Comparison

Traditional Slow Sand Filtration (TSSF) and BioSand Filtration (BSF).

November 8, 2008

Dr. David H. Manz, P. Eng., P. Ag.

Copyright Claimed by David H. Manz

Pathogen Removal – without disinfection

	Removal Rate %	
Pathogen	TSSF	BSF
Helminthes	100	100
Parasites	100	100
Bacteria	90 - 99	90 - 99
Viruses	90 - 99	90 - 99
Spores	100	100

Note:

1. TSSF and BSF require the development of a 'schmutzedeke' or biolayer to remove bacteria and viruses.
2. TSSF and BSF do not require the development of a biolayer to remove helminthes, parasites and spores.
3. Virus removal requires the biolayer and minimum depth of media for deactivation.

Pathogen Removal – with disinfection

	Removal Rate %	
Pathogen	TSSF	BSF
Helminthes	100	100
Parasites	100	100
Bacteria	100	100
Viruses	100	100
Spores	100	100

Note:

1. TSSF and BSF will remove helminthes, parasites and spores which cannot be easily killed or deactivated with chemical disinfection.
2. Disinfection without filtration may not be effective against bacteria or viruses.
3. Disinfection without filtration will consume much more chemical and may make the water undrinkable.
4. The ONLY organisms which will NOT be 100% removed by the TSSF and BSF can easily be killed with most simple disinfection procedure.

Particulate Removal

	Removal Rate %	
Parameter	**TSSF** Turbidity < 20 NTU	**BSF** Turbidity < 400 NTU
Sand	100	100
Silt	100	100
Organic Particles	100	100
Clay Particles [1.0]	Up to 100	Up to 100
BSF can be used to treat water with very high turbidity. They are simple to clean and do not consume any filtering media.		

[1.0] Pre-treatment with small amounts of coagulant, 5 mg/L, will be effective for removal or clay and other colloidal sized particulate material. This technique would not be practical with the TSSF because of the need for frequent cleaning.

Metal Removal

	Removal Rate %	
Metal	**TSSF [5.]**	**BSF**
Oxidized Iron [1.]	Not Used.	100
Oxidized Manganese [2.]	Not Used.	100
Arsenic with pre-treatment [3.]	Not Used.	100
Mercury with pre-treatment [4.]	Not Used.	100
Lead with pre-treatment [4.]	Not Used.	90 - 99

1. Iron may be oxidized or require addition of chemicals to oxidize.
2. Manganese usually requires addition of chemicals to oxidize.
3. Arsenic may be adsorbed by oxidized iron or may require addition of chemicals (oxidants and coagulants).
4. May occur as the result of formation of a biolayer or use pre-treatment using coagulants.
5. **TSSF is not used because of high suspended solid loading and cleaning requirements.**

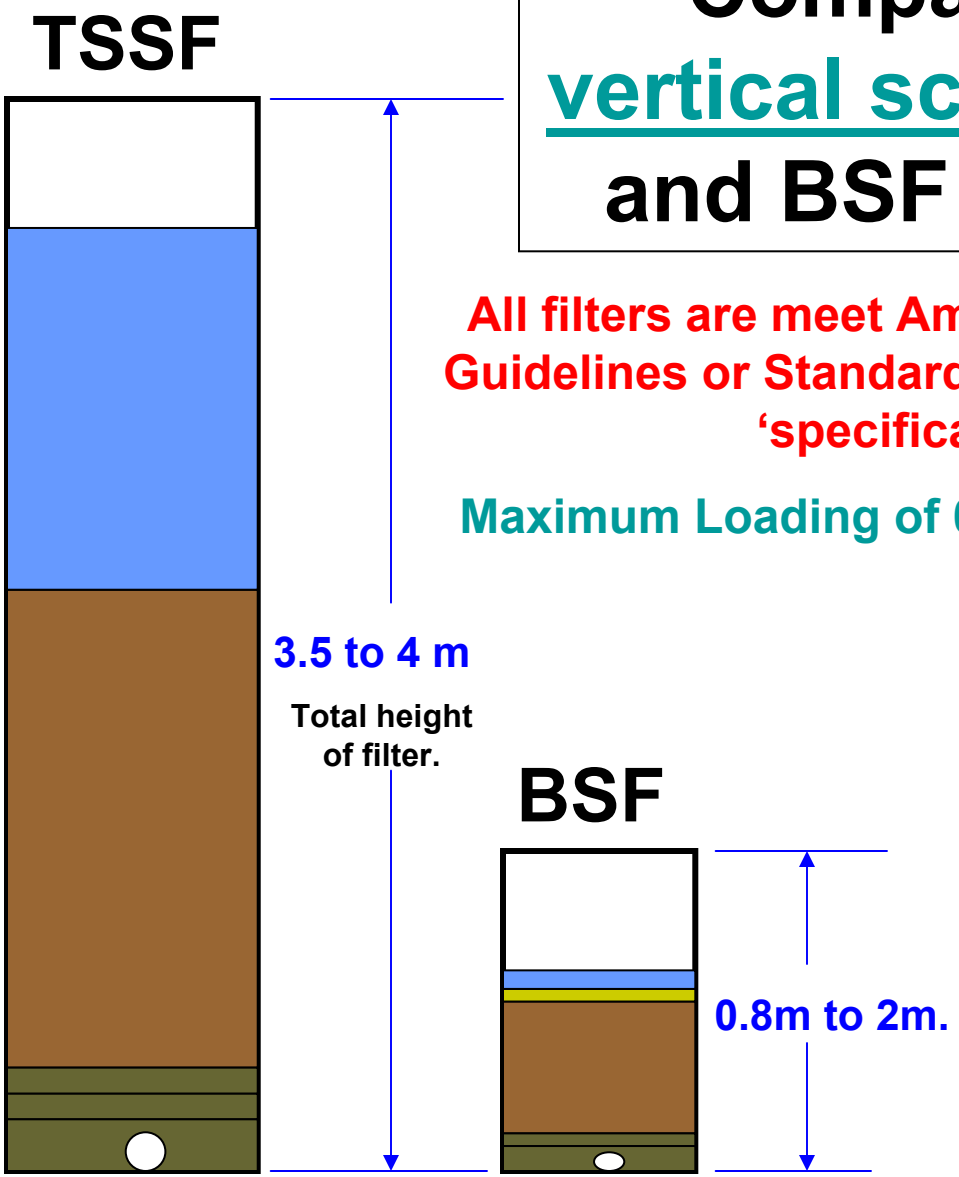
Dissolved Substance Removal

	Removal	
Substance	TSSF	BSF
Organic toxins[1]	Variable	Variable
Inorganic toxins[1]	Variable	Variable
Colour[1,4]	Variable	Variable
Fluoride with pre-treatment[2]	Not Used.	Effective
Hydrogen Sulphide with pre-treatment[3]	Not Used.	Effective
Odour with pre-treatment[4]	Not Used.	Effective

1. When a biological layer forms. 2. Lime treatment.

3. Using sodium hypochlorite. 4. Using small amount of coagulant.

Comparison of the vertical scale of the TSSF and BSF technologies.



All filters are meet American Water Works Association Guidelines or Standards for 'slow sand filter design' and 'specification of filter media'.

Maximum Loading of 0.4 m^3 per m^2 of surface per hour.

The depth of the filtering media in the BSF equals the minimum depth recommended for the TSSF. The minimum depth is thought to be necessary for deactivation of viruses.

Note on Media Selection.

The media used in the BSF is very carefully selected, prepared and installed as per several papers that may be found in the web site: www.manzwaterinfo.ca.

It is recommended that media be prepared from recently crushed rock because this material is not contaminated with organic matter – either organic particles or coated with organic material (animal feces).

If the media chosen is coated with organic material it is likely colonized by a variety of bacteria including fecal coliforms. The media can be sterilized using a variety of techniques (chlorine, boiling, etc.) but the 'food value' of the organic matter coating the media will remain. Once the still organically contaminated material is installed in the filter and untreated water containing bacteria is added, the media will be immediately colonized. The unfortunate result is that the water produced by the filter will have more (sometimes much more) bacteria than the untreated water. The problem will disappear when the food value of the organic material in the 'contaminated' media is exhausted. This process should not be confused with the formation of the biolayer (often called ripening.) The biolayer has formed, is doing its job at the media surface but the water is immediately contaminated as flow through the filter. (Parasites, helminthes, and much turbidity will be removed and simple chlorine disinfection would produce safe drinking water.

Note on Media Selection – cont'd.

It should be apparent that media for the BSF should NOT come from sources such as river beaches or banks, beaches, or any hole dug into the ground. These sources are all considered contaminated though the deeper one does dig the cleaner the material can be expected to be. Sand exposed to the sun will be dry but still contaminated!

It is very easy to contaminate media once installed in the BSF. I used to joke at workshops that giving the filter a drink of coca-cola or a beer would do the job of contamination – even if the coca-cola or beer were bacteria free. This is because the dissolved organics in the liquids would coat the media particles – top to bottom of the filter – with 'food' for the bacteria. Food should never be stored in the diffuser basin.

It has come to my attention that people have tried to use 'biolayer development accelerants'. It should be clear that this is a very tricky procedure and probably NOT POSSIBLE. Water with high dissolved biochemical oxygen (BOD), equivalent to wastewater should not be poured into any BSF.

A biolayer will form naturally in its own time depending on the nature of the aquatic ecology of the water being treated and the amount of water being treated.

Operation

TSSF: Continuous flow – operation cannot stop or will temporarily lose ability to remove bacteria and viruses.

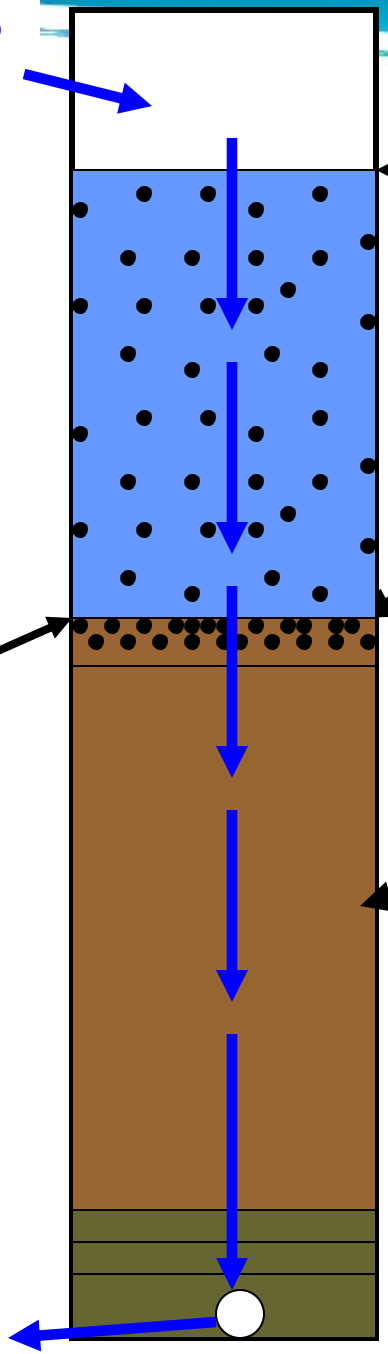
BSF: Operated when required. (Used when needed.)

