

Membrane Filters for Household Water Treatment

Technical Brief
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Technical Brief: Membrane Filters for Household Water Treatment

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This document is part of a collection of resources for learning and training about household water treatment and safe storage (HWTS). To access CAWST's other HWTS resources, visit cawst.org/resources.

1 Introduction

As technology advances, many types of **membrane filters** are being produced and marketed for household use. Relatively inexpensive membrane filter options are now available worldwide, including markets in most low- and middle-income countries.

If you want to use or implement membrane filters for **household water treatment and safe storage (HWTS)**, it is important to first understand the basics of membrane filtration. This will help you evaluate whether specific membrane filter options are appropriate for your context.

In this technical brief:

- We explain what membrane filters are and how they work.
- We show different types of membrane filters, by pore size, membrane configuration, and container setup.
- We list and describe criteria to consider when evaluating whether a membrane filter is appropriate for your context.
- We introduce some of the limitations you should be aware of before using household membrane filters.

Many types of membrane filters exist. This technical brief focuses on low-cost manufactured household membrane filters driven by gravity or pumping. More information about specific filters can be found on CAWST's HWTS Knowledge Base and HWTS fact sheets.

Key words in this document are marked in a **bold font**. If you are reading this on a screen, you can go to the definition of key words by clicking on them while holding the Ctrl button. If you are reading a printed copy, please refer to Section 7: Definitions.

2 What are Membrane Filters?

In water treatment, a **membrane** is any type of material with tiny holes (**pores**) that allow fluids to pass through but prevent the passage of certain particles or chemicals. **Membrane filters** are devices that contain a membrane and use a **driving force** (such as gravity or pumping) to push water through the membrane. The household water filters discussed in this technical brief contain membranes made of synthetic materials.

The size of the pores in a membrane determines the size of particles the membrane can remove from water. Particles that are smaller than the pores can pass through the membrane with the water, while particles that are bigger than the pores get stuck and cannot pass through. This process is shown in Figure 1 below.

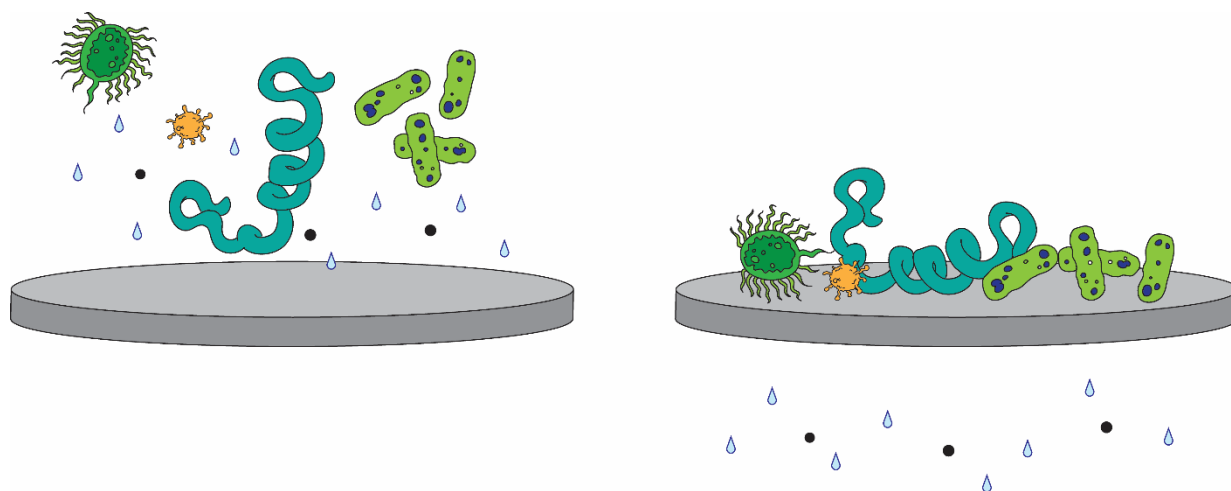


Figure 1. This illustration shows small particles (black dots) going through the membrane along with water, while larger particles and pathogens are trapped on the membrane. The size of the pores in a membrane determines what can pass through.

