

# Introduction to BioSand Filters

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This document will help you understand the basics of a BioSand Filter (BSF): how it works, the different parts, and why it might be a good technology for your project. If you have other questions about the BSF that are not answered in this document, please do not hesitate to contact us ([info@ohorizons.org](mailto:info@ohorizons.org)).

You can also download our Wood Mold Construction Manual and Appendix for free on our website ([www.ohorizons.org/resources](http://www.ohorizons.org/resources)); these documents may also help answer some of your questions about BSFs and the Wood Mold.

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## BSF Introduction

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The BioSand Filter (BSF) was invented in the 1990s by Dr. David Manz at the University of Calgary and put simply; the BSF is a household water filter that makes dirty water safe to drink. This particular type of filter is an adaptation of the traditional slow sand filter, which has been used for community water treatment for almost 200 years. The BSF is smaller and adapted for intermittent use, making it most suitable for households, typically around five people. The filter body, or the outside of the filter (also known as the filter container), is commonly made of concrete, but can also be made from plastic. Regardless of the filter body type, a BSF is filled with carefully prepared layers of sand and gravel. The BSF removes almost all of the dirt and pathogens from water- up to 99%! The BSF is a great low-tech to purify drinking water and is used in communities all over the world.

## Why Choose the BSF Technology?

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Providing access to clean drinking water is a complicated and multifaceted issue; choosing the appropriate technology is just one aspect of a project. Things like user education, teaching proper hygiene practices, and monitoring are also extremely important and need to be taken into consideration.

Providing clean water is complicated partly because water contamination can occur in many ways and can happen at almost any stage of the water collection process. Some common ways that water can be contaminated are: improper human waste disposal (inadequate sanitation facilities), poor hygiene (not washing hands), livestock feces (this is particularly true if water is collected from an unprotected river or stream), agricultural runoff, and industrial waste. These are just a few ways water can become contaminated.

In many areas, drinking water is collected from open lakes, streams, or ponds where contamination can be very high. In other places, people retrieve their drinking water from a community well or borehole. The water being pumped may or may not be clean. Even if it is clean, there are many opportunities for recontamination, particularly if it is not stored in a safe storage container.

