

Water\_Filter\_1992.txt

From : Terry      Mon 21 Dec 92 19:09

Re: water purification.

Check some of the boat/yachting mags for makers of desalinators and purifiers. They range in size from small and reasonably priced to big enough to make water for the Trump Princess and priced accordingly.

Clorine has been linked to bladder cancer and kidney related problems when used in large amounts as a water purifier - like in big city water supplies. Iodine has no such reported problems and also has the advantage of some degree of radiation blocking.

The latest batch of USGI surplus Iodine is in 10% solution one ounce bottles and should store for 10 - 15 years if kept below 90 degrees. If it crystalizes out it can be reconstuted with I believe alcohol. The stuff hasn't been a real big seller for us because halizone tastes better - but I know we have about a half case of the stuff in Tucson and about that much here in the Aiken store. There's a lot of it on the market and it is fairly cheap by the case. If somebody is really having a hard time finding the stuff let me know and I can COD a case out for you.

A barrel of charcoal would be useful for turning potatoski into vodka or filtering crud out of the water supply.

For hurricane backups around here we use 15 gallon black plastic jugs. But then water is not usually a problem in South Carolina - other then the occasional batch of too much. Set the jug in the sun for warm water with no fire, or in the shade for cool water. Two men can carry 15 gallons on a pole without too much effort. Machine gunner's shoulder pads make this easier. Ten settle the suspension in the bus  
'just right' but can be moved out individually if the roads are impassible.

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Date : 18-Dec-92 11:12  
From : Guy  
Subj : water info

--> Quoting John <--

JM> \*\*\* Answering a msg posted in area ECHOMAIL047 (SURV\_POLITICS).  
JM> Tuesday December 15 1992, Guy Putnam writes to Karen Brown:

GP> DON'T FORGET water treatment. It's #1. Get plenty of water  
GP> pureifiers. Don't get just filters, but filters with a  
GP> germicide, like silver. Have plenty of iodine purification  
GP> tablets too, for pocket carry. To carry your water (& everything  
GP> else), you need Army canteens & Army carrying equipment (web  
GP> gear), and packs.

GP> If you need more specific info on these, let me know.

JM> I would like to see any good info on designs for bulk, long term,  
JM> water filtering/purification systems that you might have..  
JM> thanks....

The best water purifier I've ever found is the Walbro. It is the only EPA registered \_purifier\_ there is, that I know of. The others refer to themselves as "water treatment" units.

A purifier kills the bad stuff. A treatment unit filters it out, & attempts to kill what's trapped in the filter. The Walbro unit does not filter, just lets the water flow through Triocide (an iodine), & as soon as the water hits the drinking container, it's pure. If you put dirty water in, it'll still be dirty, but pure. Walbro came in pocket units, all the way up to units that would

handle small towns.

Unfortunately, Walbro NO LONGER MAKES purifiers. As the survival business dropped off into the 80's, they switched to lawn mower fuel filters & such.

Since I bought a big stash of Walbro pocket models in 1978, I haven't been keeping up too much with what's state-of-the-art these days. The best is supposed to be the Swiss Katadyn. It's a hand pump that pumps the water through a ceramic filter with very fine pores. They run around \$275.

I just noticed that Brigade Quartermasters is now marketing a new purifier called Pur Explorer. It used the Tri-iodine resin like Walbro. It has a hand pump on it, but would be much faster & easier to pump than the Katadyn, which depends of filtration. The Pur Explorer is \$120 in their catalog. An iodine cartridge is good for 500 gals.

The main advantage of the Katadyn is that the ceramic filter would last forever, unless it broke.

As far as purification tablets, the research I have done indicates that iodine far surpasses chlorine tabs. The Army uses iodine. However, the storage life when unopened is only 4 years, opened, it is 1 yr.

A good product, if you can find one is an Army foot operated water pump. They'll do a quart/min. It has a circular filter disk in it that's replaceable. The unit comes in a canvas carrying case. The intake hose has a cork with a chain on it, so that the intake hose drops down below the scum level of the pond. The filter is just a dirt filter, & a purifier still has to be

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used, but this unit, used first, would keep silt & dirt out of your purifier unit. I have one of these & like it quite well.

For a survival group, a good thing to keep purified water in is the Army 36 gallon lister bag. It's a water proof canvas bag that hangs from a tree limb or improvised tripod stand. It's got 6-10 pushbutton spigots around it, so people can fill their canteens. It does have a canvas top, to keep trash out. These are hard to find also, though not as hard as the foot pump.

... Can't make my house pmt., but I got to pay out to Foreign Aid?!?

I went to the Shot Show (sporting goods manuf.) in Houston & found the company that Walbro sold their water purifier patent too. It's WTC Industries & they market the PentaPure Travel Cup, which will fit into a jacket pocket.

I have used these since 1979 & found them to be superior to all others. They are the only product I know of that is registered by the EPA as a purifier, the others being filters, treatment units, etc. The PentaPure is also used by NASA shuttle flights.

What the silver filter you described above does is trap the harmful bacteria in the filter element (only down to a certain size), and then attempt to kill it over time with exposure to the silver. If you used it a lot, the live bacteria could "stack up" in the wet filter while it was waiting to be killed, and you would be pouring your next drinking water through the bacteria again. If some bacteria happened to be too small, it would slip through the filter & you'd drink it.

With the PenataPure all the bacteria passes through....it's just

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dead by the time it hits the cup. It uses a iodinated resin.  
The older Walbro purifiers I have use a triiodide (I-3) resin.  
These new ones have pentaiodide (I-5) in them. It's claimed to  
be 1,000 times more effective than triiodide!

From the PentaPure brochure:

#### HOW PENTAPURE PURIFICATION WORKS

"PentaPure resin is a unique purification technology based on the natural process of electrostatic attraction.

"Through a complex proprietary process polyiodide ions are bound to an anion exchange resin, creating a positively charged structure. This positive charge attracts negatively charged contaminants found in water. When the contaminant comes into contact with the resin bead, sufficient iodine is released to penetrate the microorganism. By this process, bacteria, viruses and protozoa are neutralized and killed.

"There are several distinct advantages to this demand-release technology. First, sufficient iodine is released when negatively charged contaminants are present in the water. And only enough iodine is released from the beads to neutralize the microorganism. With constant-release disinfectants, such as iodine tablets (I-2), chlorine and bromine, a prescribed amount of chemical agent is consistently added to the water. No matter how many microorganisms are present. This can result in a large and dangerous chemical residual. It can also create objectionable tastes and odors. PentaPure resin leaves only a slight residual, which can be removed with a carbon filtration stage after purification.

"PentaPure resin is also more effective than constant-release disinfectants because of the phenomenon of electrostatic attraction. That means negatively charged microorganisms and positively charged resin are naturally drawn to each other -- ensuring contact and devitalization of the

contaminants. It also results in a higher concentration of the disinfectant actually penetrating the organism.

"With constant-release disinfectants, contact is random. This is why a holding time of 20-30 minutes is typically required, and the concentration of disinfectant attacking an individual organism may not be high enough to ensure a complete kill. For example, the Giardia lamblia cyst has an extremely thick cyst wall. Triiodide resin is ineffective against this cyst, and compared to PentaPure resin, constant-release disinfectants require either very high concentrations or very long contact times to kill the Giardia cyst."

These purifiers have a "cup inside a cup" setup. Unscrew the top, & set up the inner (resin) cup on top of the drinking cup. Pour the water through it, & catch it in the bottom drinking cup. That's all there is to it. It's small & compact.

It is rated at 100 gal. per cup, then you throw it away. However, unless you always put super disease-infected water in it, you will get a longer life out of it, typically 300 gal. at least. The company makes a test kit (chemical drops) you can use to test it to be sure it's still working.

PRICES/UNIT:

1 - \$30            Retail

12-47 - \$19.36

48-119 - \$17.28

120+ - \$15.19

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Packed 12 to a case. Shipping extra.

From : Guy Putnam                      9:2400/1              Sat 16 Oct 93 12:09  
To : LANCE

--> Quoting John <--

LR> Some time ago, there was a discussion here about the PentaPure line of  
LR> water purifiers. Someone posted an phone number for the manufacturer. I  
LR> called the manufacturer, shared some of the positive comments I'd seen  
LR> here and asked for a catalog.

LR> I then thrwe away the number because it would surely come with the  
LR> catalog. Too bad the catalog never showed...

LR> Could somebody please repost the phone number?

JM> I was not able to find it, but WTC is the name of the company that  
JM> bought out Walbro. I believe Guy Putnam posted the info originally.

800-637-1244

612-473-1625

Fax: 612-473-1712

The one I talked to Robin Bennett (lady). She's a wholesale acct. rep.

Are you planning on getting a wholesale order? Min. is around \$200. If  
you are interested in splitting an order, let me know.

... MuzzleFlash ----->> Austin's Machine Gun Source <<-----  
--- Blue Wave/Max v2.12 [NR]

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\* Origin: FLOTOM \* Austin, Tx \* (512)282-3941 \* H16 (9:2400/1)

From : Tom Wed 09 Mar 94 22:20

Subj : Gravity-operated water filter?

>Does anyone know of a gravity-operated water filter? Or if it's possible  
>or practical to rig a First Need up to work that way, say by hanging a  
>large water container in a tree, with a hose leading to the filter?

