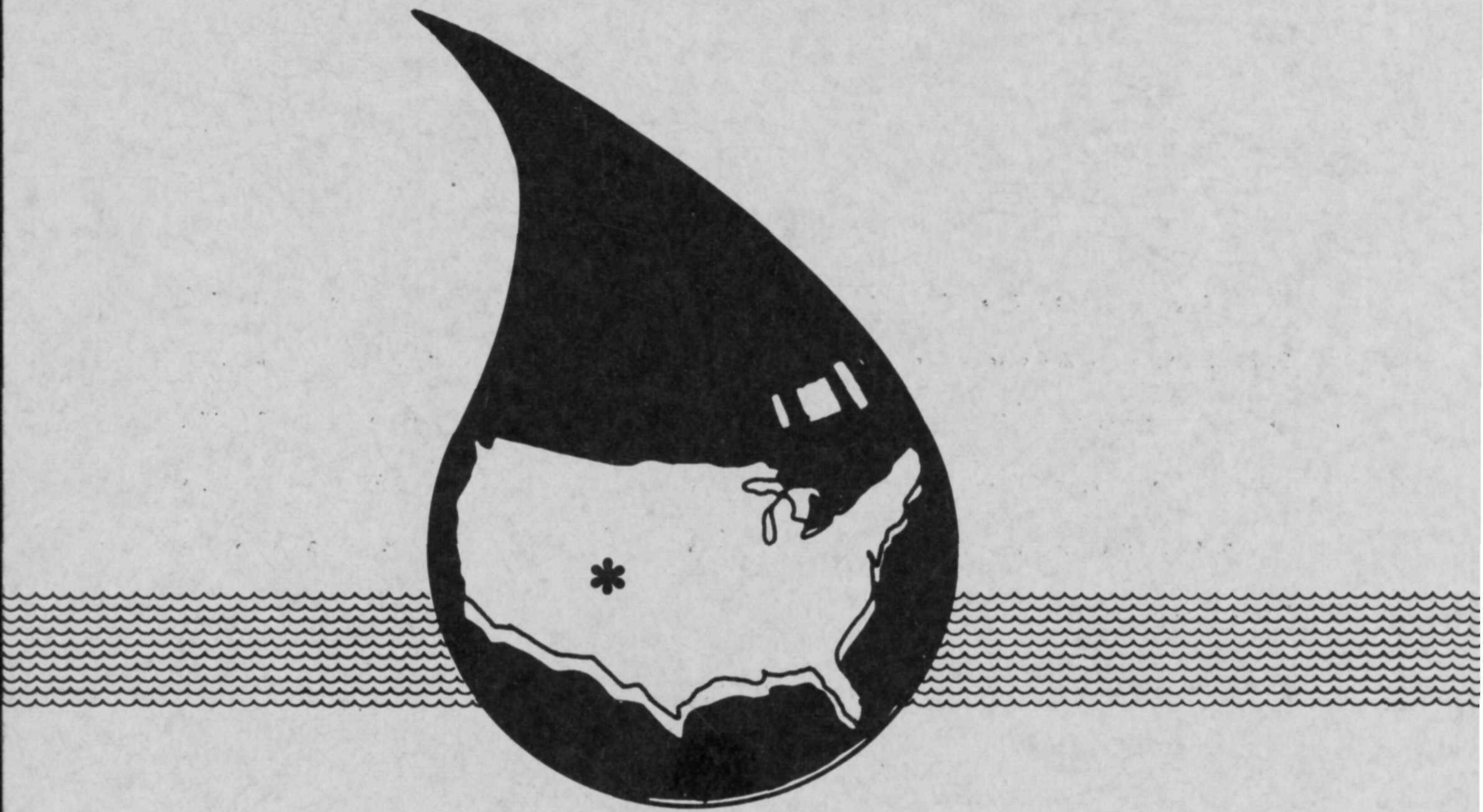
GIARDIA IN WILDLAND WATERS: INFORMATION FOR NATIONAL PARK MANAGERS



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NATIONAL PARK SERVICE
Department of the Interior

WATER RESOURCES DIVISION
NATIONAL PARK SERVICE
COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO 80523

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Chief
Water Resources Division
National Park Service
301 South Howes Street
Fort Collins, Colorado 80521

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Water Resources Report No. 86-1

Edited by

Juliette Wilson

and

Sam Kunkle

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Applied Research Branch
Water Resources Division
National Park Service
Colorado State University
Fort Collins, Colorado 80523

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FOREWORD

This report is a collection of basic information intended to be an overview on the protozoan parasite *Giardia*. The different sections of this paper are excerpted from two more lengthy documents that include a research study and a convention proceedings. The first section contains the manuscript of a paper presented at the Society of American Foresters 1985 National Convention. This paper is a brief overview of pathogens found in watersheds of the Western United States, with particular emphasis on *Giardia*, its pathogenesis, and its distribution. The second section contains an excerpt (Appendix C) from a recently published study on the incidence of *Giardia* in Rocky Mountain National Park, Colorado. In this section, backcountry water purification techniques are discussed in terms of their relative effectiveness against *Giardia*. The third section contains the bibliography from the same Rocky Mountain National Park report and is included to direct readers to other, often more comprehensive, sources of information on *Giardia*.

It is our hope that this report provides the basic information and resources necessary for National Park Service personnel to begin to familiarize themselves with this important issue. *Giardia* contamination of surface waters continues to spread into remote reaches of our national parks and other protected areas where visitors are accustomed to finding pure and safe drinking water. This is no longer the case in many areas, and public education about the risks of drinking untreated water is becoming increasingly important. Therefore, those of us working in NPS units must be informed about *Giardia* so that we can manage our parks to provide the best and healthiest outdoor experiences possible for our millions of visitors each year.

GIARDIA AND OTHER PATHOGENS IN WESTERN WATERSHEDS

Kirke Martin
Sam Kunkle
George Brown

"*Giardia* AND OTHER PATHOGENS IN WESTERN WATERSHEDS"[1]

by

Kirke L. Martin,[2] Sam H. Kunkle[3] and George W. Brown[4]

ABSTRACT.--Waterborne pathogens and parasites can be a problem in surface waters in wildland and forested areas. The parasite *Giardia* has become a particular problem in areas with cold surface waters such as the Rocky Mountains and the Pacific Northwest. Wildlife in these areas have been found to carry and transmit *Giardia* cysts, and such water-dwelling mammals as beaver and muskrats are common vectors of *Giardia*. Recently, field samplers have been developed that are suitable for testing water in remote areas for *Giardia*. Many forest management concerns arise in connection with the presence of *Giardia* in wildlands; for example, how should wildlife management goals reflect considerations of the presence and transmission of *Giardia*?

