

Giardia Lamblia and Giardiasis

With Particular Attention to the Sierra Nevada

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To Filter or Not to Filter, A Different Opinion

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Ask the average outdoors person about Giardia lamblia or giardiasis, and they have certainly heard about it. Almost always, however, they are considerably misinformed about both the organism's prevalence in wilderness water, and the seriousness of the disease if contracted.

With the advent of the Internet, the amount of information one can easily find on the subject is voluminous. Unfortunately, most of it is flawed in important aspects, being unsubstantiated, anecdotal, or merely quoting other unsubstantiated and anecdotal articles. Official sources, such as many informational publications put out by the US government, are not immune to this criticism.

This paper is the result of a critical distillation of relevant articles, retaining only those from scholarly, peer-reviewed, or otherwise professional and trustworthy sources.

"So drink freely and confidently: Proper personal hygiene is far more important in avoiding giardiasis than treating the water."

One conclusion of this paper is that you can indeed contract giardiasis on visits to the Sierra Nevada, but it won't be from the water. So drink freely and confidently: Proper personal hygiene is far more important in avoiding giardiasis than treating the water.

First, an excerpt written by a highly regarded wilderness physician:

"In recent years, frantic alarms about the perils of giardiasis have aroused exaggerated concern about this infestation. Government agencies, particularly the United States Park Service and the National Forest Service, have filtered hundreds of gallons of water from wilderness streams, found one or two organisms (far less than enough to be infective), and erected garish signs proclaiming the water 'hazardous.'" [1]

And another, by researchers who surveyed the health departments in all 50 states and scanned the medical literature looking for evidence that giardiasis is a significant threat to outdoor folk:

"Neither health department surveillance nor the medical literature supports the widely held perception that giardiasis is a significant risk to backpackers in the United States. In some respects, this situation resembles (the threat to beachgoers of a) shark attack: an extraordinarily rare event to which the public and press have seemingly devoted inappropriate attention." [2]

I explored this subject in 1987 [3] and again in 1996 [4] with an update in 1997 [5]. The conclusions have always been that the "Giardia problem" in Sierra Nevada water is grossly exaggerated, and that the cases of giardiasis subsequent to wilderness visits are wrongly blamed on the water. After incorporating

the recent information for this paper, those prior conclusions are not only still valid but also considerably reinforced.

Just who is this little guy, anyway? [6], [7], [8], [9], [10]

Giardia lamblia, now also known as *G. intestinalis* or *G. duodenalis*, was first observed in 1681 by Anton van Leeuwenhoek, inventor of the microscope. The parasite was named in 1915 for two scientists who studied it: Prof. A. Giard in Paris and Dr. F. Lambl in Prague.

Giardia is a flagellated (having whip-like appendages for locomotion) protozoan that, in the trophozoite (active) form, attaches itself with an adhesive disk to the lining of the upper intestinal tract of the host animal. There, it feeds and reproduces. Trophozoites divide by binary fission about every 12 hours. Thus, a single parasite can theoretically result in more than a million in 10 days and a billion in 15 days.

At some time in its active life, the trophozoite releases its hold on the bowel wall and floats in the fecal stream. As it makes its journey, it transforms into an egg-like structure called a cyst, which is eventually passed in the stool. Duration of cyst excretion, called shedding, may persist for months. Once outside the body, the cysts can be ingested by another animal. Then, they “hatch” into trophozoites due to stomach acid action and digestive enzymes, and the cycle repeats.

The trophozoite is 9 - 15 microns long, 5 - 15 microns wide, and 2 - 4 microns thick. Unlike the cyst, it cannot live for long outside a host. Cysts are 8 - 12 microns long by 6 - 9 microns in diameter; so a million could fit under a fingernail. Cysts can survive for as long as 2 to 3 months in cold water,[10], [11] but they cannot tolerate freezing. [9], [12]

A significant infestation can leave millions of trophozoites stuck tight to the intestinal lining. There, they cripple the gut’s ability to secrete enzymes and absorb food, especially fats, thereby producing the disease’s symptoms. The symptoms typically appear one to two weeks after ingestion, with an average of nine days, but four weeks is not uncommon. Symptoms can vanish suddenly and then reappear. They may hide for months. They may not appear at all [10], [13] .

There are three ways that giardiasis, the disease caused by ingesting *Giardia* cysts, can be contracted: contaminated water, contaminated food, and direct fecal-oral. A person who has just come down with the disease and who wishes to identify the source needs to reflect on not only the possibility of each of these, but in a suspect period ranging from typically one week to four weeks earlier.

