Purifying Water Using Sustainable Methods

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www.sustainlife.or
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The Ploughshare
Institute for Sustainable Culture

INSPIRE. INFORM. INSTRUCT

We all need water

Beautiful, clean water!

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

What Do you think?

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 – 80% of all illnesses and deaths in the developing world.

Children – nearly **two million deaths** each year.

Chemical contamination – illness, death and birth defects.

What are Pathogens?

path·o·gen [path-uh-juhn, -jen]
noun
any disease-producing agent, especially a virus, bacterium, or other microorganism.

Sources of Waterborne Disease

3 Main Sources of waterborne disease

Protozoa (parasites, amoebas, cryptosporidium, giardia, etc.)

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* Bacteria (botulism, cholera, E. Coli, salmonella, legionella, typhoid, etc.)

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* Viral Pathogens (SARS, Hepatitis A, Polio)

Safe and Clean Water

Long-term Storage Issues

- Stale, bad-tasting water
- Some containers leach
- Algae growth
- Dirt, soil or pollen
- Anaerobic conditions

Safe and Clean Water

What sustainable methods are available to treat water?

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

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
* Chemicals can reduce bio-slime

But:

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Pros and Cons of Chemicals

Bad:

* Chemicals are toxic
* Chemicals can taste bad
* Chlorine does not work well in high pH-most ground water is high pH
* Chlorine's effectiveness decreases as temperature increases
* There are new mutated forms of pathogens that are becoming increasingly resistant to these chemicals
* Disinfection byproducts are formed when pathogens are killed

* ...water needs to be disinfected to inactivate (or kill) microbial pathogens. However, disinfectants can react with naturally-occurring materials in the water to form byproducts including:
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- Trihalomethanes (THM),
- Haloacetic acids (HAA),
- Chlorite, and
- Bromate.

www.epa.gov/dwreginfo/stage-1-and-stage-2-disinfectants-and-disinfection-byproducts-rules

Chlorine

"Chlorine and chloramine are the major disinfectants used in public water systems."

"Chlorine (*and Chloramine*) levels up to 4 milligrams per liter (mg/L or 4 parts per million (ppm) are considered safe in drinking water." (according to the CDC)

"Chlorine was first used in the United States as a major disinfectant in 1908 in Jersey City, New Jersey. Chlorine use became more and more common in the following decades, and by 1995 about 64% of all community water systems in the United States used chlorine to disinfect their water."

https://www.cdc.gov/healthywater/drinking/public/water_disinfection.html

Shocking a tank of water should have the total chlorine level of 10ppm. This water should not be used for bathing or drinking. The level should fall to a maximum of 4ppm before it is considered potable. 5ppm is considered the maximum for swimming pools.

Sanitizing mixture of chlorine and water is 200ppm. This is a very toxic level. It should never be used for anything other than sanitizing.

Chlorination Chart

Amount of Bleach to use to disinfect a water tank with 5.25% Sodium Hypochlorite (Household bleach)					
Tank size-gallons	1 PPM	5 PPM	50 PPM	100 PPM	200 PPM
50	.125 oz	.64 oz	6.4 oz	1.6 cups	3.2 cups
100	.3 oz	1.3 oz	1.6 cups	3.2 cups	1.6 quarts
250	.6 oz	3.2 oz	1 Quart	2 Quarts	1 gallon
500	1.25 oz	6.4	2 Quarts	1 gallon	2 gallons
1,000	2.5 oz	1.6 cups	1 gallon	2 gallons	4 gallons
1,500	3.8 oz	2.4 cups	1.5 gallons	3 gallons	6 gallons
2,500	6.3 oz	1 quart	2.5 gallons	5 gallons	10 gallons
5,000	1.6 cup	.5 gallon	5 gallons	10 gallons	20 gallons
10,000	3.1 cups	4 quarts	10 gallons	20 gallons	40 gallons
15,000	1.25 quart	1.5 gallon	15 gallons	30 gallons	60 gallons
20,000	1.6 quarts	2 gallons	80 gallons	40 gallons	80 gallons
25,000	2 quarts	2.5 gallons	25 gallons	50 gallons	100 gallons
30,000	.6 gallons	3 gallons	30 gallons	60 gallons	120 gallons
Formula					
gallons x	**0.0025**	**0.0128**	**0.128**	**0.256**	**0.512**
Equals the desired concentration of Chlorine in water (in ounces)					
	1 PPM	5 PPM	50 PPM	100 PPM	200 PPM

Filtration

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

1)Taste and sediment filters
2)Filters that either adsorb, kill or block pathogens