INTRODUCTION

Much of the surface water in this country and in the world is highly polluted; however, there are portions of many watercourses that are of relatively high quality. These high quality waters are deceptively considered "pure" and "safe for drinking" by many people who later regret their simple act of consuming untreated water. This is especially true of many neophyte backpackers, campers, hunters, fishermen, hikers, and outdoor-oriented people. The "experienced" outdoor

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[1]A paper presented at the Society of American Foresters 1985 National Convention held in Fort Collins, Colorado, on July 28-31, 1985.
[2]Kirke L. Martin, Research Associate, Department of Microbiology and Environmental Health, Colorado State University, Fort Collins, CO.
[3]Sam H. Kunkle, Hydrologist, National Park Service Water Resources Division, Fort Collins, CO.
[4]George W. Brown, Head, Forest Engineering Department, Oregon State University, Corvallis, OR.

people, either from personal experience or other means of education, understand that it is much better to be safe and treat the water they use in order to avoid the unpleasant results possible from contracting a waterborne disease of bacterial, viral, or parasitic etiology. There exists a long list of possible waterborne diseases, and the following are only the more common ones (Brown 1983; CDC 1984):

DISEASE	AGENT
BACTERIAL DISEASES	
Legionnaire's disease	*Legionella pneumophila*
Colibacillosis	enteropathogenic *Escherichia coli*
Cholera	*Vibrio cholera*
Typhoid fever	*Salmonella typhi*
Enteric fever	*Salmonella paratyphi*
Salmonellosis	*Salmonella typhimurium*
Bacillary dysentery	*Shigella* species
Meliodidosis	*Pseudomonas pseudomallei*
Leptospirosis	*Leptospira* species
Yersiniosis	*Yersinia entercolitica*
Campylobacteriosis	*Campylobacter jejuni*
VIRAL DISEASES	
Hepatitis	Hepatitis A virus
Polio	Polio virus
Enteroviral gastroenteritis	Enterovirus
Norwalk syndrome	Norwalk virus
Rotavirus gastro-intestinal syndrome	Rotavirus

PARASITIC DISEASES

Intestinal roundworm	Ascaris
Blood flukes	Shistosoma
Amoebic dysentery	Entamoeba histolytica
Lung flukes	Paragonimus
Giardiasis	Giardia lamblia

Of these, the most prevalent reported waterborne disease in the United States has been giardiasis (CDC 1984). Giardia infections have headed the list for the last six years and have caused 43 percent of the reported waterborne disease outbreaks since 1971 (CDC 1984). In Colorado in 1984, there were 928 cases of laboratory-confirmed giardiasis (CDH 1985a,b), and Oregon reported 1,057 cases during the same year (Brown 1985). A large percentage of these cases result from drinking untreated surface water.

THE PARASITE GIARDIA

Members of the genus Giardia are pathogenic intestinal parasites that have two stages to their life cycle: the vegetative or reproductive stage that causes the symptoms of giardiasis, the trophozoite; and the dormant or transmission stage that survives out of the host and is the infective agent in waterborne giardiasis, the cyst.

The trophozoite was first described by Leeuwenhoek in 1681 (Feely et al. 1984). It is a dorsoventrally flattened, pear-shaped body. The general appearance of the trophozoite has been likened to a "monkey face." The size of the trophozoite ranges from 9-21 micrometers long, 5-15 micrometers wide, and 2-4 micrometers thick.

The Giardia cyst is oval or ellipsoidal in shape, has a thick and protective exterior wall, ranges from 10-15 micrometers by

7-10 micrometers, and generally has four nuclei. The cyst stage of the organism is resistant to some environmental stress, and infection in humans occurs by ingesting cysts.

Life Cycle and Pathogenesis

Until the early 1960's parasitologists considered Giardia to be a non-pathogenic commensal or opportunistic pathogen in humans because large numbers of cysts may be found in the stools of asymptomatic people (Lin 1985). They were wrong.

The trophozoite colonizes the upper small intestine (duodenum, jejunum and upper ileum) of humans. In severe infections trophozoites have been reported on every epithelial cell (Erlandsen and Feely 1984). The trophozoites may be excreted in the feces but will disintegrate rapidly and are not infective if ingested. For still unknown reasons, encystment occurs in the gut, and the cysts are excreted in the feces by the infected host. The cyst is somewhat resistant to various environmental factors, and it may survive for a period of from several days to several months and be infective for new hosts. Cysts require moist environments and cold temperatures for prolonged survival. Once ingested by humans, the cysts pass through the stomach to the upper small intestine, and within 30 minutes of ingestion the cyst will excyst to produce two trophozoites (Lin 1985). The trophozoites then proceed to multiply asexually and colonize the gut, thus starting the cycle again.

Infection and Symptoms

Once the trophozoites are established in the upper small intestine, they may produce the signs and symptoms of giardiasis; however, not all persons infected with Giardia will show them. Classical giardiasis is manifested by symptoms that include mild diarrhea, malaise, weakness, fatigue, dehydration, weight loss, abdominal distension, flatulence, anorexia, abdominal cramps, and epigastric tenderness, and may lead to steatorrhea and malabsorption (Wolfe 1984). The symptoms may last for many months and be difficult to eliminate if the infection is not diagnosed. Although giardiasis is not fatal (there have been four deaths attributed to giardiasis, but it is not known if death was caused by the disease or was a result of secondary complications) (Lin 1985), one might wish it were because the symptoms can be seriously debilitating.

Treatment

Generally the symptomatic cases are the only ones treated. There are three prescription drugs and one experimental drug used to treat giardiasis in the United States. Most have side effects and all must be monitored closely. The drugs are 1) quinarine (Atabrine), 2) metronidazole (Flagyl), 3) furazolidone (Furoxone), and 4) paromomycin (Humatin--EXPERIMENTAL) (Wolfe 1984).