The bad news: *Giardia lamblia* is almost everywhere [1], [6], [7], [8], [9], [10], [14], [15], [16], [17], [18], [19] .

Giardiasis has been most often associated with travel to such places as Latin America, Africa, Asia, and the former Soviet Union. However, *Giardia* has always been present in wilderness streams, in the water supplies of most cities around the world, and even in the municipal water of large US cities. In fact, in the 1930s and 1940s, before regulated municipal water treatment plants, everyone was drinking *Giardia* all the time. [20]

Currently, *Giardia lamblia* is the most commonly diagnosed intestinal parasite in North America [22]. It is the most frequently identified cause of diarrheal outbreaks associated with drinking water in this country. Fully 20 percent of the world’s population is infected, and up to 7 percent of Americans, most without any symptoms at all. [10], [21] The Centers for Disease Control and Prevention (CDC) estimates that as many as 2,500,000 cases occur annually in the US or almost one for every 100 persons. [22]

Infestation rates of 60 percent of the children in day care centers across the country have been noted. Institutions for mentally retarded persons can have high rates. Other high-rate populations include promiscuous male homosexuals, international travelers, and patients with cystic fibrosis. And family members of these individuals.

In an incident in New Jersey a child had a “fecal accident” in a 700,000-liter swimming pool, and nine swimmers came down with the disease. [23] How many Giardia cysts might have been involved? The number of cysts shed in feces is highly variable but has been estimated as high as 900 million per day for humans.

Municipal water utilities must use filters to remove the organism. San Francisco water, coming primarily from the Hetch Hetchy watershed in Yosemite National Park, has repeatedly tested positive for Giardia, although at very low levels: typically 0.12 cysts per liter [†]. Water collected in Hetch Hetchy already meets governmental standards for drinking water and is not required to be filtered before distribution because of its high quality [24]. The Los Angeles Aqueduct, which transports water to that city from the eastern slopes of the Sierra Nevada, averages 0.03 cysts per liter [25].

Drinking highly contaminated water is one way to get the disease. Less common in developed countries is direct passage from stool to the hands of a food preparer and then to the food itself. When 16 people got sick from the salad at a Connecticut picnic, the CDC tracked the source to a woman who had mixed the salad with her hands. She didn’t have giardiasis, but one of her children did—without any symptoms [13]. A similar situation occurred in New Jersey, with the salad preparer testing positive for Giardia along with her child and pet rabbit. [26]

Waterless antiseptic hand cleaner: possibly more important than a filter in preventing Giardiasis on backcountry trips.

Contaminated food may be a less-common source for the general population, but for wilderness visitors, it may be the most important one. Put another way: If the water is clean, food-borne and direct fecal-oral routes are the only pathways.

On a recent climbing expedition to Tibet, members of our party came down again and again with what was undoubtedly giardiasis. Our water came from glacial melt, but all our food in advanced base camp and below was prepared by Sherpa cooks. Much of the food they prepared—potatoes, rice, cauliflower, cabbage, onions—came from Nepal. We were continually assured that the cooks were practicing good hygiene, yet we had major intestinal problems that prevented many of the participants from getting high on the mountain.

The disease has been referred to as “beaver fever” because of a presumed link to those water-dwelling animals known to be carriers. However, it has been suggested that it is more likely that humans have carried the parasite into the wilderness and that beavers may actually be the victims. In particular, there is a growing amount of data showing that beavers living downstream from campgrounds have a high Giardia infection rate compared with a near-zero rate for beavers living in more remote areas.

In any case, beavers can and do contract giardiasis. Being water-dwellers, they are thus able to contaminate water more directly than an animal that defecates on the ground.

Other animals that can harbor Giardia are bighorn sheep, cats, cattle, coyotes, deer, dogs, elk, muskrats, pet rabbits, raccoons, and squirrels. But not horses and domestic sheep. And naturally occurring infections have not been found in most wild animals including badgers, bears, bobcats, ferrets, lynxes, marmots, moose, porcupines, rabbits, and skunks.

If “It’s everywhere!” why is it not more of a problem?

The good news: Most of the time, the concentration of Giardia cysts is very low [1], [6], [8]

Outside of places where dirty diapers congregate and cities where water treatment plants break down or are ineffective, there is little room to worry. A few Giardia cysts now and then will cause no harm and in fact may be useful in developing an immunity as will be mentioned later.