3 What are Different Types of Membrane Filters?

As mentioned above, there are many types of household membrane filters. In this section, we classify types of membrane filters by pore size. Then we show different types of membrane configurations and container setups that are commonly available in low- and middle-income countries.

3.1 Types of Membrane Filters by Pore Size

The size of a membrane's pores determines what can pass through the filter. Untreated water may contain different types of **contaminants** (chemicals, microorganisms, and particles that affect the safety or acceptability of water). These contaminants range in size from visible particles to microscopic bacteria and viruses to dissolved chemicals.

Curious about Contaminants?

For more information about drinking water contaminants, refer to CAWST Technical Brief: Introduction to Drinking Water Quality for Household Water Treatment Implementers.

Classifying membranes by pore size helps us identify the types of contaminants they can remove from water. Figure 2 shows, by pore size, four different types of membrane filters: microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. The figure also shows the typical size ranges of particles in water that can be removed by different filters. For example, ultrafiltration membranes can generally remove helminths, protozoa, bacteria, and some viruses and smaller contaminants.

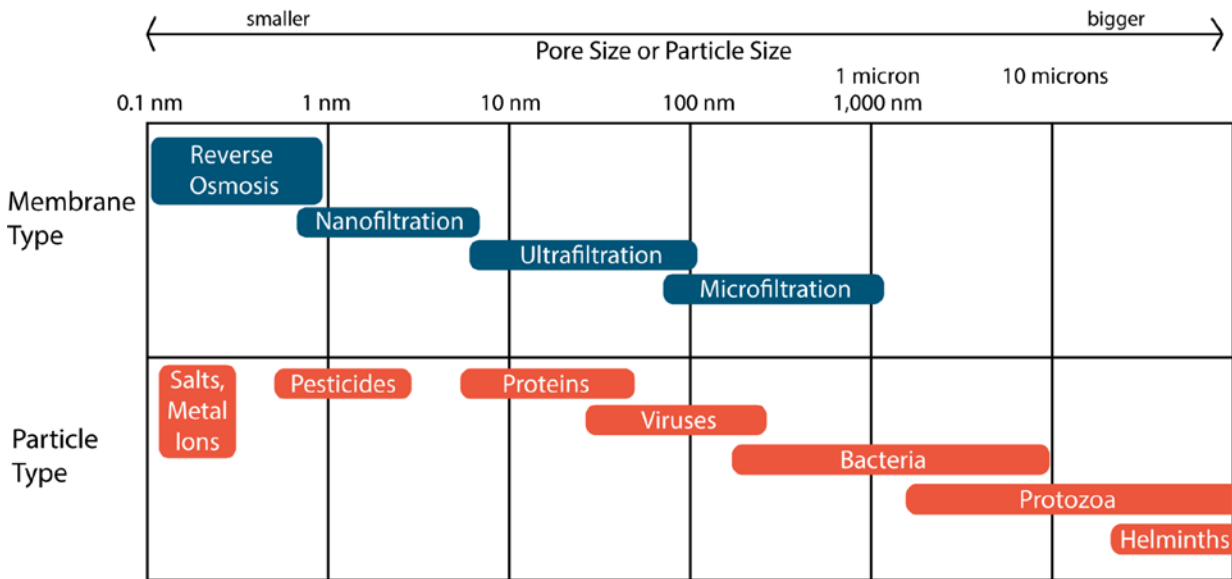


Figure 2. Pore size as it relates to membrane type and the size of particles removed. Particle size and pore size are shown on a log scale, meaning that each line on the axis from left to right represents a ten-fold increase in size. The units shown are nanometres (nm) and microns (µm).