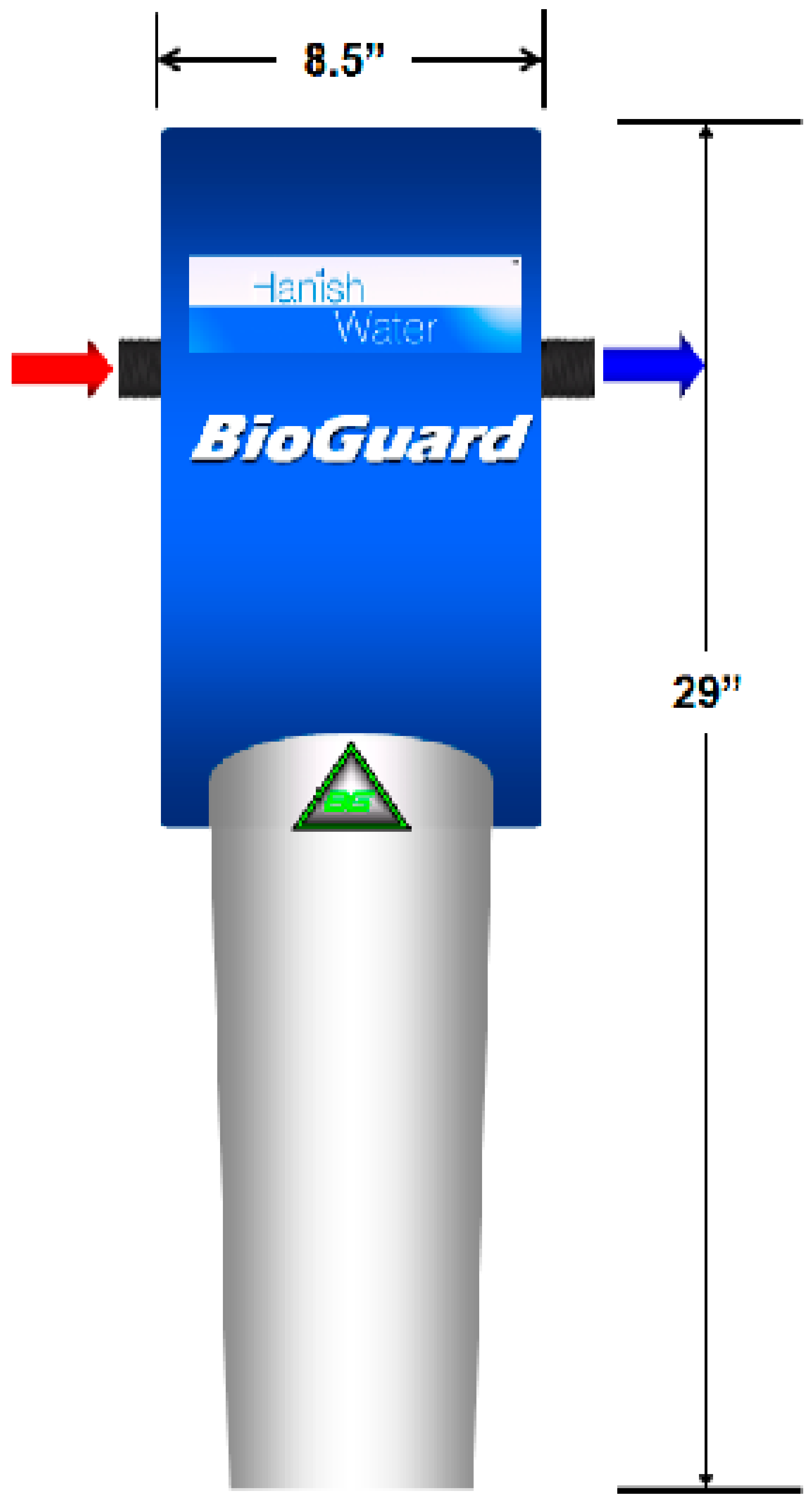
Nano Alumina Filters

They come in two basic configurations:

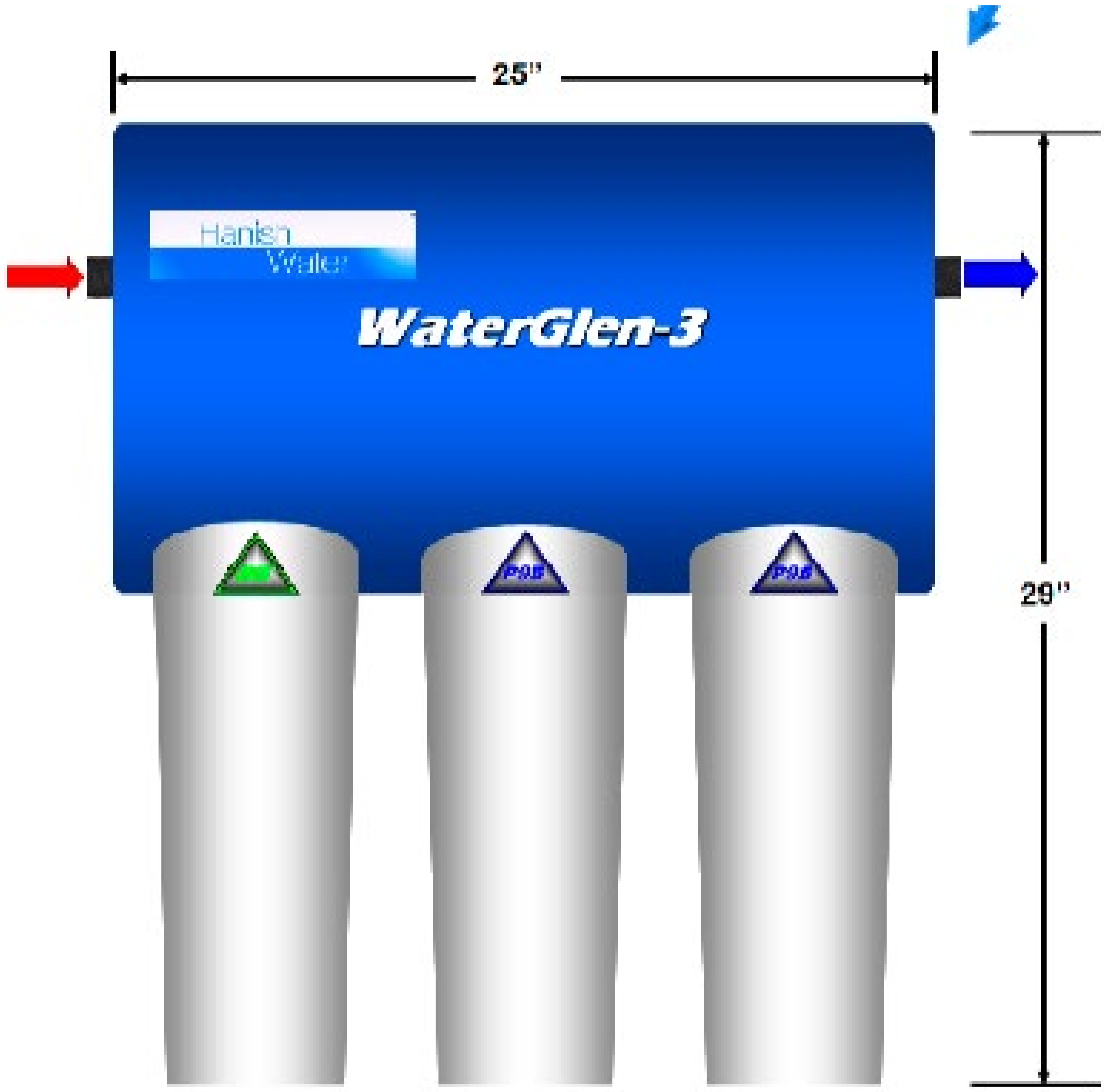
1. Standard filter cartridges under the name **NanoCeram®**
2. Special cartridges and assemblies under the name **Bioguard®**