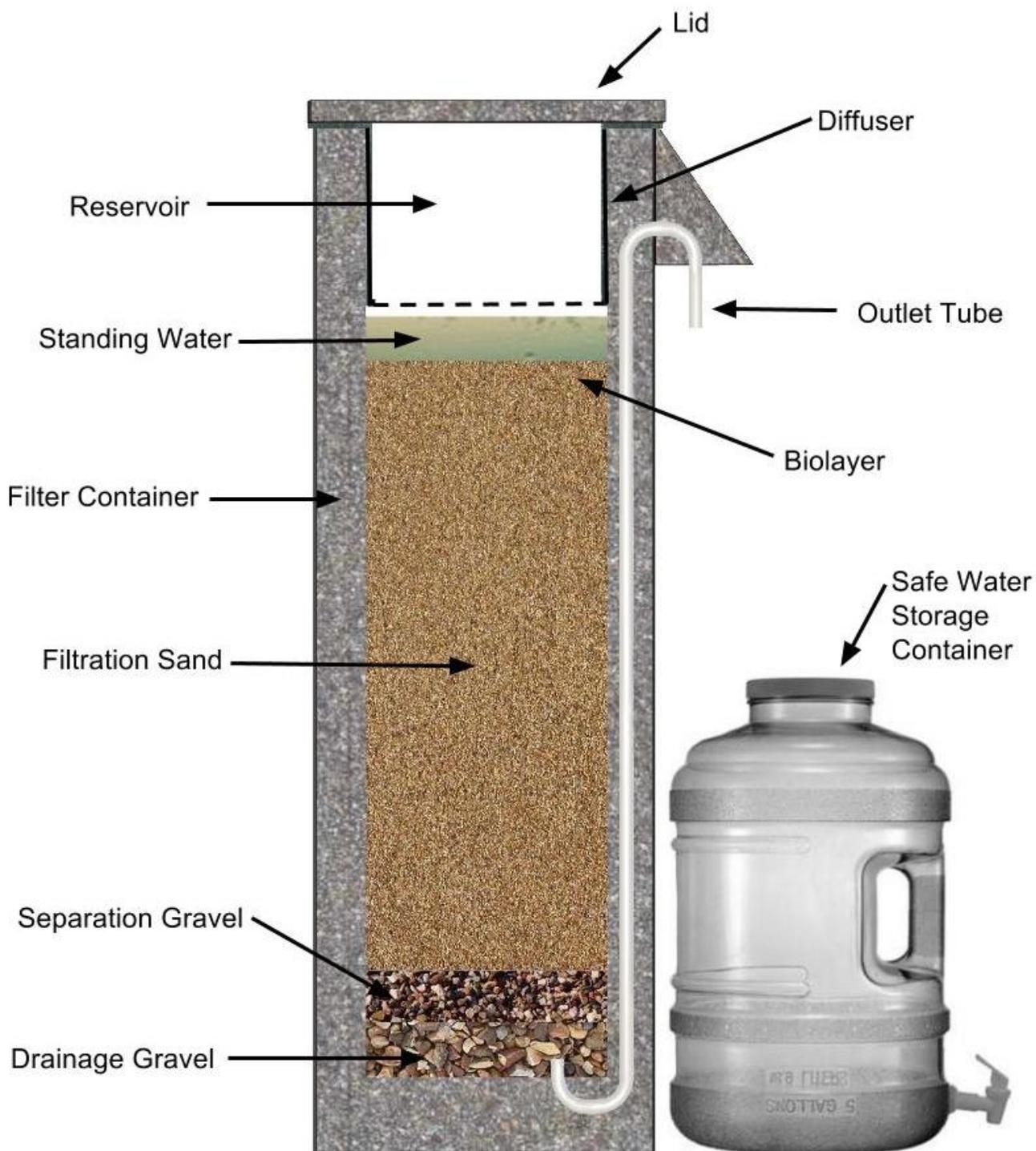
Because there are many ways water can become contaminated, even if the water collected is clean, OHorizons has focused our efforts on the BSF, which is a point of use technology. As suggested by the name, a point of use water technology treats the water where it is used, typically in the household. This allows users maximum control over the treatment of their water and reduces the chances of recontamination.

There are many point of use technologies available, but we focus specifically on the BioSand Filter. This is because we feel it is the most accessible, affordable (\$25-65), easy to use, easy to maintain, and most durable design. Using sand, gravel and natural biological processes, the BSF filters out pathogens using no electricity or complicated parts (see the following sections for exactly how the BSF filters water). It can be made with 100% locally available materials and requires little maintenance over time. If used properly, a BSF can provide a family with clean water for life. Other point of use technologies, like ceramic filters or candle filters, may also be suitable for a specific project depending on the context and community preferences. It is extremely important to take into account cultural and social contexts as well as user preferences before beginning any water project. **Regardless of the chosen technology, user education is extremely important.**

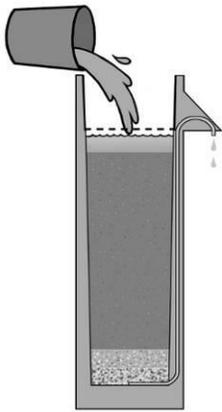
OHorizons has taken the accessibility of the BSF a step further by creating a Wood Mold that is used to create concrete BSFs. Traditionally, concrete BSFs have been cast in a steel mold. These molds are not only expensive and heavy, but they require a skilled welder and access to specialized tools and electricity. This limits the scale and distribution of BSFs, particularly in remote, rural areas. The Wood Mold is durable (around 50-60 filters made per mold), affordable (approximately \$50-80 per mold), lightweight (around 60lbs), uses 100% locally sourced materials, is easy to use, and can be made off-grid.

Our Wood Mold can be made by anyone, even if they have no construction experience, using only simple tools and our highly visual construction manual. By simplifying the process of making BSFs, we hope to scale this low-tech solution and empower communities to gain access to clean water.