TSSF technology is only practical for very large water treatment plants where operation can be continuous.

The BSF technology is ideal for very small treatment plants (household) that must be manually operated.

Operation of the TSSF.

Raw water is added to filter without disturbing surface of media.



Operating water level.

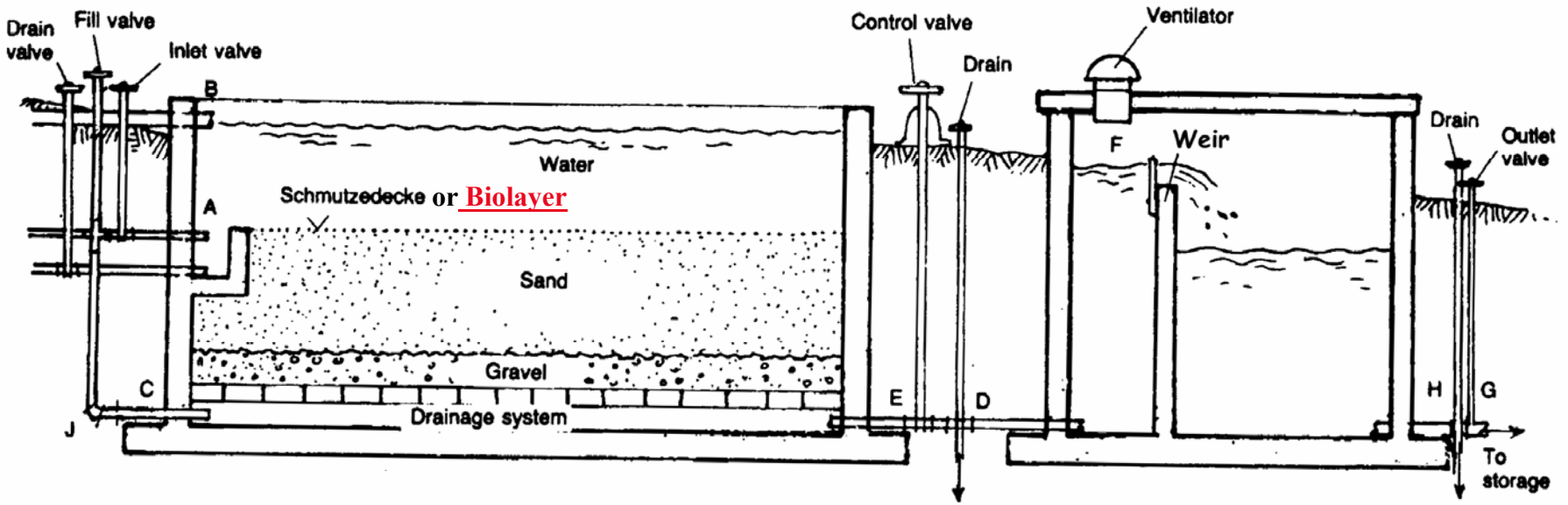
Particulate material is captured on or near surface of the very fine filtering media.

Must be operated continuously or the biological layer or 'schmutzedeke', responsible for removal of microorganisms will be damaged or killed.

No particulate material is captured within media because the water is not forced into the media as it is in rapid sand filtration or pressure filtration.

Filtered water exits filter.

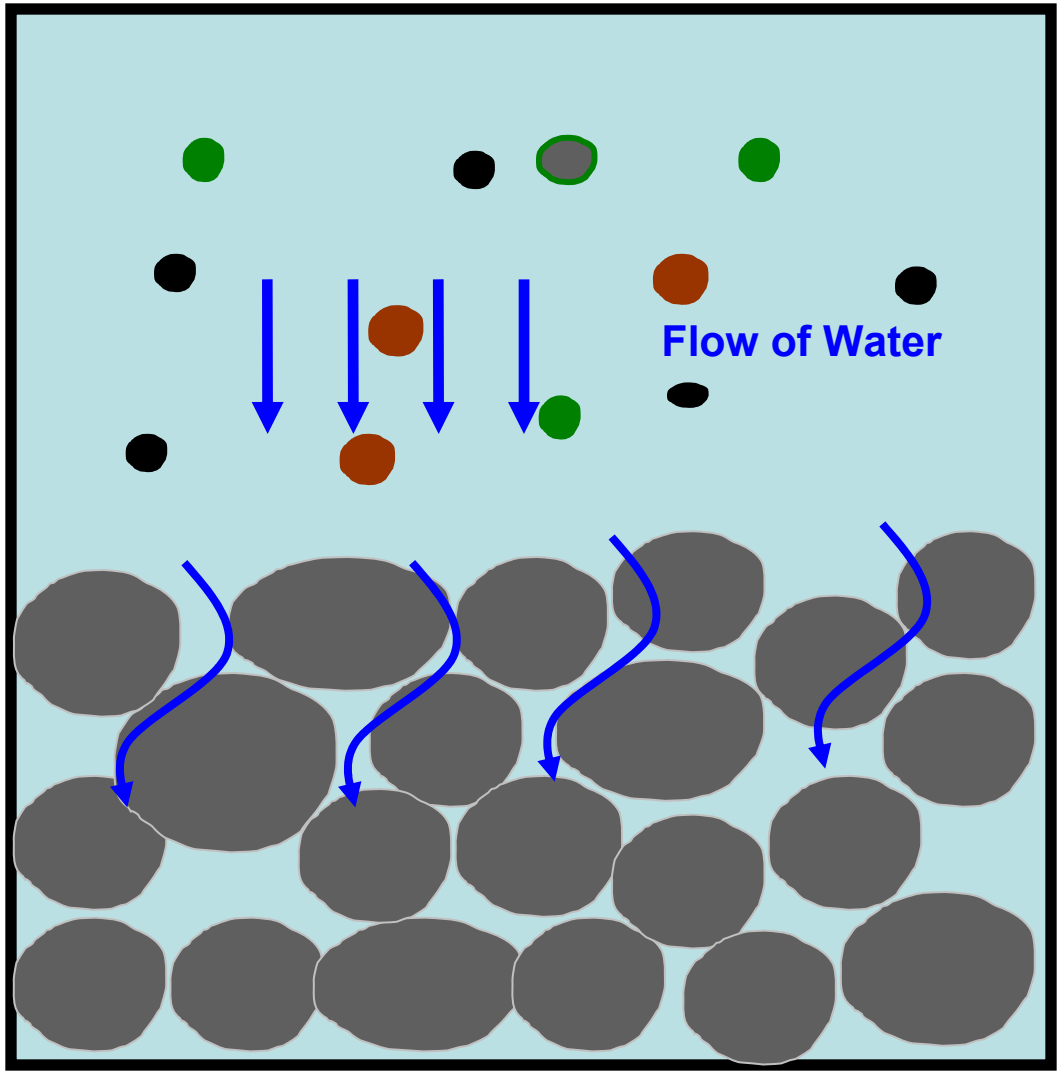
Traditional Slow Sand Filter



- **Continuously operated.**
- **Only considered practical for treating low turbidity raw water because cleaning requires considerable effort.**
- **Cleaned by removing approximately 5 cm of sand – performance is seriously impaired for at least 2 days. Filter beds have enough media for more than 10 cleaning operations.**
- **Cleaning is an onerous task which is performed as infrequently as possible.**
- **Not considered practical for iron removal or use with coagulants (cleaning is a problem).**
- **Limited to relatively large civil engineering works (significant, expensive projects).**

Operation of the TSSF.

Beginning of operation of the TSSF – no biofilm around particles and no biolayer.



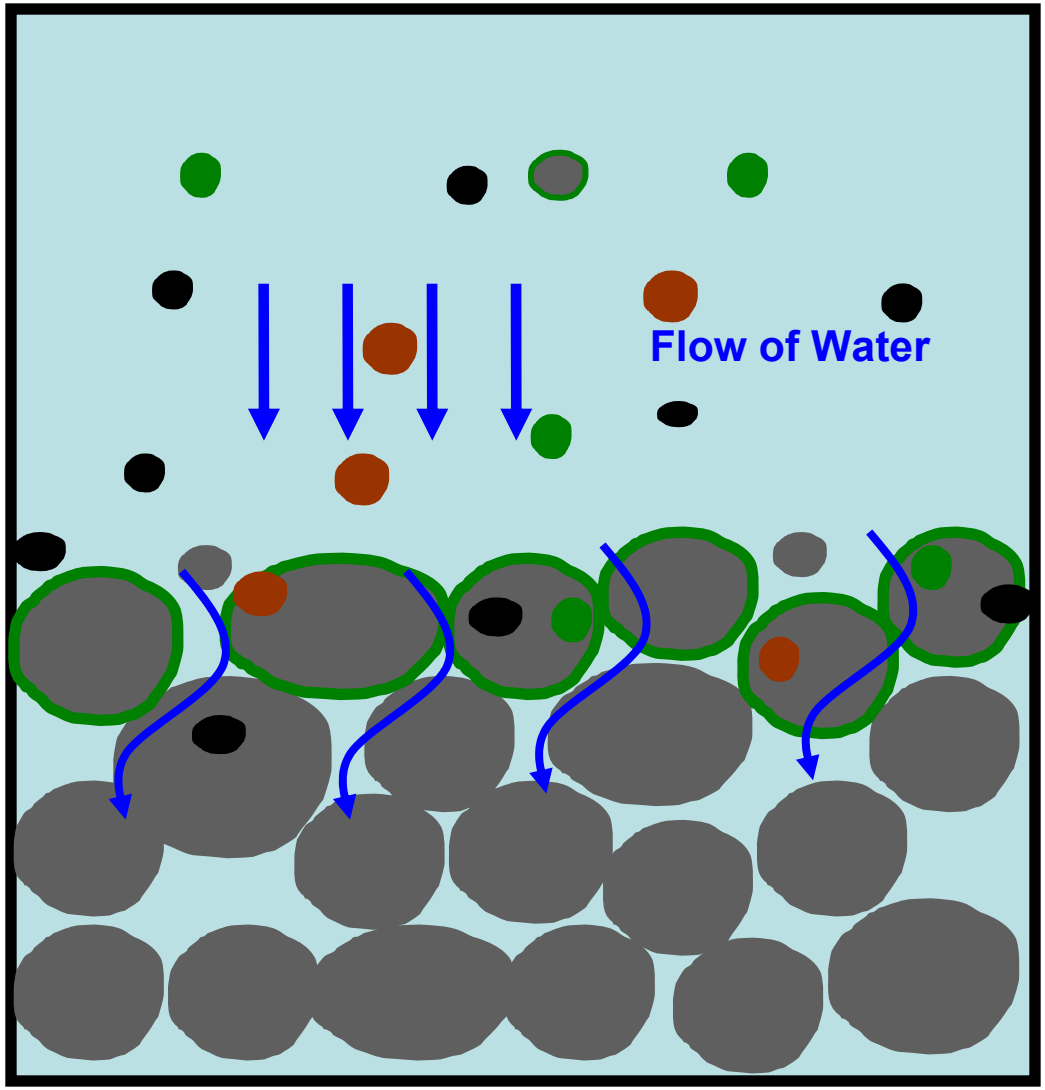
Media particle without surface biofilm.

Other mineral and organic particles or flocs of particles.