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.

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

But:

Pros and Cons of Nano Alumina

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
- 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

However…

- The worst thing is, these filters tend to be fouled by bio-slime. Bio-slime forms over time in any water that is not disinfected. In these filters, the bio-slime clogs them up and water will not pass in sufficient quantity. Chlorine can be used to shock the water and rid it of bio-slime but we are back to chemicals. We can use ozone to kill bio-slime. More about this later.

New Filters Available

Activated Alumina and Granulated Activated Charcoal filter for removing Fluoride, Chlorine, and Chemicals from tap water.

These fit a standard 10” under-counter filter base.

This filter is rated for 500 gallons.

New Filters Available

Personal sized adsorption filters

These are good for emergencies or hiking.

Shown is the GRAYL Ultralight Water Purifier ™.

It uses nanoalumina filtration It is rated for 300 gallons. This filter will also filter chemicals due to the activated charcoal mixed within the filter cell- the orange device pictured at right.

New Filters Available

Personal sized ultra fine membrane filters

These are good for emergencies or hiking. This filter is rated for 100,00 gallons. It is back washed to clean.

Shown is the Sawyer Mini ™

There are others, such as the LifeStraw™

The Most Stainable Method

An ancient method to purify water was rediscovered in the Nineteenth Century that changed the world.

It is called the Slow Sand Filter, or the SSF for short.

History of the Slow Sand Filter

Egyptians used them around 2000 BC. Other cultures have too over the centuries. But their use was lost over time.

In Paisley Scotland in 1804, John Gibb invented the 1st modern SSF. He formed the first water company known.

The first drinking water supplies for cities:
In Paris, France in 1806
In London, England in 1827,
The first SSF built in the US was in Richmond, VA in 1832.

The Metropolis Water Act of 1855 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

The big event that changed everything.

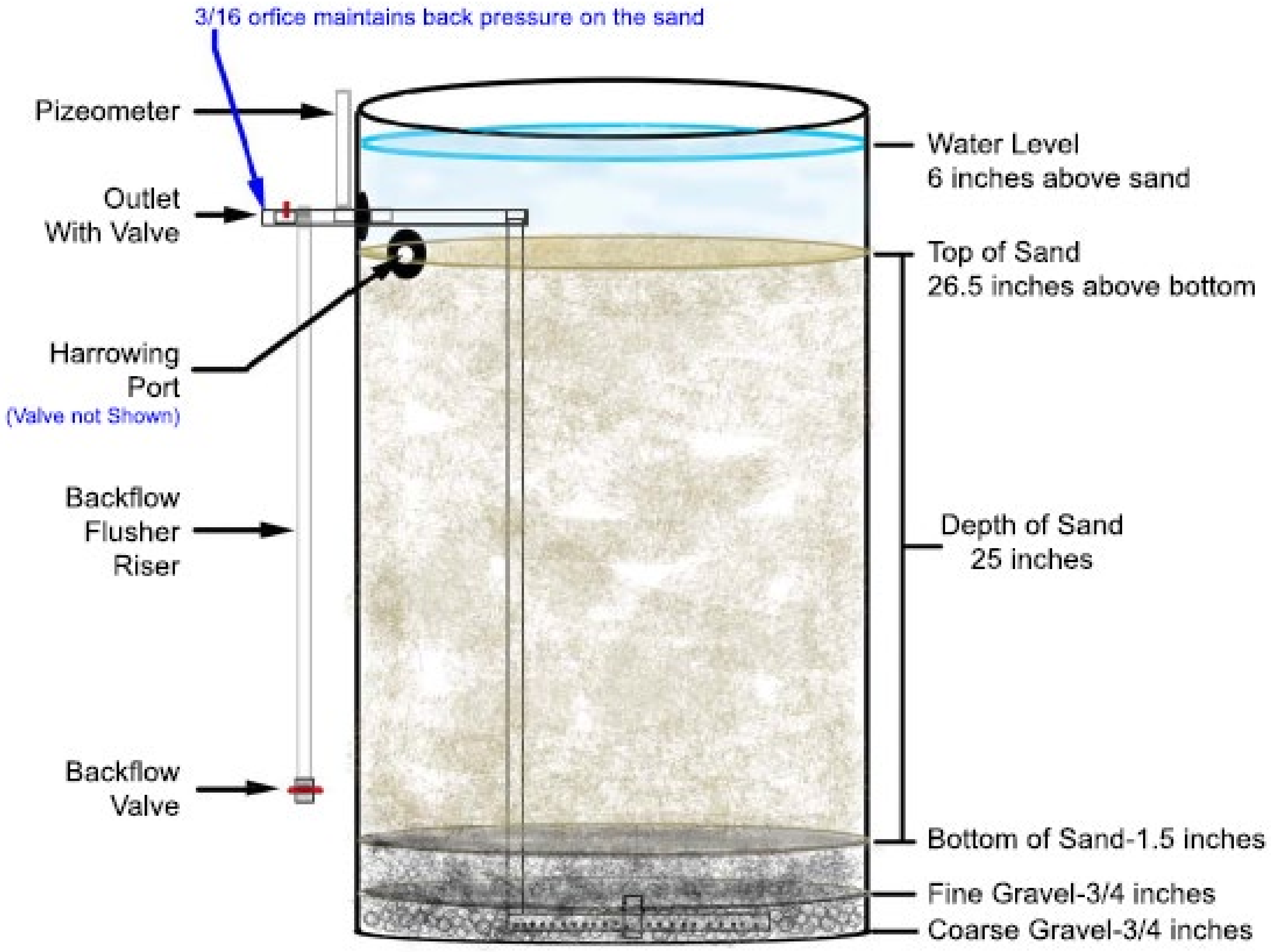
Hamburg and Altona, Germany in 1892 experienced a cholera outbreak.

