Purifying Water Using Sustainable Methods

What is Sustainablility

Sustainability means to meet the essential needs of the present without compromising the ability of folks in the future to meet their own needs.

A sustainable practice must have enduring value and worth. It should be comprehensive and embrace all areas of our life.

Purifying Water Using Sustainable Methods

Beautiful, clean water!

Is This Water Safe to Drink since the stream is running?

What Do you think?

Upstream Beyond Your View

A dead and rotting Moose in the head waters of the stream.

Assumptions About Water Quality are Dangerous

Drink from this stream without treating the water and you might die, or be so sick that you are unable to do anything.

Why Water Treatment?

Preventable waterborne diseases are responsible for approximately 80% of all illnesses and deaths in the developing world.

Children are especially susceptible, with nearly two million deaths each year.

Chemical contamination causes illness, death and birth defects.

How can we supply our water needs and maintain good health and safety?

Evaluate Your Goals

In light of your goals for preparedness or for your homestead, is water purity and safety important?

Are sustainable methods important to you?

Why should we be concerned about the topic of water treatment?

What are Pathogens?

path·o·gen [path-uh-juhn, -jen]

noun

any disease-producing agent, especially a virus, bacterium, or other microorganism.

3 Main Sources of waterborne disease

* Protozoa (parasites, amoebas, cryptosporidium, giardia, etc.)
* Bacteria (botulism, cholera, E. Coli, salmonella, legionella, typhoid, etc.)
* Viral Pathogens (SARS, Hepatitis A, Polio)

Safe and Clean Water

Long-term Storage Issues

- Stale, bad-tasting water is not desirable. It is important that the container, pathogens or objects do not contaminate the water.
- Some containers leach harmful chemicals.
- Translucent containers can grow algae.
- Dirt, soil or pollen can cause water to taste foul.
- Anaerobic conditions, particularly near the bottom of the storage container, can cause sour or dangerous water.

Taste?

Is taste important?

Yes, when people need to drink enough water to maintain adequate hydration, it is not easy to drink water that does not taste good.

Bad taste is **sometimes** a warning of a dangerous condition, but good tasting water should not be relied upon as a test to keep you safe.

Safe and Clean Water

What sustainable methods are available to treat water?

* **Chemicals**
* **Filtration**
* **Heating or vapor distillation**
* **UV light**
* **Ozone**

Chemical Treatment

* Chlorine and Chloramine and a few other chemicals are added to the water to destroy pathogens

* Some chemicals provide both primary and secondary disinfection.

  (Secondary disinfection is long-term and lasts longer than the original treatment—for example the disinfection effect continues while the water is stored or piped to the end use.)

Pros and Cons of Chemicals

Good:

- Easy to use
- Chemicals are fairly cheap
- They usually keep well over time
- Long lasting effects in the water-even during storage

Bad:

- Chemicals can be toxic
- Chemicals can taste bad
- Chlorine does not work well in high pH-most ground water is high pH
- There are new mutated forms of pathogens that are becoming increasingly resistant to these chemicals

Filtration

Filtration is the next major method of water treatment and it is used in two main ways:

1. Taste, odor and sediment are removed with mechanical filtration. Sometimes these are combined with activated charcoal or a KDF filter to remove chemicals after the water is treated with chemicals.

2. Filters that either adsorb, kill or block pathogens
   - A. **The Nano Alumina filter (Adsorption of pathogens)**
   - B. **The Slow Sand Filter (Kills pathogens with Biological action)**
   - C. **True blocking filters that only block pathogens like Reverse Osmosis or ceramic filters**

Nano Alumina Filters

This new class of filter works by the principle of **adsorption**. This is the adhesion of particles to the surface of the filter. (This is also how charcoal filters stop chemicals and taste.)

In this case, the pathogens actually stick to the surface of the filter and the water passes through until the filter clogs and becomes unable to pass water. The pathogens do not ever become free nor do they multiply inside the filter.

In effect, pathogens are trapped and unable to contaminate the water passing through the filter.

These filters were designed for NASA for space flight where water must be reused and not wasted.

How to Find Nano Alumina Filters

These filters are manufactured in the USA by Argonide and are only sold by dealers through the C.Hanish company.

They come in two basic configurations:

1. Standard filter cartridges under the name **NanoCeram®**
2. Special cartridges and assemblies under the name **Bioguard®**

The standard **NanoCeram®** cartridges **do not** meet the standards of safety to be used as disinfection units of contaminated water due to the lack of fail-safe seals in the standard water filter housing.

