GIARDIA - ITS DISTRIBUTION, IDENTIFICATION AND CONTROL

E G Carrington

June 1987

UNRESTRICTED

WRc Environment,
Medmenham Laboratory, Henley Road, Medmenham,
PO Box 16, Marlow, Bucks, SL7 2HD
Telephone: Henley (0491) 571531
A conference was recently held (24-25th February 1987) in Calgary, Canada at which the nature of the disease, Giardiasis, the distribution and identification of the causative protozoa and the role of water as a vector was reviewed. The proceedings are summarised in this report and are discussed within the context of UK experience and practices.

The report concludes that, although information about the disease and the protozoa is sparse, the cysts are readily removed from contaminated water by good water treatment practices. The risk of waterborne Giardiasis in the UK is very low and provided that Water Undertakers maintain current standards additional precautions appear unnecessary.
CONTENTS

SUMMARY

1. INTRODUCTION 1
2. GIARDIASIS - THE DISEASE 1
3. GIARDIA - THE ORGANISM 2
  3.1 Occurrence 2
  3.2 Morphology 2
  3.3 Identification 3
    3.3.1 Concentration 3
    3.3.2 Confirmation 3
4. WATER AS A VECTOR 4
  4.1 Non-water vectors 4
    4.1.1 Person-to-person transmission 4
    4.1.2 Animals as carriers 5
  4.2 Surface waters 5
  4.3 Potable waters 6
    4.3.1 Untreated or inadequately treated supplies 6
    4.3.2 Contamination of the distribution system 6
  4.4 Sewage effluents 6
5. WATER TREATMENT 7
  5.1 Legislative requirements 7
  5.2 Potable water treatment 7
  5.3 Water in distribution 11
  5.4 Waste water treatment 12
6. DISCUSSION 12
7. REFERENCES 15
1. INTRODUCTION

This report summarises the nature of the disease Giardiasis, the distribution and identification of the causative protozoa, the role of water as a vector, the measures needed to remove the cysts from raw water and their control in contaminated distribution systems. It draws mainly on the information presented at the Calgary Giardia Conference (Calgary, Alberta, Canada, 23-25 February 1987) but is supplemented from other sources.

The conference took place at the Bow Valley Hotel, Calgary. The 114 delegates were mainly from the US and Canada but representatives were present from Czechoslovakia, Australia and the UK. The intensive programme contained some 50 papers, 4 discussion sessions and a poster display covering epidemiology, immunology, taxonomy, viability testing, laboratory techniques, detection of cysts, and water treatment. It covered the work of most of the active researchers in the field. However the general standard of presentation and chairmanship could have been better and the intensity of the programme left little opportunity for informal contacts.

2. GIARDIASIS - THE DISEASE

In man Giardiasis arises from the parasitisation of the small intestine by the trophozoite stage of the flagellated protozoan Giardia lamblia, also referred to as G. duodenalis or G. intestinalis. Infection can give rise to a variety of symptoms, diarrhoea, abdominal cramps, vomiting, chills, low-grade fever, headache, generalised weakness, it may also be asymptomatic. Duration of symptoms in acute infections range from a few days to several months. Chronic infections may develop.
In the UK the number of reported cases has risen steadily from about 4300 cases in 1982 to about 5900 cases in 1986. Many of these patients have been overseas prior to the onset of symptoms. These figures relate only to cases that have received laboratory investigation. They may therefore considerably underestimate the total number of cases. This underestimating may be enhanced by the tendency for the disease to be mild and self-limiting. The figures are, however, a good estimate of the number of serious cases.

3. GIARDIA - THE ORGANISM

3.1 Occurrence

Although the genus was first described in 1859 it was not until the 1930s and 1940s that its pathogenicity was recognised and it is only in the last twenty years that the scale of the disease has been appreciated. Because of its self-limiting nature and the relatively small number of serious cases the disease has not attracted much attention from researchers. Thus the taxonomy and nomenclature of the Giardia genus is confused. The distribution of the genus is probably worldwide and members have been isolated from mammals, amphibia and birds. Epidemiological evidence and other investigations show that Giardia species are not host specific, however, recent morphological evidence suggests that some animal species may be natural hosts to specific strains of Giardia as well as a reservoir for other strains (Erlendsen and Bemrick 1987).