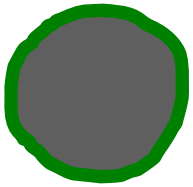
Also includes large living organisms such as algae, helminthes and the cysts of parasites.

Operation of the TSSF.

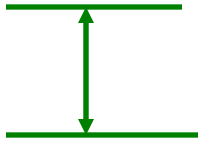
Beginning of operation of the TSSF



No biolayer is necessary for removal of parasites and larger organic material and mineral particles including oxidized iron and manganese.



Media particle covered with a surface biofilm including bacteria and organic matter.

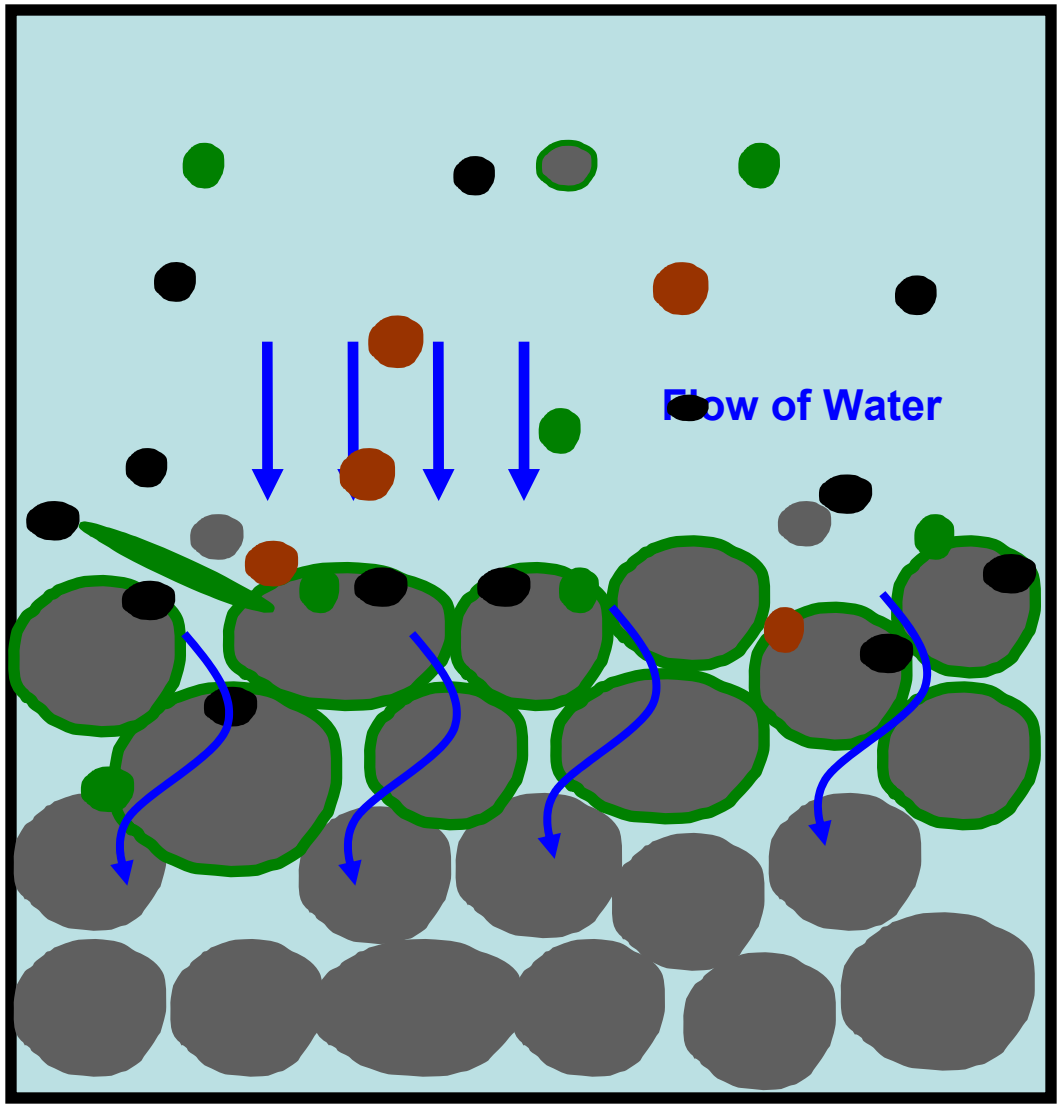


Biolayer (Mineral particles covered with a biofilm).

Formation of biofilm on the mineral particles is exactly the same as that observed in 'trickling filters' used for aerobic treatment of wastewater.

Operation of the TSSF.

Biolayer thickens with use and time.

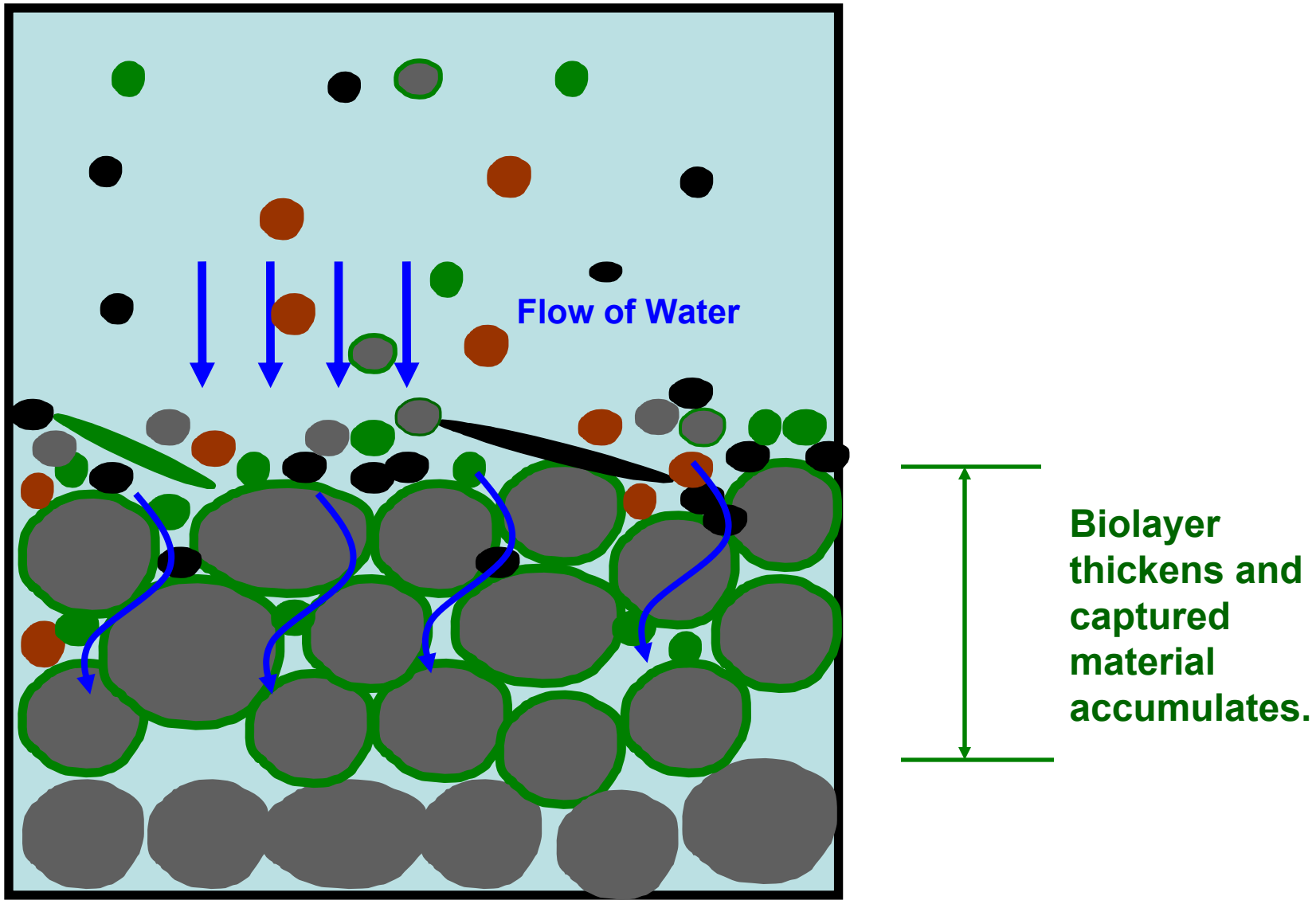


Formation of biolayer will depend on the ecology of the water being treated and the quantity of water being treated. The greater the concentration of aquatic life and the greater the quantity of water being treated the faster the biolayer will form.

Biolayer thickens.

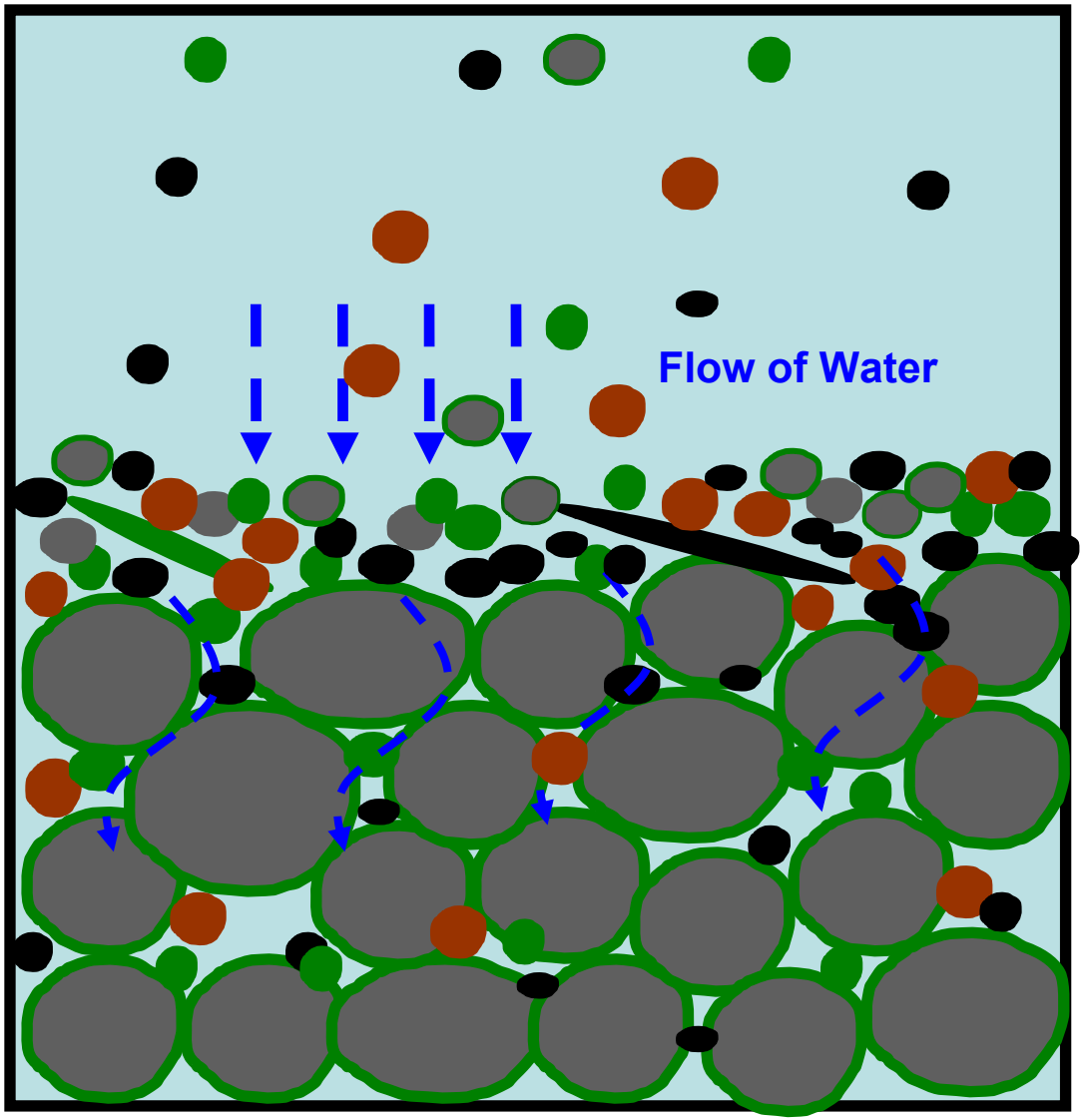
Operation of the TSSF.