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 began using Slow Sand filters to treat drinking water.

This is a diagram of the demo SSF found outside the Green Barn



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

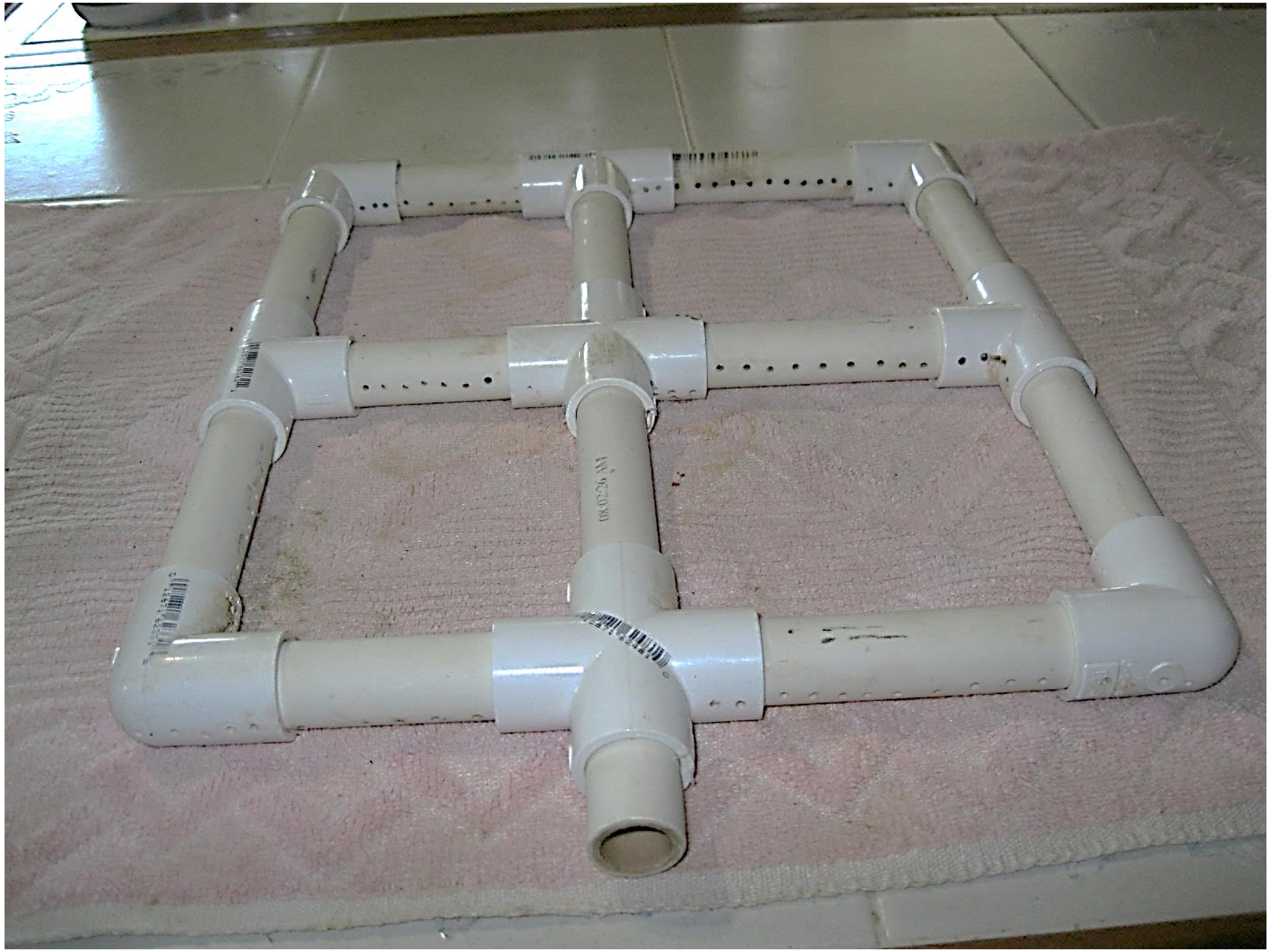
Outlet Plumbing

Clean water outlet

All Three Outlets

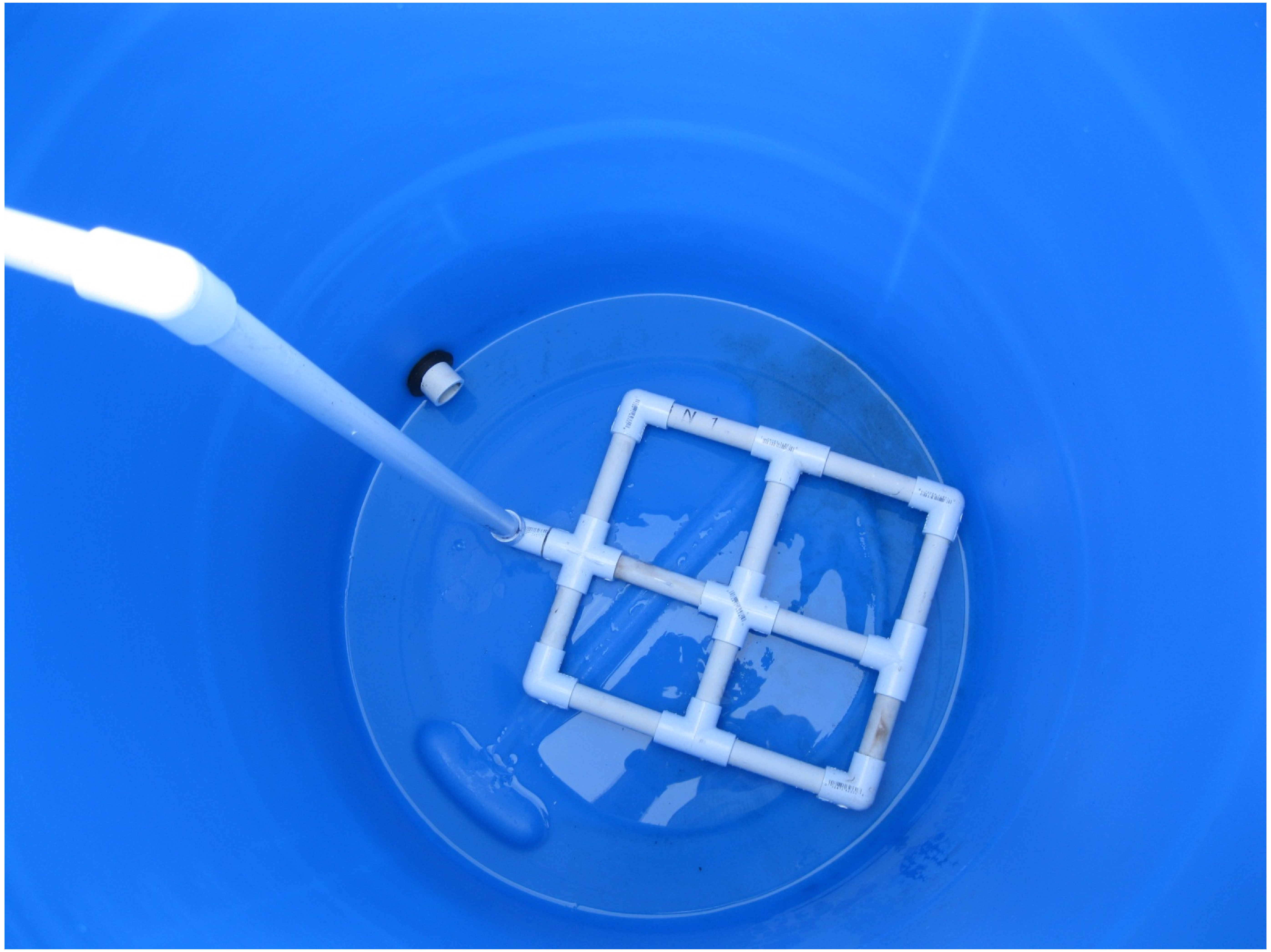
All the openings: Drain on bottom. Harrowing valve on left.
Clean water outlet on right.

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

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