How many cysts does it take to get the disease? Theoretically only one, but volunteer studies have shown that 10 or so are required to have a reasonable probability of contracting giardiasis: About one-third of persons ingesting 10 – 25 cysts get detectable cysts in their stools. [6], [7], [8], [10], [27], [28]

But be careful with statistics: Animal droppings containing 100,000 Giardia cysts deposited at the edge of a 10 million liter lake may be an average of only 0.01 per liter for the lake as a whole, but in the immediate vicinity of the deposit, the concentration can be much higher.

A comforting observation is that significant cyst inactivation, as high as 99.9 percent, can occur as a result of anaerobic digestion in sewage sludge. [29] Of course, using a simple cat hole is not exactly a good approximation to the sewage plant process, but this points out the wisdom of doing something better than just leaving it on the ground or under a rock.

Since cysts that “winter over” in the Sierra Nevada are either in liquid water for considerably more than 2 to 3 months or exposed to freezing temperatures, it would appear that few will survive the harsh Sierra winters. So, except for pollution by winter mountaineers and non-hibernating animals, Giardia contamination in the high country must begin essentially anew each spring.

More good news: If you have a Giardia infestation, you will likely have no symptoms [1], [6], [7], [15], [16], [30], [31]

The symptoms of giardiasis vary widely. Characteristic symptoms, when they occur, are mild to moderate abdominal discomfort, abdominal distention due to increased intestinal gas, sulfurous or “rotten egg” burps, highly offensive flatulence, and mild to moderate diarrhea. Stools are soft (but not liquid), bulky, and foul smelling. They have been described as greasy and frothy, and they float on the surface of water. Nausea, weakness, and loss of appetite may occur. Studies have shown that giardiasis can be suspected when the illness lasts seven or more days with at least two of the above symptoms. [7]

However, most infected individuals have no symptoms at all! In one incident studied by the CDC, disruption in a major city’s water disinfection system allowed the entire population to consume water heavily contaminated with Giardia. Yet only 11 percent of the exposed population developed symptoms even though 46 percent had organisms in their stools. These figures suggest that (a) even when ingesting large amounts of the parasite, the chance of contracting giardiasis is less than 1 in 2, and (b) if you are one of the unlucky ones to contract it, the chance of having symptoms is less than 1 in 4. But perhaps the most telling statistic is that drinking heavily contaminated water resulted in symptoms of giardiasis in only 1 case in 9.

If you have symptoms it may not be giardiasis [1], [7], [13], [16], [32]

Many people claim that they “got it” on a particular trip into the wilderness. Yet upon questioning, they usually report that the presence of Giardia was not confirmed in the laboratory. (Only 8 percent of persons with a diarrheal illness in this country seek medical care.[22] Depending on the situation, other possible offenders are Campylobacter, Cryptosporidium, Salmonella, Shigella, Yersinia, Aeromonas,

Clostridium, and Escherichia coli, with the last being the most common cause of traveler's diarrhea worldwide. Food poisoning is also a possibility.

Cryptosporidiosis, in particular, is a growing problem in this country, and currently, there is no effective treatment for it. An outbreak in Milwaukee in 1993 caused 403,000 people to become ill and 100 to die. A year later, 43 people in Las Vegas died from the same disease. [33] The severity of cryptosporidiosis depends on the condition of the host's immune system. In immunologically normal people, symptoms and duration are similar to those of giardiasis. But in persons whose immune systems have been compromised (e.g., AIDS victims), symptoms can be profound: Frequent (6 to 25), voluminous (1 to 25 liters) daily bowel movements, serious weight loss, and cyst shedding often persist for months.

The diarrhea being blamed on Giardia from that climbing trip a week ago may instead be due to some spoiled food eaten last night or Campylobacter in undercooked chicken four days ago. Or because the incubation period is usually from one to four weeks, even if it is giardiasis the uncertainty range indicates that the culprits could have been ingested anytime during a full three weeks worth of meals and beverages. People in high-risk groups for Giardia, such as family members of children in day care centers or promiscuous male homosexuals, have even more possible sources to consider. To indict a particular stream or lake under such circumstances, without being able to at least verify that cysts are indeed there at all, is illogical at best.

The type of diarrhea can help in the diagnosis: If it is liquid and mixes readily with water rather than floating on top and is not particularly foul smelling, the problem is likely something other than giardiasis. Diarrhea which lasts less than a week, untreated, is probably not from giardiasis.