## The Parts of a BSF

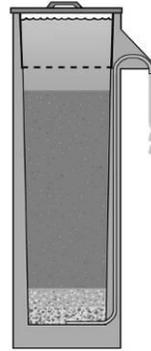


## How Does a BSF Work?



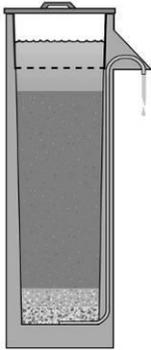
**1** Pour a bucket of dirty water in the top of the filter. Water will start to flow out of the tube. Put the lid back on the filter.

The filter should be filled between 1 and 4 times every day.

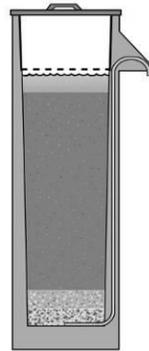


**2** The top of the filter is called the reservoir. It can hold 11 liters of water—about 1 bucket.

Water coming out will flow fastest when the reservoir is full.



**3** It usually takes at least 1 hour for the water to stop flowing.



**4** After the water stops flowing, the filter must rest. The filter must rest for at least 1 hour before pouring more water in.

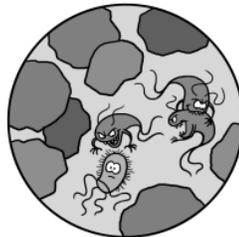
This is called the **Pause Period**.

## What Happens to the Pathogens and Dirt Inside the Filter?



**Mechanical Trapping**  
*They get trapped in the sand.*

The water can flow through the sand, but some dirt and pathogens are too big to fit through.



**Predation**  
*They get eaten.*

The microbes eat each other inside the filter, especially in the biolayer.



**Adsorption**  
*They get stuck to sand.*  
Some pathogens stick to the sand and can't get away.

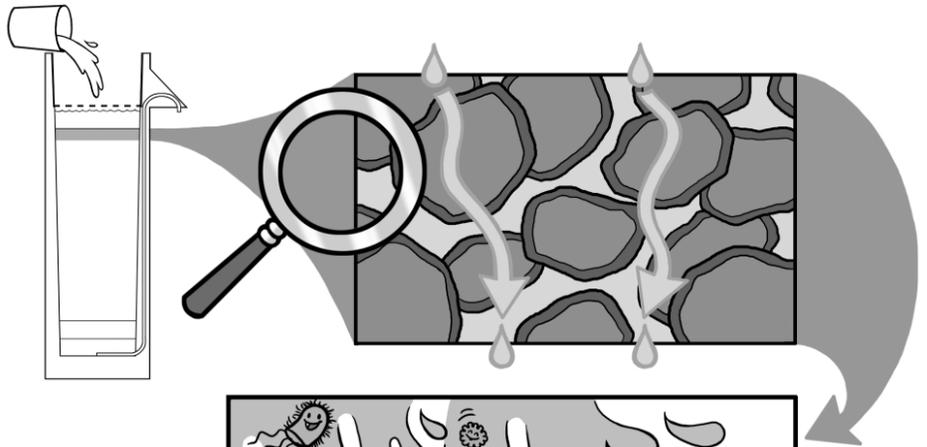


**Natural Death**  
*They die.*

Some pathogens die because there isn't enough food or air for them inside the BSF.

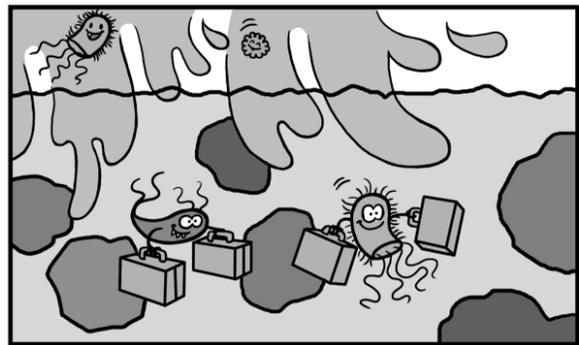
## What Makes the BSF Special? The Biolayer!

In a BSF, small microbes live in the top of the sand. This is called the **BIOLAYER**. The biolayer is very important for making the water safe to drink. The biolayer takes about 30 days to fully develop.