Transmission and Cross Transmission

Transmission of *Giardia* is via the fecal-oral route (Owen 1984). Cross transmission studies have shown that *Giardia* cysts isolated from humans, dogs, cats, muskrats, and beaver were not host-specific and could infect any or all of the other listed hosts (Jakubowski and Hoff 1979). Other domestic and wild animals have been implicated and research is underway to elucidate their role in the spread of *Giardia*.

Reported Outbreaks

The first documented outbreak of waterborne giardiasis in the United States was in Aspen, Colorado, during the 1965-66 winter ski season (CDC 1984). Previous to this time there were reported cases of giardiasis in travelers, particularly in those who had been in the Leningrad area of the Soviet Union. Most of the waterborne outbreaks in the United States have occurred in the mountainous areas of the country: New England, the Pacific Northwest, and Rocky Mountain areas. Generally these outbreaks involve small municipal water systems or semi-public systems in recreational areas (McCall et al. 1985). Most outbreaks result from consumption of contaminated untreated or minimally treated surface waters such as those that are chlorinated only. Traditionally, the mountainous areas of the country depend on surface waters for drinking water, and in these areas the water is generally assumed to be of good quality, with little or no sewage contamination; therefore, minimal treatment has been assumed to be adequate. Conversely, the plains states generally rely on ground water for drinking water. If surface waters are used as drinking water sources on the plains, the quality of the water is generally poor, and complete water treatment programs are utilized. However, consuming untreated or incompletely treated surface water in the plains areas could result in giardiasis, and outbreaks from these causes have been reported (Lin 1985; McCall et al. 1985). Most outbreaks are only reported if several people are infected from a common source. Single cases of giardiasis, such as in campers, hikers, etc., are not reported and usually are considered in a rather humorous manner, particularly when the patient is asked personal and embarrassing questions about his or her drinking and hygiene habits.

CASE STUDIES

Purgatory, Colorado. In March, 1984, there was a waterborne outbreak of giardiasis at the Purgatory ski area in southwestern Colorado.

The normal drinking water source for this small, semi-public system was a deep well, but the pump on the well had failed. The secondary water source was a surface water reservoir normally used for snowmaking. There was no capability to treat the secondary source except to chlorinate. Although the chlorine was elevated to high levels, it was insufficient to prevent Giardia cyst survival. Lawsuits have been rampant and are now being settled (AWWA 1985; CDH 1984, 1985b).

Camas, Washington. In April and May, 1976, an outbreak of waterborne giardiasis involving approximately 600 people occurred in Camas, Washington. The city water system used deep wells and surface water. Giardia was isolated from beaver in the two watersheds supplying the surface water to the city. A breakdown in the water treatment system allowed Giardia cysts to enter the distribution system (Jakubowski and Hoff 1979; Kirner et al. 1978).

Bradford, Pennsylvania. Late in 1979, an outbreak of waterborne giardiasis was reported in Bradford, Pennsylvania. Giardia cysts were isolated from a beaver in the surface water reservoir supplying the system. Chlorination was the only treatment the water received (Lippy 1981).

Uinta Mountains, Utah. In 1974, there was a waterborne giardiasis outbreak among campers using untreated surface water from an isolated stream in the Uinta Mountains (Barbour et al. 1976).

Whitefish, Montana. An outbreak of waterborne giardiasis occurred in Whitefish, Montana, in May of 1985. Surface water was used as the source for the municipal water system and the only treatment used was chlorination. Giardia cysts were found in the distribution system (Hibler 1985).

Other Cases. The list of *Giardia* outbreaks is long and involves states from coast to coast (Rome, NY; Estes Park, CO; Berlin, NH; Aspen, CO; Idyllwild, CA; Essex Center, VT; etc.). It shows that surface water with no treatment, limited treatment (chlorination only), or incomplete treatment (whether due to inadequate treatment facilities or breakdowns in treatment systems) is implicated in waterborne disease outbreaks, especially giardiasis (Lin 1985).

GIARDIA SAMPLING

Watershed management specialists sometimes need to determine if an area is infected with *Giardia*, as in a watershed where surface waters serve as the water supply for a municipality. Often the desire to test for *Giardia* follows a local epidemic and the need to confirm contamination of the water. However, *Giardia* sampling is complicated and requires special procedures. Analysis for *Giardia* requires the services of specialists.

As compared to the familiar test for coliform bacteria and other bacterial groups where procedures are simple and testing is possible in many local laboratories, there is no cultural method yet available for the detection of *Giardia* cysts in water (Jakubowski 1984). It is also not practical to rely on filtering small volumes of water for detecting *Giardia*, as can be done with bacteria. Identification of *Giardia* cysts in surface waters or in watersheds can be done in several ways, including the following three that are common:

- large volumes of water (100 gallons or more) can be pumped or allowed to flow through filters that will capture any cysts present for later identification;

- wildlife scat can be collected from a watershed for later analysis to see if the animals are infected with Giardia;

- people suspected of having giardiasis and who are using the same water supply can be tested for positive confirmation of cysts in stool specimens; such epidemiological evidence indirectly implicates the water as the Giardia source.

The water, animal scat, or stool specimens then require special preparation and microscopic examination by specialists to visibly confirm the presence of Giardia cysts. An alternate but much more time-consuming and expensive method is to feed laboratory animals the water or fecal samples to see if the animals become infected with Giardia in about 10 days or more. Some research is currently underway to utilize dyes, fluorescent antibody stains (Shulters and Sorenson 1984), or other Giardia detection methods that will reduce the time required for analysis and simplify the technique.

As yet there is no standard Giardia sampling device; they are all still in experimental stages. In 1976, EPA developed a sampler suitable for water treatment plant supplies that uses a 1.0 micrometer wound cartridge filter. Water is run through the filter (usually several hundred gallons) and the filter is transported under refrigeration to the laboratory where the filter extract is examined microscopically for Giardia cysts. Procedures involving centrifugaton of the filter extract make it possible for the analyst to isolate and detect only a few cysts occurring in several hundred gallons of the sampled water.

A modification of the original EPA model used a small flume set in a stream so that several hundred gallons of water could be sampled by gravity (Williams 1981). In their 1983 work at Lolo National Forest, watershed specialists used this gravity method to test for Giardia in streams (Metzmaker 1983; Rosquist 1984). This system is slow in collecting a sample, but the advantage is that stream flow is observed over several hours.