Biolayer thickens with use and time.



Operation of the TSSF.

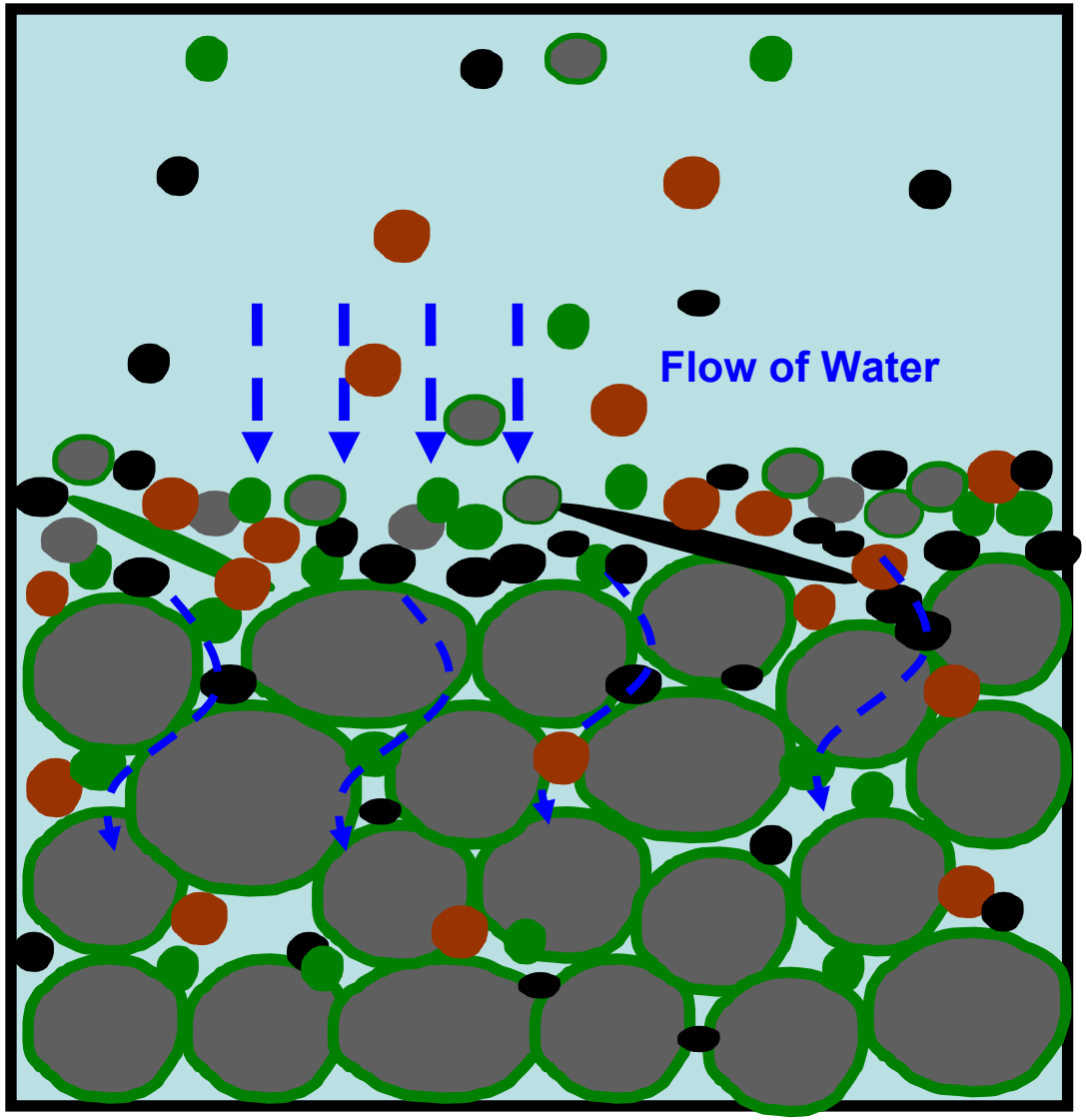
Biolayer thickens with use and time.



Biolayer thickens and captured material accumulates and starts to restrict flow.

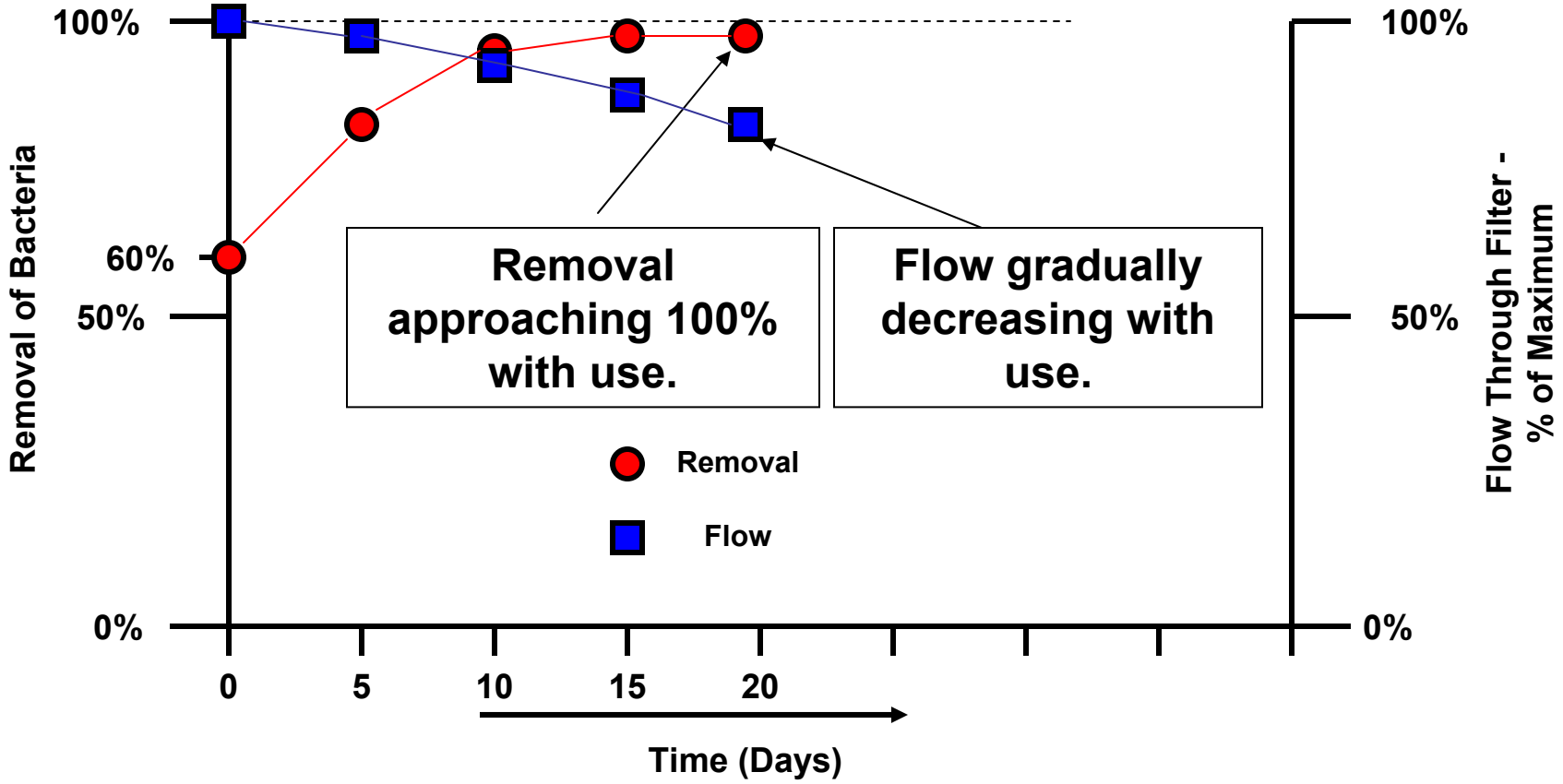
Operation of the TSSF.

Flow is unacceptably low and filter must be scraped.