3.2 Morphology

The trophozoites of Giardia lamblia are the mobile, flagellated stage of the parasite which attach to the epithelial cells of the small and large intestines. They are pear-shaped. The presence of two nuclei, a sucking disc and flagella give it
the characteristic appearance of a distorted face. The trophozoites of other species are somewhat similar. It is unusual to find trophozoites other than in material freshly removed from the intestine since in less favourable conditions, cysts are formed. Cysts are ellipsoidal and thick-walled through which the nuclei and flagella remain visible. Cysts are resistant to environmental conditions and are the usual source of infection.

3.3
Identification

3.3.1
Concentration

In infected patients, diagnosis is usually made from the qualitative presence of cysts in faecal material. Because of the large numbers present specimens can be readily prepared for microscopic examination by simple emulsification, washing and flotation onto a coverslip.

Environmental samples contain fewer cysts so some concentration is necessary. With water samples, the usual practice is for the water to be drawn through a cartridge of wound or spun polypropylene or Orlon. The amount of water used will depend upon its quality but for clean surface waters this could be as much as 3800 litres (100 US gall). The cartridge is back-washed, cut open and rinsed. The washings and rinsings are further concentrated either by membrane filtration or by centrifugation and flotation.

3.3.2
Confirmation

Concentrated cysts may be stained with iodine and examined by direct microscopy. Recently an indirect fluorescent antibody technique has been developed by Quinones et al (1987). Their view was that this technique had few advantages over the traditional methods. Although easier and requiring less training this test is more time-consuming, and
4. WATER AS A VECTOR

4.1 Non-water vectors

4.1.1 Person-to-person transmission

The main route of transmission for all intestinal infections is direct faecal to oral contact particularly where population density is high and standards of hygiene low. Mental institutions, retirement homes and nursery schools, where there is close personal contact, are specially vulnerable (Healy 1987). Studies in Czechoslovakia (Giboda 1987) show that the level of cases in children is related to their density in their accommodation; the lowest being in families where the children have little or no contact with other children and the highest occurring in institutions.

A detailed study of an outbreak in a Hutterite* community in Canada showed that the probable route of transmission, because of bad hygiene practices, was by ingesting faecal material. The water supply was not a vector (Harley 1987).

* The Hutterites are almost closed communities of German extraction based on religious beliefs
4.1.2
Animals as carriers

Giardia has been reported in many species of animals. Although usually thought of as being associated with water-mammals the organism has also been found in terrestrial mammals, such as small rodents, cows, sheep, horses and cats. A survey of 100 stray dogs found that overall 10% were infected but levels of infection varied and were as high as 33% in one town (Levis 1987). Thus it seems quite likely that pet to man transmission may occur.

4.2
Surface waters

Contamination of upstream surface waters is usually as a result of infected water-mammals defaecating into streams. Beavers are frequently blamed. The infection cycle within the animals is self-perpetuating but serological and morphological studies suggest that man (probably by casual defaecation by campers) may initiate the cycle in some instances. Contaminated waters of this type are less likely to occur in the UK than in North America because of the geographical distribution and lower densities of aquatic rodents, the smaller areas of "wild" country and camping restrictions.

There is also some evidence from Arkansas based on epidemiology and timing of rainfalls, to suggest that body contact sports may be a route of infections (Gross, 1987).

Sewage effluent is a further potential source of contamination particularly affecting lowland waters (See Section 4.4).
4.3
Potable waters

4.3.1
Untreated or inadequately treated supplies

North American mountain streams, because of the presence of rodents frequently contain Giardia cysts. These streams often serve as sources of water for remote or small rural communities. Such sources, because of their good quality and the relative high cost of treatment plants are often distributed after the minimum of treatment which can result in Giardiasis in the community. Contaminated streams also pose a hazard to campers who use them as sources of drinking water. Widespread outbreaks are much less common in larger communities since such supplies are invariably treated before distribution.

4.3.2
Contamination of the distribution system

Giardia can only multiply in the intestinal tract. Therefore cysts of Giardia that survives water treatment will not proliferate during distribution. If an outbreak of Giardiasis is believed to be waterborne and is associated with a supply that has been satisfactorily treated, then direct faecal contamination of the system must be suspected. Although such contamination is believed to be rare, mains opened for repair, unprotected service reservoirs, accidental connections to waste water systems and backsiphonage on occasions when mains pressure is lost, present opportunities for such ingress. Such an incident probably occurred in Bristol, UK in 1985, but despite intensive investigations no source of contamination was identified (Browning and Ives 1987).