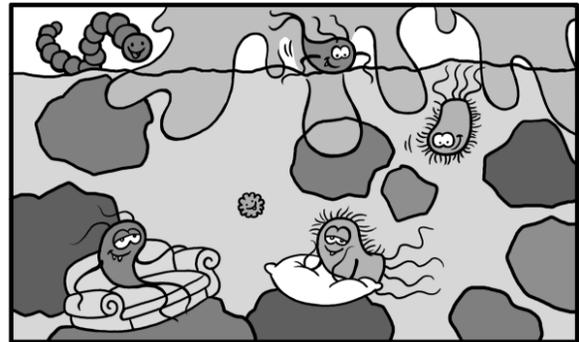
### Day 1

Many microbes live in water. They are too small to see, but they are there! When you pour water into the filter, the microbes start living in the top of the sand.



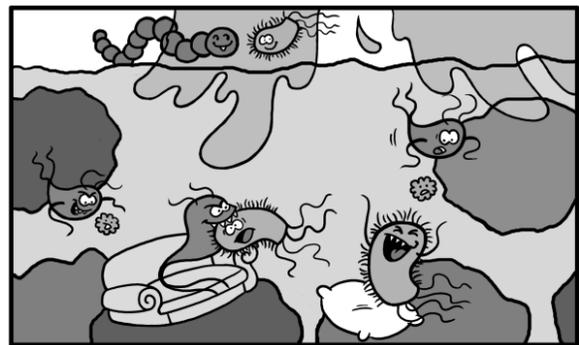
### Day 15

As you keep using the filter, more and more microbes start to live in the sand. The biolayer grows. The microbes get comfortable and start looking for food.

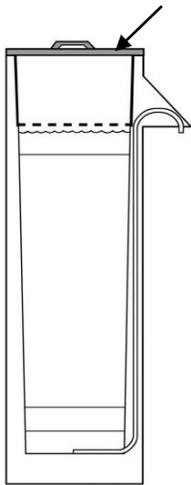


### Day 30

After a few weeks, the microbes start to eat each other. Now every time you pour water in, the microbes living in the sand will eat the new microbes in the water, including the pathogens.

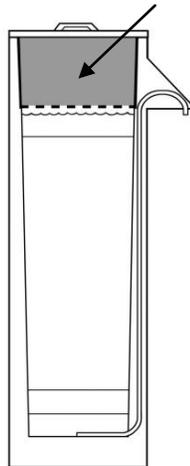


## What Does Each Part of the BSF Do?



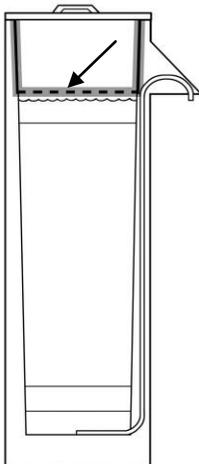
### Lid

The lid should be tight. It prevents contamination and keeps out unwanted pests.



### Reservoir

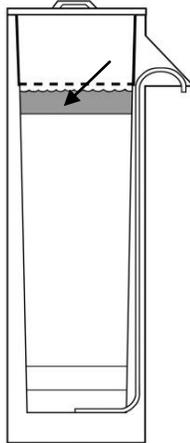
The top of the filter where water is poured in is called the reservoir. The reservoir in a BSF made from the Wood Mold can hold 11 liters of water.



### Diffuser

The diffuser catches the water poured into the BSF. It can be a box or a plate. It has small holes in it, so the water slowly drips through to the sand.

The diffuser prevents disturbing the filtration sand and protects the biolayer from damage when the water is poured into the filter.



### Standing Water

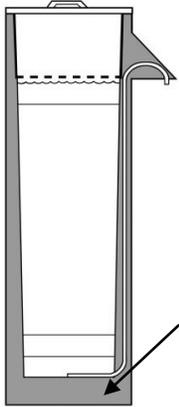
When the water stops flowing, there should be 5 cm of water on top of the sand. This layer of water protects the top of the sand and the biolayer from the force of the dripping water. The standing water also keeps the biolayer wet. The biolayer will die if it dries out. The biolayer needs oxygen. Some oxygen can still get to the biolayer through 4 to 6 cm of water. But if there is more than 6 cm of water, the biolayer may die from lack of oxygen.