I just got a First Need filter that came with some little hoses and  
connectors that are designed to convert it into a gravity-fed unit  
(The nylon bag that it comes with is lined with a disposable plastic  
bag, which holds the water over the filter.)

I got mine in a package with the filter for \$40 or \$50 (I can't  
remember which), at REI.

But for your purposes, you might want larger capacity than the little  
nylon bag. All you have to do is remove the filter from the pump  
assembly and run a rubber hose from your water supply above into the  
filter on top. If you have a large enough water supply, you won't  
have to worry about priming the pump.

--

-Tom

From : Mike Swatko

1:105/30

Mon 07 Feb 94 18:16

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Subj : how to store water filters for winter?

--

In article <1994Jan26.184359.1004@guinness writes:

>Hopefully just a quick question - I came across my PUR SCOUT  
>water filter the other day, and it occurred to me that I never  
>put any thought into whether I should have stuffed it in a  
>pack and left it for the winter, or whether I should have specifically  
>taken it apart and dried it out. I couldn't find the instruction  
>booklet, so, ... any thoughts out there?

If I remember correctly, it says to pump a mild bleach solution through the filter (few drops of bleach in a cup of water?), then pump in the air to drain excess water and store it away. The insides are to remain moist - don't dry it out.

When it's time to use it again, run a few cups of fresh water through. The first few cups will be kind of musty, then it will run normally.

From : Bob           Wed 02 Feb 94 19:17

Subj : how to store water filters for winter?

I've discovered that something in my First Need dries out over winter, and i have to submerge the whole unit in a bucket of faucet water for a day or so to restore function.

--

Bob

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From : Alan Feb 94 22:37

Subj : how to store water filters for winter?

> I've discovered that something in my First Need dries out over winter,  
> and i have to submerge the whole unit in a bucket of faucet water for  
> a day or so to restore function.

Huh, mine's never done that. I do store it with the rubber cap on one  
end of the filter and the pump + hose on the other end, in a plastic  
bag. Maybe that's the answer?

When you say "restore function" do you mean the pump just wouldn't work,  
or what? If that's all, try coating the plunger with a bit of vaseline  
as recommended by the manufacturer.

.

From : Bog Sniezek

1:105/30

Thu 03 Feb 94 18:21

Subj : "Magnesium" in well water

Gary wrote:

: From article <1994Jan19.200814.19104@draper.com>, by sniezek@bugs.draper.com  
(Bog Sniezek):

: > Gary Ross (ross@newton.emba.uvm.edu) wrote:

: > : Hi. I've been folowing a thread on "magnesium" in well water. I believe  
: > : that it is really manganese that you refer to. Manganese generally occurs  
: >

: > I had the same problem at my house (LOTS of iron and other minerals). I  
: > let

: > I stumbled on a good solution while talking to a water filter salesman. He

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: > had one product in particular made by Cuno that removed iron through

: Can you tell me the manufacturer's name and tel# or address if possible?

: Thanks.

Sorry for the long delay. The info I read off the the filter is:

Model # AP IRS (Iron Removal System)

CUNO Consumer Products

From : Jake Jun 94 01:46

Subj : Water filter

DP>I am a little confused. I had heard that the filters will not get  
DP>everything out of the water and that the water should be treated with  
DP>pills or drops before drinking. Is there a filter that will tke ALL  
DP>harmeful things <polutants and microbes> out of the water? It sure would  
DP>be nice to drink cold water from a stream thru a filter instead of  
DP>boiling and treating.

Excuse me for jumping in. My suggestion would be to disinfect the water  
first and then filter it. I would only do this with water that looks  
clear to begin with. If the water is dirty the disinfection will require  
more CL2 (or whatever you use). Use a chlorine residual tester to check  
the demand, this way you can add only what is needed to insure proper  
disinfection. I am not aware of any filter that can safely disinfect the  
water, but I can think of many filters that will get the residual CL2  
out. Try to give the disinfectant as much time to react with the water  
as possible, that way you wont need to add as much CL2. The water

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district I work for maintains a chlorine residual of about .6 ppm throughout the distribution system. And thats being on the safe side. At that level I cant even notice it. But I live in So Cal so that probably makes me less sensitive to tastes and oders. I have quite a few books regarding water treatment, if you would like me to look up something specific let me know.

Cheers-

From : Wilbur Thu 03 Mar 94 19:04

Subj : Sweetwater filter

The Sweetwater filter (the Guardian, I believe) is made by Sweetwater in Boulder, Colorado. The filter retails for \$49.95.

I just bought one (but haven't used it in the field). It looks and handles really nice. Designed by people who actually use filters (unlike those totally un-ergonomic First Needs). I'm looking forward to trying it in the field. To clean it, all you need is to unscrew the outer cover and brush with a toothbrush.

-W

From: eugene  
Subject: [1/m 9/25/92] Water filters & Giardia Distilled Wisdom (9/28) XYZ  
Organization: NAS Program, NASA Ames Research Center, Moffett Field, CA  
Date: Sat, 9 Jan 93 12:20:20 GMT

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Index:

a. (Title?)

[Comparison of filters, boiling and iodine]

Filters: First Need, Katadyn,  
Boiling,  
Iodine: PolarPure, Potable-Aqua

Bill Tuthill  
1991 - 1992

Based on "Medicine for Mountaineering", owner's manuals and  
personal experience of author

b. GIARDIASIS

Memo from Center from Disease Control  
Dennis D. Juranek  
Chief, Epidemiology Activity  
Parasitic Diseases Branch  
Division of Parasitic Diseases  
Centers for Disease Control  
1990

c. Back-country water treatment to prevent giardiasis.

American Journal of Public Health  
December 1989, Vol 79, No 12, pp 1633-1637.  
Copyright 1989 AJPH 0090-0036/89\$1.50 [used without permission]  
Filters: First Need, H2OK, Katadyn, Pocket Purifier, Water Purifier  
Chemicals: Polar Pure, Coghlan's Emergency Germicidal Drinking  
Water Tablets, Potable Aqua, 2% iodine,  
Sierra Water Purifier, Halazone, commercial liquid bleach

Jerry E. Ongerth, PhD, PE,  
Ron L. Johnson,  
Steven C Macdonald, MPH,  
Floyd Frost, PhD,  
Henry H. Stibbs, PhD

- d. REI Water Filter Chart (2 similar articles)  
Comparison of specs: pore size, weight, capacity, filter life,  
cost/gallon, price, replacement cost,  
elements  
Filters: Katadyn, MSR, PUR, First Need, Basic Designs, Timber Line  
199x?

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Unpurified drinking water may contain four things that pose health risks: protozoan parasites (e.g. giardia), toxic bacteria, harmful viruses, and poisonous chemicals. Of the methods available in the field, only boiling and iodine are entirely effective against the first three, and only charcoal filtration is effective against the fourth.

The First Need(R) water filter is cheap (less than \$40), but is effective merely against protozoan parasites. Its .4 micron filter pores are smaller than giardia cysts at 3.5 microns, but larger than some bacteria, such as E. coli at .3 to .9 microns. The First Need's charcoal canister is not big enough to be effective against poisonous chemicals -- you need a pound of charcoal for this -- so it just adds unnecessary weight, and provides a potential haven for the growth of harmful bacteria. If you own a First Need filter, flush it with iodine after each trip.

The Katadyn(R) water filter is expensive (over \$200), but is completely effective against bacteria as well as giardia. Moreover, it can be cleaned after it clogs up. The Katadyn is effective at removing smaller bacteria

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such as E. coli. However, its .2 micron filter is not effective against any virus. If you travel abroad (to Nepal for example), you risk viral infections such as Hepatitis A and Hepatitis non-A non-B, among others.

MSR has a new water filter, which may be superior to the Katadyn. Results from the field aren't in yet.

To be entirely safe, water should be boiled for at least five minutes. Giardia is killed in less than a minute at 176 degrees, well under the boiling point. Bacteria and viruses last somewhat longer, but are probably killed in less than five minutes at 190 degrees. Some viruses may last longer; nobody knows. At 10,000 feet water boils at 194 degrees; above this altitude boil water about an extra minute for each 1000 feet.

If you have neither the time nor the inclination to boil water, iodine is equally effective. After 15 minutes (30 minutes for very cold water), a sufficient dose of iodine kills all protozoa, bacteria, and viruses. One readily-available choice is Potable-Aqua(R) tablets. Dissolve one tablet per liter of water (two tablets if cloudy) and wait. The problem with iodine tablets is that they degrade upon contact with moisture, so keep that bottle dry, and discard it upon returning home.

Avoid halazone and Clorox, because chlorine is volatile, slow to disinfect, and works differently against protozoa and viruses at various pH levels. It also reacts with organic compounds to form carcinogenic chloramines.

Iodine is not highly toxic, and in fact is an essential ingredient of human nutrition. However, continuous ingestion of large doses may cause health problems, so don't iodinate all your water for more than a few months at a time.

The accepted concentration for iodine disinfection is 8 milligrams per liter, but this is mostly to get rid of protozoan parasites. A good way to reduce overall iodine consumption and minimize that iodine flavor is

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to filter first, then use a low concentration of iodine to get rid of bacteria and viruses. For this, a concentration of .5 mg/L is deemed adequate, so one capful of PolarPure or one Potable-Aqua tablet should disinfect around 16 liters of lightly filtered water. The Timberline(R) filter, with its 2 micron pores, is fine for removing protozoa.