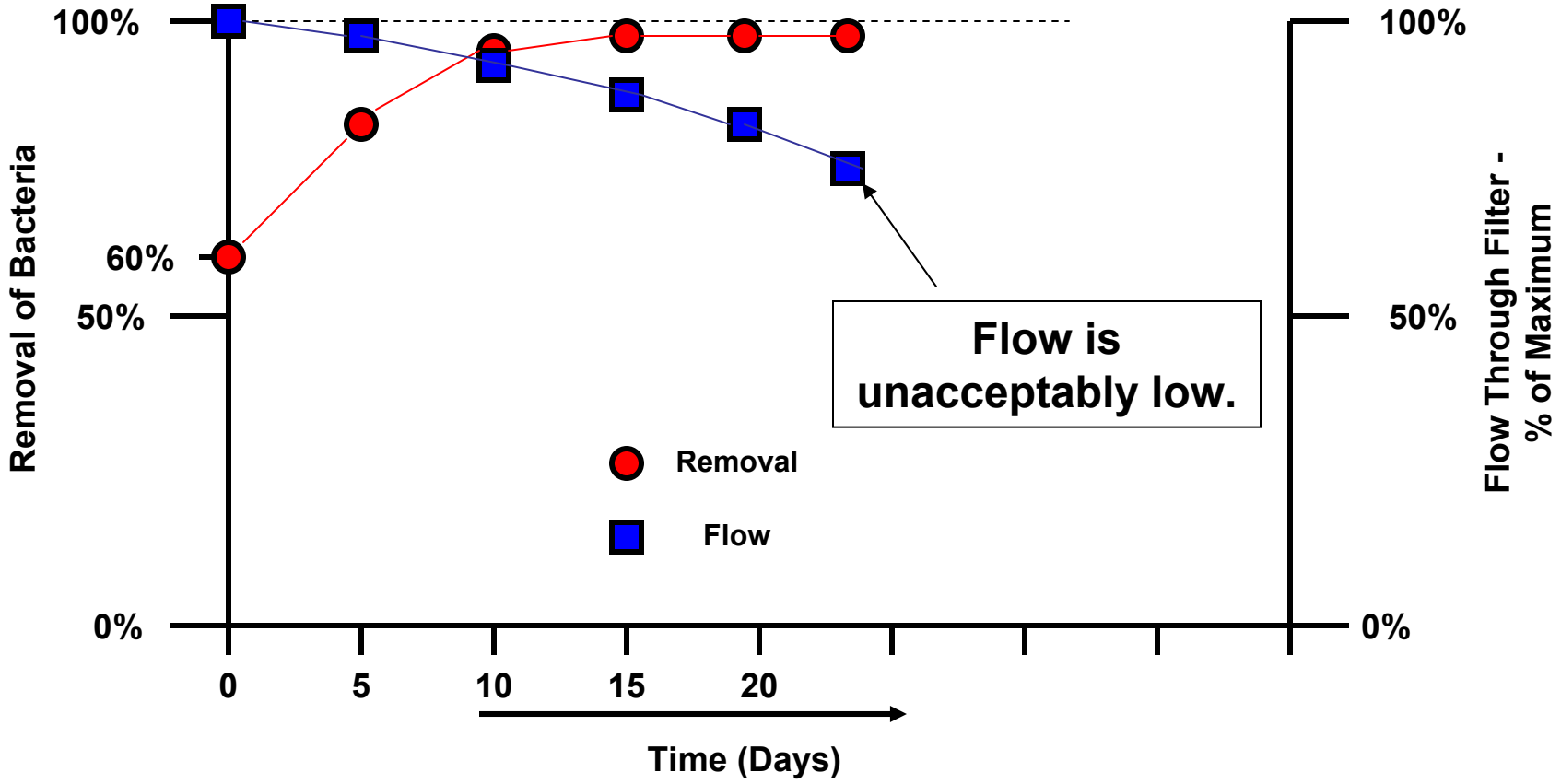


The scraping process will remove the biolayer.

Typical Performance of a Traditional Slow Sand Filter -TSSF



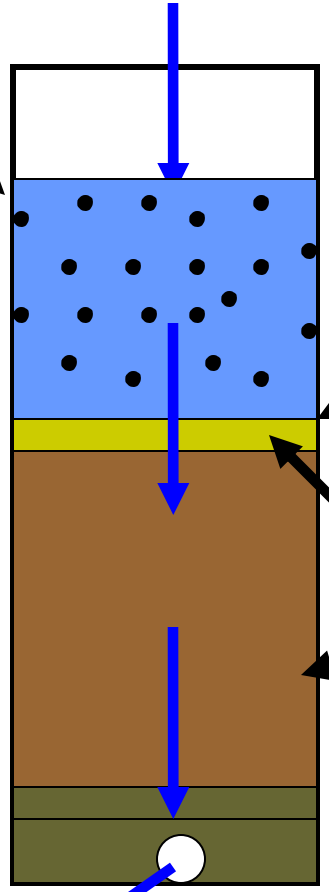
Typical Performance of a Traditional Slow Sand Filter



Operation of the BSF.

Raw water is added to filter without disturbing surface of media.

Operating water level.



Similar to traditional slow sand filtration, particulate material is captured on or near surface of the very fine filtering media.

Unlike traditional slow sand filtration, the BSF can be operated on a demand basis when removing micro-organisms.

No particulate material is captured within media because the water is not forced into the media as it is in rapid sand filtration or pressure filtration.

Filtered water exits filter.

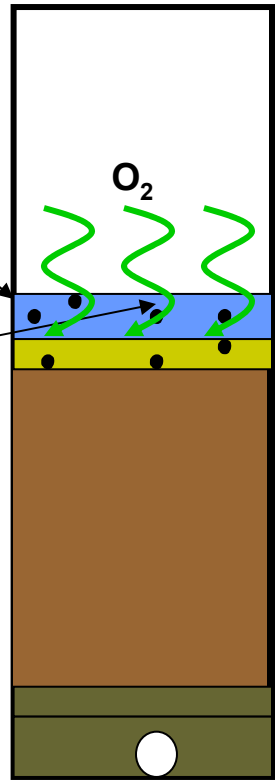
Operation of the BSF when flow is stopped and resumes.

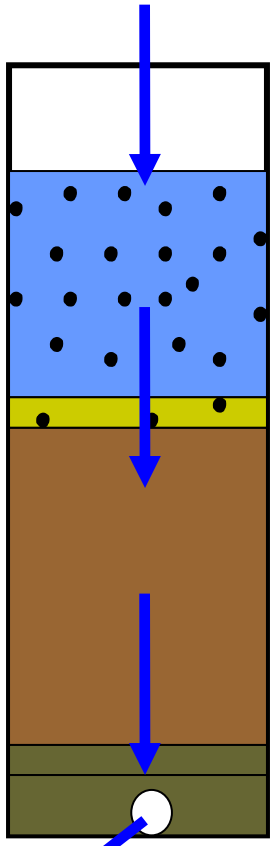
Flow to filter is stopped.

Flow to filter resumes.

Water level drains to paused or minimum depth – minimum 5cm.

Sufficient oxygen can diffuse through the shallow layer of water to keep aerobic biolayer alive.





Mature healthy biolayer still present.

Filtered water exits filter.

Note: Paused depth should NOT be less than 5 cm as the biolayer will be disturbed when water is added. Paused depths much greater than 5 cm may limit transfer of oxygen to the biolayer impairing its performance. 5 cm is considered the optimum.

- Untreated water enters filter when the lid is removed and water is poured in directly.

Biosand Water Filter

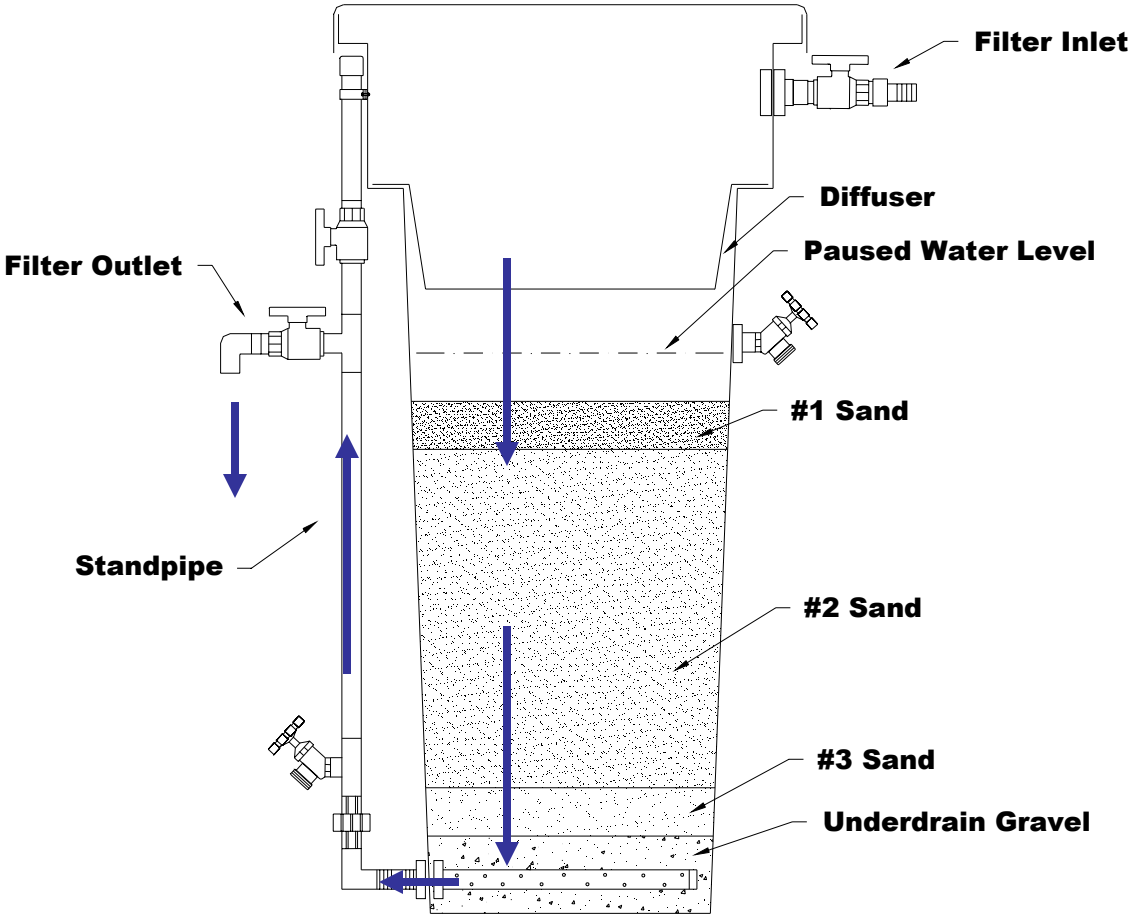
- Water passes through the sand to the underdrain, up the standpipe and out into the bucket below.

The biological layer forms naturally as the organisms in the water are captured and collect on the top of the filter sand.

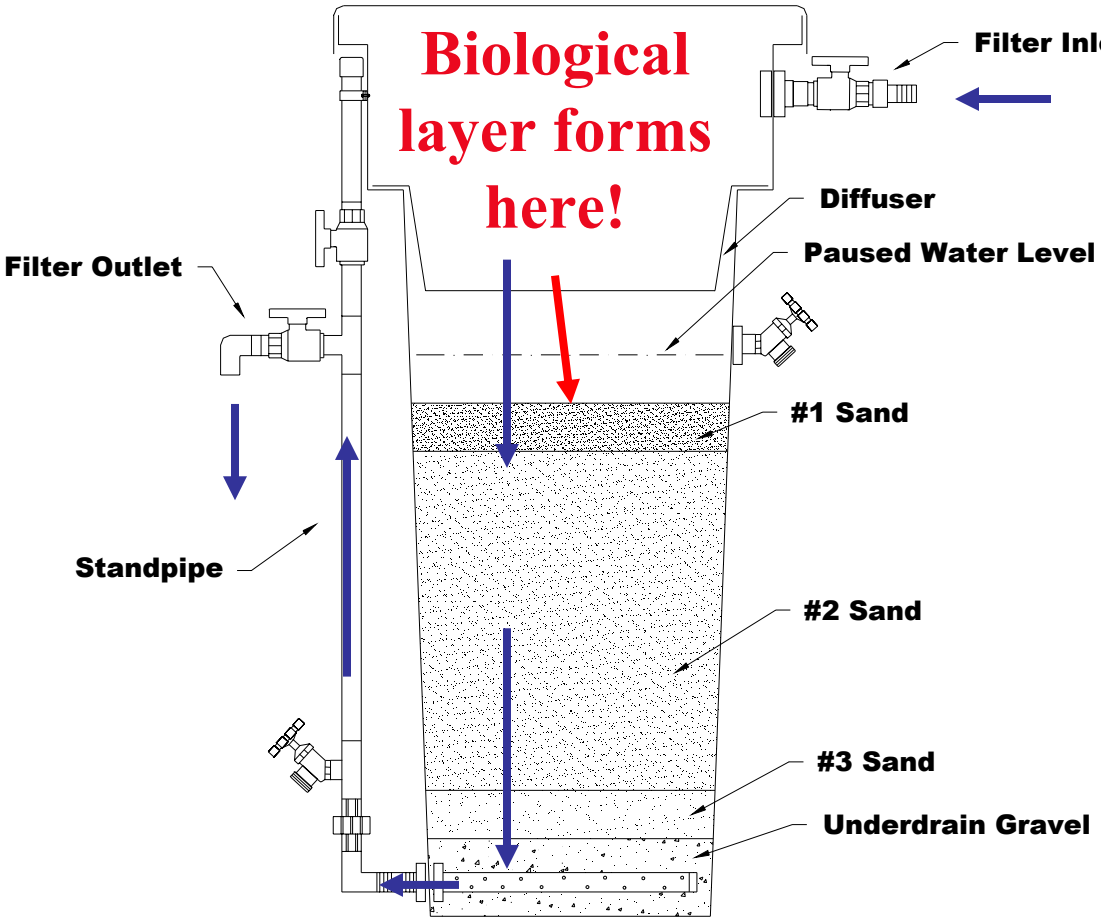
The accumulation of organisms and organism parts enables the biolayer to get better and better at capturing disease causing bacteria and viruses. (Recall: Up to 99%.)