### What is the most important part?

#### THE SAND!

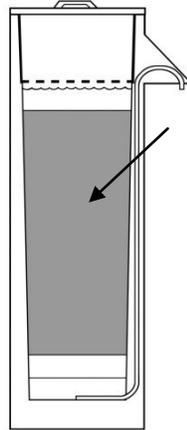
The sand removes pathogens from the water. The biolayer lives in the sand. If you do not get the right kind of sand, or do not prepare the sand properly, the BioSand Filter will not work well.

## What Does Each Part of the BSF Do? –Continued



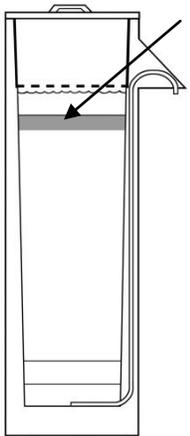
### Filter Container

The container can be made out of concrete or plastic. It can be square or round, depending on which type of Mold you use. It holds the sand, gravel, and water. It can be painted on the outside to make it look nice.



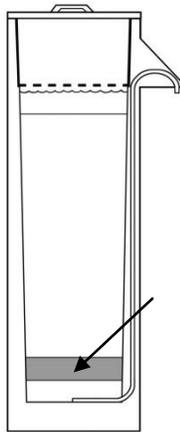
### Filtration Sand

The sand inside the filter is the most important part. The sand removes almost all the pathogens and dirt from the water. The sand must be prepared correctly for the filter to work properly.



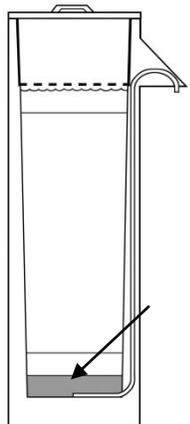
### Biolayer

The biolayer is the top layer of sand (1-2 cm or 0.8" deep), where very small microbes live. You cannot see them - they are too small. They eat the pathogens in the water that make you sick.



### Separation Gravel

The small gravel stops the sand from moving down and blocking the outlet tube.



### Drainage Gravel

The large gravel stops the small gravel from moving and blocking the outlet tube. The large gravel is too big to get inside the outlet tube.



### Outlet tube

Water that comes out of the outlet tube is safe to drink.

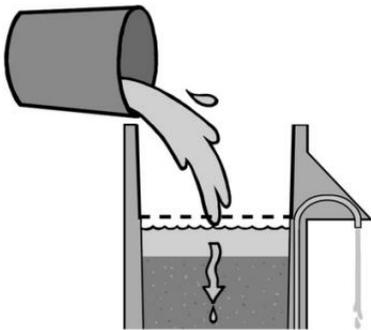
### Safe Storage

You must have a clean safe water storage container to collect and store the water as it flows out of the outlet tube.

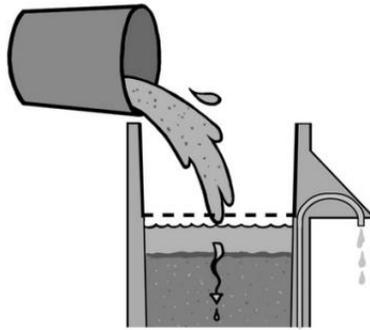
## What Kind of Water Can I Use?

You can use any kind of water in the BSF: water from the river, from a pond, from a well, or rainwater.

- **Use the best quality water you can in the filter.** The water should be the cleanest available since the filter is not able to remove 100% of the pathogens and turbidity (dirtiness or cloudiness). If the source water is very contaminated, the filtered water may still have some contaminants.
- **Use clear water.** The turbidity of the source water is also a key factor in the operation of the filter. Higher turbidity levels will plug the filtration sand layer more quickly. In this case, the user will need to do maintenance (a process called Swirl and Dump) more often to maintain a convenient flow rate. If the source water is over 50 NTU, it is recommended to use a sedimentation method before pouring the water into the filter. A simple test to measure the turbidity is to use a 2 liter clear, plastic bottle filled with the source water. Place this on top of a paper with large letters on it. If you can see the letters looking down through the top of the bottle, the water probably has a turbidity of less than 50 NTU.
- **Do not pour water that has been chlorinated into the filter.** The chlorine will kill the biolayer.