The smaller a membrane’s pores, the greater the pressure required to force water through the membrane. For households in low- and middle-income countries, filters that do not require electricity or batteries are usually the most appropriate. As a result, microfiltration and ultrafiltration are the most commonly used types because the required pressure can be created by gravity or simple pumping systems. Pore sizes of common household membrane filters used in this context typically range from 0.01 microns (10 nm) to 0.1 microns (100 nm). CAWST’s HWTS fact sheets specify the pore size and microbiological removal performance of different household membrane filters.

3.2 Types of Membrane Filters by Membrane Configuration

A membrane filter always contains at least one cartridge, which is the unit containing the membrane. Within a cartridge, membranes can have different configurations. These configurations determine how water moves through the membrane. Three common configurations are:

1. Large tube membrane (Figure 3): In these filters, the membrane itself takes the form of a big, porous tube. Water can pass through pores in the walls of the tube, leaving behind particles that are too big to pass through.

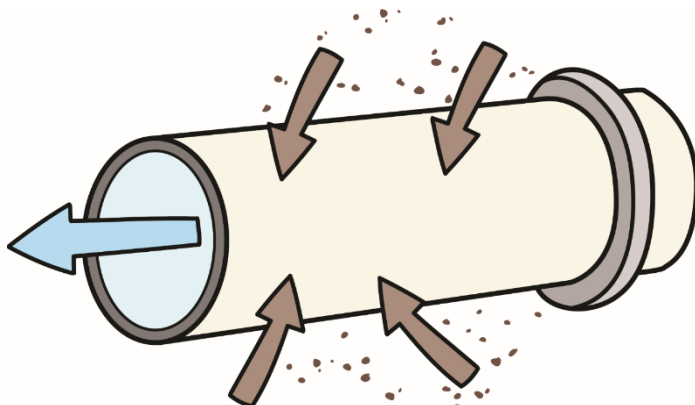


Figure 3. Example of a large tube membrane. Untreated water (brown arrows) moves through the pores of the tube wall (membrane). Treated water (blue arrow) flows out.

2. Spiral-wound membranes (Figure 4): In these filters, the membrane is a flat sheet that is wrapped multiple times around a central tube. Water must move through tiny pores in the layers of membrane to reach the central tube. Particles that are too big to pass through the pores of the membrane get trapped in the membrane layers.

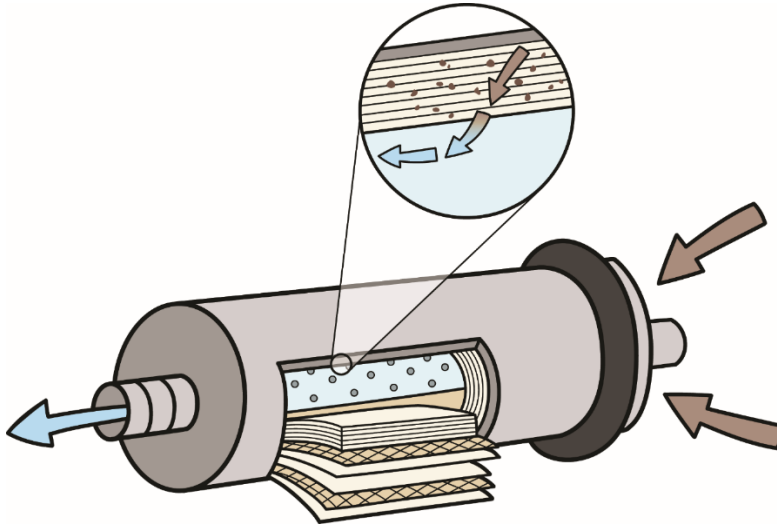


Figure 4. Example of a spiral-wound membrane. Untreated water (brown arrows) moves into the cartridge and travels through wrapped layers of membrane to reach a central tube. Treated water (blue arrows) flows out of the central tube.