Safe Nano Alumina Filters

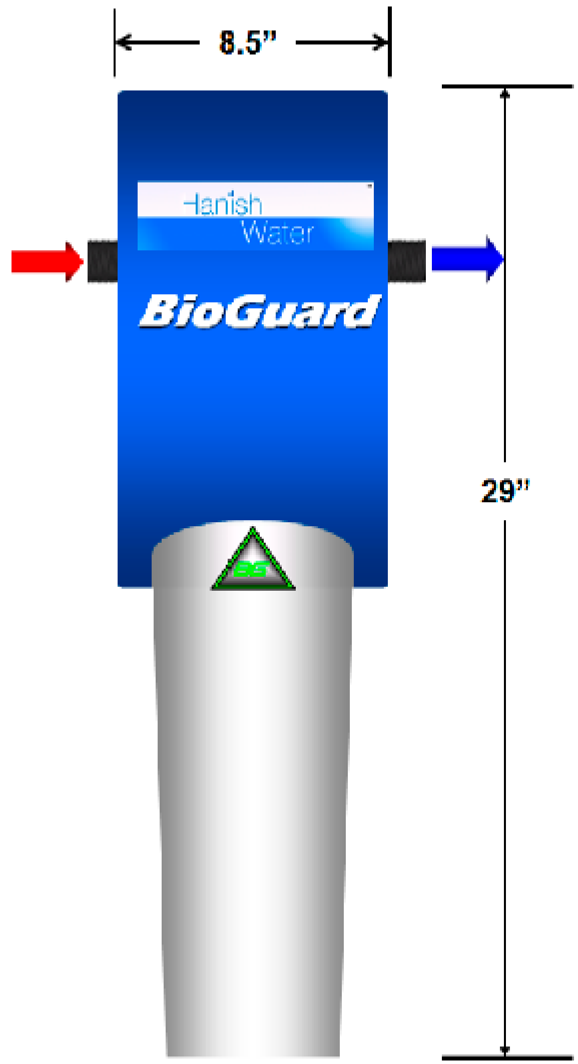
The units designed to purify water to safe drinking standards surpass the quality of the ceramic filters with none of the drawbacks.

The huge positive of these units is the amount of water flow. These filters can move from 10 to 20 gpm while trapping 99.999% of bacteria, Cryptosporidium and protozoa. They can trap 99.99999% of viruses.

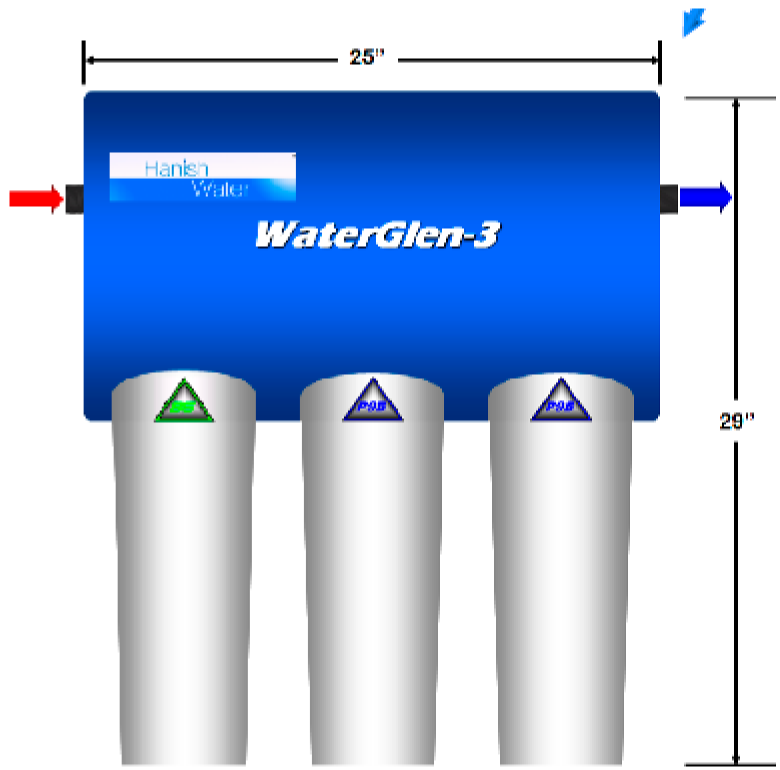
When the filter is clogged with contaminants, it will slow down but not release the pathogens into the water flow. The user will change out the filter when it slows down.

Filtering all the water going into a home will allow the filter to last for 6 months to one year.

Single Cartridge BioGuard®



Three Cartridge WaterGlen® System



The systems with multiple cartridges consist of various filtration levels and one BioGuard®

Pros and Cons of Nano Alumina

Good:

- Very good filtering-equal to the Reverse Osmosis
- Very fast flow-no slow down in home water system even if filtering all the water for the home
- Easy to maintain-owner can change out the filter easily
- The filter cartridges are fairly inexpensive
- There is no back flushing or water waste

Bad:

- The filter must be changed every 6 months to 1 year in normal use
- The units can only be purchased from authorized dealers
- The units are about the same price as UV lights at first purchase
- Care must be taken to pre-filter the water well
- There must be at least 1.5 psi of pressure for the filter to function-water source would be at least 3.5 ft. above filter for a gravity feed

The Most Sustainable Filter

The **Slow Sand Filter (SSF)** uses a bio-active layer to accomplish the destruction of pathogens. It is not depending on filtration for this action. The sand filtration media is actually just the bed that holds the bio-active layers in place.

They have been called "the best, most economical primary method of purifying water" according to the World Health Organization and is accepted by the EPA as a safe, effective method of primary disinfection.

SSFs are recognized by the WHO, Oxfam, United Nations and the EPA as a superior technology for the treatment of surface water.

Slow Sand Filtration The WHO 1974

The World Health Organization in the document
Slow Sand Filtration published in 1974 states:

“Under suitable circumstances, slow sand filtration may be not only the cheapest and simplest but also the most efficient method of water treatment. Its advantages have been proved in practice over a long period, and it is still the chosen method of water purification in certain highly industrialized cities as well as in rural areas, mid-sized and small communities.”

Continued…

Slow Sand Filtration Quote

“No other single process can effect such an improvement in the physical, chemical, and bacteriological quality of normal surface waters as that accomplished by biological filtration.