	feet	inches
Convert feet to inches	0	0

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

Choose if cylinder or rectangle	cylinder

	Diameter	Height	
Enter drum dimensions	23.75	34.5	inches

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

	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
- There is no secondary disinfection

Blocking Filters

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

Reverse Osmosis
Ceramic filters

Reverse Osmosis

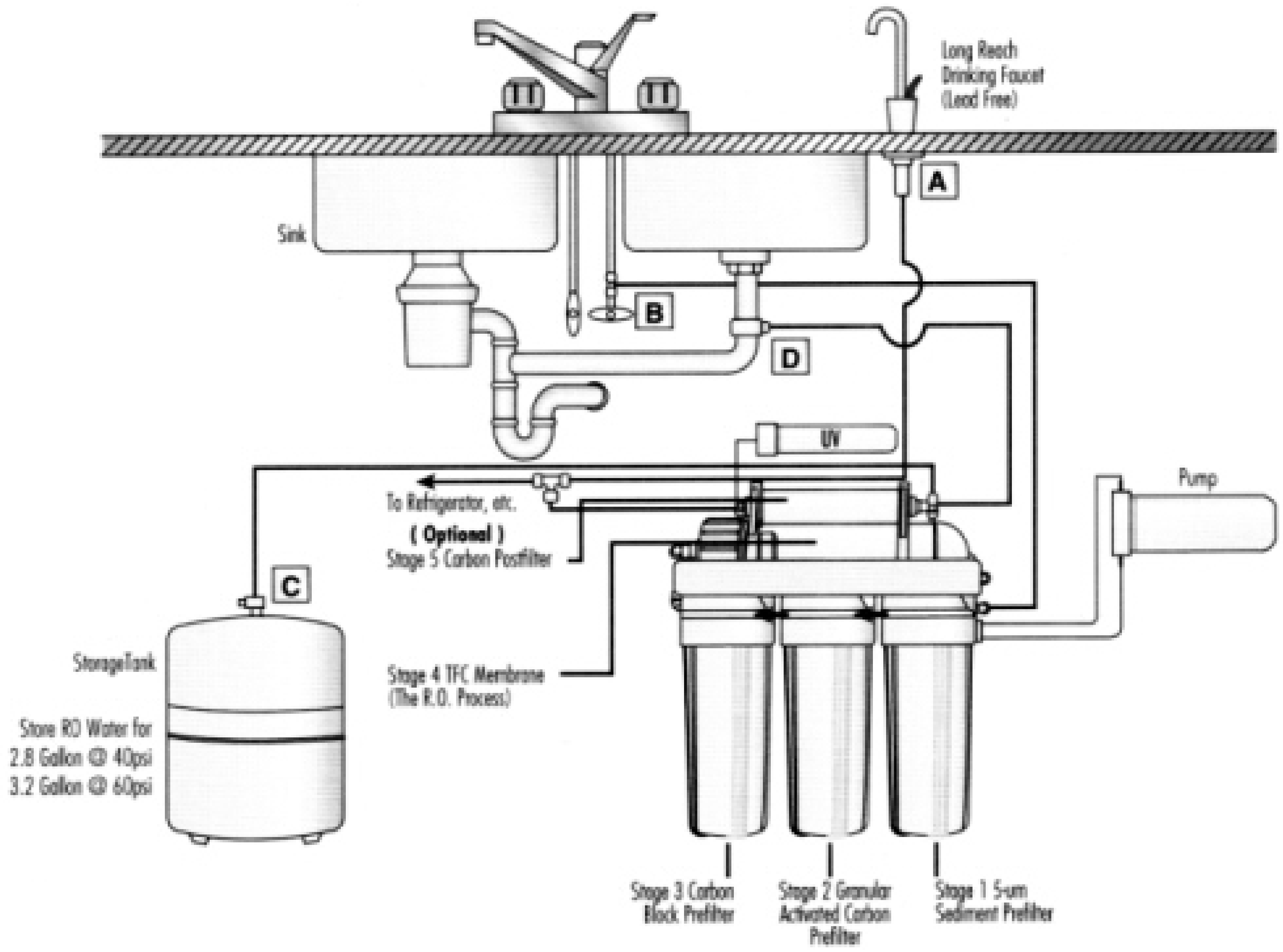
The Good:

* 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, Doulton, 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
* Ceramic element clogs over time
* The elements are expensive
* Does not remove chemicals unless combined with activated charcoal
* Undetectable, hairline cracks <u>can</u> 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

1. Boiling
2. Distillation
3. Pasteurization
4. UV Treatment
5. Ozone Treatment

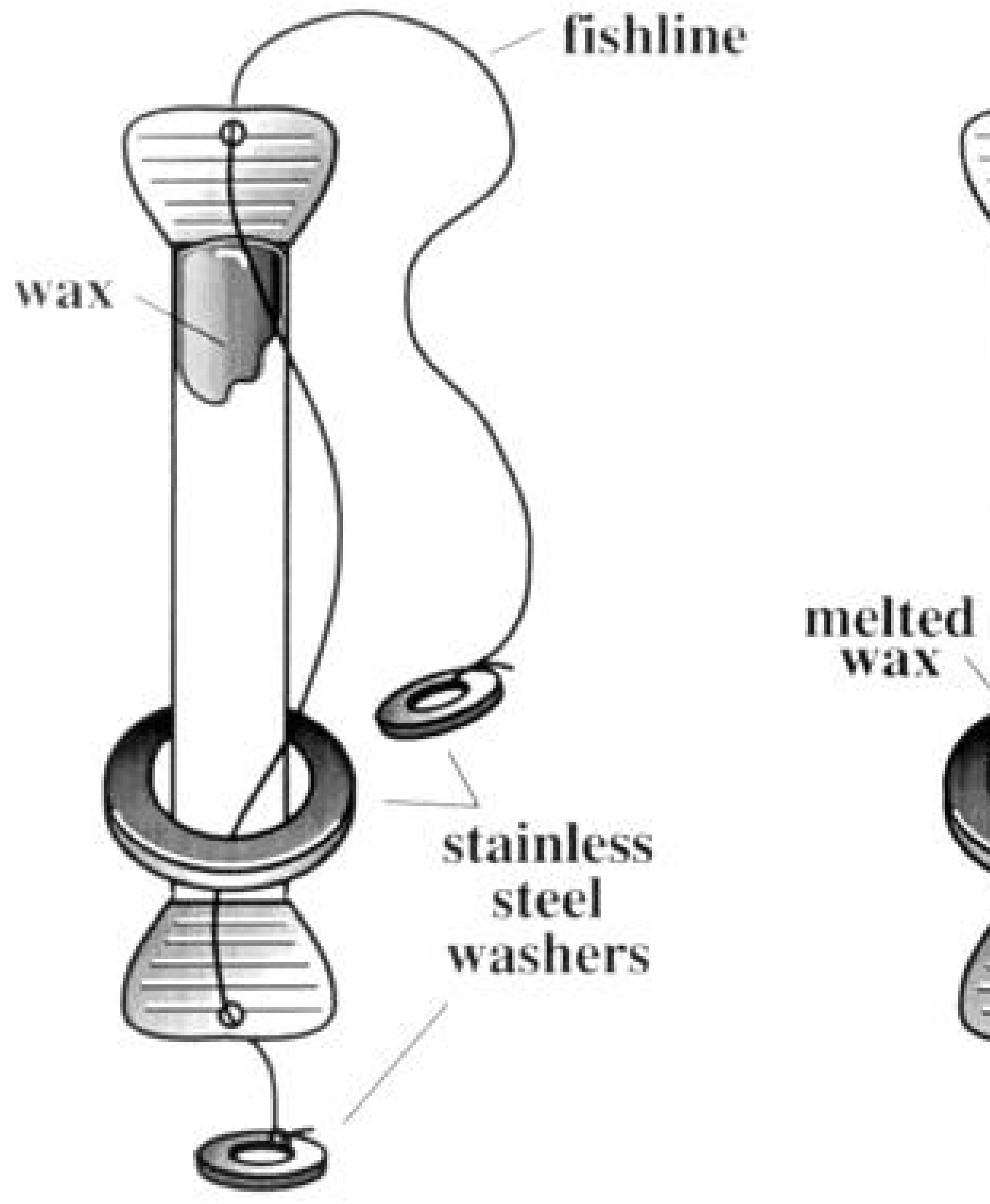
Solar Still

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

Another great method to purify water is using Ultra Violet light. UV light in sunlight is what allows sunlight to kill pathogens.