Giardia has become a well-known, almost fashionable, outdoor hazard. Many people who experience gastro-intestinal problems after drinking bad water think they have contracted giardia. In many cases they have contracted something else. Since the only FDA-approved treatment for giardia (Flagyl) is very nasty, it's wise to make sure you really have giardia before taking Flagyl. Most low-grade bacterial infections go away on their own, and Flagyl is ineffective against viral infections. One alternative to Flagyl is quinacrine. In many parts of the world (Asia for example) Tinidazole is available, and is preferable to Flagyl because it is less toxic and quicker acting.

[This information based on "Medicine for Mountaineering", various owner's pamphlets, and personal experience.]

Addedum 1992

A packet of information arrived recently from Recovery Engineering in Minneapolis, which I'll summarize as promised.

They have a new product, the Pur Scout, which I believe is destined to replace the First Need as the most popular low-cost filter. It has the same 1 micron filter plus iodine matrix as the Pur Explorer, pumps a quart in 120 seconds, but weighs only 12 oz! Capacity is 200 gallons, twice the First Need, but its \$60 cost is less than twice as much. The Scout is not self-cleaning like the Explorer, and is only half the speed, with 2/5 the filter life.

Unlike other water filters, all Pur products meet EPA's purification

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guidelines. No other filter does this, because no other filter can remove viruses. Here is the abstract from a study done at U Arizona on the Pur Tritex(tm) system:

"Three identical [Pur Traveller water filters] were evaluated for their ability to inactivate/remove *Klebsiella terrigena*, poliovirus type1, rotavirus SA-11, and *Giardia lamblia* cysts. The units were operated according to the manufacturer's instructions until the designed lifetime of 100 gallons (378 liters) passed through. The units were challenged with [the micro-organisms mentioned above] after a passage of 0, 50, 75 and 100 gallons. At the 75% lifetime challenge, 'worst case' water quality of 1500 mg/l dissolved solids, 10 mg/l organic matter, 4 degrees C, with a turbidity of 30 NTU and a pH of 9 was used. For the 100% lifetime test the worst case water quality at pH 5 was used. The units were also tested after stagnation for 48 hours at the 50%, 75%, and 100% [stages].

"At 0 and 50% lifetime test points, > 99.9999% of the bacteria, > 99.9% of the *Giardia* cysts, and > 99.99% of the test viruses were removed. With worst case water two passages of the test water through the units was required to achieve these same removals. These units would comply with criteria guidelines suggested by the US EPA...

"One passage of the pH 9 worst case water was not sufficient to remove the *Klebsiella terrigena* and poliovirus type1 to the required reduction. However, the required reduction [was] achieved by passage of the test water through the units a second time... Holding the water for 5 to 10 minutes after it had passed through the units also resulted in a further reduction of test bacteria and viruses."

What is *Klebsiella terrigena* anyway? I assume it's a bacteria, but

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what disease does it cause? And what does NTU stand for? Also, is parts per million (ppm) the same as milligrams per liter (mg/l)?

Here is the residual iodine in ppm after treatment:

|      | cup1 | cup2 | cup3 |
|------|------|------|------|
| 0%   | .7   | .7   | .7   |
| 50%  | .6   | .5   | .6   |
| 75%  | .6   | .6   | .7   |
| 100% | .7   | .6   | .8   |

This indicates that the filter still had plenty of life at 100 gallons. It also indicates that there is enough residual iodine to kill off all viruses and bacteria overnight (assuming ppm = mg/l). At these levels some iodine taste may be present, which can be removed with the optional charcoal filter. Since the charcoal filter also removes iodine, it would be prudent to use it only when filtering good quality water above 5 degrees C. It's a tradeoff, though: when travelling thru agricultural areas, charcoal filtration helps remove pesticides and herbicides.

All in all, I've decided to trade in my Katadyn for a Pur Explorer. I used an MSR last week on the Rogue, and liked its pump action and bottle attachment, but it \*did\* start to clog. Anybody want to buy my Katadyn (in excellent condition) for a mere \$185? F\*ck the Swiss.

=====

OCR'ed memo from the Center from Disease Control:

#### GIARDIASIS

GIARDIASIS: By Dennis D. Juranek, Chief, Epidemiology Activity  
Parasitic Diseases Branch  
Division of Parasitic Diseases  
Centers for Disease Control

## Transmission and Control

### Introduction

During the past fifteen years giardiasis has been recognized as one of the most frequently occurring waterborne diseases in the United States (1). *Giardia lamblia* have been discovered in the United States in places as far apart as Estes Park, Colorado (near the Continental Divide); Missoula, Montana; Wilkes-Barre, Scranton, and Hazleton, Pennsylvania; and Pittsfield and Lawrence, Massachusetts just to name a few. In light of recent large outbreaks of waterborne giardiasis, it seem timely to present reliable information on the way in which giardiasis is acquired, treated, and prevented.

### Giardiasis: Prevalence and Symptoms

Giardiasis is a disease caused by a one-celled parasite with the scientific name *Giardia lamblia*. The disease is characterized by intestinal symptoms that usually last one week or more and may be accompanied by one or more of the following: diarrhea, abdominal cramps, bloating, flatulence, fatigue, and weight loss (see Table 1). Although vomiting and fever are listed in Table 1 as relatively frequent symptoms, they have been uncommonly reported by people involved in waterborne outbreaks of giardiasis in the United States. Table 1 also suggests that 13 percent of patients with giardiasis may have blood in their stool. *Giardia*, however, rarely causes intestinal bleeding. Therefore, blood in the stool of a patient with giardiasis almost always indicates the presence of a second disease.

While most *Giardia* infections persist only for one or two months, some people undergo a more chronic phase, which can follow the acute phase or may become manifest without an antecedent acute illness. The chronic phase is characterized by loose stools, and increased abdominal gassiness with cramping, flatulence and burping. Fever is not common, but malaise, fatigue,

and depression may ensue (2). For a small number of people, the persistence of infection is associated with the development of marked malabsorption and weight loss (3). Similarly, lactose (milk) intolerance can be a problem for some people. This can develop coincidentally with the infection or be aggravated by it, causing an increase in intestinal symptoms after ingestion of milk products.

Some people may have several of these symptoms without evidence of diarrhea or have only sporadic episodes of diarrhea every 3 or 4 days. Still others may not have any symptoms at all. Therefore, the problem may not be whether you are infected with the parasite or not, but how harmoniously you both can live together, or how to get rid of the parasite (either spontaneously or by treatment) when the harmony does not exist or is lost.

#### Medical Treatment

Three drugs are available in the United States to treat giardiasis: quinacrine (Atabrine\*), metronidazole (Flagyl\*), and furazolidone (Furoxone\*). All are prescription drugs. In a recent review of drug trials in which the efficacies of these drugs were compared, quinacrine produced a cure in 93% of 129 patients, metronidazole cured 92% of 219, and furazolidone cured 84% of 150 patients (4). Quinacrine is generally the least expensive of the anti-Giardia medications but it often causes vomiting in children younger than 5 years old. Although the treatment of giardiasis is not an FDA-approved indication for metronidazole, the drug is commonly used for this purpose. Furazolidone is the least effective of the three drugs, but is the only anti-Giardia medication that comes as a liquid preparation, which makes it easier to deliver the exact dose to small children and makes it the most convenient dosage form for children who have difficulty taking pills. Cases of chronic giardiasis refractory to repeated courses of therapy have been noted, one of which responded to combined quinacrine and metronidazole treatment (5).

(\*) Use of trade names is for purposes of identification only.

## Etiology and Epidemiology

Giardiasis occurs worldwide. In the United States, Giardia is the parasite most commonly identified in stool specimens submitted to state laboratories for parasitologic examination. From 1977 through 1979, approximately 4% of 1 million stool specimens submitted to state laboratories were positive for Giardia (6). Other surveys have demonstrated Giardia prevalence rates ranging from 1 to 20% depending on the location and ages of persons studied. Giardiasis ranks among the top 20 infectious diseases that cause the greatest morbidity in Africa, Asia, and Latin America (7); it has been estimated that about 2 million infections occur per year in these regions (8).

People who are at highest risk for acquiring a Giardia infection in the United States may be placed into five major categories:

- 1) People in cities whose drinking water originates from streams or rivers and whose water treatment process does not include filtration, or filtration is ineffective because of malfunctioning equipment.
- 2) Hikers/campers/outdoorspeople.
- 3) International travelers
- 4) Children who attend day-care centers, day-care center staff, and parents and siblings of children infected in day-care centers.
- 5) Homosexual men.

People in categories 1, 2, and 3 have in common the same general source of infections, i.e., they acquire Giardia from fecally contaminated drinking water. The city resident usually becomes infected because the municipal water treatment process does not include a filter that is necessary to physically remove the parasite from the water. The number of people in the United States at risk (i.e., the number who receive municipal drinking water from unfiltered surface water) is estimated to be 20 million. International travelers may also acquire the parasite from improperly treated municipal waters in cities or villages in other parts of the world, particularly in developing

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countries. In Eurasia, only travelers to Leningrad appear to be at increased risk. In prospective studies, 88% of U.S. and 35% of Finnish travelers to Leningrad who had negative stool tests for Giardia on departure to the Soviet Union developed symptoms of giardiasis and had positive tests for Giardia after they returned home (10,11). With the exception of visitors to Leningrad, however, Giardia has not been implicated as a major cause of traveler's diarrhea. The parasite has been detected in fewer than 2% of travelers who develop diarrhea. Hikers and campers risk infection every time they drink untreated raw water from a stream or river.