Almost always, giardiasis goes away without treatment [1], [6], [7], [13], [14], [15], [30], [34]

If you are unlucky enough to get giardiasis with symptoms, the symptoms will probably go away in a week or so without treatment. You may still be harboring the cysts, however, and can unknowingly spread the disease. Thus, practicing commonly recommended wilderness sanitary habits—defecating 100 feet from water, burying or packing out feces and toilet paper, washing before handling food, etc.—is an excellent idea.

The Food and Drug Administration, observing that giardiasis is more prevalent in children than adults, suggests that many individuals seem to have a lasting immunity after infection. [35] Furthermore, citizens of cities and countries where the parasite is numerous clearly seem to have few if any problems with their own water, which also points to an acquired immunity. So there is a possible bright side to contracting the disease.

Looking for cysts and trophozoites in stool specimens under the microscopic has been the traditional method for diagnosing giardiasis, but it is notoriously unreliable. Now, however, an immunologic test (enzyme-linked immunosorbent assay, or ELISA) for the detection of Giardia antigens in stool samples is available. The antigens are present only if there is a Giardia infection. ELISA is a big improvement over the microscopic search, with detection sensitivities of 90 percent or more.

Rare individuals not only do not spontaneously rid themselves of the organisms but instead develop serious symptoms of malabsorption, weight loss, ulcer-like stomach pain, and other chronic disturbances. Fortunately, this occurs in fewer than 1 percent of those with infestations. These unlucky people need medical treatment.

Metronidazole (Flagyl) has been the standard medication, with about a 92 percent cure rate. Recommended by the CDC, it is not approved by the FDA for giardiasis because it can have some serious side effects and is potentially carcinogenic. Quinacrine (Atabrine) and furazolidone (Furoxone) are also prescribed. Tinidazole (Tinebah) is highly effective in single doses and is widely used throughout the world, but it is not available in the US; it can be purchased over-the-counter in many developing countries.[7], [22]

Giardiasis has been called a disease of “somes.” Some people do not contract it even from heavily contaminated sources. Some infestations vanish with no treatment at all. Some people become asymptomatic carriers. Some evidence suggests that some people acquire a natural immunity to some strains. And some strains seem more virulent than others.[13]

The problem may not be whether you are infected with the parasite but how harmoniously you both can live together. And how to get rid of the parasite when the harmony does not exist or is lost [6].

So, what about the Sierra Nevada? [1], [6], [7], [8], [14], [16]

A water filter: standard equipment for all Sierra wilderness trips.

In 1984, the US Geological Survey in cooperation with the California Department of Public Health examined water at 69 Sierra Nevada stream sites that were selected in consultation with Park Service and National Forest managers [36]. Forty-two of the stream sites were considered “high-use” (high probability of human fecal contamination), and 27 were “low-use.” Cysts were found at only 18 (43 percent) of the high-use sites and at 5 (19 percent) of the low-use sites. The highest concentration of Giardia cysts was 0.108 per liter of water in Susie Lake, south of Lake Tahoe. The next highest was 0.037 per liter near Long Lake, southwest of Bishop. Samples taken in the Mt. Whitney area varied from 0 (most sites) to 0.013 (Lone Pine Creek at Trail Camp) per liter. The concentration was 0.003 per liter in Lone Pine Creek at Whitney Portal.

Recall that San Francisco water can contain a concentration of 0.12 cysts per liter [24], a figure now seen to be higher than that measured anywhere in the Sierra. San Francisco city officials go to great lengths to assure their citizens that the water is safe to drink, and if true—as it most assuredly must be—this comparison alone is quite revealing.

Even Los Angeles Aqueduct water, with only 0.03 cysts per liter [25], has a higher concentration of Giardia than all but two of the 69 Sierra sites examined.

Taking the highest concentration measured in the Sierra (0.108), we can make some calculations. The probability [‡] of finding 10 or more cysts in a liter of water—to have at least a one-third chance of contracting giardiasis—is about 10-17. Ten cysts in 10 liters of water, about 10-7. In fact, one would have to drink over 89 liters to have a 50 percent probability of ingesting 10 or more cysts.

A word of caution: The concentration is never uniform, as suggested by the “lake incident” above.

Another reason for caution: 1984 was some time ago, and areas of the Sierra may be differently contaminated now: perhaps more, perhaps less. Also, while so much attention is being given to Giardia, there are worse organisms to worry about such as Campylobacter, Cryptosporidium, E. coli, and the other organisms mentioned earlier.