UV light deactivates pathogens if the light can reach all the water with enough energy and it is not moving too fast.

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

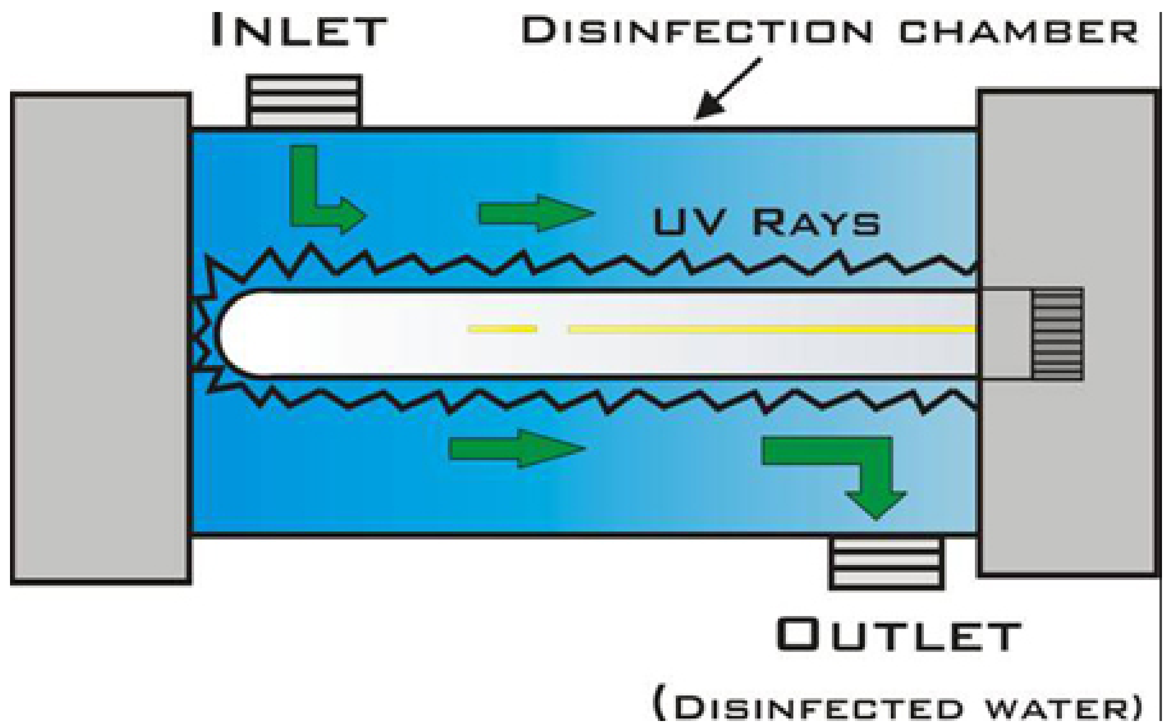
Bad:

- 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

In my water business, I have adopted the UV treatment standard as my own.

UV Light


UVSS-10
UVSS-6
C
US


INLET
DISINFECTION CHAMBER
UV RAYS
OUTLET
(DISINFECTED WATER)