Biological layer forms here!

Plastic Version of BSF – Pure Filtered Water Ltd.



- Water passes through the diffuser, through the water above the sand, through the sand to the underdrain, up the standpipe and out through the filter outlet.



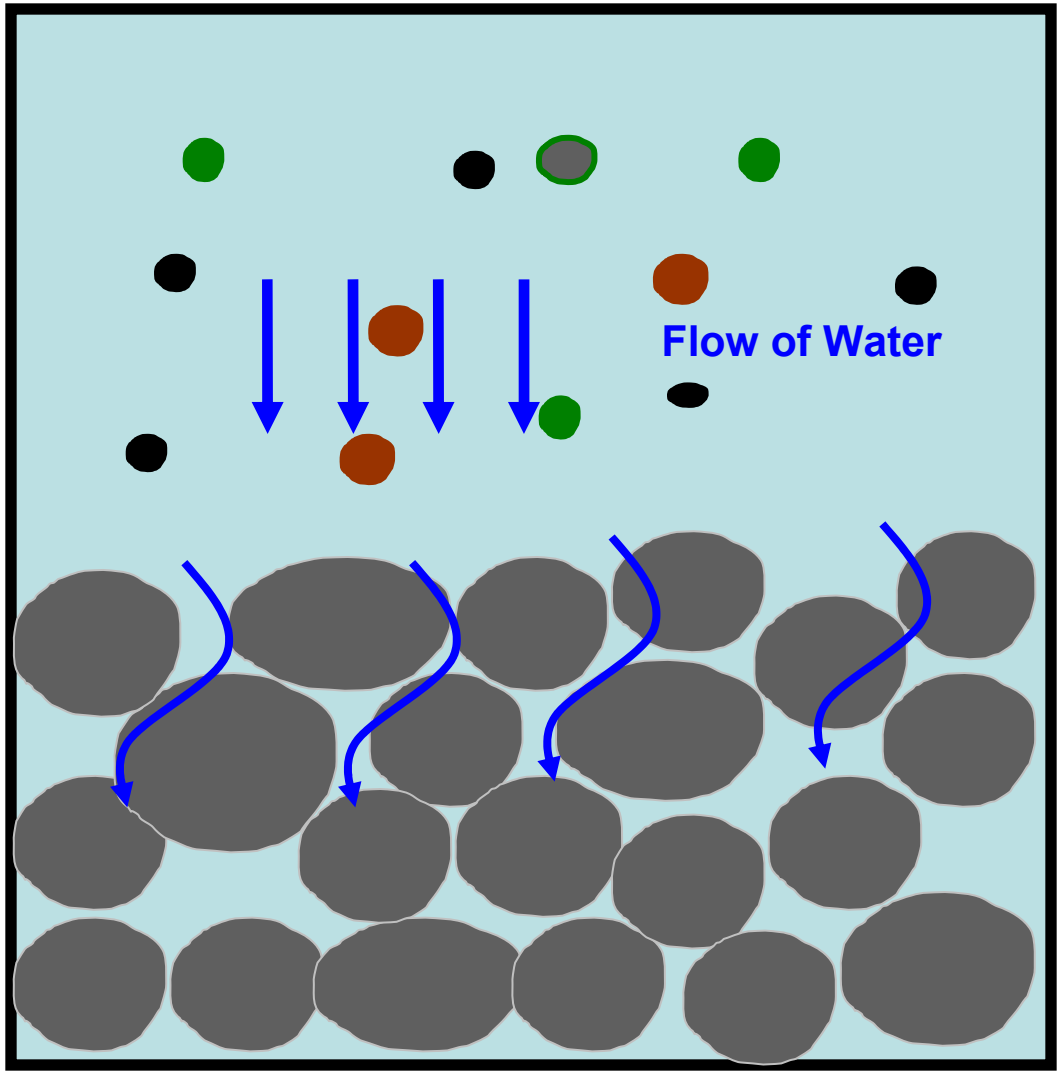
- With use, a biological layer forms on the surface of the sand - similar to traditional slow sand filters.

-The biological layer will not form if there are no living organisms in the water (iron removal).

The <u>biological layer</u> is only necessary when the removal of bacteria and viruses to subinfectious concentrations is required. Post filtration disinfection is ALWAYS recommended.

Operation of BSF.

Beginning of operation of the BSF – no biofilm around particles and no biolayer.



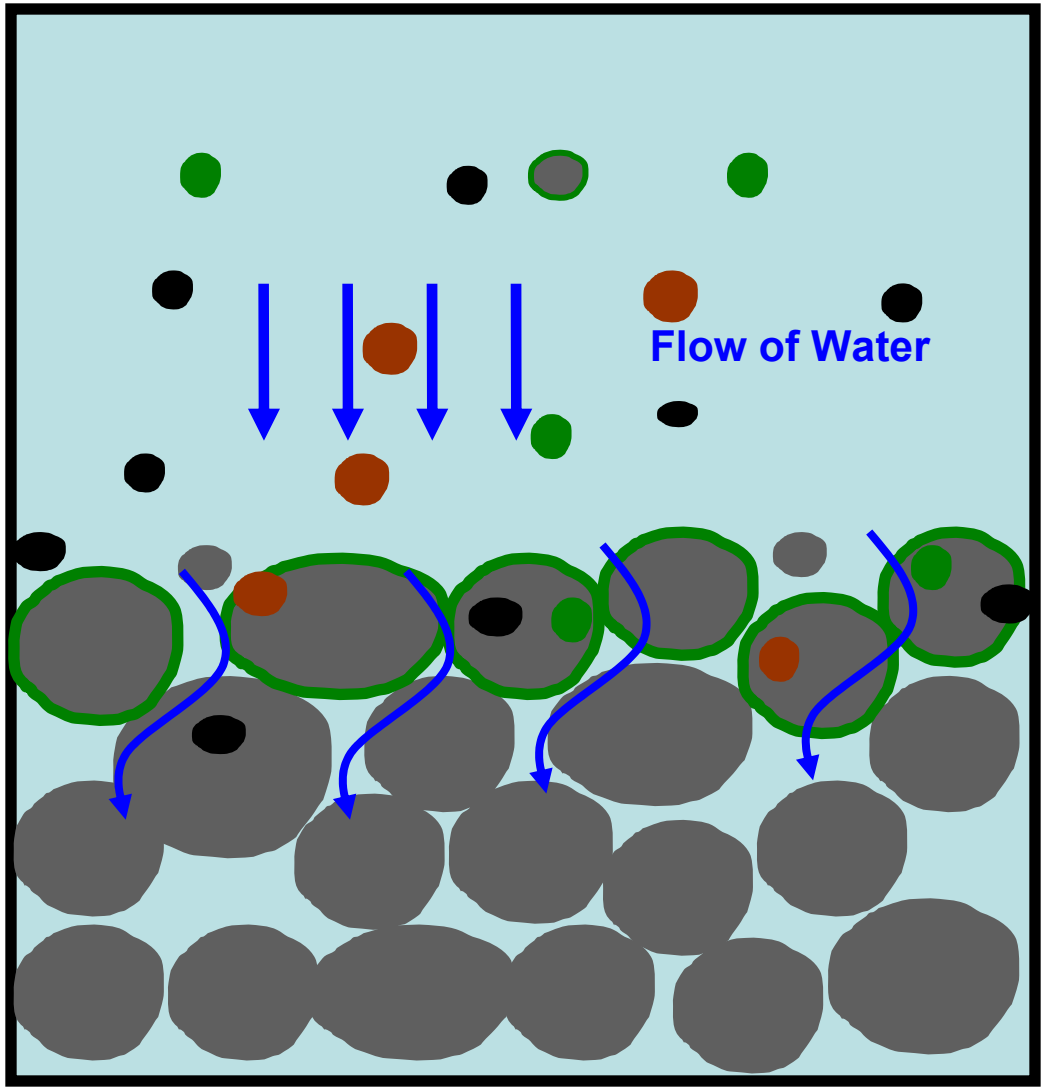
Media particle without surface biofilm.

Other mineral and organic particles or flocs of particles.

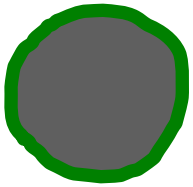
Also includes large living organisms such as algae, helminthes and the cysts of parasites.

Operation of BSF.

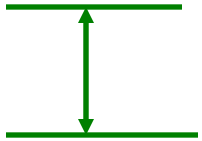
Beginning of operation of the BSF



No biolayer is necessary for removal of parasites and larger organic material and mineral particles including oxidized iron and manganese.



Media particle covered with a surface biofilm including bacteria and organic matter.