Monzingo and others at Colorado State University use a small bilge pump, filter holder, and automobile battery (Monzingo 1985). The U.S. Geological Survey (Sorenson 1984; Suk 1984) in California and the National Park Service in Colorado (Kunkle et al. 1985) have employed a lighter gel-cell battery to develop a backpack sampler. The advantage is that large-volume samples can be gathered in a shorter period of time than with the slower gravity-flow models. Handpump models also have been tested, but sampling several hundred gallons by hand obviously represents a certain bicep expense.

In some cases beaver and muskrat scat have been collected from watersheds or trapped animals. Scat samples positive for Giardia cysts are used as indices of the presence of Giardia in surface waters (Dykes et al. 1980; Frost et al. 1983; Meyer 1982; Williams 1981).

All water filters or recent animal scat samples must be kept cool and transported to the trained analyst for examination within two days or less.

MANAGEMENT IMPLICATIONS

The incidence of Giardia contamination is on the rise in forested and backcountry areas, partly because physicians are now more aware of its occurrence and are therefore able to diagnose it more frequently, and partly because it is now an officially reportable disease in many states. Similarly, managers of wildlands that provide domestic water to municipalities or backcountry recreation areas have become acutely aware of its presence.

Giardia can be transmitted through fecal contamination of water by many animals, including beaver, muskrats, and dogs, as well as people; therefore, controlling contamination is almost impossible. Management approaches have included control of beaver populations by trapping, closing certain municipal watersheds to human entry, and restricting hikers from bringing dogs into backcountry watersheds, but such measures are at best difficult and not known to be successful. Once *Giardia* has been introduced into a watershed, the area will likely continue to harbor *Giardia* in wildlife hosts; thus, restricting dogs, for instance, in such areas probably would serve no function. In some cases filters have been utilized for backcountry water supply systems, but such approaches are not generally a practical option.

Today, the principal method for control of *Giardia* by managers of wildlands is to inform the public of the dangers of drinking untreated water in the backcountry and to train people about the best methods for backcountry water treatment. These methods include use of backpack-size filters, ways of making certain chemicals more effective against *Giardia*, and advice to boil water in places where boiling is a feasible option. Continued education on waste disposal and water treatment for personal supplies remain the best tools against *Giardia* at this time. Watershed specialists often need education on *Giardia* as well.

Research continues to play an important role in resolving *Giardia* problems. We need to better understand the mechanisms of *Giardia* transmission, especially its presence in wildlife populations. Easier, less expensive ways to detect *Giardia* in streams are needed. The expensive treatment methods for backcountry water still need further development in view of the fact that some people will hesitate to pay $40-150 for a backpack-style filter unit for an occasional hiking trip, and that boiling water often is not a realistic option. Further research on hiker attitudes also might help us understand how we can best educate people to dispose of their wastes properly and treat surface water supplies adequately to protect themselves against *Giardia* and other pathogens. Because the distribution of *Giardia* in wildlands follows certain ecological patterns, better understanding of these patterns can help to predict where *Giardia* is likely to be a serious problem. Data on *Giardia* are needed in some areas simply to discover whether the danger exists.

A more complete understanding of *Giardia* through research and strong education programs can help us learn to recognize and manage *Giardia* as part and parcel of our management of water resources of parks, forests, and other wildlands.

REFERENCES

AMERICAN WATER WORKS ASSOCIATION (AWWA). Colorado ski area sued for Giardia outbreak. AWWA Mainstream, Feb. 1985:3.

BARBOUR, A. G., C. R. NICHOLS, and T. FUKUSHIMA. 1976. An outbreak of giardiasis in a group of campers. Am. J. Trop. Med. Hygiene 25(3): 384.

BROWN, G. W. 1983. Forestry and water quality, 2nd ed. Oregon State University Book Stores, Inc., Corvallis, OR. 142 pp.

BROWN, G. W. 1985. Personal communication.

CENTERS FOR DISEASE CONTROL (CDC). 1984. Water-related disease outbreaks: Annual summary 1983.

COLORADO DEPARTMENT OF HEALTH (CDH). 1984. Giardiasis at Purgatory. Bi-Weekly Disease Summary. Vol. XII, No. 7.

COLORADO DEPARTMENT OF HEALTH (CDH). 1985. Waterborne disease 1979-1984. Bi-Weekly Disease Summary. Vol. XIII, No. 8.

COLORADO DEPARTMENT OF HEALTH (CDH). 1985. Giardiasis in Colorado. Bi-Weekly Disease Summary. Vol. XIII, No. 9.

DYKES, A. C., D. D. JURANEK, R. A. LORENZ, S. SINCLAIR, W. JAKUBOWSKI, and R. DAVIES. 1980. Municipal waterborne giardiasis: An epidemiological investigation. Ann. of Intern. Med. 92(1):165.

ERLANDSEN, S. L., and D. E. FEELY. 1984. Trophozoite motility and the mechanism of attachment, pp. 33-63. In S. Erlandsen and E. Meyer (eds.), Giardia and Giardiasis. New York: Plenum Press.

ERLANDSEN, S. L., and E. A. MEYER, eds. 1984. Giardia and giardiasis: Biology, pathogenesis, and epidemiology. New York: Plenum Press. 407 pp.

FEELY, D. L., S. L. ERLANDSEN, and D. G. CHASE. 1984. Structure of the trophozoite and cyst, pp. 3-31. In S. Erlandsen and E. Meyer (eds.), Giardia and Giardiasis. New York: Plenum Press.

FROST, F. L., L. HARTER, B. PLAN, K. FUKUTAKI, and B. HOLMAN. 1983. Giardiasis in Washington state. Project Summary. Environmental Protection Agency. EPA-600/S1-82-016.

HIBLER, C. P. 1985. Personal communication.

JAKUBOWSKI, W. 1984. Detection of Giardia cysts in drinking waste: State-of-the-art, pp. 283-286. In S. Erlandsen and E. Meyer (eds.), Giardia and Giardiasis. New York: Plenum Press.

JAKUBOWSKI, W., and J. C. HOFF, eds. 1979. Waterborne transmission of giardiasis: Proceedings of a symposium. Environmental Protection Agency. EPA-600/9-79-001. 306 pp.

