329
1.6	111	132	158	192	232	281	337
1.8	114	135	162	196	238	287	345
2.0	116	133	165	200	243	294	353
2.2	118	140	169	204	248	300	361
2.4	120	143	172	209	253	306	368
2.6	122	146	175	213	258	312	375
2.8	124	148	178	217	263	318	382
3.0	126	151	182	221	268	324	389

CT = Chlorine (g/m3) x contact time (minutes)

C.T values for 99.9% inactivation of Giardia lamblia by free chlorine at 10.0C.

Residual Chlorine (g/m3)	pH						
	<6.0	6.5	7.0	7.5	8.0	8.5	<9.5
<0.4	73	88	104	125	149	177	209
0.6	75	90	107	128	153	183	218
0.8	78	92	110	131	158	189	226
1.0	79	94	112	134	162	195	234
1.2	80	95	114	137	166	200	240
1.4	82	98	116	140	170	206	247
1.6	83	99	119	144	174	211	253
1.8	86	101	122	147	179	215	259
2.0	87	104	124	150	182	221	265
2.2	89	105	127	153	186	225	271
2.4	90	107	129	157	190	230	276
2.6	92	110	131	160	194	234	281
2.8	93	111	134	163	197	239	287
3.0	95	113	137	166	201	243	292

C.T values for 99.9% inactivation of Giardia lamblia by free chlorine at 15.0C.

Residual Chlorine (g/m3)	pH						
	<6.0	6.5	7.0	7.5	8.0	8.5	<9.5
<0.4	49	59	70	83	99	118	140
0.6	50	60	72	86	102	122	146
0.8	52	61	73	88	105	126	151
1.0	53	63	75	90	108	130	156
1.2	54	64	76	92	111	134	160
1.4	55	65	78	94	114	137	165
1.6	56	66	79	96	116	141	169
1.8	57	68	81	98	119	144	173
2.0	58	69	83	100	122	147	177
2.2	59	70	85	102	124	150	181
2.4	60	72	86	105	127	153	184
2.6	61	73	88	107	129	156	188
2.8	62	74	89	109	132	159	191
3.0	63	76	91	111	134	162	195

CT = Chlorine (g/m3) x Contact time (minutes)

C.T values for 99.9% inactivation of Giardia lamblia by free chlorine at 20.0C.

Residual Chlorine (g/m3)	pH						
	<6.0	6.5	7.0	7.5	8.0	8.5	<9.5
<0.4	36	44	52	62	74	89	105
0.6	38	45	54	64	77	92	109
0.8	39	46	55	66	79	95	113
1.0	39	47	56	67	81	98	117
1.2	40	48	57	69	83	100	120
1.4	41	49	58	70	85	103	123
1.6	42	50	59	72	87	105	126
1.8	43	51	61	74	89	108	129
2.0	44	52	62	75	91	110	132
2.2	44	53	63	77	93	113	135
2.4	45	54	65	78	95	115	138
2.6	46	55	66	80	97	117	141
2.8	47	56	67	81	99	119	143
3.0	47	57	68	83	101	122	146

C.T values for 99.9% inactivation of Giardia lamblia by free chlorine at 25.0C and higher.

Residual Chlorine (g/m3)	pH						
	<6.0	6.5	7.0	7.5	8.0	8.5	<9.5
<0.4	24	29	35	42	50	59	70
0.6	25	30	36	43	51	61	73
0.8	26	31	37	44	53	63	75
1.0	26	31	37	45	54	65	78
1.2	27	32	38	46	55	67	80
1.4	27	33	39	47	57	69	82
1.6	28	33	40	48	58	70	84
1.8	29	34	41	49	60	72	86
2.0	29	35	41	50	61	74	88
2.2	30	35	42	51	62	75	90
2.4	30	36	43	52	63	77	92
2.6	31	37	44	53	65	78	94
2.8	31	37	45	54	66	80	96
3.0	32	38	46	55	67	81	97

CT = Chlorine (g/m3) x Contact time (minutes)

APPENDIX IV

Canterbury Area Health Board Giardia Questionnaire

Canterbury
AREA HEALTH BOARD

HEALTH PROTECTION SERVICES
PRIMARY HEALTH DIVISION
P BOX 1475, CHRISTCHURCH
PHONE: (03) 799-480
FAX: (03) 796-125

(Computer number _____)

(90Q1:Case)

GIARDIA QUESTIONNAIRE

(If you have any problems with this questionnaire please contact this office)

Name_____ Date of birth ___/___/___

Address _____ Male / Female

Suburb/Town _____ Ethnic origin _____

Phone(Home) _____ (Work) _____

Left hand column: tick for YES, blank for NO.

1 SYMPTOMS

What was the date of onset of the first symptoms ? ___/___/___

2 HUMAN CONTACTS

__ Any contact with a known case in the 2 weeks before the onset of symptoms ?

__ Any contact with a possible case in the 2 weeks before the onset of symptoms ?

DETAILS

If YES
Who was the contact ? (eg Son)

__ Had contact recently been overseas ?

Where was the contact ? (eg Home)

3 RECENT HUMAN CONTACTS

__ Has any recent contact of the case subsequently developed similar symptoms ?

DETAILS

If YES, who ? (eg Friend)

'Towards a Healthy Canterbury for and with the People'

QF417

4 PRESCHOOLER/CONTACT WITH PRESCHOOLER

__ Is the case a preschooler ?

If YES
__ In nappies ?
__ Does he/she eat soil ?