*Clear water*  
The filter will work well. You will not have to clean the top of the sand very often.



*Dirty water*  
After a few weeks, the filter will start to flow slowly. You will have to clean the top of the sand sometimes to make it flow faster.



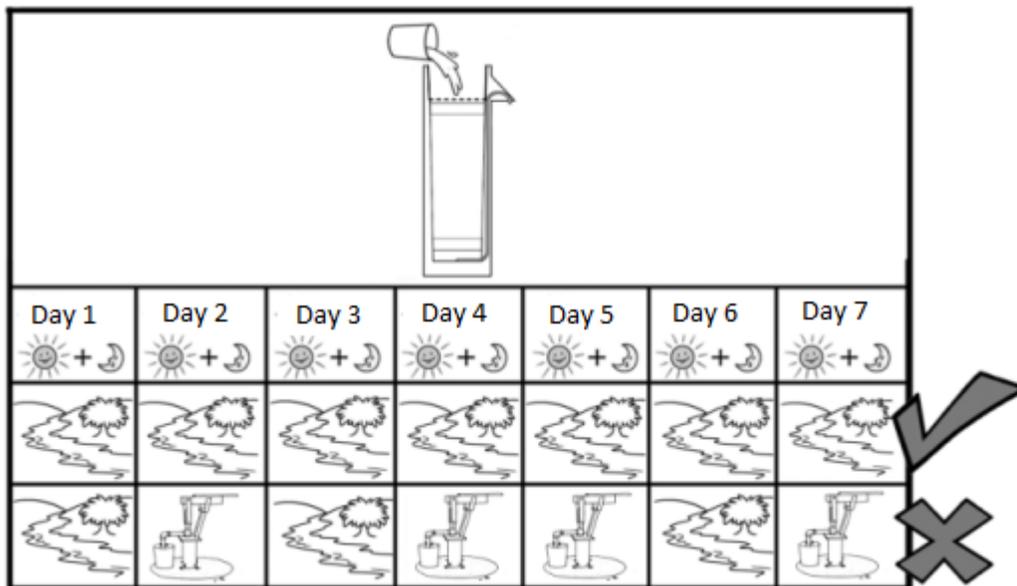
*Very dirty water*  
The filter will quickly start to flow too slowly. You will have to clean the top of the sand often to make it flow faster.

If you have dirty water, settle the dirt out of the water by letting it sit in a bucket for a few hours before pouring it into the BSF.



**It is best to use water from the same source every time in the filter.**

- Over time, the biolayer becomes adapted to a certain amount and type of contamination from the source water.
- If you change the water source (for example, when the rainy season starts) it will have a different level and type of contamination.
- It may take the biolayer several days to adapt to the level of contamination and nutrients in the new source water. For a few days, the water coming out of the filter may not be as good quality as usual because the biolayer may not be able to consume all of the pathogens in the new water. You can drink this water, but it is a good idea to also disinfect the filtered water using chlorine, SODIS, or by boiling the water.
- It is recommended to use the same source water all the time to get the cleanest, safest water.



## How Well Does the BioSand Filter Work?

Water naturally contains many living things. Some of these living things are harmless and others can make people sick. Living things that cause disease are also known as **pathogens**. They are sometimes called other names, such as micro-organisms, microbes or bugs, depending on the local language and country. There are four different categories of pathogens: **bacteria, viruses, protozoa and helminths (worms)**. Contaminated water may contain hundreds or thousands of pathogens per liter.

The physical characteristics of drinking water are usually things that we can measure with our senses: turbidity, color, taste, smell and temperature. **Turbid water looks cloudy, dirty or muddy**. Turbidity is caused by sand, silt, and clay that are floating in the water. Drinking turbid water will not make people sick by itself. However, viruses, parasites and some bacteria often attach themselves to the suspended particles in water. **This means that turbid water usually has more pathogens. Drinking turbid water increases the chances of becoming sick.**

The BioSand Filter removes most of the turbidity as well as most of the pathogens from contaminated water. The BioSand Filter can remove almost all the protozoa and worms, 98% of bacteria, and more than 70% of the viruses. How many pathogens the BioSand Filter removes from the water depends on several factors, including how contaminated the water is before treatment. If there are a high number of bacteria in the water, even if the BioSand Filter removes 98% of them, there may still be some bacteria left in the filtered water.