The delivered water does not support after-growth in the distribution system, and no chemicals are added, thus obviating one cause of taste and odor problems.”

Continued…

Slow Sand Filtration Quote

"…it is still the most useful all-round treatment process. Within a single unit it incorporates settlement, straining, filtration, organism removal, organism inactivation, chemical change, and (to some extent) storage…

It probably represents the nearest approach, in each of its functions, to the processes that occur in nature. Perhaps because of this, it has unusual powers to suffer misuse without failure, and a capacity for self-regeneration after such misuse."

History of the Slow Sand Filter

The earliest recorded use is found in Greek and Indian writings from 2000 BC. Along with heating water to purify it, sand filters and gravel filtration was used.

In 1804, the first drinking water supply for a city was built in Paisley, Scotland by John Gibb.

By 1806, Paris operated a large water treatment plant. In 1827, James Simpson built a sand filter in England for safe drinking water.

The first SSF built in the US was in Richmond, VA in 1832.

The Metropolis Water Act of 1852 in Britain, was the first law concerning water treatment and it required all water supplied to London to be treated by SSF.

History of the Slow Sand Filter

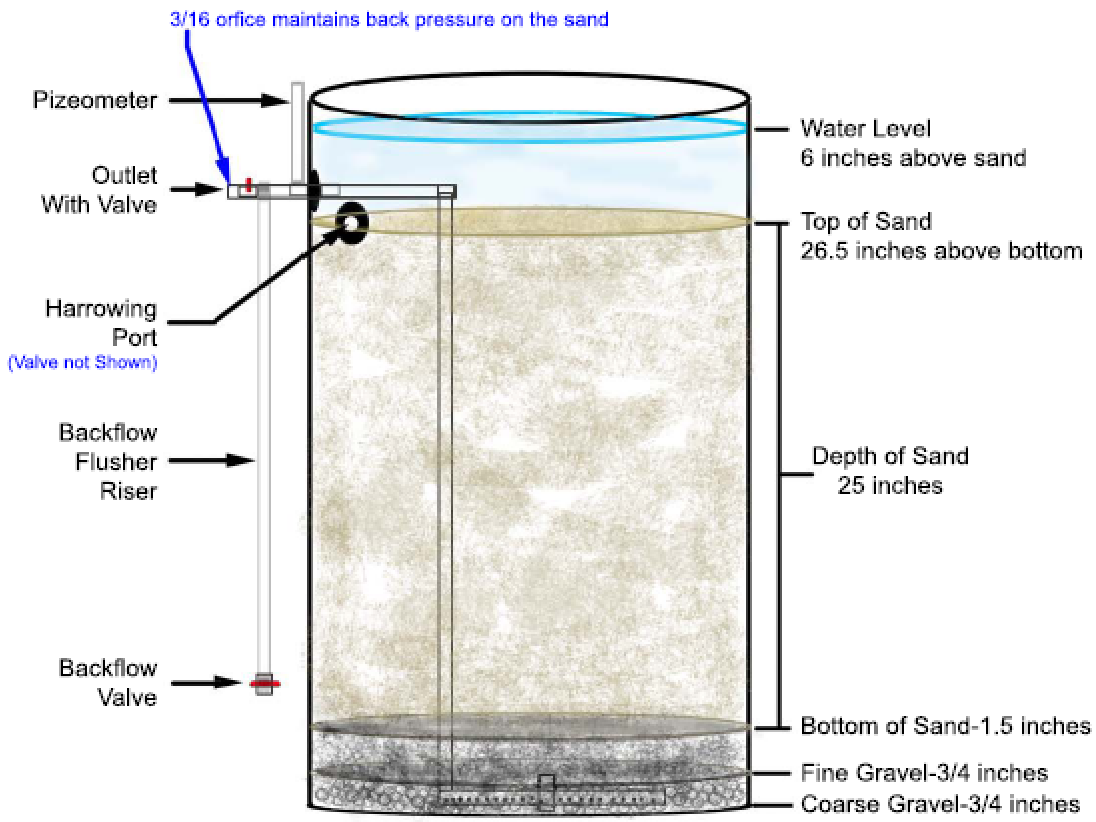
In 1892, two neighboring cities, Hamburg and Altona, which drew their drinking water from the River Elbe, experienced a cholera outbreak.

Hamburg did not filter the water taken from the river while Altona used SSFs.

Hamburg suffered 30% of the population infected with 7500 deaths and Altona was almost totally unaffected.

In the light of this development, all Europe used Slow Sand filters to treat drinking water.

This is a diagram of a typical SSF



What is a Slow Sand Filter

SSFs are essentially a container filled with one or more layers of graduated media (usually sand). At the top there is a chamber of raw water. Gravity forces the water through the sand to the bottom where there is an drain.

As the water passes through the first few inches of the top, it is affected by a naturally occurring, biologically active layer called the *schmutzdecke* (dirt blanket in German).

Various biological activity continues to consume pathogens down to around 15.5 inches.

Current Uses

Many philanthropic and missionary organizations are providing SSFs and SSF-building training for developing nations.

The US Navy has distributed thousands of SSFs in Haiti and in Southeast Asia

SSFs have been widely used in Europe since the early 1800s.

In the US primarily small cities in New England continue to use them. However, the recent *Surface Water Treatment Rule* by the EPA has caused renewed interest in SSFs for communities.