Persons in categories 4 and 5 become exposed through more direct contact with feces of an infected person, e.g., exposure to soiled diapers of an infected child (day-care center-associated cases), or through direct or indirect anal-oral sexual practices in the case of homosexual men.

Although community waterborne outbreaks of giardiasis have received the greatest publicity in the United States during the past decade, about half of the Giardia cases discussed with staff of the Centers for Disease Control in the past 2 to 3 years have a day-care center exposure as the most likely source of infection. Numerous outbreaks of Giardia in day-care centers have been reported in recent years. Infection rates for children in day-care center outbreaks range from 21 to 44% in the United States and from 8 to 27% in Canada (12,13,14,15,16,17). The highest infection rates are usually observed in children who wear diapers (1 to 3 years of age). In one study of 18 randomly selected day care centers in Atlanta (CDC unpublished data), 10% of diapered children were found infected. Transmission from this age group to older children, day-care staff, and household contacts is also common. About 20% of parents caring for an infected child will come infected.

It is important that local health officials and managers of water utility companies realize that sources of Giardia infection other than municipal drinking water exist. Armed with this knowledge, they are less likely to make a quick (and sometimes wrong) assumption that a cluster of recently diagnosed cases in a city is related to municipal drinking water. Of course, drinking

water must not be ruled out as a source of infection when a larger than expected number of cases are recognized in a community, but the possibility that the cases are associated with a day-care center outbreak, drinking untreated stream water, or international travel should also be entertained.

## Parasite Biology

To understand the finer aspects of Giardia transmission and the strategies for control, one must become familiar with several aspects of the parasite's biology. Two forms of the parasite exist: a trophozoite and a cyst, both of which are much larger than bacteria (see Figure 1). Trophozoites live in the upper small intestine where they attach to the intestinal wall by means of a disc-shaped suction pad on their ventral surface. Trophozoites actively feed and reproduce at this location. At some time during the trophozoite's life, it releases its hold on the bowel wall and floats in the fecal stream through the intestine. As it makes this journey, it undergoes a morphologic transformation into an egglike structure called a cyst. The cyst, which is about 6 to 9 micrometers in diameter x 8 to 12 micrometers (1/100 millimeter) in length, has a thick exterior wall that protects the parasite against the harsh elements that it will encounter outside the body. This cyst form of the parasite is infectious for other people or animals. Most people become infected either directly by hand-to-mouth transfer of cysts from the feces of an infected individual, or indirectly by drinking feces-contaminated water. Less common modes of transmission included ingestion of fecally contaminated food and hand-to-mouth transfer of cysts after touching a fecally contaminated surface. After the cyst is swallowed, the trophozoite is liberated through the action of stomach acid and digestive enzymes and becomes established in the small intestine.

Although infection after the ingestion of only one Giardia cyst is theoretically possible, the minimum number of cysts shown to infect a human under experimental conditions is ten (18). Trophozoites divide by binary fission about every 12 hours. What this means in practical terms that if a

person swallowed only a single cyst, reproduction at this rate would result in more than 1 million parasites 10 days later, and 1 billion parasites by day 15.

The exact mechanism by which Giardia causes illness is not yet well understood, but is not necessarily related to the number of organisms present. Nearly all of the symptoms, however, are related to dysfunction of the gastrointestinal tract. The parasite rarely invades other parts of the body, such as the gall bladder or pancreatic ducts. Intestinal infection does not result in permanent damage.

#### Transmission

Data reported to the CDC indicate that Giardia is the most frequently identified cause of diarrheal outbreaks associated with drinking water in the United States. The remainder of this article will be devoted to waterborne transmission of Giardia. Waterborne epidemics of giardiasis are a relatively frequent occurrence. In 1983, for example, Giardia was identified as the cause of diarrhea in 68% of waterborne outbreaks in which the causal agent was identified (19). From 1965 to 1982, more than 50 waterborne outbreaks were reported (20). In 1984, about 250,000 people in Pennsylvania were advised to boil drinking water for 6 months because of Giardia-contaminated water. Many of the municipal waterborne outbreaks of Giardia have been subjected to intense study to determine their cause. Several general conclusions can be made from data obtained in those studies. Waterborne transmission of Giardia in the United States usually occurs in mountainous regions where community drinking water is obtained from clear running streams, is chlorinated but is not filtered before distribution. Although mountain streams appear to be clean, fecal contamination upstream by human residents or visitors, as well as by Giardia-infected animals such as beavers, has been well documented. It is worth emphasizing that water obtained from deep wells is an unlikely source of Giardia because of the natural filtration of water as it percolates through the soil to reach underground cisterns. Well-water sources that pose the greatest risk of fecal contamination are those that are poorly constructed or improperly located. A few outbreaks have occurred in towns that included

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filtration in the water treatment process, but the filtration was not effective in removing Giardia cysts because of defects in filter construction, poor maintenance of the filter media, or inadequate pretreatment of the water before it was filtered. Occasional outbreaks have also occurred because of accidental cross-connections between water and sewerage systems.

One can conclude from these data that two major ingredients are necessary for waterborne outbreak. First, there must be Giardia cysts in untreated source water and, second, the water purification process must either fail to kill or fail to remove Giardia cysts from the water.

Although beavers are often blamed for contaminating water with Giardia cysts, it seems unlikely that they are responsible for introducing the parasite into new areas. It is far more likely that they are also victims: Giardia cysts may be carried in untreated human sewage discharged into the water by small-town sewage disposal plants or originate from cabin toilets that drain directly into streams and rivers. Backpackers, campers, and sports enthusiasts may also deposit Giardia-contaminated feces in the environment that are subsequently washed into streams by rain. In support of this concept is a growing amount of data that indicate a higher Giardia infection rate in beavers living downstream from U.S. National Forest campgrounds compared with a near zero rate of infection in beavers living in more remote areas.

Although beavers may be unwitting victims in the Giardia story, they still play an important part in the transmission scheme, because they can (and probably do) serve as amplifying hosts. An amplifying host is one that is easy to infect, serves as a good habitat for the parasite to reproduce, and, in the case of Giardia, returns millions of cysts to the water for every one ingested. Beavers are especially important in this regard because they tend to defecate in or very near the water, which ensures that most of the Giardia cysts excreted are returned to the water.

The contribution of other animals to waterborne outbreaks of Giardia is less clear. Muskrats (another semiaquatic animal) have been found in several parts

of the United States to have high infection rates (30 to 40%) (21). Recent studies have shown that muskrats can be infected with Giardia cysts obtained from humans and beavers. Occasional Giardia infections have been reported in coyotes, deer, elk, cattle, dogs, and cats, but not in horses and sheep, encountered in mountainous regions of the United States. Naturally occurring Giardia infections have not been found in most other wild animals (bear, nutria, rabbit, squirrel, badger, marmot, skunk, ferret, porcupine, mink, raccoon, river otter, bobcat, lynx, moose, bighorn sheep) (22).

#### Removal from Municipal Water Supplies

During the past 10 years, scientific knowledge about what is required to kill or remove Giardia cysts from a contaminated water supply has increased considerably. For example, it is known that cysts can survive in cold water (4 deg C) for at least 2 months and that they are killed instantaneously by boiling water (100 deg C) (23,24). It is not known how long the cysts will remain viable at other water temperatures (e.g., at 0 deg C or in a canteen at 15-20 deg C), nor is it known how long the parasite will survive on various environment surfaces, e.g., under a pine tree, in the sun, on a diaper-changing table, or in carpets in a day-care center.

The effect of chemical disinfection, such as chlorine, on the viability of Giardia cysts is an even more complex issue. It is clear from the number of waterborne outbreaks of Giardia that have occurred in communities where chlorine was employed as a disinfectant that the amount of chlorine used routinely for municipal water treatment is not effective against Giardia cysts. These observations have been confirmed in the laboratory under experimental conditions (25,26,27). This does not mean, however, that chlorine does not work at all. It does work under certain favorable conditions. Without getting too technical, one can gain some appreciation of the problem by understanding a few of the variables that influence the efficacy of chlorine as a disinfectant.

1) Water pH: at pH values above 7.5, the disinfectant capability of

chlorine is greatly reduced.

- 2) Water temperature: the warmer the water, the higher the efficacy. Thus, chlorine does not work well in ice-cold water from mountain streams.
- 3) Organic content of the water: mud, decayed vegetation, or other suspended organic debris in water chemically combines with chlorine making it unavailable as a disinfectant.
- 4) Chlorine contact time: the longer Giardia cysts are exposed to chlorine, the more likely it is that the chemical will kill them.
- 5) Chlorine concentration: the higher the chlorine concentration, the more likely chlorine will kill Giardia cysts. Most water treatment facilities try to add enough chlorine to give a free (unbound) chlorine residual at the customer tap of 0.5 mg per liter of water.

