SKILL GUIDE · WATER & FOOD

Building a Biosand Water Filter

A commercial gravity filter (Berkey-, Sawyer-style) is a stored, finite resource: the cartridge eventually wears out and needs replacing. A properly built biosand filter is the renewable alternative the Water & Food chapter's Tier 3 has in mind, sand and gravel don't run out, but it only works if it's built to the real specification, not the popular internet shortcut.

The real design, and the one that isn't

Two very different things get called a "sand and charcoal water filter." The one with decades of field deployment and published pathogen-removal data behind it is the **biosand filter (BSF)**, a design standardized by CAWST (the Centre for Affordable Water and Sanitation Technology) and used by aid organizations worldwide. The one that shows up in most online tutorials, a bucket layered with sand, gravel, and charcoal that drains at a normal gravity-fed pace, is a different device. It's a reasonable sediment pre-filter. It is **not** a tested purification method, and no credible source has published pathogen-removal data for it. The difference between the two isn't the materials; it's the flow rate, and that's the entire subject of this guide.

What the biosand filter actually is

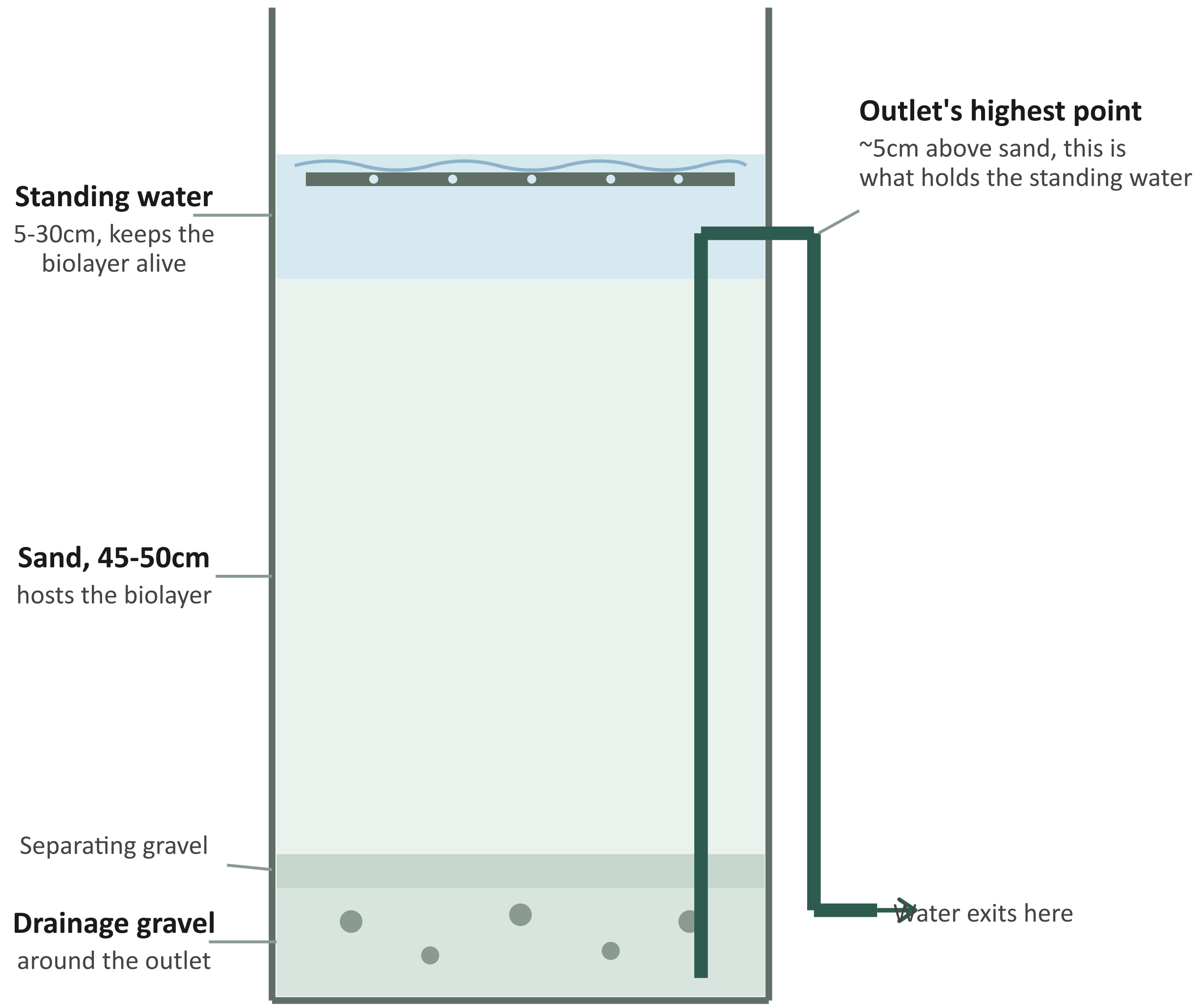
A biosand filter is a container of sand and gravel that water passes through slowly enough for a living biological layer, the **schmutzdecke** (German for "dirt layer"), to establish on top of the sand and do most of the actual pathogen removal. It's the same principle municipal water utilities have used since London's Chelsea Waterworks first installed slow sand filtration in 1829, scaled down to a household container.