SSFs have no secondary disinfection effects and stored filtered water can become contaminated so care must be exercised in water storage.

Building a Slow Sand Filter

SSFs are very easy to build

Preparing the Vessel

Drilling hole for grommet seal for the harrowing valve

Installing Ports

Installing grommet seal

Outlet Plumbing

Clean water outlet

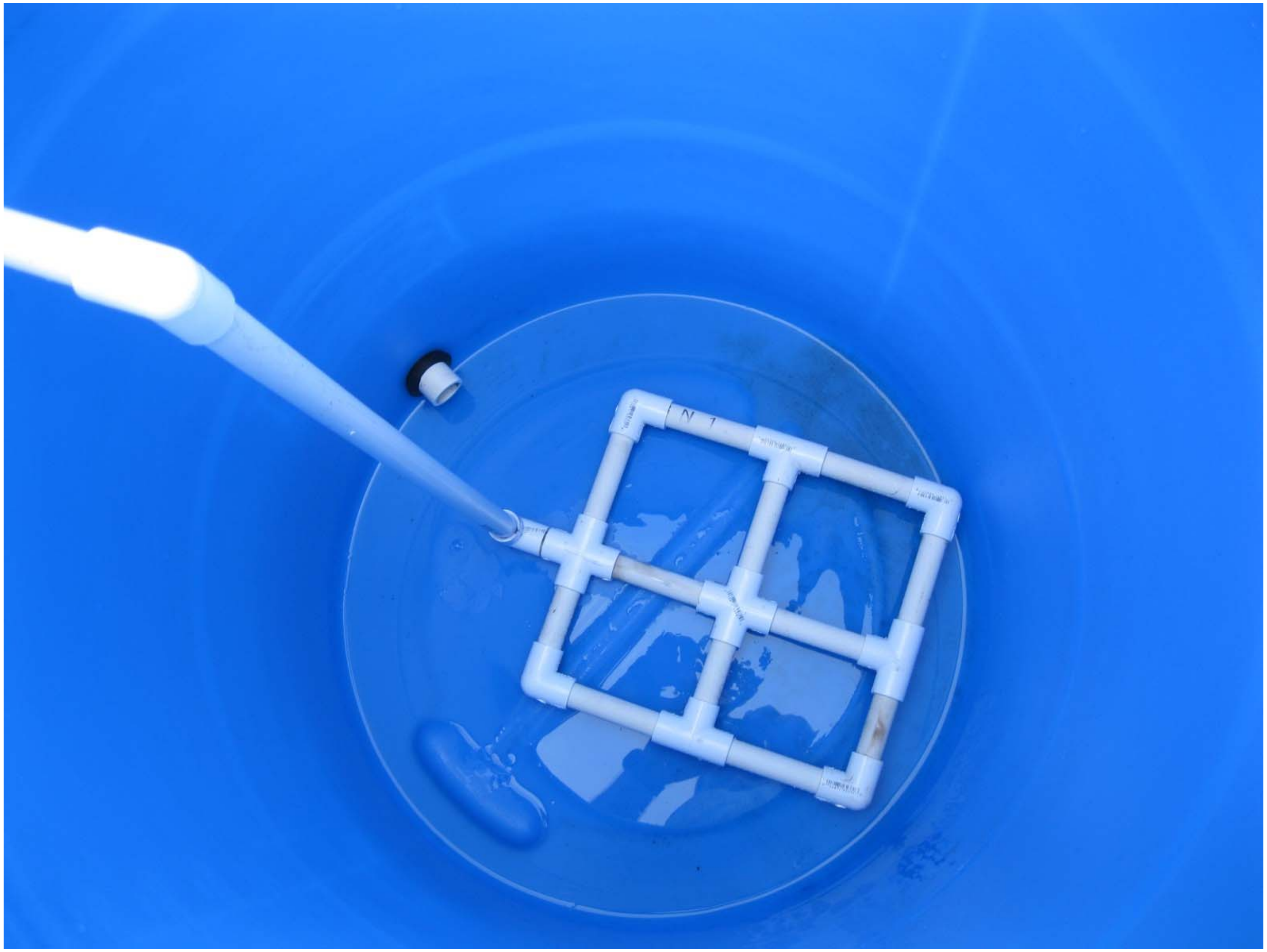
All Three Outlets

All the openings: Drain on bottom. Harrowing valve on left. Clean water outlet on right.

Clean Water Manifold

Manifold goes in the bottom to take water from various positions. Notice the tiny holes.

Installing Manifold



Manifold placed in the bottom of the filter. Drain on the left.

Installing Gravel Media

Gravel covering the manifold at the bottom of the filter

Installing Sand Media

Notice the downpipe is not against the wall of the filter

Flushing Silt at First Fill

The brown color in the water is silt from construction

Contaminated Water Level

About 6-6.5 inches of water sits over the sand layer

Operation of the Filter

Once the silt is washed out from the construction, the filter sits and passes water 24 hours a day or water can be poured in as needed.

The schmutzdecke begins to form over time. In cool weather it takes about 2 weeks. In warmer weather, it happens faster.

One filter we built from a 55 gallon drum is making about 220 gallons per day. When the bio-active layer is fully functioning, that water will be perfectly safe to drink.