3. Hollow fibre membrane (Figure 5): Cartridges in these filters contain hollow fibres that look similar to large tube membranes, but are much thinner. Many tiny tubes (fibres) are contained in a single cartridge.

Most low-cost household membrane filters contain hollow fibre membrane cartridges. It is impossible to know exactly how the hollow fibres are configured within the cartridge unless the manufacturer provides such information or you break the cartridge open. Manufacturers rarely provide details about the membrane configuration within their cartridges.

To the best of our knowledge, most hollow fibre membrane filters use a configuration similar to the one shown in Figure 5. In this design, the fibres form a U-shape inside the filter cartridge. Water enters through the top of the cartridge. When pressure is applied, the water is forced through the walls of the hollow fibres and into their centre, where it flows down and out of the cartridge through the tube openings at the bottom. Particles too large to fit through the pores in the walls of the hollow fibres are left on the untreated side.



Figure 5. Example of a hollow fibre membrane. Untreated water (brown arrows) moves into the cartridge and travels through tiny pores in the walls of the hollow fibres. Treated water (blue arrows) then flows through the hollow fibres and out of the cartridge.

3.3 Types of Membrane Filters by Container Setup

The filters discussed in this technical brief rely on either gravity or pumping to push water through the membrane. The type of force used to move water through the membrane determines the overall filter design and setup.

Most low-cost household membrane filters are driven by gravity. This means that the pressure forcing water through the membrane comes from the difference in height between the water level (when water is first poured into the filter) and the filter cartridge.

In gravity-driven filters, the untreated water is always poured into a reservoir or container that is above the filter cartridge(s). The two most common setups for gravity-driven filters are the tabletop setup and the hanging setup.

1. Tabletop setup (Figure 6): This consists of two containers stacked on top of each other with the filter cartridge forming the connection between them. Users pour untreated water into the upper container. Water must pass through the membrane cartridge to get to the bottom safe storage container.



Figure 6. Tabletop setup examples: Generic illustration (left), UZima filter (centre), LifeStraw Family 2.0 filter (right). Images from “UZima Filters” (<http://www.uzimafilters.org>) and “LifeStraw Family 2.0” by Vestergaard (<https://www.vestergaard.com/lifestraw-family-2-0>).

2. Hanging setup (Figure 7): This consists of a raised container for untreated water, a connecting tube, and a membrane cartridge. Users pour water into the upper container. Water flows down the tube, through the membrane cartridge that hangs below, and into a safe storage bucket.



Figure 7. Hanging setup examples: Generic illustration (left), LifeStraw Family 1.0 (centre—shown without safe storage bucket), Sawyer PointOne (right—shown without safe storage bucket). Images from “LifeStraw Family” (<https://www.lifestraw.com/products/lifestraw-family>) and “Sawyer PointOne Filter with Bucket Adapter Kit” by Sawyer International (<https://international.sawyer.com/products/sawyer-pointone-filter-bucket-adapter-kit-1-ft-hose>).

Some filters use pumps instead of gravity as the driving force. Pump-driven membrane filters may rely on manual pumping action to pull water directly from a container and push it through the membrane filter (for example, the in-line pump of the Grifaid Family Filter, shown in Figure 8 left). Alternatively, the pump may be used to build up pressure in an untreated water container, which then forces water to pass through the membrane (for example, the pump in the LifeSaver Cube, shown in Figure 8 right).



Figure 8. Pump-driven filter examples: Grifaid Family Filter (left—in-line pump is controlled by the blue handle on top of the filter), and Lifesaver Cube (right—pump is controlled by the blue handle on the side of the filter). Images from “Grifaid Water Filters” (<https://www.grifaid.org/our-filters>) and “LifeSaver Cube” by LifeSaver (<https://iconlifesaver.com/product/lifesaver-cube>).

CAWST HWTS fact sheets and CAWST HWTS Knowledge Base provide additional details about many membrane filter products, including those shown in the figures above.