If NO
__ Did you have any contact with a child in nappies in the 2 weeks before the onset of symptoms ?

DETAILS

If YES
Who ? (eg Daughter)

Where ? (eg Home)

5 CHILDCARE/INSTITUTION VISITS

NAME OF PLACE

Did the case attend any of the following in the 2 weeks before the onset of symptoms ?

__ Childcare centre
__ Home, school or institution for the intellectually handicapped
__ Hospital or other institution
__ School camp

6 OCCUPATION

DETAILS

What does your work involve ?

__ Foodhandler
__ Childcare worker
__ Healthcare worker
__ Other
__ Not applicable because child/student

7 OVERSEAS TRAVEL

COUNTRIES

__ Any overseas travel in the 2 weeks before the onset of symptoms ?

__ Probable country where infected ?

__ Did you return to New Zealand by sea ?
If YES, give details

DETAILS

Name of ship ?
Duration of voyage ?
Ports visited ?
Any illness on board ?

8 WATER

__ Any water consumed from sources, other than the Christchurch mains, in the 2 weeks before the onset of symptoms ?
If YES, where ?

	WHERE	NUMBER OF CUPS
__	Town	
__	Farm	
__	Country	
__	Reserve/National Park	
__	Other	

	SOURCE (if known)	UNTREATED	BOILED	CHLORINATED	FILTERED	UNKNOWN
__	Well					
__	River/Creek					
__	Spring					
__	Rainwater					
__	Other					
__	Unknown					

DETAILS

___ Any recent problems with your domestic water supply ?

__ Any 'Party Ice' consumed in the 2 weeks before the onset of symptoms ?
If YES, give details including where obtained ?

9 SEWAGE

DETAILS

What kind of sewerage system do you have ?
__ City/Borough council system
__ Septic Tanks
__ Deep Hole Latrine
__ Other

___ Any sewage or human wastes handled at work or at home in the 2 weeks before the onset of symptoms ?

___ Any recent problems with your sewage disposal system ?

10 PETS

__ Any contact with pets or domestic animals in the 2 weeks before the onset of symptoms ?

If YES, Which ones ?
___ Cat
___ Dog
__ Bird
___ Other

__ Any handling of a sick pet in the 2 weeks before the onset of symptoms ?

11 ANIMALS/BIRDS

___ Any contact with or handling of any of the following in the 2 weeks before the onset of symptoms ?

DETAILS

___ Cows
___ Sheep
___ Goats
___ Horses
___ Pigs
___ Poultry
___ Ducks
___ Deer
___ Sick Animal
___ Rodents (rats/mice)
___ Wild Animals (possums,hedgehogs,etc)
___ Animal Manure (eg garden use)
___ Other

Any time spent on a farm in the 2 weeks prior to the onset of symptoms ?
___ Farm visitor
___ Farm resident

12 RAW MEAT

___ Any handling of raw meat in the 2 weeks before the onset of symptoms ?

DETAILS

___ Beef
___ Mutton
___ Pork
___ Poultry
___ Offal
___ Other

13 MEALS

Where were the meals eaten in the 2 weeks before the onset of symptoms ?

___ Home

PREMISES

___ Restaurant
___ Cafe
___ Friends
___ Function (wedding etc)
___ Service Station
___ Other
(Takeaways; see next question)

14 TAKEAWAYS BRAND WHERE PURCHASED

___ Chicken
___ Chinese
___ Other Ethnic Foods
___ Hamburgers
___ Meat Pies
___ Fish & Chips
___ Ham Roll/Sandwiches
___ Salads
___ Other

15 RAW FOODS

___ Any raw foods eaten in the 2 weeks before the onset of symptoms ?
BRAND WHERE PURCHASED

___ Raw meat
___ '' fish
___ '' shellfish
___ Salads
___ Raw Vegetables/Coleslaw
___ Raw Mushrooms
___ Unpasteurised milk
___ '' cream
___ Other unpasteurised dairy products
___ Other raw foods

16 PERSON'S/PARENT'S IMPRESSION AS TO SOURCE

What do you think was the source of the infection given that it usually takes 5 - 10 days to develop the illness after the initial contact with the Giardia organism.

(Answer only one) DETAILS
___ Source known
___ " suspected
___ Possible source
___ Source unknown

17 TYPE OF OUTBREAK SUSPECTED

___ Single case
___ More than one

___ Household
___ Institutional
___ Public place
___ Public function
___ Private function

___ Waterborne spread
___ Foodborne "
___ Person to person "
___ Other "
___ Unknown "

18 ANY OTHER COMMENTS

We would also like to ask some of the same questions, for comparison, to someone else who doesn't live with you but who is of the same Age and Sex as yourself/your child and who lives in the same Neighbourhood, but who has not been sick. We would therefore be very grateful if you could provide us with the details of 2 such people. We can assure you that neither your name nor your details will be given to them.

a) Name _____ Approximate Age _____ yrs

Address _____ Suburb _____

b) Name _____ Approximate Age _____ yrs

Address _____ Suburb _____

Name of person completing the questionnaire _____

Your relationship (eg his/her mother) to the person who has had Giardia if that person is too young to answer the questions _____

Date ___/___/___

As soon as possible after completion of the questionnaire, we would appreciate it if yc could return it in the enclosed envelope.

Thank you for your assistance.