Slow Sand Filter Delivery at Maximum Safe Flow Rate

Filter surface in Sq.Ft	Gallons at 7.4 gal/hr/sq.ft.	Gallons per 24 hours	Gallons per minute	Oz/minute
0.25	1.85	44.4	0.03	3.95
0.5	3.7	88.8	0.06	7.89
0.75	5.55	133.2	0.09	11.84
1	7.4	177.6	0.12	15.79
1.5	11.1	266.4	0.19	23.68
2	14.8	355.2	0.25	31.57
2.5	18.5	444.0	0.31	39.47
3	22.2	532.8	0.37	47.36
3.5	25.9	621.6	0.43	55.25
4	29.6	710.4	0.49	63.15
4.5	33.3	799.2	0.56	71.04
5	37	888.0	0.62	78.93
5.5	40.7	976.8	0.68	86.83
10	74	1,776.0	1.23	157.87
10.5	77.7	1,864.8	1.30	165.76
11	81.4	1,953.6	1.36	173.65
12	88.8	2,131.2	1.48	189.44
13	96.2	2,308.8	1.60	205.23
14	103.6	2,486.4	1.73	221.01
15	111	2,664.0	1.85	236.80
Do not exceed these numbers!				
Minimum Safe Depth of Media is 15.75 inches!				

Sand Filter Calculations

Known Items:	Diameter	Height
30 gal drum	19.5	29.5
55 gal drum	23.75	34.5

Convert feet to inches	feet	inches
	0	0

play sand	$ 3.47
filter sand	$ 5.48
size-cu.ft.	0.5

Enter data in green cells only
Blue cells are results of calculations
Yellow cells are known data

Choose if cylinder or rectangle	cylinder		
	Diameter	Height	
Enter drum dimensions	23.75	34.5	inches

	length	width	height	
Enter rectangle				inches

Choose head height	8	choose gravel height	5	inches

Enter size of gravel bag	0.5	price:	$ 3.47	each
Enter size of sand bag	0.5	price:	$ 5.48	each

Choose sand Type	filter sand

Calculating safe daily flow rate		
Enter maximum need	100	gal/day
Required sq.ft.	0.28	sq.ft for low flow
	0.57	sq.ft for Maximum flow
Chosen sq. ft.	3.08	safe

There is no lower limit on flow. Lower is better.

Materials	
Number of gravel bags:	3
Number of sand bags:	11
Cost of gravel:	$ 10.41
Cost of sand:	$ 60.28
Total media cost:	$ 70.69

Sieving play sand is hard labor
Play sand has loss from sieving it.
Filter sand is cleaner and more uniform
Filter sand should be used if possible

Range of safe flows				
Low flow	15.10	Gal/hr	0.25	Gal/min
Maximum flow	22.65	Gal/hr	0.38	Gal/min
Low flow	60.4034	quarts/hr	32.22	oz/min
Maximum flow	90.61	quarts/hr	48.32	oz/min

Do not exceed maximum flow rates!

Media Depth:	26.5	inches
Tap height from bottom:	28	inches
Sand height from bottom:	21.5	inches
Head in ft:	0.67	inches
pressure:	0.29	PSI

Minimum sand safe height:	15.75	safe	by	5.75	inches

Pros and Cons of the SSF

Good:

- Once the filter is constructed, it is the most sustainable water treatment device available and will last forever if maintained properly.
- It is time-tested since 1804 to be very reliable and safe.
- Thousands, if not millions, are using SSFs today to prevent waterborne diseases.
- Smaller units can be made for less capacity if attention to the specifications is observed.

Bad:

- It is very heavy and is a permanent fixture unless you remove the sand.
- Inattention to details on the specifications could result in unsafe conditions

Blocking Filters

We will look at two types of filters that block pathogens:

Reverse Osmosis using a membrane and flushing the membrane to unclog when it fills.

Ceramic filters that use very fine ceramic filters to let water pass through slowly as a drip.

Reverse Osmosis

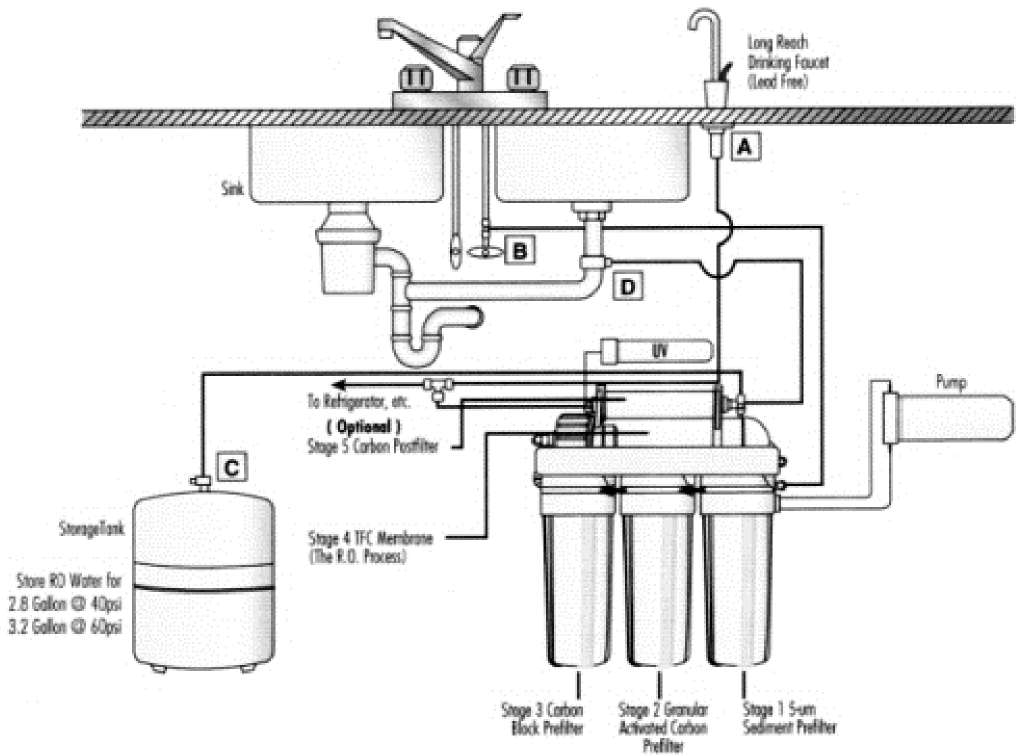
The Good:

* Very pure water-the purest water except laboratory distillation
* Water is softened by removing minerals

The Bad:

* Very high ratio of waste water to filtered water—about 4-10 gallons of waste per gallon of filtered water-much too high for situations where there isn't an abundance of water.
* Pressure is required for the system
* The process is slow-perhaps 1-1.5 gallons per hour or longer
* The water is too soft in some cases to the point the water will pull minerals from your body as distilled water will.
* There is no secondary disinfection so you must exercise care in storing the drinking water

Typical Reverse Osmosis Unit



Ceramic filtration

Examples: Berkey, Katadyn, etc.

The Good

* Very effective filter
* Can be small and carried into zones with contaminated water for individuals or larger ones used by families for drinking water needs

The Bad

* Extremely slow drip-time depends on the number of ceramic elements
* Ceramic element clogs over time
* The elements are expensive
* Does not remove chemicals unless combined with activated charcoal (which will clog over time also)
* Undetectable, hairline cracks can develop in the ceramic
* Some people do not like the taste of the water after it has been used many times
* There is no secondary disinfection

Ceramic Filters

These are true blocking filters

Other Treatment Methods

These methods kill or de-activate pathogens

- Boiling
- Distillation
- Pasteurization
- UV Treatment
- Ozone Treatment

Using Heat to Treat Water

Boiling will destroy or deactivate pathogens in the water. It will not remove minerals. Most people do not like the taste of boiled water.

Distillation is defined as capturing the water vapor from steam by condensation. It is free from pathogens and inorganic compounds, such as metals and minerals. However, inorganic compounds, such as petroleum products, will vaporize and re-condense back into the water.

Boiling or distillation is not needed if the contamination is only biological. Neither are considered the best long-term water treatments due to high energy use and the difficulty of processing the water.

Solar stills are an exception. Solar pasteurizers are preferred to actually boiling the water.

Solar Still

Pasteurization

Disease-causing organisms in water are killed by exposure to heat in a process called pasteurization.

It is not necessary to boil water to make it safe. The WHO recommends bringing water up to a rolling boil, but this is merely a good visual indicator that the water has reached high enough temperatures to kill the pathogens.

Water that has been heated to 65ºC (150ºF) for 6 minutes is free from microbes including Escherichia coli, Rotaviruses, Giardia and the Hepatitis A virus.

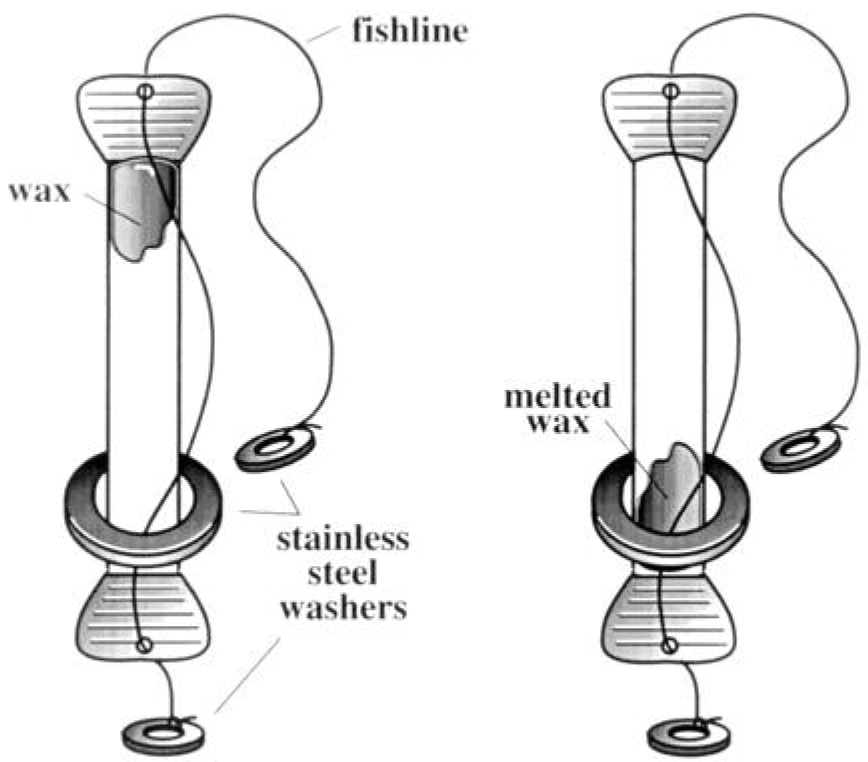
Hepatitis A is the most heat resistant pathogen, but it is killed in pasteurization.