4.4
Sewage effluents

Infected patients will excrete large numbers of cysts into the waste water system and these may eventually be transferred to local water courses
where they will pose a potential hazard to participants of water sports, wild animals and water intakes. The regular presence of Giardia cysts in sewage polluted surface waters was demonstrated by Sykorá et al (1987a). In a 23 month survey, all 36 samples taken from a Pennsylvanian river below eight sewage treatment works contained Giardia cysts are levels between 1 and 438 per US gall (0.26 - 116 l⁻¹).

5. WATER TREATMENT

5.1 Legislative requirements

Much of the current interest in Giardia, arises from the US Clean Water Act which will be promulgated in December 1987. This Act defines that surface water treatment systems should achieve, amongst other requirements, at least a 3 log (ie 1000-fold) reduction in Giardia cysts. This requirement is to be met by the use of design specifications rather than monitoring.

Other countries do not specify Giardia in their water legislation.

5.2 Potable water treatment

Physical methods of potable water treatment, such as slow sand filters, diatomaceous earth filters, coagulation and microstrainers are an effective means of removing Giardia cysts from raw waters. These are an attractive proposition in terms of capital and operating costs and operating simplicity for small communities.

In British Columbia, after pilot scale evaluation, slow sand filters were installed for a community of 2000 persons where 60 cases of waterborne Giardiasis had been confirmed in 1981 (Bryek 1987). The plant was monitored regularly during the first year of operation (1985-6). Cysts were found in
11/22 raw water samples at a mean level of 0.1 per US gallon (0.026 l\(^{-1}\)) but no cysts were found in the finished water. Initially, coliform removal was not good but improved during the year to yield only a few coliforms per 100 cm\(^3\) water.

Slow sand filtration, diatomaceous earth (DE) filtration and coagulation-filtration (including conventional treatment, direct filtration and in-line filtration), have been evaluated by the US EPA for *Giardia* cyst removal in pilot plant and/or in the field (Logsdon 1987). Properly designed and operated, the above processes can attain a 99 percent cyst reduction, or higher. Logsdon (1987) discussed relative advantages and disadvantages of the processes, and factors that may result in success or failure of treatment. He suggests that slow sand filtration is the least complicated process to operate and thus the most appropriate for small systems.

DE filtration is very effective for cyst removal, but removal of very small particles requires use of fine grades of DE or chemical preconditioning of DE. Operator skills required are mostly of a mechanical nature.

Coagulation-filtration has the greatest flexibility, and can remove 99 to 99.9% of *Giardia* cysts. Many factors influence process performance so a good understanding of coagulation chemistry is needed for most effective operation regardless of plant size. This requires the greatest level of operator ability for continued, dependable performance. Logsdon (1987) also provided data on the relative performance of these processes with regard to other aspects of water quality, eg removal of other micro-organisms and of turbidity.
Pilot scale studies at a Montana (USA) resort which had approximately 850 cases of Giardiasis per annum in a population of 2000 led to a modified direct filtration system with filter aids, which used an absorption-destabilisation regime in summer (alum 11.2 mg l\(^{-1}\), anionic polymer 0.56 mg l\(^{-1}\)) and a flocculation-adsorption regime in winter (alum 2.3 mg l\(^{-1}\), anionic polymer 0.48 mg l\(^{-1}\)) followed by simple chlorination (Alberi et al 1987). Raw water turbidity ranged between 0.5 and 8.2 NTU and the finished waters averaged 0.54 NTU. In January 1986 9 cysts were detected in 400 US gal. (1.5 m\(^3\)) of raw water but none were detected in 1400 gal (5.3 m\(^3\)) of finished water.

Point-of-use devices have been evaluated on a laboratory rig in Canada (Cullimore and Jacobsen 1987). The relative efficiencies of the devices tested could be grouped by the elimination of viable cysts as:

(i) high efficiency – ultraviolet irradiation, ozone;

(ii) moderate efficiency – reverse osmosis;

(iii) poor efficiency – granulated activated carbon, and various tap attachments.