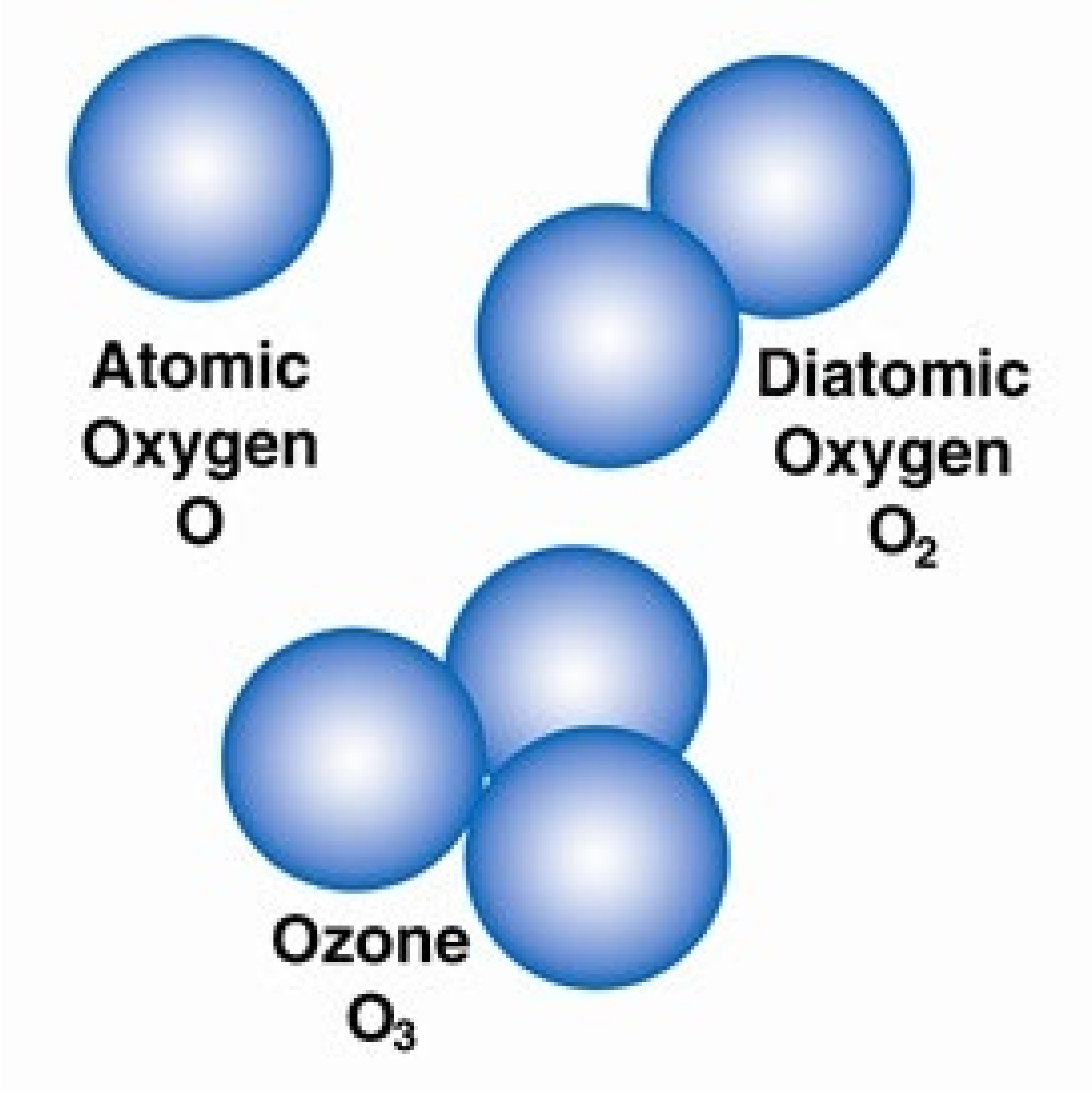
Ozone

The “new” treatment method.
Actually, it is not new at all. Ozone has been used since the early Twentieth Century and Europe uses it everywhere. In Los Angeles, CA, millions of gallons of water is purified every day with Ozone.

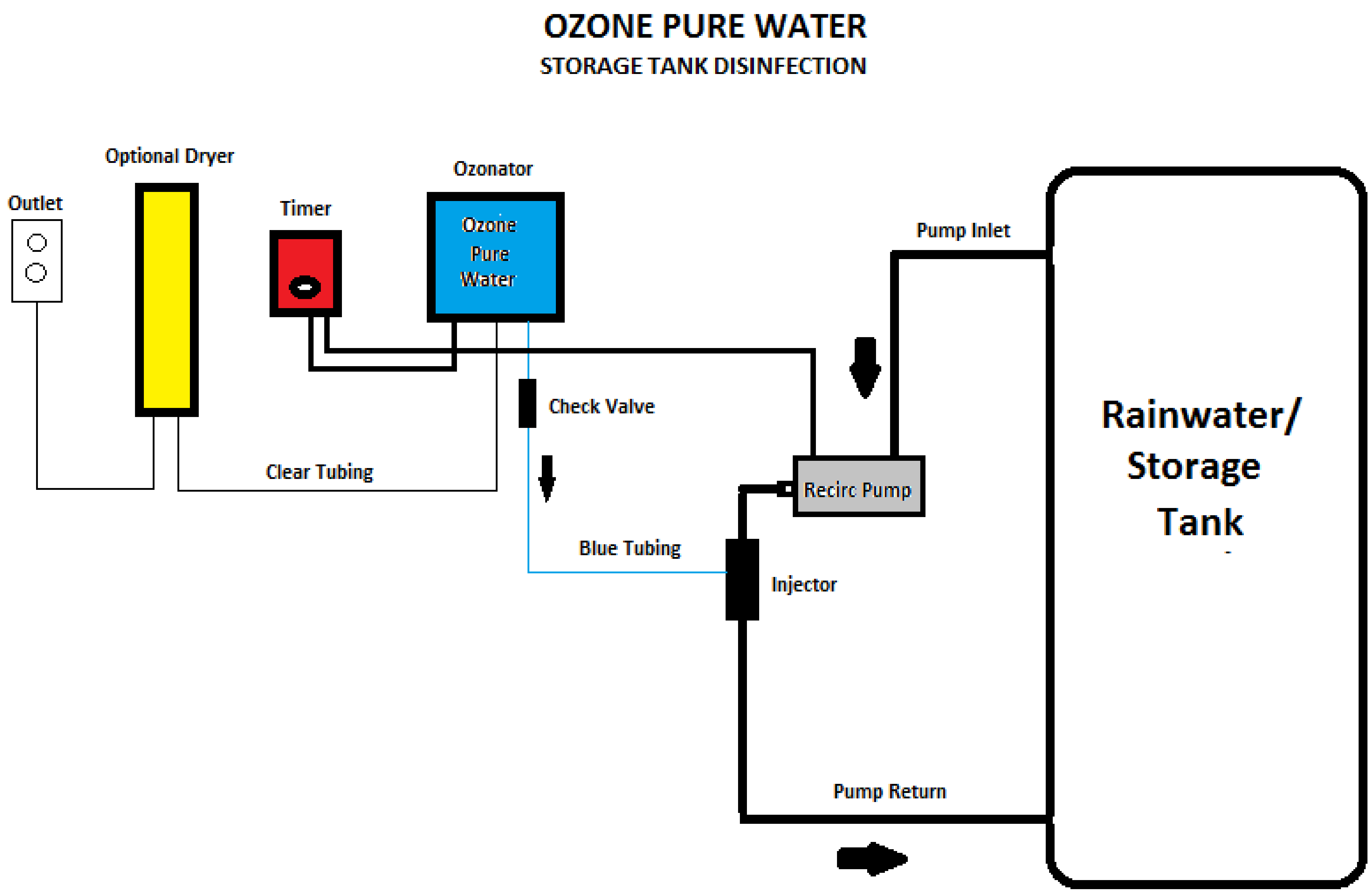
What is the power of Ozone?

Understanding Ozone Molecules

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



Ozone in a Rainwater System



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 water purifier generators

Do You Want More

There is much more to be covered in water treatment. Please let us know if you would like to have more seminars concerning this topic.

Please attend the companion seminar
Collecting and Storing Water for the Small Homestead

Contact Information

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Notes, PowerPoints and Spreadsheets found at:

www.chesneyservices.com/2013-fair.html