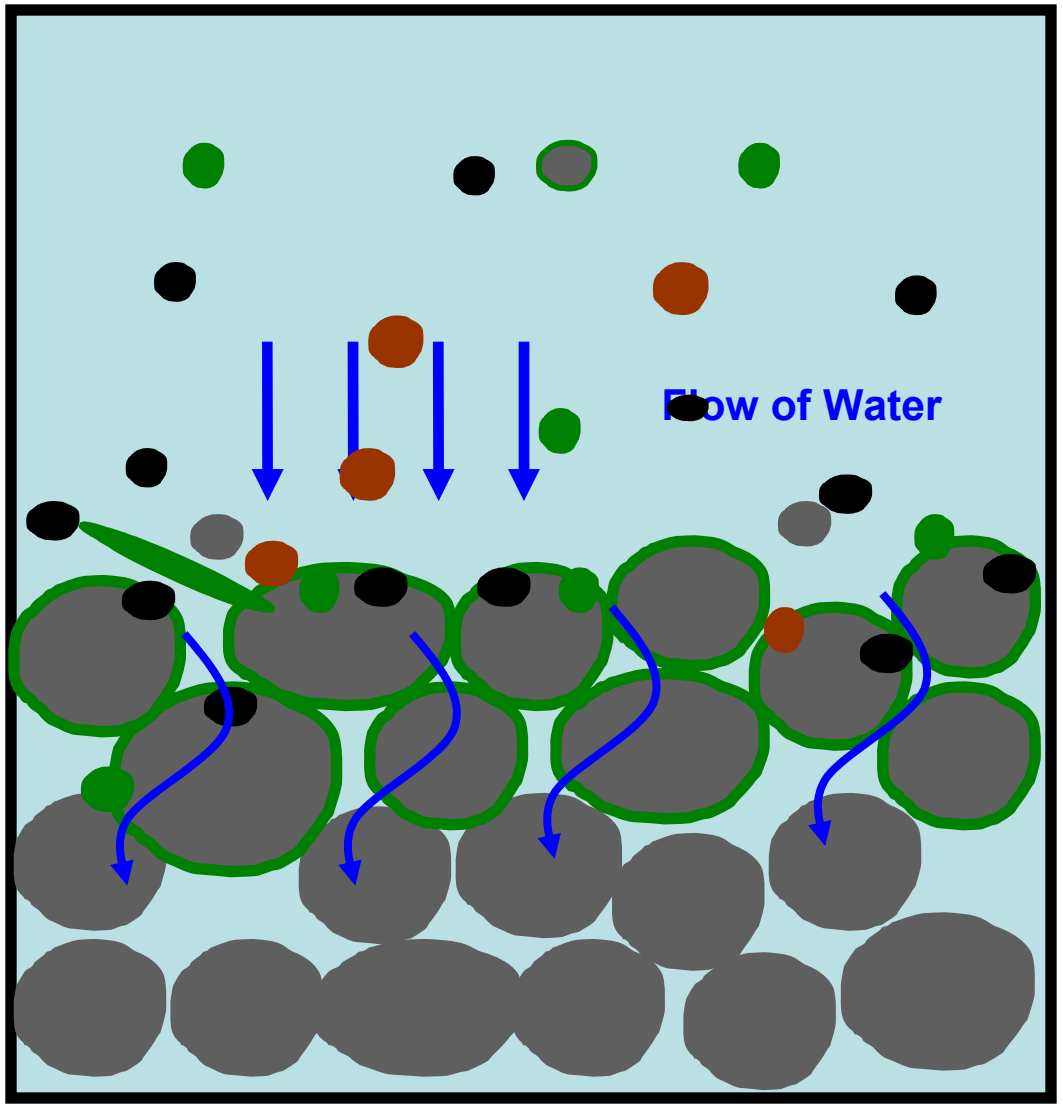


Biolayer (Mineral particles covered with a biofilm).

Formation of biofilm on the mineral particles is exactly the same as that observed in 'trickling filters' used for aerobic treatment of wastewater.

Operation of BSF.

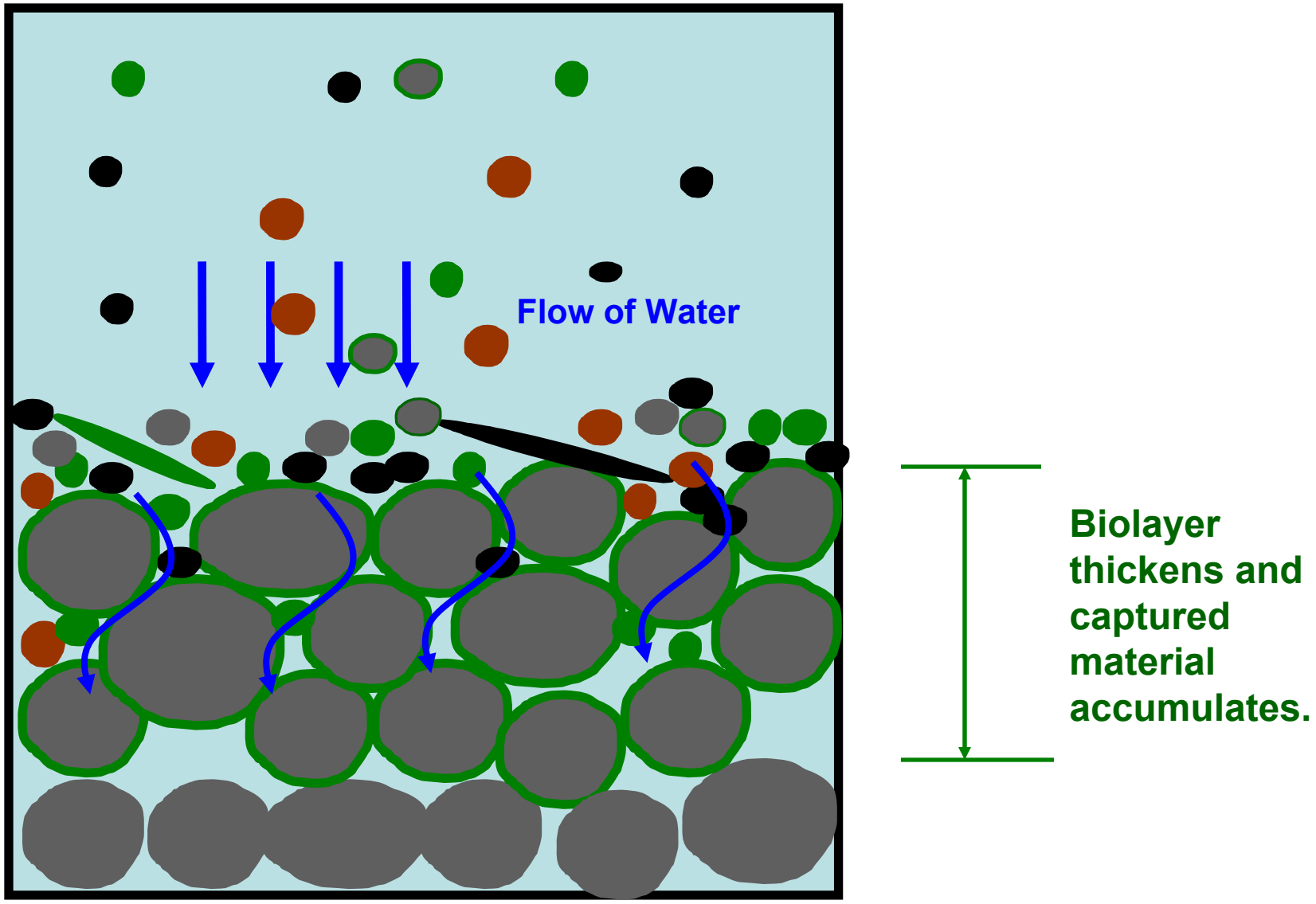
Biolayer thickens with use and time.



Biolayer thickens.

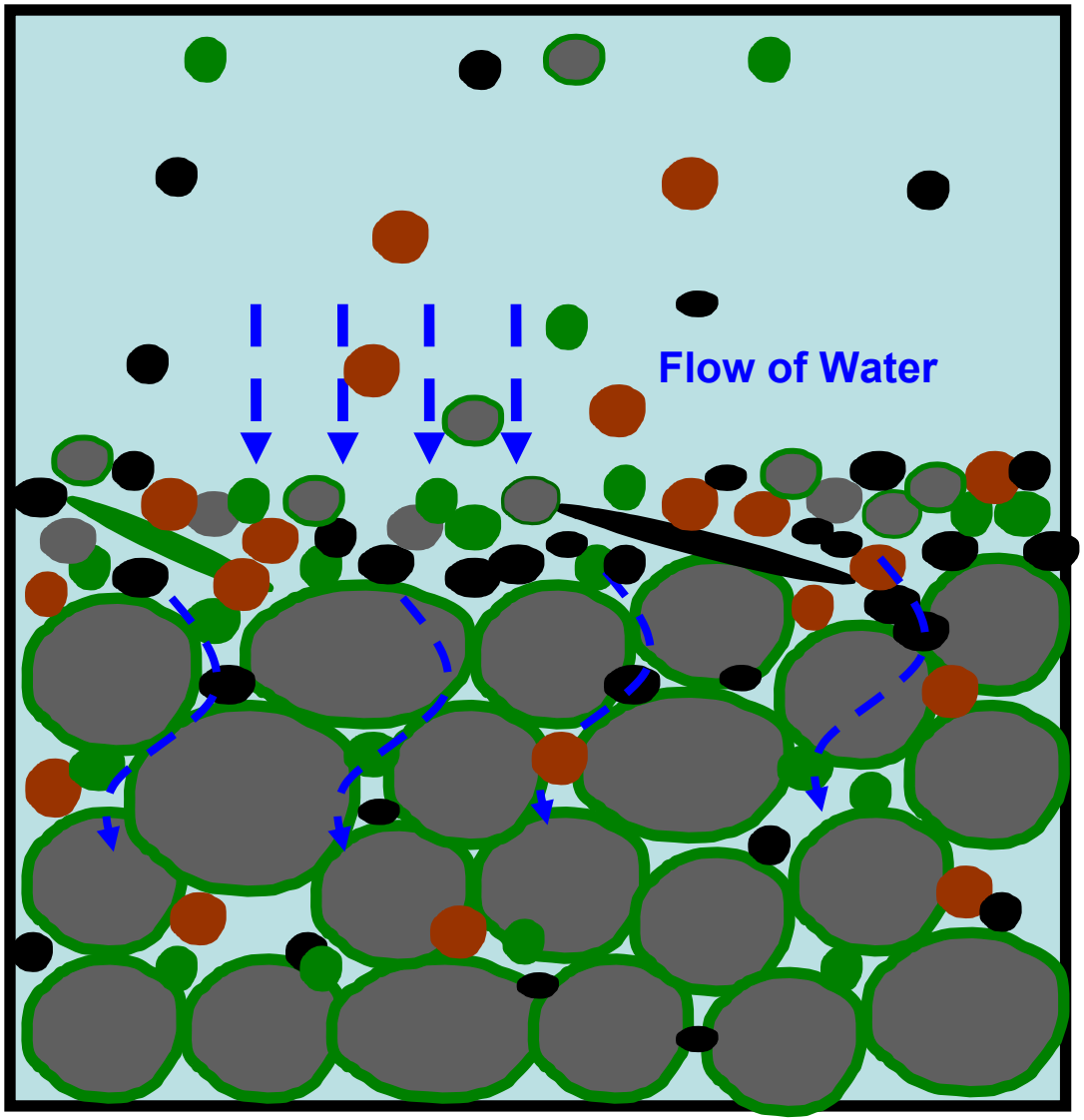
Operation of BSF.

Biolayer thickens with use and time.



Operation of BSF.