Solar Pasteurization in Africa

Pasteurization will not remove inorganic nor most organic compounds. It does not provide secondary disinfection.

Solar Pasteurization Tools

Water Pasteurization Indicator. Developed in 1992. Low cost. Reusable, indicates when the water reached the necessary temperature even after the water has cooled



UV Light

UV light deactivates pathogens as long as the light can reach all the water and it is not moving too fast. De-activation means the organisms are not able to reproduce after being exposed to UV light.

UV treatment is rather high-tech and requires several important things to be functioning in order to do its work as a disinfectant.

UV Light

- High voltage must be supplied to the lamp
- The water passing by the lamp must be very clear
- The water must not pass through the assembly too quickly
- The lamp has to be left on at all times so no water passes without being treated
- The lamp must retain enough of its useful life to generate enough UV to de-activate the pathogens
- The quartz sheath over the lamp needs to be cleaned fairly often
- The lamp must be replaced when it is weakened
- Only a Class A UV lamp has sensors to tell the user if the lamp is generating sufficient UV to de-activate the pathogens. These are more expensive units.

UV Light

Good:

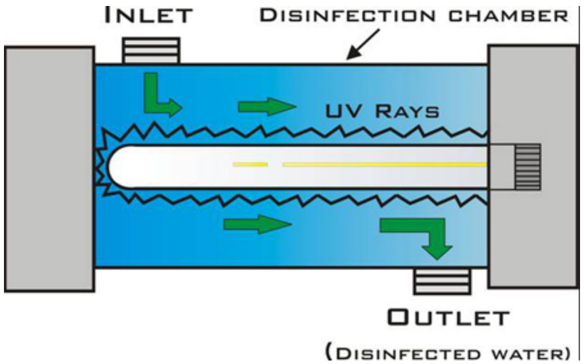
- The water flows through at normal rates of speed
- The units make the user feel like he is actively treating his water
- As long as all the conditions are met and the lamp is still strong enough to treat the water, the result is ok

Bad:

- They require diligent maintenance
- The lamps and sheaths break easily
- They use power
- If you don’t buy a Class A you will not know when your water ceases to be treated

UV Light

UVSS-10
UVSS-6



Inlet
Disinfection chamber
UV Rays
Outlet
(Disinfected water)

Ozone

Ozone oxidizes pathogens in the water (as it does in the air). The Ozone (O_3) molecule is very unstable and an extra oxygen atom tries to jump from this molecule to return to being a more stable oxygen molecule (O_2) leaving a free O atom.

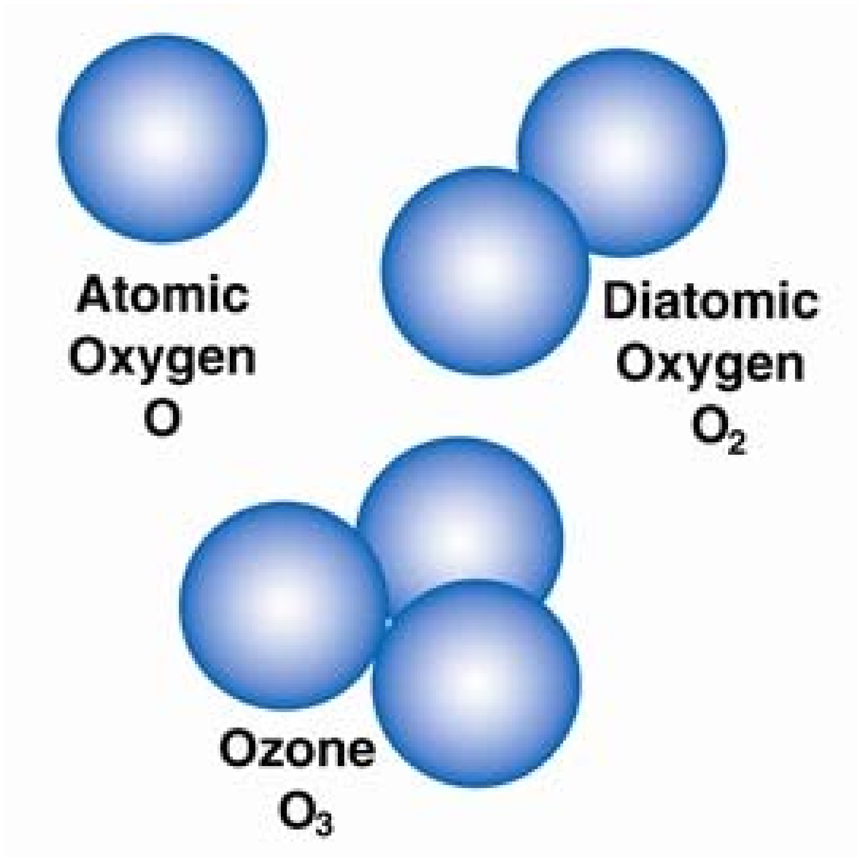
In neighboring organic materials, the oxygen atom oxidizes and neutralizes the material when it forms chemical bonds with it. This is similar to burning organic things like wood which leaves ash.

Because ozone is so unstable, it rapidly dissipates and the treated water returns to water and free oxygen. For this reason, even though it is 80 times more powerful than chlorine, it can’t be used for secondary disinfection.