KIRNER, J. C., J. D. LITTLE, and L. A. ANGELO. 1978. A waterborne outbreak of giardiasis in Camas, Washington. J. Am. Water Works Assoc. 70(1):35.

KUNKLE, S., N. COWDIN, J. WILSON, J. GRONDIN, T. RICKETTS, and M. FLORA. 1985. Field survey of *Giardia* in streams and wildlife of the Glacier Gorge and Loch Vale basins, Rocky Mountain National Park. National Park Service Natural Resources Report Series 85-3. 64 pp.

LIN, S. D. 1985. *Giardia lamblia* and water supply. J. Am. Water Works Assoc. 77 (2):40.

LIPPY, E. C. 1981. Waterborne disease: Occurrence is on the upswing. J. Am. Water Works Assoc. 73(1):57.

MCCALL, R. G., J. A. COTRUVO, D. W. HENDRICKS, W. JAKUBOWSKI, R. KARLIN, G. LOGSDON, and W. NEUMAN, participants. 1985. Roundtable: Waterborne *Giardia*: It's enough to make you sick. J. Am. Water Works Assoc. 77(2):14.

METZMAKER, J. B. 1983. An investigation into the potential for a *Giardia lamblia* contamination in the Rattlesnake NRAW. M.S. thesis, University of Montana, Missoula.

MEYER, E. A. 1982. The incidence of *Giardia* infections in beaver and other semi-aquatic mammals in selected watersheds in Oregon. Final Progress Report. U.S. Environmental Protection Agency.

MONZINGO, D. L. 1985. The prevalence of *Giardia* in a beaver colony and the resulting environmental contamination. Ph.D. diss., Colorado State University, Fort Collins.

ROSQUIST, A. E. 1984. Personal communication.

SHULTERS, M. V., and S. K. SORENSON. 1984. Personal communication.

SORENSON, S. K. 1984. Personal communication.

SUK, T. J. 1984. Personal communication.

WILLIAMS, O. R. 1981. *Giardia* and the waterborne transmission of giardiasis: A general review. Watershed Systems Development Group, USDA Forest Service, Fort Collins, CO. WSDG-TP-00003.

WOLFE, M. S. 1984. Symptomatology, diagnosis, and treatment, pp. 147-161. *In* S. Erlandsen and E. Meyer (eds.), *Giardia* and Giardiasis. New York: Plenum Press.

WATER PURIFICATION
PRINCIPLES AND METHODS

Nancy Cowdin
Juliette Wilson
Sam Kunkle

WATER PURIFICATION PRINCIPLES AND METHODS

Introduction

Backcountry use is on the rise and with it comes increased potential for watershed contamination through fecal pollution of streams. Knowledge of water purification procedures is essential in limiting the incidence of illness from raw-water consumption in the backcountry; however, many recreationists are confused or unsure about purification procedures. In an effort to protect the public and the watersheds, wildland managers are continually striving to provide accurate information on the available methods of purification.

For one-day ventures, an individual can easily carry in a sufficient water supply (approximately 2 liters per person per day is recommended, depending upon activity level). When backpacking for an extended period, packing in water is an expense in terms of weight: one gallon (3.7 liters) weighs about nine pounds. This burden is unnecessary as purification of stream or lake water can be achieved with a minimum of difficulty. The following water purification options are readily available to the backcountry user.

Boiling

Boiling is a frequently used, generally effective form of water disinfection. Most waterborne pathogens are readily harmed by heat, and a period of boiling will kill them. Since some pathogens require a longer heat exposure to be destroyed, recommendations for boiling time vary. In addition, boiling times must be increased at higher elevations where water boils at a lower temperature (Table C-1). *Giardia* cysts, for example, are destroyed after one minute of boiling at sea level; at 3050 m (10,000 ft) or higher, it may take 5-10 minutes of boiling to destroy the cysts as well as bacteria and viruses. Some specialists recommend boiling for as long as 15 minutes (Alsaker 1982).

Table C-1. Boiling points of water at various elevations.

Elevation		Boiling Point	
(m)	(feet)	(°C)	(°F)
Sea level		100	212
500	1641	98.9	210
1000	3281	97.9	208
1500	4922	96.8	206
2000	6562	95.7	204
2500	8203	94.7	202
3000	9843	93.6	200
3500	11,484	92.5	199
4000	13,124	91.4	197

While the often-recommended boiling offers the backcountry user a relatively effective and inexpensive method of water purification, in many cases it is not practical or convenient. Boiling takes time; and in areas where wood fires are not allowed (which is often the case in national forest, park, and wilderness areas), boiling alone uses a significant amount of fuel.

Chemical Treatment

Chemical means of water purification generally involve disinfection with various chlorine or iodine preparations. These chemicals are available in pure form or under such brand names as Halazone (chlorine) and Globaline, Coughlan's, and Potable-Aqua (tetraglycine hydroperiodide). Even household chlorine bleach can be used. But in treating water this way, several factors must be considered. First, both chlorine and iodine are more effective in clear water, at warmer temperatures, and with increased contact times. Therefore, the number of required drops or tablets of disinfectant per liter varies with the temperature and clarity of the water. While chemical treatments are usually adequate for the elimination of most bacteria and viruses, chemicals have a less dependable effect on Giardia; therefore, extra contact time is essential. A minimum of 30 minutes of purification time is recommended; however, in order to improve the effectiveness of the treatment as well as the taste of the water, some suggest allowing the chemical to work for an hour or more (State of New Mexico 1983; Centers for Disease Control n.d.) or even overnight (Knotts 1983). It is important that turbid water be allowed to settle prior to treatment, as suspended matter in water will hinder purification effects of the disinfectant. Some specialists have found that the use of a coagulant will expedite the settling process (Tunnicliff and Brickler 1984).

Iodine is more effective in killing Giardia than chlorine over wider temperature and pH ranges. One writer (Manley 1983) recommends keeping a saturated solution of iodine on hand by pouring more than the required amount of iodine crystals (0.29 g per 100 cc of water) into a bottle and filling it with 100 cc of water. Once the solution is saturated, the excess crystals will remain on the bottom, and the mixture can be spooned a tablespoonful at a time into containers of water to be purified. If that water is warmed to 20°C, a tablespoonful of the iodine solution per liter will kill Giardia cysts (Manley 1983). However, the use of pure iodine crystals presents some risk of poisoning, and care should be taken not to ingest any of the crystals, which are toxic, or to ingest highly concentrated iodine solutions. Normally, this is not a practical concern since high concentrations of iodine make the water extremely unpalatable.