How well the BioSand Filter treats water is also affected by how it is manufactured, installed, and used. For example, the following factors can affect filter performance:

- Quality of the prepared filtration sand
- Quality of filter installation
- How frequently users pour water into the filter
- How frequently users clean the top of the sand (Swirl and Dump)
- Whether users always fill the filter with water from the same source

The following table shows the BioSand Filter performance based on results in published literature (studies and field trials). The table shows the percentage of pathogens and turbidity removed by the BioSand Filter.

**BioSand Filter Treatment Efficiency**

	<b>Bacteria</b>	<b>Viruses</b>	<b>Protozoa</b>	<b>Helminthes</b>	<b>Turbidity</b>	<b>Iron</b>
<b>Laboratory</b>	Up to 98.5%	70 to >99%	>99.9%	Up to 100%	95% <1 NTU	Not available
<b>Field</b>	87.9 to 98.5%	Not available	Not available	Up to 100%	85%	90-95%

Several studies have been done to estimate the health impact of using BioSand Filters. Overall, these studies estimate a 30-61% reduction in diarrhea among all age groups, including children under the age of five (an especially vulnerable population), from using a BioSand Filter.

In addition to removing microbiological contaminants and turbidity, the BioSand Filter can also remove iron from water. In areas where iron in the water is a problem (it can turn laundry and food red), this can help gain people’s acceptance of the filter. The filter can also remove some heavy metals, although the long-term removal ability of the filter for metals has not been well studied.

Like all filters, the BioSand Filter **cannot** remove dissolved organic or synthetic chemicals (such as pesticides), hormones, or other dissolved substances. It will also not usually remove fluoride from water. Whether the filter will remove some metals and chemicals depends on the general chemistry of the water being poured into the filter. The amount of certain chemicals (or metals) in the water may either increase or decrease the filter’s removal of other chemicals or metals from the water.

## Frequently Asked Questions about the BioSand Filter

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### How much water can be filtered per day?

A BioSand Filter made from the OHorizons Wood Mold will filter 11 liters per use, meaning it will filter 11 liters each time a load of water is poured into the filter. It is recommended to fill the filter a maximum of four times a day and a minimum of one. This means filter owner can get anywhere from 11 to 44 liters of water or approximately 3-12 gallons daily. A maximum of four pours per day is recommended to allow long enough pause periods in between each pour.

### How much does a BioSand Filter cost?

The cost will change depending on where the filter is being made and the local cost of materials and labor. Typically, costs range from 25 to 65 USD per filter.

### How much does one filter weigh?

An installed filter (with filter media) can weigh up to 350 lbs or 160kgs. **Once installed, the filters should never be moved.** The settling of the sand helps to improve the pathogen removal and the sand could be disrupted by moving the filter. The concrete filter body weighs approximately 150lbs or 70kgs. If the filter must be moved, then the sand and gravel should be taken out, washed, and reinstalled in the filter's new location.

### How long does the biolayer take to develop?

After approximately 30 days of use, the biolayer will be fully developed and the filter will be working at its optimal rate of pathogen removal. During the first 30 days of use the filter is still removing approximately 70% or more of pathogens and effectively removing 100% of chlorine-resistant pathogens. During this period, water from the filter can still be consumed, but we recommend that users additionally boil the water or use chlorine to ensure the water is completely safe to drink.

OHorizons recommends this multi-barrier approach even beyond this initial 30-day period. Although the filter is functioning optimally after the first month, a variety of factors could change its effectiveness over time such as improper use by the user or changes in water source contamination levels. Using a multi-barrier approach throughout the life of the filter ensures users are drinking the safest water possible at all times.

### Why does the sand not go down into the hose or PVC pipe?

Sand is only the top layer. The bottom two layers of the filter consist of small and large gravel. The small gravel prevents the sand from leaking and the large gravel prevents the small gravel from leaking or clogging the outlet tube.

### Besides filling the filter with water, how else is the filter maintained? How do you clean it?

The BioSand Filter requires very little cleaning. After the concrete body has cured completely, it should be cleaned out well with water and soap to remove any leftover grit or dirt. After that it can be safely filled with sand, gravel, and water in the user's home. Regularly wiping down the outside, lid, and diffuser plate is recommended.