4 Should I Choose a Membrane Filter?

This section provides some important criteria to consider as you decide whether a membrane filter is appropriate for your context. We briefly introduce and describe criteria here, and we encourage you to consult CAWST's HWTS fact sheets for information about the specific filters you are considering. For general guidelines about technology selection, refer to CAWST Technical Brief: Selecting Household Water Treatment and Safe Storage (HWTS) Options.

4.1 Performance Criteria

One of the first things you will want to consider is how well a membrane filter can address the drinking water quality issues you are trying to solve. Criteria to consider when evaluating filter performance include:

- Microbiological performance: Can the filter remove pathogens of concern?
- Source water requirements: Can the filter treat the type of water you want to treat?
- Batch volume and flow rate: Can the filter treat the amount of water you need in the time you have?
- Safe storage: Does the filter protect the water from recontamination after treatment?
- Lifespan: Will the filter continue to treat water for an acceptable amount of time?

4.1.1 Microbiological performance

The main reason most people use a filter is to remove pathogens. Therefore, it is important to select a water filter that can remove the pathogens of concern. Most microfiltration and ultrafiltration filters perform well in removing bacteria and protozoa. Because they have smaller pores, many ultrafiltration membranes can also remove viruses. However, the smaller the pores are in your filter, the more pressure is required for water to pass through. Filters with smaller pores will also clog more quickly if you are filtering **turbid** (cloudy) water. Although microbiological removal will be high, you may experience a slow flow rate and reduced lifespan. This trade-off between microbiological performance and other criteria is almost always a consideration when selecting household filters.

4.1.2 Source water requirements

When assessing available water treatment options, it is important to consider the type of water you want to treat. In particular, the **turbidity** (cloudiness) of your water is an important consideration for membrane filters. Generally, membrane filters should be used with clear source water (most manufacturers recommend turbidity below 50 **NTU**). If the source water is turbid, the user should settle or strain large particles from the water before filtration. Otherwise, the tiny pores of membrane filters can quickly become clogged with particles. This clogging will reduce the flow rate, sometimes to a rate that is unacceptably slow to the user. Although certain types of clogging can be addressed by routine maintenance, clogging is sometimes irreversible and can reduce the lifespan of the filter (see Section 5.1).

Low-cost, gravity or pump-driven household membrane filters typically contain microfiltration or ultrafiltration membranes. Therefore, the pore size is generally not small enough to remove pesticides, heavy metals, or salts. If you are concerned about chemical

contaminants, you will want to find another water source or a different means of water treatment.

4.1.3 Batch volume

As you evaluate filter options, you will want to consider how much water they can process—and whether this meets the needs of all household members. Batch volume, or the amount of water that can be treated at a time before refilling the filter, depends on the volume of the untreated water container. Batch volumes for household membrane filters typically vary from 2.5 L (for example, the LifeStraw Family Filter 1.0 shown in Figure 7) to 20 L (for example, the UZima filter shown in Figure 6, which uses a standard bucket). Filters with smaller untreated water containers (and thus smaller batch volumes) require more frequent filling.

4.1.4 Flow rate

Flow rate, or how quickly a filter can process water, depends on the filter setup and pore size. It will also be affected by the turbidity of the source water. Flow rates advertised by filter manufacturers are often based on best-case scenarios: a new filter, a full untreated water container, and

Manufacturer-Stated Flow Rate Examples:

- UZima filter (tabletop): 1 L/min
- Grifaid filter (pump-driven): 1.5 L/min
- Village bucket filter (hanging): 1 L/min
- Sawyer PointOne (hanging): 0.5–0.8 L/min

source water with low turbidity. You can expect the flow rate to decline over time as particles that can't pass through the pores build up on the untreated side of the membrane (McBride, 2016; Pérez-Vidal, Diaz-Gómez, Castellanos-Rozo, & Usaquen-Perilla, 2016).