The five variables above are so closely interrelated that an unfavorable occurrence in one can often be compensated for by improving another. For example, if chlorine efficacy is expected to be low because water is obtained from an icy stream, either the chlorine contact time or chlorine concentration, or both could be increased. In the case of Giardia-contaminated water, it might be possible to produce safe drinking water with a chlorine concentration of 1 mg per liter and a contact time as short as 10 minutes if all the other variables were optimal (i.e., pH of 7.0, water temperature of 25 deg C, and a total organic content of the water close to zero). On the other hand, if all of these variables were unfavorable (i.e., pH of 7.9, water temperature of 5 deg C, and high organic content), chlorine concentrations in excess of 8 mg per liter with several hours of contact time may not be consistently effective. Because water conditions and water treatment plant operations (especially those related to water retention time and, therefore, to chlorine contact time) vary considerably in different parts of the United States, neither the U.S. Environmental Protection Agency nor the CDC has been able to identify a chlorine concentration that would be safe yet effective against Giardia cysts under all water conditions. Therefore, the use of chlorine as a preventive measure against waterborne giardiasis generally has been used under outbreak conditions when the amount of chlorine

and contact time have been tailored to fit specific water conditions and the existing operational design of the water utility.

In an outbreak, for example, the local health department and water utility may issue an advisory to boil water, may increase the chlorine residual at the consumer's tap from 0.5 mg per liter to 1 or 2 mg per liter, and, if the physical layout and operation of the water treatment facility permit, increase the chlorine contact time. These are emergency procedures intended to reduce the risk of transmission until a filtration device can be installed or repaired or until an alternative source of safe water, such as a well, can be made operational.

The long-term solution to the problem of municipal waterborne outbreaks of giardiasis will involve improvements in and more widespread use of filters in the municipal water treatment process. The sand filters most commonly used in municipal water treatment today cost millions of dollars to install, which makes them unattractive for many small communities. Moreover, the pore sizes in these filters are not sufficiently small to remove a Giardia (6 to 9 micrometers x 8 to 12 micrometers). For the sand filter to remove Giardia cysts from the water effectively, the water must receive some additional treatment before it reaches the filter. In addition, the flow of water through the filter bed must be carefully regulated.

An ideal prefilter treatment for muddy water would include sedimentation (a holding pond where the large suspended particles are allowed to settle out by the action of gravity) followed by flocculation or coagulation (the addition of chemicals such as alum or ammonium to cause microscopic particles to clump together). The large particles resulting from the flocculation/coagulation process, including Giardia cysts bound to other microparticulates, are easily removed by the sand filter. Chlorine is then added to kill the bacteria and viruses that may escape the filtration process. If the water comes from a relatively clear source, chlorine may be added to the water before it reaches the filter. The point here is that successful operation of a complete water treatment facility is a complex process that requires considerable training.

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Troubleshooting breakdowns or recognizing potential problems in the system before they occur often requires the skills of an engineer. Unfortunately, most small water utilities that have a water treatment facility that includes filtration cannot afford the services of a full-time engineer. Filter operation or maintenance problems in such systems may not be detected until a Giardia outbreak is recognized in the community. The bottom line is that although, in reference to municipal systems, water filtration is the best that water treatment technology has to offer against waterborne giardiasis, it is not infallible. For municipal water filtration facilities to work properly, they must be properly constructed, operated, and maintained.

#### Water Disinfection in the Out-of-Doors

Whenever possible, persons in the out-of-doors should carry drinking water of known purity with them. When this is not practical, and water from streams, lakes, ponds, and other outdoor sources must be used, time should be taken to disinfect the water before drinking it.

#### Boiling

Boiling water is one of the simplest and most effective ways to purify water. Boiling for 1 minute is adequate to kill Giardia as well as most other bacterial or viral pathogens likely to be acquired from drinking polluted water.

#### Chemical Disinfection

Disinfection of water with chlorine or iodine is considered less reliable than boiling for killing Giardia. However, it is recognized that boiling drinking water is not practical under many circumstances. Therefore, when one cannot boil drinking water, chemical disinfectants such as iodine or chlorine should be used. This will provide some protection against Giardia and will destroy most bacteria and viruses that cause illness. Iodine or chlorine concentrations of 8 mg/liter (8ppm) with a minimum contact time of 30 minutes are recommended.

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If the water is cold (less than 10 deg C or 50 deg F) we suggest a minimum contact time of 60 minutes. If you have a choice of disinfectants, use iodine. Iodine's disinfectant activity is less likely to be reduced by unfavorable water conditions, such as dissolved organic material in water or by water with a high pH, than chlorine.

Below are instructions for disinfecting water using household tincture of iodine or chlorine bleach. If water is visibly dirty, it should first be strained through a clean cloth into a container to remove any sediment or floating matter. Then the water should be treated with chemicals as follows:

IODINE

Tincture of iodine from the medicine chest or first aid kit can be used to treat water. Mix thoroughly by stirring or shaking water in container and let stand for 30 minutes.

| Tincture of Iodine | Drops* to be Added per Quart or Liter |                        |
|--------------------|---------------------------------------|------------------------|
|                    | Clear Water                           | Cold or Cloudy Water** |
| 2%                 | 5                                     | 10                     |

\* 1 drop = 0.05ml

\*\* Very turbid or very cold water may require prolonged contact time; let stand up to several hours or even overnight.

CHLORINE

Liquid chlorine bleach used for washing clothes usually has 4% to 6% available chlorine. The label should be read to find the percentage of chlorine in the solution and the treatment schedule below should be followed.

Drops\* to be Added per Quart or Liter

| Available Chlorine | Clear Water | Water_Filter_1992.txt  |  |
|--------------------|-------------|------------------------|--|
|                    |             | Cold or Cloudy Water** |  |
| 1%                 | 10          | 20                     |  |
| 4% to 6%           | 2           | 4                      |  |
| 7% to 10%          | 1           | 2                      |  |
| Unknown            | 10          | 20                     |  |

\* 1 drop = 0.05ml

\*\* Very turbid or very cold water may require prolonged contact time; let stand up to several hours or even overnight.

Mix thoroughly by stirring or shaking water in container and let stand for 30 minutes. A slight chlorine odor should be detectable in the water; if not, repeat the dosage and let stand for an additional 15 minutes before using.

### Filters

Newcomers in the battle against waterborne giardiasis include a variety of portable filters for field or individual use as well as some household filters. Manufacturers' data accompanying these filters indicate that some can remove particles the size of a Giardia cyst or smaller and may be capable of providing a source of safe drinking water for an individual or family during a waterborne outbreak. Such devices, if carefully selected, might also be useful in preventing giardiasis in international travelers, backpackers, campers, sportsmen, or persons who live or work in areas where water is known to be contaminated.

Unfortunately, there are yet few published reports in the scientific literature detailing both the methods used and the results of tests employed to evaluate the efficacy of these filters against Giardia. Until more published experimental data become available, there are a few common sense things that a consumer should look for when selecting a portable or household

filter. The first thing to consider is the filter media. Filters relying solely on ordinary or silver-impregnated carbon or charcoal should be avoided, because they are not intended to prevent, destroy, or repel micro-organisms. Their principal use is to remove undesirable chemicals, odors, and very large particles such as rust or dirt.

Some filters rely on chemicals such as iodide-impregnated resins to kill Giardia. While properly designed and manufactured iodide-impregnated resin filters have been shown to kill many species of bacteria and virus present in human feces, their efficacy against Giardia cysts is less well-established. The principle under which these filters operate is similar to that achieved by adding the chemical disinfectant iodine to water, except that the micro-organisms in the water pass over the iodide-impregnated disinfectant as the water flows through the filter.

While the disinfectant activity of iodide is not as readily affected as chlorine by water pH or organic content, iodide disinfectant activity is markedly reduced by cold water temperatures. Experiments on Giardia indicate that many of the cysts in cold water (4 deg C) remain viable after passage through filters containing tri-iodide or penta-iodide disinfectants (28). As indicated earlier, longer contact times (compared to those required to kill bacteria) are required when using chemical filters to process cold water for Giardia protection. Presently available chemical filters also are not recommended for muddy or very turbid water. Additionally, filters relying solely on chemical action usually give no indication to the user when disinfectant activity has been depleted.

The so-called microstrainer types of filters are true filters. Manufacturer data accompanying these filters indicate that some have a sufficiently small pore size to physically restrict the passage of some micro-organisms through the filter. The types of filter media employed in microstraining filters include orlon, ceramic, and proprietary materials. Theoretically, a filter having an absolute pore size of less than 6 micrometers might be able to prevent Giardia cysts of 8 to 10 micrometers in diameter from passing.

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However, when used as a water sampling device during community outbreaks, portable filters in the 1- to 3- micrometer range more effectively removed Giardia cysts from raw water than filters with larger pore sizes. For effective removal of bacterial or viral organisms which cause disease in humans, microstraining filters with pore sizes of less than 1 micrometer are advisable. However, the smaller the pores, the more quickly the filters will tend to clog. To obtain maximum filter life, and as a matter of reasonable precaution, the cleanest available water source should always be used. Keep in mind, however, that even sparkling, clear mountain streams can be heavily contaminated.

Secondly, because infectious organisms can be concentrated on the filter element/media, it is important to consider whether the filter element can be cleaned or replaced without posing a significant health hazard to the user. Properly engineered portable filters should also minimize the possibility of contaminating the "clean water side" of the filter with contaminated water during replacement or cleaning of the filter element. This is especially important for filters used in the field where they are often rinsed or "cleaned" in a stream or river that may be contaminated.

Ongerth (29) recently evaluated four filters (First Need, H20K, Katadyn, the Pockett Purifier) for their ability to remove Giardia cysts from water. Only the First Need and Katadyn filters removed 100% of the cysts.