The effectiveness of such devices also relies on the enthusiasm of the householder to carry out the required maintenance.

A mobile water treatment plant has been used by van Roodselaar and Wallis (1987) to evaluate disinfectants under field conditions. Although early experiments suggested that more than 99% cysts were killed with chlorine concentrations and contact times lower than predicted from the literature, subsequent experiments with different strains of *Giardia* revealed a wide range of
response to chlorine dose. Initial experiments with chloramine and chlorine dioxide suggest that neither were effective at normal dosages but these experiments are not yet complete.

The action of chlorine upon Giardia cysts is influenced by several variables. The chlorine requirements are usually quoted as CT values where C is the concentration of free chlorine in mg l\(^{-1}\) and T is the contact time in minutes required to give 99% kill, assuming that first-order kinetics (Chick's law of disinfection) are obeyed. With chlorine, it is found that C is inversely proportional to T, so that CT is constant under practical conditions. It is usually assumed that T has a minimum value of 60 and concentrations of chlorine above 2.5 mg l\(^{-1}\) are not recommended. A 10 °C rise in temperature will lower the CT value by about 3-fold and at pH values above 8 the CT estimates are unreliable. The CT estimates are specific to genus, CT values for Giardia can be 10 times higher than those for Escherichia coli and are modified by unique characteristics of the source water (Marrocco et al 1987, Hibler et al 1987, Hoff 1987, van Roodseelaar 1987). From literature studies Marrocco et al (1987) suggest the following free chlorine CT values for waters up to pH 8.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>CT value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5</td>
<td>300</td>
</tr>
<tr>
<td>5 - 15</td>
<td>240</td>
</tr>
<tr>
<td>16 - 25</td>
<td>180</td>
</tr>
<tr>
<td>&gt; 25</td>
<td>90</td>
</tr>
</tbody>
</table>

At a plant near Boston, Massachusetts, it was found that CT values for ozone were between 10 and 250 times lower than those for chlorine depending upon the ambient temperature (Nebel 1987). An air-ozone
mixture was fed into the contact tanks to give a predicted level of ozone of 5 mg l\(^{-1}\); the level in the water leaving the tanks was 1 mg l\(^{-1}\).

5.3 Waters in distribution

After two outbreaks of possibly waterborne Giardiasis in the province, Alberta has regularly monitored public water supplies for the presence of Giardia cysts. In 4 years 700 samples (a total of 40 \(\times\) 10\(^3\) litres) from 40 communities have been examined and only 3 cysts found (McClure and Mackenzie 1987). The authors conclude that, although the survey had produced useful information on plant performance, it is not very effective, as a monitoring system since it is time-consuming and expensive. They consider that until there are improvements in Giardia cyst detection, more traditional indicators of plant performance, such as absence of faecal indicator bacteria, will be more effective in ensuring cyst-free drinking water. A different view was expressed by Sykora et al (1987b) who believe that the actions taken after finding a cyst during the regular monitoring of a finished water after a waterborne epidemic of Gardiasis prevented a second outbreak.

A number of delegates at the Conference in discussions expressed the view that it was impracticable, uneconomic and undesirable to routinely maintain chlorine levels in the distribution system high enough to destroy any cysts might gain access to the system such as appears to have happened in Bristol in 1985. In their view there should be more mandatory use of backflow prevention devices, close co-operation between the health and the water authorities to detect any suspicion of waterborne disease and rapid issue of "boil water" notices followed by a thorough investigation of the incident.
5.4  
Waste water treatment

A comprehensive survey of the Youghiogheny River area, Pennsylvania (Sykorá et al 1987a) indicated that over the 11 sewage treatment works examined the removal rates ranged from 81.0% to 99.8%. Between 1 and 40 cysts per litre were observed in raw sewage and 1 cyst was observed in the effluents in volumes ranging from 1 to 380 litres. The results of the study imply that, since some of the works more efficient at cyst removal had only primary treatment, settling is the main factor in removing cysts during waste water treatment.