For safety and convenience, the commercial preparations may be a better choice. Commercially distributed tablets of the compound tetraglycine hydroperiodide (TGHP) contain a premeasured dose of iodine (8 ppm) and are generally stable. Chlorine preparations in tablet form are less stable and become less effective upon exposure to heat and air, so that old Halazone tablets, for example, should not be used (Knotts 1983).

Mechanical Filters

Commercially available mechanical filters exhibit varying degrees of effectiveness in the removal of Giardia. In a study by Hibler (1984), seven filters for tap water purification were tested in the laboratory. Four of these were found to be 100 percent effective, but the other three ranged from as low as 66.4 percent to 97.6 percent effective. Backpacking filters may vary similarly in their effectiveness. Therefore, in choosing a filter, several important factors should be considered. To effectively filter out Giardia and other microorganisms, the filter should have a pore size of 2.0 microns or less. Such a size counters the pliability of Giardia cysts, a characteristic that allows them to squeeze through apertures somewhat smaller than their actual size. To also remove bacteria and smaller pathogens, one filter system that uses a 0.4 micron filter induces electrical charges in the filter that attract and hold particles smaller than 0.4 microns (Knotts 1983). When the turbidity is high, filters can become clogged and rendered ineffective. Turbid water should be allowed to "settle" or be treated with a coagulant before filtering.

Filtering units are relatively expensive, ranging from about $40.00 to over $170. Even so, frequent users of the backcountry might find that a well-designed, effective filter is worth its price. Better quality filters have a provision for backwashing the filter; or, if needed, replacement filters are usually available.

Alternatives

A combination of water treatment methods might provide a viable alternative for many backcountry users. It has been shown, for example, that at a temperature of 20°C (68°F), iodine successfully destroys Giardia cysts (Manley 1983). This means that by boiling only one-fifth of the desired volume of water (one-fourth the volume at high altitudes) and then mixing it with the remaining cold water, the temperature of the cold water would be raised to 20°C (Manley 1983). This would significantly reduce the amount of fuel needed for boiling. The amount of saturated iodine solution (prepared by putting crystals in water) needed per liter of 20°C water is about one tablespoon (15 cc). Or, commercial preparations of iodine or chlorine can be used according to directions. In the warmer water, these disinfectants will act with increased effectiveness and eliminate the need for extended boiling.

There are other options to boiling which can elevate the water temperature to an appropriate level. A canteen or plastic water container placed in the sunlight for a length of time would raise the temperature significantly; or, chemically treated water can be placed in a sleeping bag overnight (Knotts 1983). This would warm the water as well as provide for a longer contact time with the chemical. In short, any technique that raises the water temperature and increases chemical contact time is likely also to increase the purifying effectiveness of disinfectant chemicals.

Conclusions

Much has been said about water purification in the backcountry, but documentation on the effectiveness of the various treatment methods is limited. There appears to be a need for comprehensive information which is research-based, and claims made by manufacturers of water purification products should be supported by independent research. In the meantime, we suggest the following reading material for those wishing to know more about *Giardia* and water purification in the backcountry:

1. Centers for Disease Control. n.d. *Giardia lamblia* information paper. Available from Department of Health and Human Services, CDC, Atlanta, GA 30333.

2. Erlandsen, S., and E. Meyer. 1984. *Giardia* and giardiasis. New York: Plenum Press. 407 p.

3. Knotts, D. M. 1983. Purifying water in the wild. Sierra 68(4):57-59.

4. Manley, H. An easy preventative for "backpacker's disease." Backpacker 11(2):95.

5. State of New Mexico Health and Environment Department. 1981. Water disinfection for campers and backpackers. Brochure issued by Health Services and Environmental Improvement Divisions, P.O. Box 968, Santa Fe, NM 87504-0968.

BIBLIOGRAPHY

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BIBLIOGRAPHY

Alsaker, D. 1983. Untitled. Opflow (a monthly publication for members of the American Water Works Association) 8(3):1-2.

American Public Health Association. 1980. Standard methods for the examination of water and wastewater. Washington, D.C.

Baker, D. 1985. Giardia! Nat. Wildlife 23(5):19-21.

Barbour, A. G., C. R. Nichols, and T. Fukushima. 1976. An outbreak of giardiasis in a group of campers. The Am. J. Trop. Med. Hygiene 25:384-389.

The beaver may be innocent. High Country News (Paonia, CO), March 25, 1985.

Bellamy, W. D., F. P. Silverman, D. W. Hendricks, and G. S. Logsdon. 1985. Removing Giardia cysts with slow sand filtration. Am. Water Works Assoc. J. 77(2):52-60.

Brady, P. G., and J. C. Wolfe. 1975. Giardia in water. Reply to letter of R. C. Rendtorff. Letter to the editor. Ann. Intern. Med. 82(2):281.

Braidech, T. E., and R. J. Karlin. 1985. Causes of a waterborne giardiasis outbreak. Am. Water Works Assoc. J. 77(2):48-51.

Brandborg, L. L., moderator; R. Owen, R. Fogel, H. Goldberg, J. Garvie, and S. Grossman, discussants; H. Shapiro, R. Ockner, and R. Schmid, participants. 1980. Giardiasis and traveler's diarrhea. Gastroenterology 78:1602-1614.

Buchanan, W. 1983. Troubled waters: Will Giardia take the fun out of wilderness travel? Unpublished paper. 9 p. (Available from William Buchanan, 12 Midhill Dr., Mill Valley, CA 94941.)

Centers for Disease Control. n.d. Giardia lamblia information paper. (Available from Department of Health and Human Services, CDC, Atlanta, GA 30333).

Colorado ski area sued for Giardia outbreak. 1985. Am. Water Works Assoc. Mainstream (February 1985):3.

The Conservation Foundation. 1984. State of the environment: An assessment at mid-decade. Washington, D.C.

Craun, G. F. 1979. Waterborne giardiasis in the United States: A review. Am. J. Public Health 69(8):817-819.