#### Conclusion

In conclusion, during the past fifteen years, giardiasis has been recognized as one of the most frequently occurring waterborne diseases in the United States. The most common sources of water contamination include improperly treated municipal sewage, infected animals, and indiscriminate defecation by outdoorsmen. Chlorine concentrations in the 0.1 mg per liter to 0.5 mg per liter range are largely ineffective against Giardia at the contact times commonly employed by municipal water utilities. The long-term solution to the problem of municipal waterborne outbreaks of giardiasis will involve

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appropriate pretreatment combined with improvements in and more widespread use of filters in the municipal water treatment process. While both micrometer- and submicrometer-rated filters are being employed on a limited scale for personal or household use, further evaluation of the efficacy of filters distributed by different manufacturers is needed to enable individuals and public health personnel to distinguish those that are safe and effective from those that are not.

TABLE I

|                               | Percentage | Number<br>of Patients |
|-------------------------------|------------|-----------------------|
| Symptoms                      |            |                       |
| Diarrhea*                     | 84         | 516                   |
| Malaise                       | 80         | 56                    |
| Weakness                      | 72         | 324                   |
| Abdominal cramps              | 63         | 412                   |
| Weight loss (0.5 - 11 kg)     | 63         | 412                   |
| Greasy, foul smelling stools  | 59         | 412                   |
| Nausea                        | 57         | 444                   |
| Headaches                     | 53         | 92                    |
| Anorexia                      | 49         | 156                   |
| Abdominal bloating            | 45         | 380                   |
| Flatulence                    | 41         | 388                   |
| Constipation                  | 25         | 88                    |
| Vomiting                      | 24         | 488                   |
| Fever                         | 22         | 32                    |
| Physical finding              |            |                       |
| Abdomen tender to palpitation | 66         | 92                    |
| Laboratory findings           |            |                       |

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|                        |    |     |
|------------------------|----|-----|
| Blood                  |    |     |
| Anemia                 | 15 | 124 |
| Leukocytosis           | 9  | 32  |
| Stool                  |    |     |
| Increased mucus        | 56 | 32  |
| Increased neutral fats | 50 | 32  |
| Blood                  | 13 | 156 |

\* Index symptom; may be biased (upward)

TABLE 1 - Based on data from Fifty diseases: Fifty Diagnoses, by M.G. Periroth and D.J. Weiland.

Year Book Medical Publishers, Inc., Chicago, 1981, pp. 158-159. Reprinted by special arrangement with Year Book Publishers, Inc.

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Back-country water treatment to prevent giardiasis.

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Abstract

This study was conducted to provide current information on the effectiveness of water treatment chemicals and filters for control of Giardia cysts in areas

where treated water is not available. Four filters and seven chemical treatments were evaluated for both clear and turbid water at 10C. Three contact disinfection devices were also tested for cyst inactivation. Filters were tested with 1-liter volumes of water seeded with  $3 \times 10^4$  cysts of *G. lamblia* produced in gerbils inoculated with in vitro cultured trophozoites; the entire volume of filtrate was examined for cyst passage. Chemical treatments were evaluated at concentrations specified by the manufacturer and for contact times that might be expected of hikers (30 minutes) and campers (eight hours, i.e., overnight). Two of the four filter devices tested were 100 percent effective for *Giardia* cyst removal. Of the other two filters, one was 90 percent effective and the other considerably less effective. Among the seven disinfection treatments, the iodine-based chemicals were all significantly more effective than the chlorine-based chemicals. None of the chemical treatments achieved 99.9 percent cyst inactivation with only 30-minute contact. After an eight-hour contact each of the iodine but none of the chlorine preparations achieved at least 99.9 percent cyst inactivation. None of the contact disinfection devices provided appreciable cyst inactivation. Heating water to at least 70C for 10 minutes was an acceptable alternative treatment.

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## Introduction

*Giardia lamblia* is the most commonly identified human intestinal parasite in the United States. Giardiasis is commonly transmitted between humans, especially among small children. It is also transmitted in water, particularly in the mountainous regions of the U.S. Since 1965, over 80 waterborne outbreaks of giardiasis have occurred in community water systems, affecting more than 20,000 persons (1). Giardiasis in hikers and campers has also been documented (2,3); indeed, it is commonly considered a backpackers' illness. *Giardia* cysts in concentrations as high as four per gallon have been detected in untreated surface water in northeastern and western states (4).

Concern over waterborne transmission of *Giardia* has led to development of a

variety of chemical disinfectants and portable filters for individual use in the backcountry. Although some information on such methods has been reported (2,5,6), there is no comprehensive guide to their reliability in actually removing or inactivating Giardia cysts. We tested four commercially available portable filters and one contact disinfection device for their ability to remove Giardia cysts from water. We also evaluated the cysticidal effectiveness of seven chemical disinfectants and three contact disinfection devices.

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## Methods

Cysts of *G. lamblia* were prepared for use in both the filtration and disinfection tests by propagation in gerbils inoculated with trophozoites from sterile culture. Trophozoites were of two isolates: one from a beaver (Be-4 isolate from Alberta) and one from a human (H-2 CSU isolate from Colorado). Cysts were concentrated from crushed, filtered gerbil feces by flotation on zinc sulfate (sp. gr. 1.18), cleaned, and stored in distilled water at 4C for up to 10 days before use. Similarly, *G. muris* cysts of an isolate originally obtained from hamsters (7) were purified from feces of infected athymic (nu/nu) mice and stored before use. Cyst concentrations were determined with a Coulter Counter (Model ZBI, Coulter Electronics, Hialeah, FL) and a haemocytometer. Except where noted, cysts were added to water samples in concentrations of about  $3 \times 10^4$ /ml. Cyst viability was assayed by fluorogenic staining (8) and in vitro excystation (7). In the former method, live cysts are distinguished by two fluorescing dyes. One dye is fluorescein diacetate (FDA), which when absorbed by cysts produces a fluorescent green only in live cysts; the second dye, either propidium iodide (PI) or ethidium bromide (EB), is excluded efficiently by live cysts but absorbed by dead cysts, resulting in red fluorescence.

## Filter testing

The following backpacker-type water filters were purchased from local retailers: First Need Water Purification Device (First Need), General Ecology Inc.,

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Lionville, PA; H2OK Portable Drinking Water Treatment Unit Model No. 6 (H2OK), Better Living Laboratories Inc., Memphis, TN; Katadyn Pocket Filter (Katadyn), Katadyn Products Inc., Wallisellen, Switzerland; and Pocket Purifier, Calco Ltd, Rosemont, IL. Also noted in this category is the Water Tech Water Purifier (Water Purifier), Water Technologies Corp., Ann Arbor, MI. Although it is not advertised as a filter and was not specifically tested for Giardia cyst removal, we report qualitative observations made during disinfection testing (see below) because its configuration and mode of operation suggest that particle removal may occur. Physical and operating information provided in the filter packaging is summarized in Appendix A. Each device was tested when it was new. Devices that removed all cysts when new were retested after a period of use approximating several months for a regular weekend user.

Each filter was prepared for testing by filtering four liters of tap water to purge loose carbon particles or debris. The cyst removal performance of each filter was determined by filtering one liter of spring water, turbidity of 0.1 NTU, to which formalin-fixed *G. lamblia* cysts had been added. The entire filtrate volume was passed through a 25-mm dia., 5-um pore size, polycarbonate membrane (Nuclepore, Pleasanton, CA). stained with EB (100 ug/ml), and mounted under a cover slip. Cysts were counted at x250 magnification with the aid of epifluorescence microscopy. A representative portion of each filter was examined to quantify cyst recovery as described previously (9). The area examined was inversely proportional to the number of cysts found and ranged from 3.5 percent of seeded positive control filters to 25 percent (one quadrant) of filters with cyst densities less than one per field. Total numbers of cysts present were estimated by extrapolation in direct proportion to the area examined. In extensive work on recovery of Giardia cysts using the procedures described above, cyst retention on the 5-um polycarbonate membrane in a single filtration step has routinely averaged 80 to 90 percent (Ongerth JE: unpublished). Accordingly, the ability to identify high levels of cyst removal, which would result in passage of very few or no cysts, is excellent. This ability is unaffected by the factors that contribute to lack of precision in counting large numbers of cysts on filters; such inaccuracies usually occur when only small representative subareas are examined and the total numbers are

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estimated by extrapolation. A seeded positive control and an unseeded negative control were processed with each batch of filter evaluations. The cyst removal performance evaluation was replicated three times for each filter device, with results expressed as the arithmetic average and corresponding standard deviation.

#### Contact Disinfection Testing

The Water Purifier is described in packaging information as a contact disinfection device. Likewise, the H20K and Pocket Purifier devices are described as providing disinfection as well as removing cysts by filtration. These devices were therefore tested for their effect on cyst viability in addition to filtration efficiency. A single 500-ml sample for each device was seeded with approximately  $2.5 \times 10^4$  cysts and passed through the device. Filtrate was collected and filtered as described above to recover cysts. The viability of cysts was then assessed by FDA and EB staining as described below.

#### Disinfectant Testing

The cysticidal effects of seven commercially available and commonly used disinfectant preparations were tested with identical procedures. Four of the products were iodine based: Polar Pure Water Disinfectant (Polar Pure), Polar Equipment, Saratoga, CA; Coghlan's Emergency Germicidal Drinking Water Tablets (CEGDWT). Coghlan's Ltd, Winnipeg, Canada; Potable Aqua Drinking Water Germicidal Tablets (Potable Aqua), Wisconsin Pharmacal Inc., Jackson, WI; and 2 percent iodine prepared from I2 reagent grade (Baker, Phillipsburg, NJ). The remaining three products were chlorine-based: Sierra Water Purifier (Sierra), 4 in 1 Water Co., Santa Fe, NM; Halazone, Abbott Laboratories, North Chicago, IL; and commercial liquid bleach (5.25 percent sodium hypochlorite). Disinfectant solutions were characterized by pH and total halogen concentration (Appendix B), the latter being determined colorimetrically using the DPD method.