Ozone, and particularly ozone water, has unique qualities. A strong concentration of ozone dissolved in water can be used to disinfect surfaces for about 15 minutes. Then it becomes plain water. The strong ozone water can be drunk with no ill effects.

The Molecules

This diagram shows Ozone (O_3), a normal Oxygen molecule (O_2) and a free Oxygen atom (O)



Ozone

Ozone is an irritant to sensitive tissues in the respiratory tract. For this reason, ozone should not be inhaled in strong concentrations. In extreme doses, ozone can cause a pneumonia-like condition that can be fatal.

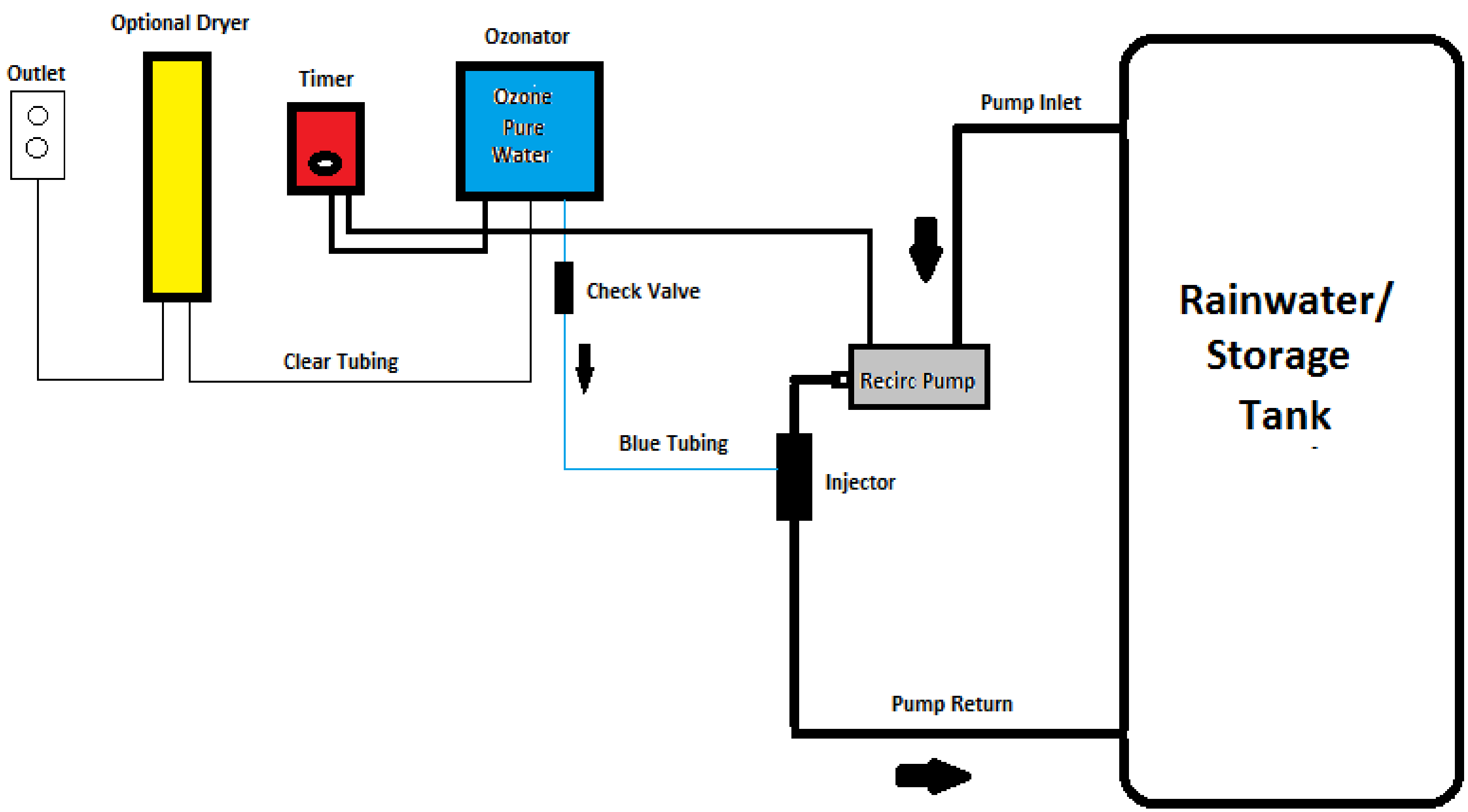
Ozone treatment requires a balance between the amount of saturation to the period of time the ozone is in a certain quantity of water.

Currently there are few sources of ozone treatment generators. However ozone shows promise for several reasons and large cities use ozone to treat municipal water supplies. Soft drink and water bottlers use ozone to kill all pathogens before bottling their products.

Ozone in a Rainwater System

OZONE PURE WATER

STORAGE TANK DISINFECTION



Pros and Cons of Ozone

Good:

- Destroys all organic materials and leaves water extremely pure
- Brings a freshness to the water like nature

Bad:

- Care must be exercised to prevent breathing concentrated ozone
- It is so unstable that there is no lingering effect after 15 minutes
- It requires modest power resources
- Not many sources of generators

A Sustainable Homestead

There is much more that could be covered in water treatment. Issues like water softening, iron and manganese removal, to name only a few.

Contact Information

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Plans and calculating spreadsheets for Slow Sand Filters are available. Please use the email address above to request copies.

Please contact me if you would like to have personal consultation concerning sustainable water sources, water storage and water purification.