6. DISCUSSION

Giardiasis is a worldwide disease. Like most intestinal tract infections it is mainly spread by the faecal-oral route and is most frequently observed in high-density populations such as residential institutions. However, the disease is not confined to man and cycles of infection can be established involving man, animals and surface waters. The infective dose is low. For example, Hibler (1987) reports that in infectivity experiments, 5 cysts caused infection in all gerbils receiving that dose.

Infections can occur when inadequately treated water is drunk. Although community outbreaks are not common, there have been 62 such outbreaks in the last 20 years in the US (Craun 1986) and only 5 outbreaks occurred in 102 communities where cysts were found in the treated waters (Hibler 1987).

There is at the present time, arising from the 1987 US Clean Water Act, considerable interest in controlling the organism. Although the parasite was first recognised about 100 years ago, its pathogenicity has only been appreciated in the last 20 years. Because the disease is normally mild and self-limiting it has not attracted much attention
from medical or environmental researchers. Thus, the taxonomy of species within the genus, host specificity and infectivity are unclear.

Although modern diagnostic aids such as immunofluorescent and monoclonal antibody techniques are being developed, these are not yet readily available. Current diagnostic tests rely on concentration procedures, which are not very efficient, and upon tedious microscopic examination and the application of experience in identification. Most waterborne outbreaks have occurred in small communities where surface water was contaminated by water mammals that were infected. The beaver is frequently implicated. Such animals frequent remote areas where, because of the apparent good quality of the raw water and the economy of small rural communities, minimal water treatment is used. Experience and research has shown that although Giardia cysts can be killed by the use of disinfectants they are readily removed by filtration systems which may be cheaper and less technically demanding to operate.

Outbreaks have also occurred when water has become contaminated within the distribution system as a result of cross-connections to waste-water systems or bad practice during mains repair.

It is unlikely that community outbreaks arising from contaminated raw water would occur in the UK. Suitable carrier animals are rare. The general lack of large remote areas open to tourism and the control of camping effectively reduce the risks of contaminating streams and infecting wildlife by casual defaecation. The relatively small portion of the population infected and the high standard of sevage and of sewage treatment mean that the potential for contamination of lowland waters is low. Public water supplies in Britain are of a
high standard. Contamination of distribution mains may occur during emergencies and in repairs but maintenance of good working practices, as detailed in 'Water Supply Hygiene' (National Water Council 1979) and use of back-flow prevention devices and co-operation between the water supply and health authorities should minimise this risk. Experience and epidemiological evidence indicates that in the UK the risk of waterborne Giardiasis is very low and provided that water undertakers maintain their present high standards there is no need for additional precautions.
REFERENCES


*GROSS M (1987) Giardiasis in Arkansas


*HIBLER C P, HANCOCK C M, PARGEK I M, WEGRZYN J G and SWABBY K D (1987) Inactivation of Giardia cysts with chlorine at 0.5 to 5.0 °C.


*QUIMONES B E, HIBLER C P and HANCOCKS C M (1987) Comparison of the zinc sulphate technique with the indirect fluorescent antibody technique for the detection of Giardia cysts in water.


WRc ENGINEERING
P O Box 85
Frankland Road
Blagrove, Swindon
Wilts SN5 8YR
Tel: Swindon (0793) 488301
Telex: 449541

WRc ENVIRONMENT
Medmenham Laboratory
Henley Road, Medmenham
P O Box 16 Marlow
Bucks SL7 2BD
Tel: Henley (0491) 571531
Telex: 848632

WRc (Headquarters)
John L van der Post Building
Henley Road, Medmenham
P O Box 16 Marlow
Bucks SL7 2BD
Tel: Henley (0491) 571531
Telex: 848632

WRc PROCESSES
Stevenage Laboratory
Elder Way
Stevenage, Herts
SG1 1TH
Tel: Stevenage (0438) 312444
Telex: 826168

WRc SCOTTISH OFFICE
1 Snowdon Place
Stirling FK8 2NH
Tel: Stirling (0786) 71580

WRc WATER BYELAWS ADVISORY SERVICE
660 Ajax Avenue
Slough, Bucks
SL1 4BG
Tel: Slough (0753) 37277
Telex: 449541

Registered Offices:

WRc
WRc CONTRACTS
CABLETIME INSTALLATIONS LTD
Henley Road, Medmenham
P O Box 16 Marlow
Bucks. SL7 2BD
Tel: Henley (0491) 571531
Telex: 848632