Two water sources were used, one to reflect clear high-mountain conditions, the other to reflect downstream, more turbid conditions. Water sources were

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characterized by pH, turbidity, and free chlorine demand (Appendix C). The upstream source was from a small, spring-fed tributary to the Snoqualmie River near North Bend, Washington. Samples were taken from the stream approximately 50 yards downstream from the spring. The downstream source was the discharge from Lake Washington in Seattle, Washington. Samples were taken in midstream at the entrance to Portage Bay, adjacent to the University of Washington campus. Water samples were prepared for testing by adding disinfectant, according to manufacturers' instructions, to one liter of water in stoppered glass bottles (Appendix B).

Cysticidal properties of the chemical treatments were determined as follows.

- 1) Water was put in 50-ml disposable plastic centrifuge tubes and placed in a 10C incubator.
- 2) *G. lamblia* cysts were added to each test sample at time zero.
- 3) Tubes were vortex-mixed, sampled, and returned to the incubator.
- 4) At each sampling time, i.e., time 0, 30 minutes and 8 hours, a 10-ml sample was withdrawn; a portion was used for measuring disinfectant concentration, and in the remainder the disinfectant was quenched with 0.1-mM sodium thiosulphate.
- 5) Cysts in the quenched sample portion were exposed to aqueous solutions of the viability indicators, FDA (25 ug/ml) and EH (100 ug/ml), filtered on to a 13-mm dia. 5-um pore-size filter membrane, and rinsed with distilled water (10 ml).
- 6) Filters were mounted on glass slides, sealed under coverslips and examined by epifluorescence microscopy at x250 magnification (Model 16, Carl Zeiss, Inc., Thornwood, NY) to enumerate proportions of red and green fluorescing cysts indicating dead and live status, respectively. The viability baseline of the cysts was established by running a control sample of untreated water seeded with cysts through each test, using procedures identical to those for disinfectant-treated samples. Data are presented in terms of percent survival relative to

the controls (Figure 2). The effectiveness of each disinfectant for killing cysts in both upstream and downstream water was determined in triplicate, with results expressed as the arithmetic average and corresponding standard deviation.

The Water Tech Water Purifier, a contact disinfectant, was also tested as a chemical disinfectant. The test water was 100 ml of spring-source water seeded with Giardia cysts. The treated water was filtered, stained, and examined for cyst viability as described in steps 5 and 6 above. Three replicates were assayed.

#### Heat Inactivation

Inactivation of *G. lamblia* and *G. muris* cysts by heating was established as follows. Cysts were added to distilled water in 15-ml glass test tubes. The seeded tubes were incubated for 10 minutes at temperatures ranging from 10C to 70C. Afterwards, cyst suspensions were cooled immediately by swirling in 10C water for one minute. Cyst viability was determined either by excystation or by staining. If by the latter, FDA and EB were added to the samples, the tubes were vortex-mixed, and a 1-ml aliquot was filtered through a 13-mm dia. 5-um pore-size filter membrane. Filters were rinsed, mounted, and examined as described above to enumerate the live and dead cysts.

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#### Results

##### Filter Device Tests

The four filters differed significantly in their ability to remove Giardia cysts (Figure 1). The number of cysts recovered from water having passed through the filter devices ranged from zero to greater than  $10^4$  in individual tests. The performance of individual devices was consistent as indicated by the standard deviations for each of the three replicate test sets (Figure 1). The percentage

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of cysts removed by the devices, corresponding to 100 minus the percent of cysts recovered from the filtrate, was 100 percent for the First Need and Katadyn filters and approximately 90 percent for the H20K filter. The concentration of cysts in the Pocket Purifier effluent was not statistically different from the seed concentration.

The First Need and Katadyn filters were then subjected to a period of moderate use and then retested. The volume of water processed during the simulated use period was not the same for the two filters owing to differences in their operation. The difference in volume had no apparent effect on performance of the two filters. A total of 88 liters of tap water (turbidity of 0.3 NTU) was filtered with the First Need. During the process it was back-flushed, as recommended in package instructions, because the filtration rate decreased after 50, 71, and 75 liters had been filtered. After 88 liters had been processed, the filtration rate was about 25 percent lower than when the filter was new, and it was retested in that condition. The Katadyn filter was subjected to use by filtering one liter of tap water four times a day for five days. At the end of each day, the filter was cleaned according to package instructions by disassembling, brushing the filter element, and allowing it to air-dry overnight before reassembly. After the respective periods of use, these two filters were tested in triplicate for efficiency of cyst removal. Performance of these filters was the same, 100 percent cyst removal, when they were retested.

#### Cyst Inactivation

Contact Disinfection Devices - The effect of each of the contact disinfection devices on *G. lamblia* cyst viability was limited. The Water Purifier inactivated about 15 percent of the cysts added in 100 ml of upstream (low turbidity) water; the H20K filter inactivated about 5 percent of the cyst challenge, and the Pocket Purifier inactivated about 2 percent of the cyst challenge.

Chemical Disinfectants - The effectiveness of seven disinfecting chemical preparations ranged from only a few percent to greater than 99.9 percent,

depending on the chemical and its concentration, the contact time, and the disinfectant demand of the water (Figure 2). None of the disinfectants was more than 90 percent effective after a contact time of 30 minutes. After eight-hour contact, the four iodine-based disinfectants, each caused a greater than 99.9 percent reduction in viable cysts. The chlorine-based disinfectants were clearly less effective than the iodine-based ones at both contact times.

Heating in Water - Experiments conducted with cysts of *G. lamblia* and of *G. muris* indicated that the two species have virtually the same sensitivity to inactivation by heating. Cysts at both species were completely inactivated by heating to 70C for 10 minutes. Heating to 50C and 60C for 10 minutes produced 95 and 98 percent inactivation, respectively (Figure 3).

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## Discussion

To remove *Giardia* cysts from water, one must use a filter with sufficiently small pores to trap the cysts and sufficiently large capacity to produce a useful volume of treated water before backwashing or replacement is necessary. Although a number of manufacturers advertise that their filters remove *Giardia* cysts, the only previously published account of filter performance was for the Katadyn unit (6). Our filter evaluation study showed that only the First Need and the Katadyn filters removed cysts with at least 99.9 percent effectiveness. Under the same test conditions, the H20K filter was approximately 90 percent effective and the Pocket Purifier was less than 50 percent effective for cyst removal. The analysis of viability for the cysts collected in the effluent of the Water Purifier, H20K, and Pocket Purifier indicates that passage through the device did not significantly reduce the percentage of viable cysts.

The current study showed that none of the chemical treatments could inactivate more than 90 percent of cysts with 30 minutes of contact time at 10C. At both 30 minutes and eight hours of contact time, the iodine-based disinfectants inactivated a higher fraction of cysts than did the chlorine-based products.

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All methods inactivated a lower percentage of cysts in cloudy or turbid water than in clear water. All disinfectants performed better with eight hours of contact time than with 30 minutes. Only the iodine-based compounds inactivated 99 to 99.9 percent of cysts, within eight hours of contact time for both turbid and clear water. As observed by Jarroll, et al (5), the 2 percent tincture of iodine was less effective than the other iodine preparations with 30 minutes of contact time, but it was as effective as the others at eight hours. Comparison of our results with those of Jarroll, et al (5), is complicated by differences between test conditions used. However, our results generally indicate more stringent requirements for effective inactivation of Giardia cysts. Differences between cyst populations used in the two studies could account for the observed differences, even though both were *G. lamblia*. Cysts produced in our trophozoite - gerbil system had consistently high intrinsic viability (>80 percent), excysted efficiently when fresh (80 to 90 percent), and have appeared more resistant to halogen disinfectants than reported previously (Ongerth J.E.: unpublished).

The results of heat inactivation in our study correspond to previous reports indicating that heating to between 60C and 70C kills Giardia cysts efficiently. In addition, our data illustrate the correspondence between the fluorogenic staining and in vitro excystation procedures for assessing cyst viability. When applied to cysts of the same condition. Staining indicates a slightly higher proportion of viable cysts than does excystation. Overall, however, the two procedures provide comparable information.

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Figure 1 - Effectiveness of Four Portable Water Filters for Removal of Giardia Cysts from One-Liter Volumes of Water Each containing approximately  $3 \times 10^4$  Cysts (dotted line). [A bar chart showing the positive and negative controls and results from the filters, on a log scale. The First Need and Katadyn results and the negative control were all zero. The Pocket Purifier and the positive control were approximately the same - i.e. the Pocket Purifier did not remove cysts at all. The H2OK results were somewhat below the positive control,

actually -- due to the log scale -- indicating 90% removal.]