In an informative study, [37] investigators contacted thousands of visitors to one of the high-use sites during the summers of 1988 through 1990. Water samples taken on 10 different dates at each of three locations exhibited Giardia cyst concentrations between 0 and 0.062 (average 0.009) per liter. A goal

was to enlist volunteers who were cyst-negative before their trip, verified by stool analysis, and then determine what fraction were cyst carriers after the trip. Unfortunately, stool collection is not a particularly enjoyable task, and only 41 people agreed to participate. Of these, two acquired Giardia cysts during their trip, but neither came down with symptoms. Six of the others exhibited post-visit intestinal symptoms, but none tested positive for Giardia (interestingly, all six had filtered their water). In sum, no cases of laboratory-confirmed giardiasis were found.

The water that wilderness travelers are apt to drink, assuming that they use a little care, seems almost universally safe as far as Giardia is concerned. The study referred to earlier,² in which the researchers concluded that the risk of contracting giardiasis in the wilderness is similar to that of a shark attack, is telling. What they did find is that Giardia and other intestinal bugs are for the most part spread by direct fecal-oral or food-borne transmission, not by contaminated drinking water. Since personal hygiene often takes a backseat when camping, the possibility of contracting giardiasis from someone in your own party—someone who is asymptomatic, probably—is real. Recalling that up to 7 percent of Americans, or 1 in 14, are infected, it is not surprising that wilderness visitors can indeed come home with a case of giardiasis contracted not from the water ... but from one of their friends.

This theme, that reduced attention to personal hygiene is an important factor for contracting giardiasis in the wilderness, is becoming more frequent in the literature.[2], [10], [14], [37], [38]

Outside of the Sierra, Giardia cysts in concentrations “as high as four per gallon [§]” have been detected in untreated water in northeastern and western states. [39] But even with this concentration, one would have to consume over nine liters of water to have a 50 percent chance of ingesting 10 or more cysts.

Indeed, there may be as much unwarranted hysteria surrounding Giardia in wilderness water in these other areas as there is for the Sierra. For example, an oft-cited report describing acquisition of the disease by 65 percent of a group of students hiking in the Uinta Mountains of Utah [40] is now viewed with considerable skepticism. Specifically, the attack rate was far beyond that usually seen with water-contracted giardiasis, no cysts were identified in the suspect water, there was no association between water consumption rates and the likelihood of the disease, and the authors categorically discounted food-borne or fecal-oral spread, stating that it had never been reported (correct at the time).[2]

Personal observations

I started visiting the Sierra Nevada in the early 1950s and have spent much of my free time there. I have never treated the water, and I have never had symptoms of giardiasis as a consequence of my visits. My many similarly active friends and acquaintances also drink the water with no ill effects. But because of other organisms possibly present, we are always careful to “drink smart”:

Drink from large fast-flowing streams whenever possible, preferably those entering from the side rather than those paralleling the trail.

Drinking water from a lake is best advised at the inlet, with the next best place at the hopefully fast-flowing outlet.

Few Giardia cysts survive harsh Sierra winters. Contamination begins essentially anew each year, so springtime water is safer than summer or fall.

Water at higher elevations is safer than lower, partly because of reduced human and animal presence up high, and partly because water flowing to lower elevations picks up more contaminants the more distance it travels.

The colder the water is, the more likely it is freshly melted, meaning less opportunity for contamination.

Because filtration of water through soil removes Giardia cysts, deep well water is considered safe.[7] By implication, springs in the wilderness should be, too.

One would think that after a heavy snow year, when streams run full and long, some kind of “flushing out” effect of lakes and streams must be occurring. Conversely, it makes sense to be more cautious in dry years.

Avoid water that likely could have passed through an area subject to heavy human or animal use.

If it doesn't look good—it's cloudy or has surface foam—treat it or don't drink it.

If in doubt, treat it—but how? While useful in many instances, chlorine is not in general effective for Giardia disinfection, which is why swimming pools are primary sources for the disease. The best filters work, although they are costly, heavy, and bulky, and many are somewhat awkward to use.[8], [41]

Boiling is usually inconvenient, but if you are preparing hot water for meals anyway, you may as well take advantage. Giardia cysts are highly susceptible to heat, and simply bringing water to 150° F. for five minutes [10], to 176° for a minute [8] or 190° momentarily, will kill them. But boiling for a few minutes at altitude is usually recommended because of the other organisms that may be present. At 10,000 feet elevation, water boils at 194°; at 14,000 feet, 187°.