4.1.5 Safe storage

Safe storage is an important consideration because of the risk of recontamination of water after treatment. Whether a filter provides safe storage depends on its design and setup. Typically, tabletop setups include a safe storage container (the lower container). Hanging filters and other one-container setups may not come with safe storage containers. CAWST recommends that users or implementers purchase and use a safe storage container for any filters that do not include built-in safe storage.

4.1.6 Lifespan

As with flow rate, the manufacturer-stated lifespan is often calculated or tested based on ideal conditions (for example: well-trained user, high quality source water, gentle handling). Research on the use of membrane filters in actual households in low- and middle-income countries has found that filter lifespan varies widely, from several months to several years. Factors that influence lifespan include source water quality, frequency of maintenance, and general handling of the filter by the user (Murray et al., 2015; South Sudan WASH Cluster Household Water Treatment Technical Working Group, 2016). Given this variability in lifespan, filter performance must be monitored closely and users must be given clear instructions on when and how to replace the filter when it reaches the end of its lifespan.

4.2 Operation and Maintenance Criteria

Membrane filters are often advertised as straightforward and easy to use. This can be true when the unit is functioning properly and the user is well-trained and supported in operation and maintenance. However, because the membrane is usually contained within a cartridge and is out of sight and access of the user, it can be difficult to know whether the filter is working properly.

If users are expected to correctly and consistently use a filter for the long term, it must not only perform well, but also be easy to use and maintain. Criteria to consider when evaluating operation and maintenance include:

- Operation: Is the filter easy to use?
- Backwashing: If the filter gets clogged, can the user reestablish flow? If so, how?
- Repair and replacement: What parts need to be replaced and how often? Can the user replace them?

4.2.1 Operation

Operation refers to how much physical effort it takes to use the filter and how straightforward it is for people to use the filter. Does the filter require a lot of effort, such as regularly refilling a reservoir or cleaning parts between uses? Does the user need to go through multiple steps, such as pumping, backwashing, or opening and closing taps, to get treated water every day? How likely is it that a user could incorrectly use the filter, reducing its performance or lifespan? These factors vary between membrane filters and affect how likely a person is to use the filter correctly and consistently over time.

4.2.2 Backwashing

As discussed above, membrane filters can quickly become clogged if they are used to treat turbid water. Even if the source water is relatively clear, particles will build up on the membrane over time. **Backwashing** is a maintenance activity that reverses the flow of water, using pressure to force particles off of the membrane, unblocking the pores. Depending on the filter, backwashing may be recommended after every use or only when the flow rate becomes unacceptably slow.

The procedure for backwashing varies. For many of the filters discussed in this technical brief, backwashing requires a syringe and clean water (manual backwashing). Some products have built in backwashing devices, and in some cases the user must perform multiple steps to backwash a filter. There is a greater potential for user error when manual backwashing is required. Errors could include:

- Not following the recommended procedure.
- Using untreated water for backwashing, which contaminates the treated water side.
- Using too much pressure, which can lead to membrane rupture (see Section 5).
- Losing the syringe.

Examples of filters with built-in backwashing devices:

- Lifestraw Family 1.0 and 2.0
- Grifaid Family Filter

4.2.3 Repair and replacement

Our understanding is that all low-cost membrane filters designed for household use have membranes that are inaccessible to users. This design aspect is intended to protect the membrane from damage during handling, operation, and maintenance. However, it also means that the user cannot access the membrane for repair or replacement. As a result, when a membrane reaches the end of its life, users have to replace the entire membrane cartridge or the entire filter, depending on the design and setup. For some filters, other parts—such as spouts, containers, lids, and tubing—can be replaced individually. This requires access to a supply chain with replacement cartridges, new filters, and/or the spare parts needed to maintain the filter over time.