The filter is quite simple to use and comparable to taking care of a houseplant. The most important part of maintenance is making sure the biolayer remains healthy by feeding it one to four times a day with contaminated water. Once fed, the biolayer needs to digest and recover, so there should be at least one hour in between each use. Much like a houseplant, the biolayer cannot survive if there is too much or too little water. When not in use, a 5 cm layer of water covers the top of the sand. This layer must be maintained or the living microorganisms may die. If pouring turbid or visibly dirty water into the filter, the sand will collect dirt and slow down the flow of water. To fix this, a noninvasive method that does not disrupt the biolayer called, “swirl and dump,” is used to clean the top of the sand and improve the flow.

### **Who is responsible for maintaining the BioSand Filters?**

It is the filter owner’s responsibility to maintain the filter. They are typically trained in maintenance before or during filter installation. OHorizons ensures all of our partners have in-depth maintenance and installation training. These partners are available to households to answer questions, make repairs, re-educate, and provide further assistance, as necessary.

### **How long does a filter last? How often do you replace the sand?**

Barring any unique circumstances that would cause a leak in the concrete body, there should not be any reason to replace the filter. If properly maintained and installed, a filter can last a lifetime and the sand will not need replacement. If using particularly turbid or visually dirty water, the filter owner will use the swirl and dump technique to remove the dirt regularly. This method removes a small amount of sand and over time the filter may need to have some additional filtration sand added to the filter.

### **Does it need a pump, electricity, or some kind of mechanical system to run it?**

No, the BioSand Filter works through the power of gravity. Gravity pulls the water down through the sand and out the hose due to a naturally occurring siphon effect. No electricity or pumps are involved. This means it is a great solution for areas that are not connected to an electrical grid.

### **Are specific types of sand needed?**

Yes, the best sand to use is crushed rock that can be obtained at most local quarries. Crushed rock does not contain any organic material or salt that is often found in river or beach sand. Sand from crushed rock is also more varied in size and shape which produces a more effective filter. The sand should be washed and sifted before it is used in the filter so that only grains of a specific size range are used and nothing harmful makes its way into the filter. The gravel should also be of varying shapes and be washed before it is placed in the filter. Please see our Appendix for more information on which type of sand is best to use for the filter media.

## Where Does the Wood Mold Fit In?

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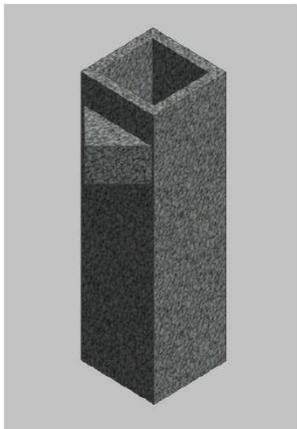
The Wood Mold is used to make concrete BioSand Filters. The Mold materials are easily sourced from local shops for communities in need. This allows for low start-up costs and the freedom to have several Molds creating filters at one time. With more Molds, people can make and receive filters much faster. See below for how the Wood Mold works.



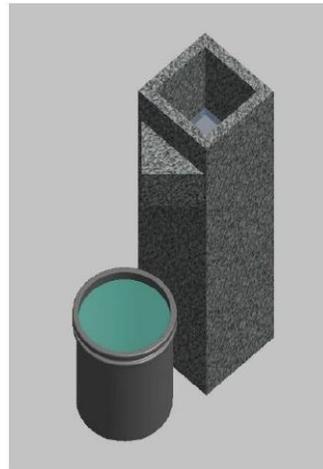
**Step 1:**  
Construct and  
assemble the  
Wood Mold



**Step 2:**  
Mix and pour  
concrete into  
the Mold, let it  
sit overnight



**Step 3:**  
De-mold the  
BSF and  
prepare the  
filtration sand  
and gravel



**Step 4:**  
Install the  
filtration sand  
and gravel and  
operate the  
BSF



Parts of this document contain information modified from the CAWST BioSand Filter Construction Manual. The full CAWST Manual can be found at [www.cawst.org](http://www.cawst.org).