Davies, R. B., K. Fukutaki, and C. P. Hibler. 1981. Cross-transmission of Giardia. Final report to EPA. Health Effects Research Laboratory, Environmental Protection Agency, Research Triangle Park, NC. 23 p.

Davies, R. B., and C. P. Hibler. 1979. Animal reservoirs and cross-transmission of Giardia, pp. 104-126. In W. Jakubowski and J. C. Hoff (eds.), Waterborne transmission of giardiasis. EPA 600/9-79-001. Environmental Protection Agency, Cincinnati, OH.

Dykes, A. C., D. D. Juranek, R. A. Lorenz, S. Sinclair, W. Jakubowski, and R. Davies. 1980. Municipal waterborne giardiasis: An epidemiologic investigation. Ann. Intern. Med. 92(2):165-170.

Erlandsen, S. L., and E. A. Meyer. 1984. Giardia and giardiasis: Biology, pathogenesis and epidemiology. New York: Plenum Press. 407 p.

Filice, F. P. 1952. Studies on the cytology and life history of a Giardia from the laboratory rat. Univ. Cal. Publ. Zool. 57:53-143.

Frost, F., B. Plan, and B. Liechty, 1980. Giardia prevalence in commercially trapped mammals. J. Environ. Health 42(5):245-248.

Frost, F., L. Harter, B. Plan, K. Fukutaki, and B. Holman. 1983. Giardiasis in Washington state. Project summary. Report No. EPA-600/S1-82-016. Environmental Protection Agency, Center for Environmental Research Information, Cincinnati, OH.

Galazka, S. S. 1982. Giardia lamblia: A clinical-epidemiological case report. The J. Fam. Pract. 15(6):1165-1169.

Galbraith, A. F. 1980. Water quality and wildland resource management, pp. 298-310. In Proceedings of the Symposium of Watershed Management, American Society of Civil Engineers, Boise, ID, July 21-23, 1980.

General Ecology, Inc. 1984. Guide to choosing a water filter/purifier for Giardia protection. Technical Memorandum No. 040484. Lionville, PA.

Giardia suits may be tried together. 1984. U.S. Water News (November 1984):16.

Giardiasis. 1982. State of Maryland, Division of Communicable Diseases and Epidemiology Newsletter. June 1982.

Giardiasis in Plumas County. 1979. California Morbidity (weekly report from the Infectious Disease Section, State Dept. of Health Services, CA) No. 46 (Nov. 23, 1979).

Griffith, E. W. 1982. Giardiasis in the Salmon River basin. Unpublished paper. Salmon River Ranger District, Klamath National Forest, Etna, CA. 3 p.

Hach Chemical Co. 1984. Giardiasis. News and Notes for the Analyst 8(3):11.

Hibler, C. 1982. Epizootiology of waterborne giardiasis in Colorado. Project proposal. Dept. of Pathology, Colorado State University, Fort Collins, CO. 18 p.

Hibler, C. 1984. An evaluation of filters in the removal of Giardia lamblia. Water Technol. 7(4):34-36.

Hibler, C. 1984. Inactivation and/or destruction of the cysts of Giardia with photozone. Unpublished paper. Dept. of Pathology, Colorado State University, Fort Collins, CO. 12 p.

Hibler, C. P., and C. M. Helmick. n.d. Diagnosis of waterborne giardiasis: State-of-the-art. Unpublished paper. Dept. of Pathology, Colorado State University, Fort Collins, CO.

Holman, B., F. Frost, B. Plan, K. Fukutaki, and W. Jakubowski. 1983. Recovery of Giardia cysts from water: Centrifugation vs. filtration. Water Res. 17(11):1705-1707.

Istre, G. R., T. S. Dunlop, G. B. Gaspard, and R. S. Hopkins. 1982. Waterborne giardiasis at a mountain resort: Evidence for possible acquired immunity. Unpublished paper. 14 p. (Available from G. R. Istre, Field Services Division, EPO, Centers for Disease Control, Atlanta, GA 30333.)

Jakubowski, W. 1984. Detection of Giardia cysts in drinking water: State-of-the-art, pp. 263-285. In S. L. Erlandsen and E. A. Meyer (eds.), Giardia and giardiasis: Biology, pathogenesis, and epidemiology. New York: Plenum Press.

Jakubowski, W., and J. C. Hoff (eds.). 1979. Waterborne transmission of giardiasis. Proceedings of a symposium sponsored by the Health Effects Research Laboratory and the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio, Sept. 1978. EPA 600/9-79-001. 306 p. (Available from National Technical Information Service, Springfield, VA 22151.)

Jarroll, E. L., J. C. Hoff, and E. M. Meyer. 1984. Resistance of cysts to disinfection agents, pp. 311-328. In S. L. Erlandsen and E. A. Meyer (eds.), Giardia and giardiasis: Biology, pathogenesis, and epidemiology. New York: Plenum Press.

Johnston, L. 1978. An investigation of animals hosts for Giardia lamblia in the Bridger Wilderness Area. Unpublished paper. Bridger-Teton National Forest, Jackson, WY. 18 p.

Kirkpatrick, C. E., and J. P. Farrell. 1982. Giardiasis. Compend. Contin. Educ. 4(5):367-377.

Knotts, D. M. 1983. Purifying water in the wild. Sierra 68(4):57-59.

Kunkle, S. H., and J. R. Meiman. 1968. Sampling bacteria in a mountain stream. Colorado State University, Hydrology Paper Series No. 28. March 1968. 28 pp.

Lee, R. 1984. Experience with cartridge filters at Longmire, FY 1983 and January 1984. Unpublished report. National Park Service. Pacific Northwest Regional Office, Seattle, WA. 29 p.

Levine, N. D. 1961. Protozoan parasites of domestic animals and of man. Minneapolis: Burgess Publishing Co. 411 p.

Lin, S. D. 1985. Giardia lamblia and water supply. Am. Water Works Assoc. J. 77(2):40-46.

Lippy, E. C. 1978. Tracing a giardiasis outbreak at Berlin, New Hampshire. Am. Water Works Assoc. J. 70(9):512-520.

Logsdon, G. S., V. C. Thurman, E. S. Frindt, and J. G. Stoecker. 1985. Evaluating sedimentation and various filter media for removal of Giardia cysts. Am. Water Works Assoc. J. 77(2):61-66.