5 What are the Limitations of Membrane Filters?

5.1 Membrane Fouling

Membrane fouling is the technical term for the clogging of a membrane over time as particles and minerals deposit onto the membrane's surface. Some fouling is reversible, meaning the particles can be forced off of the membrane by backwashing. Other fouling is irreversible, meaning the particles are strongly attached and cannot be removed without the use of chemicals. In a typical household setting, such chemical treatment is usually not possible.

Reversible fouling will affect flow rate in the short term, but backwashing can help to reestablish the flow rate to an acceptable level. However, because irreversible fouling cannot be addressed by backwashing, flow rates typically decrease over time. At a certain point, a filter's flow rate will decrease to an unacceptable level—or may stop flowing at all—and the user will be unable to reestablish an acceptable flow rate through backwashing. At this point, the filter has reached the effective end of its lifespan.

5.2 Membrane Rupture

A related concern with hollow fibre membrane filters is the possibility of membrane rupture, which is when a membrane bursts due to too much pressure being applied by the user during backwashing. If irreversible fouling has occurred on the membrane, then it may not be possible for the applied pressure to force the particles off. The pressure building in the membrane then finds a different path of release by bursting through the membrane itself.

Once a membrane has ruptured, it is possible for untreated water to pass directly through the filter, without being filtered. In some cases, the untreated water may pick up extra microorganisms as it passes through the untreated side of the membrane, causing it to become more contaminated than it was when it entered the filter (Murray et al., 2015, 2017). As discussed above, the membrane in household filters is usually inaccessible to users. This means that the user cannot observe when membrane rupture has occurred. The best indication of membrane rupture is a sudden increase in flow rate, but microbiological testing is required to determine whether water is passing through unfiltered.

Certain membrane filters have been designed to limit the amount of pressure that can be applied during backwashing as a way to address this issue.

6 Summary

As technology advances, household membrane filters are increasingly popular and affordable. The household membrane filters described in this technical brief come in many designs, but all use gravity or pumping to push water through the pores in a thin synthetic membrane.

Before using or implementing membrane filters in households, it is important to assess whether they are appropriate for your context. Criteria to consider include microbiological removal, source water requirements, batch volume, lifespan, operation and maintenance procedures, and access to spare parts. It is also important to be aware of the limitations of membrane filters, such as the potential of membrane fouling and membrane rupture, so that you can consider these possibilities in your program design.

7 Definitions

Backwashing: A maintenance activity that reverses the flow of water, using pressure to force built-up materials off a membrane’s surface to unblock the pores and thereby improve flow rate.

Contaminant: In the context of water treatment: anything that, when found in water, reduces the safety or acceptability of the water for drinking. Examples include suspended particles, chemicals, and microorganisms.

Driving force: The type of pressure (such as gravity or pumping) that pushes water through a membrane (from the untreated side to the treated side).

Household water treatment and safe storage (HWTS): Activities by which household members treat and store water in their homes. Also referred to as treating water at the point of use (POU).

Nephelometric Turbidity Units (NTU): Unit of measure for the turbidity of water. A measure of the cloudiness of water, as measured by a nephelometer.

Membrane: A barrier that allows some things to pass through but not others. In water treatment, a thin layer of material (often synthetic) with tiny holes (pores) that allow fluids to pass through but do not allow the passage of certain particles or chemicals.

Membrane filter: In water treatment, any filter that contains a membrane and uses a driving force (such as gravity or pumping) to push water through the membrane.

Membrane fouling: The clogging of a membrane over time as particles and minerals deposit onto the membrane’s surface.

Pores: Small openings or holes in the surface of a membrane. The size of these pores determines what can pass through.

Turbidity: The “cloudiness” of water. Turbidity is caused by suspended solids, such as sand, silt, and clay, floating in water. Light reflects off these particles, making the water look cloudy. Turbidity is often measured in nephelometric turbidity units (NTU).

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Calgary, Canada | www.cawst.org | support@cawst.org

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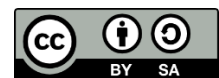
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