Figure 2 - Effect of Time and Disinfectant Concentration of Seven Chemical Disinfectants on Survival of *G. lamblia* Cysts in Turbid and in Clear Water. [A rather striking bar chart comparing chemical treatments under varying conditions. The chlorine compounds were basically ineffective, with no significant effect at 30 minutes; at 8 hours the Sierra was still totally ineffective, the bleach killed about half the cysts, and the Halazone killed 70-90% of the cysts (better in clear water). The iodine compounds were poor at 30 minutes in turbid water (half killed), only a little better at 30 minutes in clear water (70-90% killed, with Potable Aqua the best), but completely effective (100% killed) after 8 hours.]

Figure 3 - Inactivation of *Giardia* Cysts as a Function of Temperature (10-minute exposures) as Indicated by Ethidium Bromide Staining and by in vitro Excystation. [A line chart showing cyst survival at different temperatures. Four combinations of *Giardia* species, source, and laboratory technique are shown, but all show approximately the same results. 40C kills no cysts; 50C kills a lot of cysts, 60C kills most cysts, 70C kills all cysts.]

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#### Acknowledgements

References to commercial products shall not be construed to represent or imply the approval or endorsement by project investigators or sponsors.

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 Appendix A: Water Filter characteristics Listed by Manufacturers on Packaging or  
 Instruction Insert

[Manufacturer column omitted. See text for this information.]

| Name                  | Filter Type   | Operating Mode | Operating Rate | Useful Life     | Restrictions /Limitations |
|-----------------------|---|----------------|----------------|-----------------|---------------------------|
| First Need            | 0.4 um microscreen plus adsorber                                  | hand pump      | 1 pt/min       | up to 800 pints | A                         |
| H20K                  | 6 um mesh, 3 in. activated carbon w/Ag                            | gravity        | 1 qt/min       | 2000 gal        | A, B                      |
| Katadyn Pocket Filter | 0.2 um ceramic, Ag-impregnated                                    | hand pump      | 1 qt/min       | many years      | A                         |
| Pocket Purifier       | 10 um (nominal), halogenated resin (38% I), Ag-impregnated carbon | mouth suction  | -              | -               | A                         |
| Water Purifier (a)    | Polystyrene resin bed (46% I2 as I5)                              | gravity        | -              | 100 gal         | A, C                      |

- A - Does not desalinate; not for saltwater or brackish water.
- B - Pretreat with I2 for bacterially contaminated water.
- C - Not for use with muddy water.
- (a) Not described as a filter by package information.

## Appendix B: Characteristics of Disinfectant Preparations

[Manufacturer column omitted. See text for this information.]

| Name            | Active Chemical  | Recommended Application  | Total Halogen Concentration (a), (mg/liter) | pH (b) |
|-----------------|--|--|---|--------|
| Polar Pure      | Crystalline iodine, 99.5%                                  | 1-7 capfuls per quart depending on temperature   | 2.4 (1 cap/quart)                           | 6.1    |
| CEGDWT          | Tetraglycine hydro-periodate 16.7% (6.68% titrable iodine) | 1 tablet per liter or quart  | 4.5 (1 tab/quart)                           | 5.6    |
| Potable Aqua    | Tetraglycine hydro-periodate 16.7% (6.68% titrable iodine) | 1 tablet per liter or quart  | 5.3 (1 tab/quart)                           | 5.6    |
| 2% Iodine       | Iodine   | 0.4 ml per liter   | 4.5   | 6.5    |
| Sierra          | Calcium hypochlorite & hydrogen peroxide                   | 100 crystals (50 mg) Ca(OCl) <sub>2</sub> + 6 drops H <sub>2</sub> O <sub>2</sub> per gallon | 11.6  | 6.7    |
| Halazone        | p-dichloro-sulfamoyl benzoic acid, 2.87%                   | 5 tablets per quart  | 7.5   | 6.7    |
| Chlorine bleach | sodium hypo-chlorite, 5.25%                                | 5 ml per gallon  | 3.9   | 7.1    |

(a) As prepared according to package instructions.

(b) In water treated according to package instructions.

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Appendix C: Characteristics of Disinfectant Test Water

| Source          | pH  | Turbidity (NTU) | Chlorine Demand (a)<br>(mg.liter) |
|-----------------|-----|-----------------|-----------------------------------|
| Spring-fed      | 6.8 | 0.09            | 0.3                               |
| Lake Washington | 7.1 | 0.75 - 0.80     | 0.7                               |

(a) 30 minutes, free chlorine demand (5).

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The authors

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REI Water Filter Chart

REI Water Filters Comparison Chart:

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|  | Katadyne        | MSR                                       | PUR                          | First Need  |
|--|-----------------|---|------------------------------|-------------|
| Minimum Pore Size                      | .2 absolute     | .1 absolute                               | 1.0 nominal                  | .4 absolute |
| Weight                                 | 23 oz.          | 19 oz.                                    | 21 oz.                       | 14 oz.      |
| Number of Filter Elements              | 2               | 4   | 2                            | 1           |
| Types of Elements                      | Screen, Ceramic | Foam, Screen<br>Carbon, Paper<br>Membrane | Glass Fibre,<br>Iodine resin | Charcoal    |
| Cost Per Gallon                        | \$.25           | \$.28                                     | \$.24                        | \$.37       |
| Appr. Filter Life (in Gallons)         | 1000            | 500                                       | 500                          | 100         |
| Approximate Filtering Time (in Quarts) | 120 seconds     | 90 seconds                                | 60 seconds                   | 90 seconds  |
| Cost of Replacement Filter             | \$89.00         | Two Parts<br>\$20.00 &<br>\$30.00         | \$40.00                      | \$24.00     |
| Price                                  | \$225.00        | \$140.00                                  | \$130.00                     | \$37.00     |

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For room reasons I left off two filters. Its specs are in order:

Basic Designs

1.0 absolute, 12 oz., 2, Granular active carbin & ceramic, \$.07,  
1000, 60 MINUTES!, \$40.00, \$60.00.

Timber Line:

2.0 absolute, 6 oz., 1, Spun Polypro, \$.30,  
100, 70 Seconds, \$??, \$30.00.

The filtering times are probably based on a new unit. Some units are easy to clean, one can't be properly, and one can be cleaned on the fly.

Lower prices can be found elsewhere than REI. REI charges list mostly.

Also note some units are easier to use (and clean) than others.

|               | Katadyn | MSR    | PUR        | 1stNeed | line    | Designs |               |
|---------------|---------|--------|------------|---------|---------|---------|---------------|
| min pore size | .2      | .1     | 1 + I      | .4      | 2       | 1       |               |
| dry weight    | 23 oz   | 19 oz  | 21 oz      | 14 oz   | 6 oz    | 12 oz   |               |
| seconds/qt    | 120     | 90     | 60         | 90      | 70      | grav-   | (when new)    |
| seconds/qt    | 120     | 180    | 60         | 180     | 140     | ity     | (after usage) |
| filter life   | 1000    | 500    | 500        | 100     | 100     | 1000    | (in gallons)  |
| cost/gallon   | \$.25   | \$.28  | \$.24      | \$.37   | \$.30   | \$.07   |               |
| retail price  | \$225   | \$140  | \$130      | \$ 38   | \$ 30   | \$ 65   |               |
| replacement   | \$ 89   | \$ 50  | \$ 40      | \$ 24   | n/a     | \$ 40   | (filter cost) |
| # elements    | 2       | 4      | 3          | 1       | 1       | 2       |               |
| elements      | screen  | foam   | screen     | carbon  | polypro | carbon  |               |
|               | ceramic | screen | glassfiber |         |         | ceramic |               |
|               |         | carbon | iodine     |         |         |         |               |
|               |         | paper  |            |         |         |         |               |

Notes: 1st Need, Timberline, and Basic Designs require iodine to treat bacteria and viruses. Katadyn and MSR require iodine to treat viruses. Only PUR requires no additional iodine. With carbon elements, only MSR, 1st Need, and Basic Designs remove harmful chemicals.

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- 10/ Words from Rachel Carson
- 11/ Snake bite
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- 13/ Questions on conditions and travel
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- 15/ Leopold's lot.
- 16/ Morbid backcountry/memorial
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- 6/ Non-wisdom: fire-arms topic circular discussion
- 7/ Phone / address lists
- 8/ Fletcher's Law of Inverse Appreciation and advice

Subject: Re: good water filters?

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Date: 22 Sep 1995 22:51:28 GMT

Katadyn water filters are a little more expensive up front but will last for thousands of gallons making them the cheapest filter per gallon on the market. For more info: on Katadyns try:

<http://rrnet.com/~subrosa>

once there go to the on-line catalog. There is also an extensive list of links to survival and freedom related sites.

Subject: Water Purifier Pointer

Date: 4 Oct 1995 17:05:10 GMT

I am posting this info for anyone in the market for a portable water purification system. I know a guy who has designed and is marketing one. He doesn't have access to the net and I have no connection with this business, so please don't write me about it. Here's the general info:

Water Doctor portable water purification system with a 12 volt self priming pump plugs into cigarette lighter of car and will pump water from eight feet away. Filters water eight times before U.V. sterilization that kills any, and all viruses, bacteria and microorganisms. Built in 12 volt to 120 volt D.C. to A.C. power inverter will power cellular phone, radio, computer, or other small appliances. Comes with 2.2 gallon storage tank but will deliver 30 gallons per day. Optional accessories include solar panels and storage

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batteries. Uses no chemicals in process.

For detailed info:

John Tate  
The Water Doctors  
P.O. Box 1684  
Winnemucca, NV 89446  
ph: (702) 623-9057  
fax: (702) 623-3354

Hope this info is helpful to someone!

K.C.