Component	Specification
Housing	A tall, narrow container, roughly 0.3m square or in diameter and 0.9m tall: food-grade plastic buckets, a 55-gallon food-grade drum, or CAWST's standard concrete or high-density plastic housing all work, as long as the proportions hold
Sand layer	Effective size 0.15-0.30mm, uniformity coefficient 1.5-3.0, at least 45-50cm deep. This is the layer that hosts the biolayer; it is not just a strainer
Separating gravel	0.7-6mm, a thin layer between the sand and the drainage gravel so sand doesn't wash down into it
Drainage gravel	6-12mm, at the base, surrounding the outlet pipe
Diffuser	A flat plate drilled with a uniform pattern of small holes, mounted roughly 70mm (2.8in) above the sand surface, so incoming water spreads out and drips instead of jetting straight down and cratering the sand
Standing water	5cm of water always sitting above the sand at rest, refilled to 20-30cm when you add water; this layer keeps the biolayer organisms alive between uses

Building it

1. Screen your sand and gravel to the sizes above. This is the step people skip, and it's the one that determines whether the finished filter actually works: a controlled comparison found 99% Cryptosporidium removal with well-graded sand versus just 48% removal with coarser, poorly-graded sand of otherwise the same design. You can check your own screened sand against the CAWST specification with a home sieve analysis: run a weighed sample through a graduated stack of sieves, then find the sieve size that let through the smallest 10% of the sample by weight, that opening size is your **effective size (ES)**. Do the same for the size that let through the smallest 60%, that's your **d60**. Divide d60 by ES to get your **uniformity coefficient (UC)**. If ES falls outside 0.15-0.30mm or UC falls outside 1.5-3.0, re-screen before building.
2. Wash all media thoroughly before loading it, sand and gravel straight from a source carries fine silt that will cloud your first several batches of water and can clog the bed prematurely.
3. Layer from the bottom up: drainage gravel around the outlet, separating gravel above it, then the full sand depth on top.
4. Mount the diffuser plate roughly 70mm above the finished sand surface, not resting directly on it, so poured water sprays through its holes and lands as a spread-out drip rather than a jet that digs a crater in the sand and disturbs the biolayer underneath.

5. Build the outlet as a tube whose highest point sits inside the container roughly 5cm above the sand surface: from the drainage gravel at the base, the tube rises up inside the housing to that height, bends over, and runs back down and out through the wall or base. That rise is what physically holds 5cm of standing water above the sand at rest, water can't drain below the height of the tube's highest point, which is what keeps the biolayer wet and alive between uses. There is no flow-control valve to buy or install; the slow flow rate itself comes from the resistance of the sand bed plus the height of water pushing down on it (the head), not from anything restricting the outlet pipe.



WARNING

Flow rate is not a limitation, it's the mechanism

A properly built biosand filter runs at roughly **0.4 liters per minute or slower** (CAWST's own maximum for its standard unit), regardless of how large the container is. That slowness is what gives the biolayer enough contact time to actually remove pathogens; a filter built the same way but allowed to run faster is not a faster biosand filter, it's a device with no biological treatment happening at all. If your build drains in a few minutes instead of tens of minutes, it is functioning as a sediment filter, not a purifier, no matter what media you loaded into it. If flow ever drops below about 0.1 liters per minute, the surface has clogged and needs maintenance (see below), not a redesign to make it flow faster.

What size actually gets you what flow rate

CAWST's maximum safe loading rate works out to roughly **400 liters per hour per square meter** of sand cross-section, a physical constraint tied to contact time, not to container size. That means output scales with the footprint of your sand bed, not with how big or dramatic the container looks. Before building, it's worth knowing what you're actually going to get:

Container	Approx. sand cross-section	Physics-derived maximum output
5-gallon bucket	~0.066 m^2	~26 L/hour (~6.9 gal/hour)
55-gallon drum	~0.26 m^2	~102 L/hour (~27 gal/hour)
CAWST standard unit (concrete/plastic housing)	n/a	0.4 L/minute (~24 L/hour), CAWST's own directly published maximum, the reference figure the estimates above are derived from

Those are ceilings, not targets, running at the maximum starves the biolayer of contact time the same way an oversized outlet does. Claims online of a single household filter producing over a thousand liters a day are not consistent with this physics and shouldn't be relied on; a single 5-gallon-bucket-scale unit is realistically a slow, steady household supplement, not a whole-family primary water source on its own. Multiple units run in parallel, not one unit run faster, is the correct way to scale up output.