Iodine is probably the best treatment choice, being inexpensive, convenient, and safe. Iodine is effective against most bacteria and viruses, too—and over a wide range of temperatures. (But Cryptosporidium may be resistant to iodine.) A popular system uses iodine crystals in a saturated water solution. Methods exist to mask or remove the iodine taste.

Summary figures

Here are some of the Giardia cyst concentrations discussed in various places above. Units are cysts per liter.

~1000 = Typical swimming pool contamination

~100 = Giardiasis is plausible [**]

~10 = Minimum needed to contract giardiasis**

~1 = Some wilderness water outside California

0.12 = San Francisco water

0.108 = Worst Sierra Nevada water

0.030 = Los Angeles water

0.013 = Trail Camp on the Mount Whitney Trail

0.003 = Whitney Portal

Conclusions

In a recent letter [42] the Supervisor of the Inyo National Forest admitted: “As to whether or not Giardia exists in the Sierra, we are not in a position to state a fact one way or the other.” This is a significant admission. So why do they persist in informing everyone that giardiasis is a potential hazard when visiting the Sierra Nevada?

First: They know that some waters might be contaminated by something, and Giardia is the organism on people’s minds so needs no elaboration. Contaminated water is certainly possible at lower elevations and in some locales. Noting in particular that novice hikers cannot be expected to make correct choices of which sources may be safe to drink, they point out that a conservative approach is to treat all water.

Second: If a person believes, albeit incorrectly, that they contracted giardiasis from Sierra Nevada water, they cannot accuse the Forest Service of not warning them. Potential lawsuits, for example to recoup medical expenses, are therefore avoided.

Unfortunately, this approach results in an incorrect perception of overall water quality in the Sierra by the general public. It also means that if someone contracts a gastrointestinal illness after a visit, they will be more apt to blame the water, having been “forewarned” that all water is suspect. And so the myth is perpetuated.

Untreated Sierra Nevada water should be, almost everywhere, safe to drink—if you “drink smart.” If you don’t “drink smart” you may ingest diarrhea-causing organisms. But it won’t be Giardia.

Because up to 1 in 14 of us carries the Giardia parasite, we all need to do what we can to keep the water pure. Defecate away from water, and bury it or carry it out.

Camp cooks in particular need to pay special attention to cleanliness. Wash hands thoroughly, especially before handling utensils and preparing meals. If you contract giardiasis in the backcountry, blame your friends...not the water.

Sierra Nevada water has far too few Giardia cysts for you to contract an infestation from it. Even if you go somewhere where the concentration is high, you probably won’t get giardiasis. If you do get giardiasis, you probably won’t have any symptoms. If you have symptoms, they will probably go away by themselves in a week or so. If they don’t or you develop serious persistent symptoms, you should seek medical treatment. Finally, those contracting giardiasis may develop immunity to it, thus lowering the likelihood that they will get it again.

There is certainly no reason for anxiety about giardiasis. Fewer than 1 percent of those who have an infestation, or about 5 percent of those with symptoms, need medical help.

Recommendation

Our wilderness managers are in a position to educate the outdoor public about the real culprit in the Giardia lamblia story: inadequate human hygiene. When they acknowledge that Sierra Nevada water has fewer Giardia cysts than, for example, the municipal water supply of the city of San Francisco, maybe they will turn their attention to it.

The thrust of the following observation is long overdue:

“Given the casual approach to personal hygiene that characterizes most backpacking treks, hand washing is likely to be a much more useful preventative strategy than water disinfection! [††] This simple expedient, strictly enforced in health care, child care, and food service settings, is rarely mentioned in wilderness education materials.” [2]

About the author

Bob Rockwell has a BS in physics from the University of California, Berkeley, and PhD in biomedical engineering from Stanford University. He made his first trip into the Sierra Nevada in 1952 to climb Mount Whitney, and he repeats this climb several times annually. In the course of making over a thousand Sierra Nevada ascents of hundreds of individual mountains, he has never filtered or otherwise treated the water and has never contracted symptoms of giardiasis. Retired since 1990, he is now able to fully indulge in his favorite pastime and spends more time there, enjoying the water, than ever before.

References

[†] The referenced sources use a variety of units for portraying cyst concentration: cysts per 100 liters, per 100 gallons, etc. For uniformity, all have been converted to cysts per liter since that is the size of the typical backpacker's canteen.

[‡] These calculations involve use of a tool called the Poisson distribution.

[§] Author's words.

[**] If one liter is consumed.

[††] Emphasis is in the original.

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