Manley, H. 1983. An easy preventative for "backpacker's disease." Backpacker 11(2):95.

McNenny, D. 1982. Giardia: Northern region experiences. Unpublished paper. U.S. Forest Service, Northern Region, Missoula, MT. 6 p.

Meredith, T. 1983. Natural history of the disease giardiasis. Unpublished paper. University of Colorado, Boulder. 11 p.

Metzmaker, J. B. 1983. An investigation into the potential for a Giardia lamblia contamination in the Rattlesnake NRAW. M.S. thesis, University of Montana, Missoula. 63 p.

Meyer, E. A. 1982. The incidence of Giardia infections in beaver and other semi-aquatic mammals in selected watersheds in Oregon. Final project report to EPA. Oregon Health Sciences University, Portland, OR. 13 p.

Meyer, E. A., and E. L. Jarroll. 1980. Giardiasis. Am. J. Epidemiol. 111(1):1-12.

Michaels, B. 1982. Giardia lamblia: A microscopic enigma. Unpublished paper. 14 p.

Monzingo, D. L. 1985. The prevalence of Giardia in a beaver colony and the resulting environmental contamination. Ph.D. diss., Colorado State Univ., Fort Collins, CO. (In press)

Moore, G. T., M. Cross, D. McGuire, C. S. Mollohan, N. N. Gleason, G. Healy, and L. H. Newton. 1969. Epidemic giardiasis at a ski resort. New England J. Med. 281(8):402-407.

Moss, V. 1984. Experts warn mountain water may cause intestinal disease: Purifying pump ensures safety of drinking water. In The Coloradoan (Fort Collins daily newspaper) (August 1, 1984):B1.

National Park Service. Giardiasis. Interim guidelines. GPO 868-934.

Oregonians find bad water a little hard to swallow. U.S. Water News (November 1984):15.

Osterholm, M. T., J. C. Forfang, T. L. Ristinen, A. G. Dean, J. W. Washburn, J. R. Godes, R. A. Rude, and J. G. McCullough. 1981. An outbreak of foodborne giardiasis. New England J. Med. 304(1):24-28.

Rendtorff, R. C. 1954. The experimental transmission of human intestinal protozoan parasites. II. Giardia lamblia cysts given in capsules. Am. J. Hygiene 59:209-220.

Rendtorff, R. C. 1975. Giardia in water. Letter to the editor. Ann. Intern. Med. 82(2):280.

Rosquist, A. E., Jr. 1983. A Giardia source investigation in a national forest municipal supply watershed. Unpublished paper. 8 p. (Available from: Lolo National Forest, Missoula, MT 59801.)

Rosquist, A. E., Jr. 1984. Lolo National Forest Giardia source investigation in Rattlesnake Creek, July 5-October 31, 1983. Report to District Ranger, U.S. Forest Service, Missoula, MT, 7 February 1984.

Schuman, S. H. 1983. Clues for suspecting giardiasis in a day-care center. Letter to the editor. The J. Fam. Pract. 17(1):23-24.

Singer, A. 1980. Giardiasis: Is it a public health problem in the United States? Unpublished paper. 15 pp.

Smith, P. D., C. O. Elson, D. B. Keister, and T. E. Nash. 1982. Human host response to Giardia lamblia. I. Spontaneous killing by mononuclear leukocytes in vitro. J. Immunol. 128(3):1372-1376.

Starr, R. 1981. Giardiasis confirmed at Olympic NP. Park Science 2(2):10.

State of New Mexico Health and Environment Department. 1981. Water disinfection for campers and backpackers. (Brochure issued by Health Services and Environmental Improvement Divisions, P.O. Box 968, Santa Fe, NM 87504-0968.)

Suk, T. J. 1983. Investigation of animal hosts for Giardia spp. in California's Sierra Nevada mountains. Cooperative Park Studies Unit, University of California, Davis, California. Contribution number CPSU/UCD 187/01. 21 p.

Thomas, E. F. 1982. Giardia occurrences in the Pacific Northwest region. Unpublished paper. U.S. Forest Service, Pacific Northwest Region, Portland, OR. 5 p.

Tipton, W. M. 1980. A case evaluation of excessive bivouac use, Rocky Mountain National Park. Unpublished paper. Rocky Mountain National Park, Estes Park, CO. 14 p.

Tucker, B. 1983. Giardia: Maybe it's the voles? Montana Kaimin (Missoula, MT) (Sept. 30):8+.

Tucker, B. 1983. Giardiasis medication may have side effects. Montana Kaimin (Missoula, MT) (Oct. 5):1+.

Tunnicliff, B., and S. K. Brickler. 1984. Drinking water treatment and procedures for Colorado River Corridor raft trips, Grand Canyon National Park. School of Renewable Natural Resources, Univ. of Arizona, Tucson. 52 p.

U.S. Department of Agriculture-Forest Service. 1980. What bugs you? 1980-680-250. U.S. Government Printing Office, Washington, D.C.

U.S. Department of Agriculture-Forest Service. Back country safety tips: Pacific Southwest Region. Brochure.

Vernon, T. M. 1975. Giardia in water. Letter to the editor. Ann. Intern. Med. 82:280.

Waterborne Giardia: It's enough to make you sick. 1985. Roundtable discussion. Am. Water Works Assoc. J. 77(2):14+.

Weniger, B. G., M. J. Blaser, J. Gedrose, E. C. Lippy, and D. D. Juranek. 1983. An outbreak of waterborne giardiasis associated with heavy water runoff due to warm weather and volcanic ashfall. Am. J. Public Health 73:868-872.

What if? 1985. Am. Survival Guide 7(2):10.

Williams, O. R. 1981. Giardia and the waterborne transmission of giardiasis: A general review. Watershed Systems Development Group Report No. WSDG-TP-00003, USDA Forest Service, Fort Collins, CO. 25 p.

Wilson, A. 1984. Mysterious Giardia. World Health (March 1984):22-24.

Wright, R. A. 1975. Giardial infection from water. Letter to the editor. Ann. Intern. Med. 82(4): 589-590.

Wright, R. A., H. C. Spencer, R. E. Brodsky, and T. M. Vernon. 1977. Giardiasis in Colorado: An epidemiologic study. Am. J. Epidemiol. 105(4):330-336.