Ripening the biolayer

A freshly built filter does not work yet. The schmutzdecke takes roughly **2 to 4 weeks** to establish, and pathogen removal during that window is meaningfully worse than once it's mature: one study found bacteria removal rising from about 63% in an unripe filter to 98-99% once fully matured. Build and start ripening a filter well before you need to depend on it, not during an actual emergency.

Between uses, let the standing water sit for **6 to 12 hours** (minimum 1 hour, maximum 48 hours) before drawing the next batch. This pause is when the biolayer organisms actually feed; too short a pause doesn't give them time to work, and too long a pause in a hot, dry climate risks the standing water evaporating away and the biolayer drying out and dying.

What it actually removes, and what it doesn't

A mature, correctly built biosand filter is genuinely effective against bacteria and, especially, protozoa like Giardia and Cryptosporidium, often exceeding 99% removal once ripened. Virus removal is the real weak point, and it's worth being honest about rather than repeating a confident-sounding percentage: published results vary enormously by virus type and filter maturity, with at least one peer-reviewed bench study finding reductions as low as 50% for some virus surrogates, well short of the World Health Organization's own minimum performance target for household water treatment.

WARNING

Never rely on filtration alone if you suspect viral contamination

This is the same rule this site's Water Purification guide already gives for commercial filters, and it applies here without exception: no filter, biosand or commercial, should be trusted alone against a water source that might carry human sewage (a flooded municipal line, a compromised septic system). Pair this filter with a disinfection step, boiling, bleach, or chlorine dioxide tablets, on the same schedule you'd use for any other filtered water. Treat the biosand filter as the sediment and bacteria/protozoa stage of a two-stage system, not a complete one by itself.

Charcoal's real role: taste and odor, not purification

Some biosand builds add a charcoal layer, and it's worth understanding exactly what that layer is doing, because it isn't purification. Raw charcoal from a wood fire has a surface area of roughly 2 to 5 square meters per gram; commercially activated carbon, steam- or chemically-treated specifically to open up its pore structure, reaches 500 to 1,500 square meters per gram, a hundred to a thousand times more adsorption surface. Homemade charcoal will noticeably improve taste and odor and adsorb some organic compounds. It will not reliably remove bacteria, viruses, or protozoa, and it does nothing for dissolved minerals, nitrates, or most chemical contamination.

If you're pairing a charcoal stage with chlorination, order matters

Activated carbon and raw charcoal both adsorb free chlorine. If a charcoal layer sits after your disinfection step, it will strip the chlorine residual you just added, the exact thing meant to keep the water safe through storage. Put any charcoal stage before disinfection, never after.

Maintenance: swirl and dump first, scrape only as a last resort

When flow slows to a crawl, the sand surface has clogged, not failed, and the fix that actually preserves the biolayer is "swirl and dump," not scraping. Pour about a gallon of water into the empty filter, use a clean hand to gently swirl just the top layer of sand so the trapped dirt suspends in the water, then pour that dirty water off the top before it settles back down. Smooth the sand surface flat again and repeat two or three times until flow noticeably improves. This works because it resuspends and removes the clogging sediment without stripping away the living schmutzdecke itself, the way scraping does.

Reach for scraping only when repeated swirl-and-dump no longer restores flow. Drain the standing water, then scrape off the top 1 to 3 centimeters of sand, the clogged schmutzdecke layer, and remove it. Refill with water and let it sit and recirculate for several hours before returning to normal use, giving a new biolayer time to begin establishing. Municipal slow sand filtration plants run this same scrape-and-rest cycle on a rotation of multiple beds so treatment never fully stops; a household filter just goes offline for a few hours instead. Once repeated scrapings have thinned the sand bed down to within about 10cm of the minimum 45-50cm depth, stop scraping and add fresh, properly screened sand back on top instead, continuing to scrape a bed that's gotten too shallow starves the biolayer of the depth it needs to work.

Before you need it

The Water & Food addendum's own goal is owning at least two independent water treatment methods so a single point of failure doesn't leave a household without safe water. A biosand filter is a strong second method precisely because it doesn't depend on a replaceable cartridge, but only if it's already built, already ripened, and already tested with your own water before an emergency is the first time you need it working. Build it now, run water through it for the several weeks the biolayer needs, and confirm your own flow rate matches what you'd expect from the table above before counting on it.

Sources

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