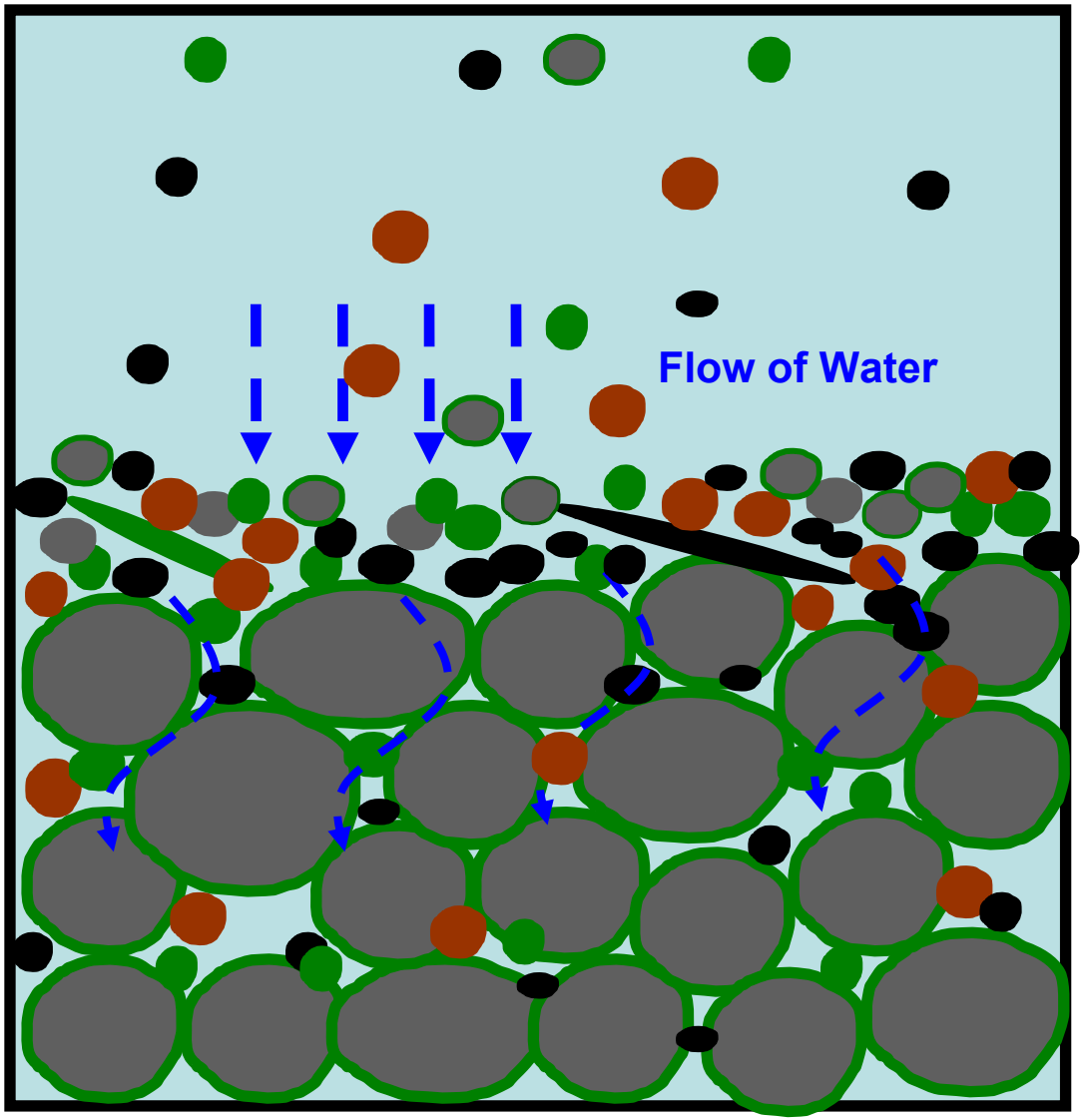
Biolayer thickens with use and time.



Biolayer thickens and captured material accumulates and starts to restrict flow.

Operation of BSF.

Biolayer thickens with use and time.

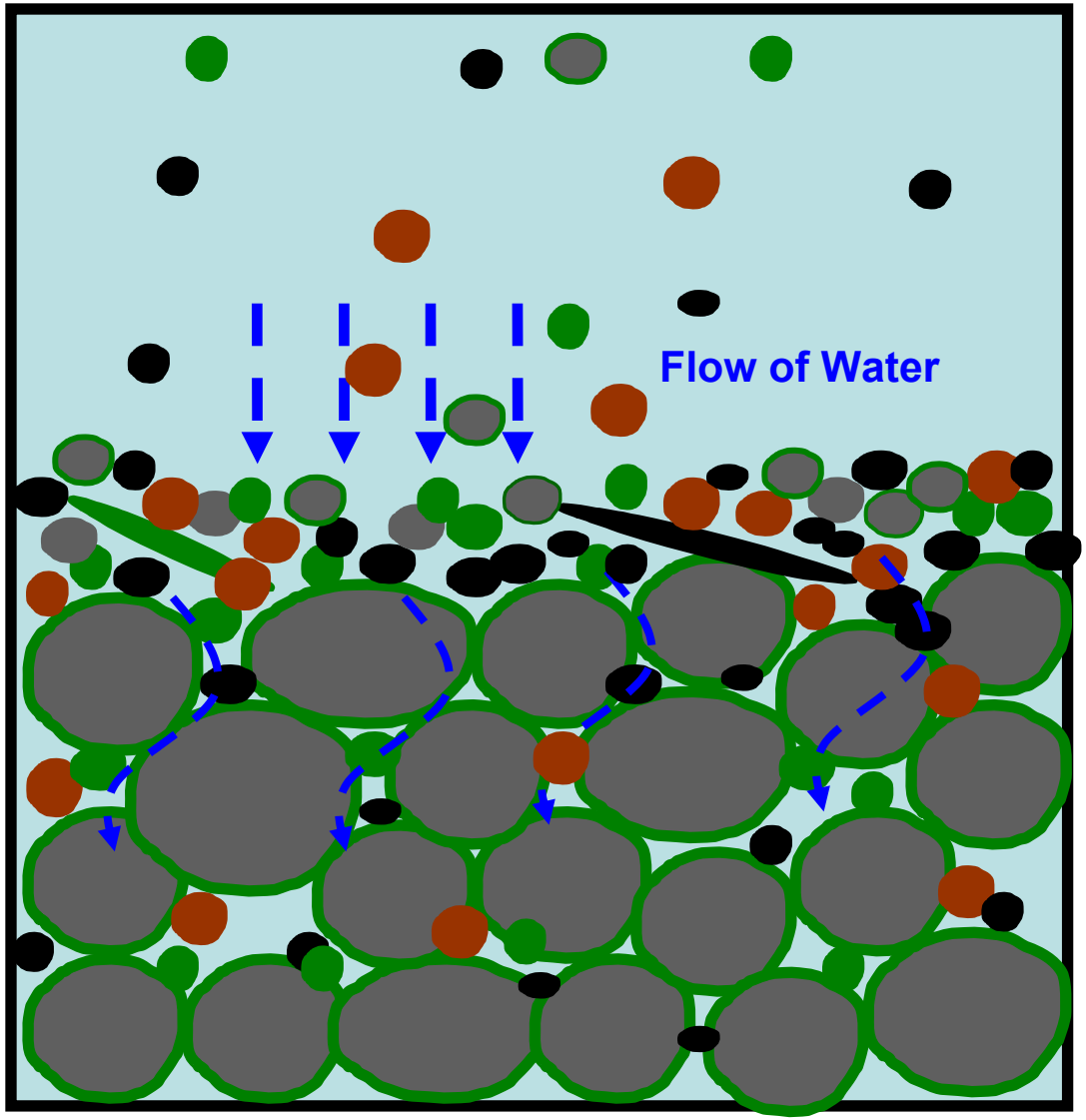


Formation of biolayer will depend on the ecology of the water being treated and the quantity of water being treated. The greater the concentration of aquatic life and the greater the quantity of water being treated the faster the biolayer will form.

Biolayer thickens and captured material accumulates and starts to restrict flow.

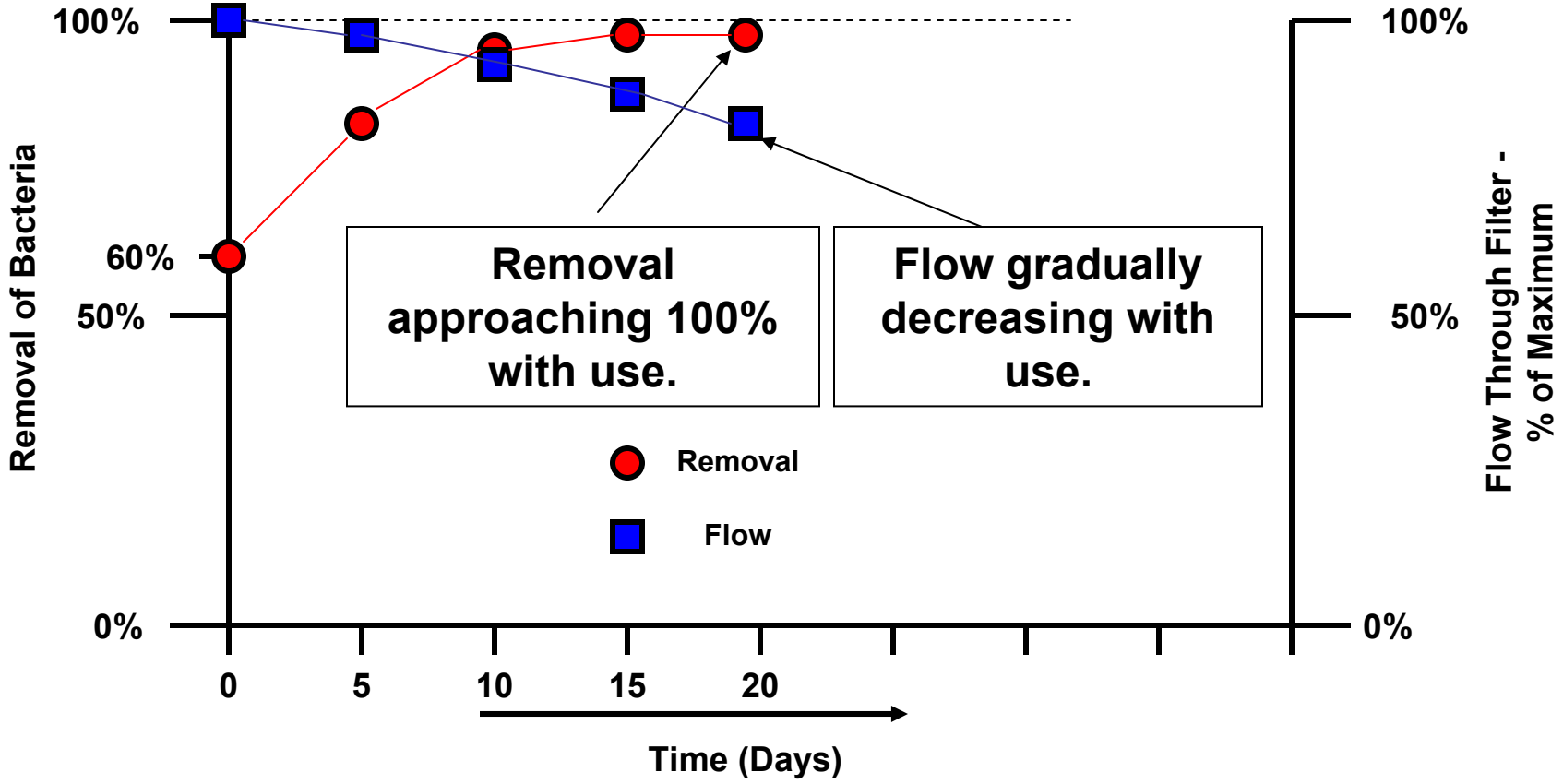
Operation of BSF.

Flow is unacceptably low and surface layer must be cleaned.

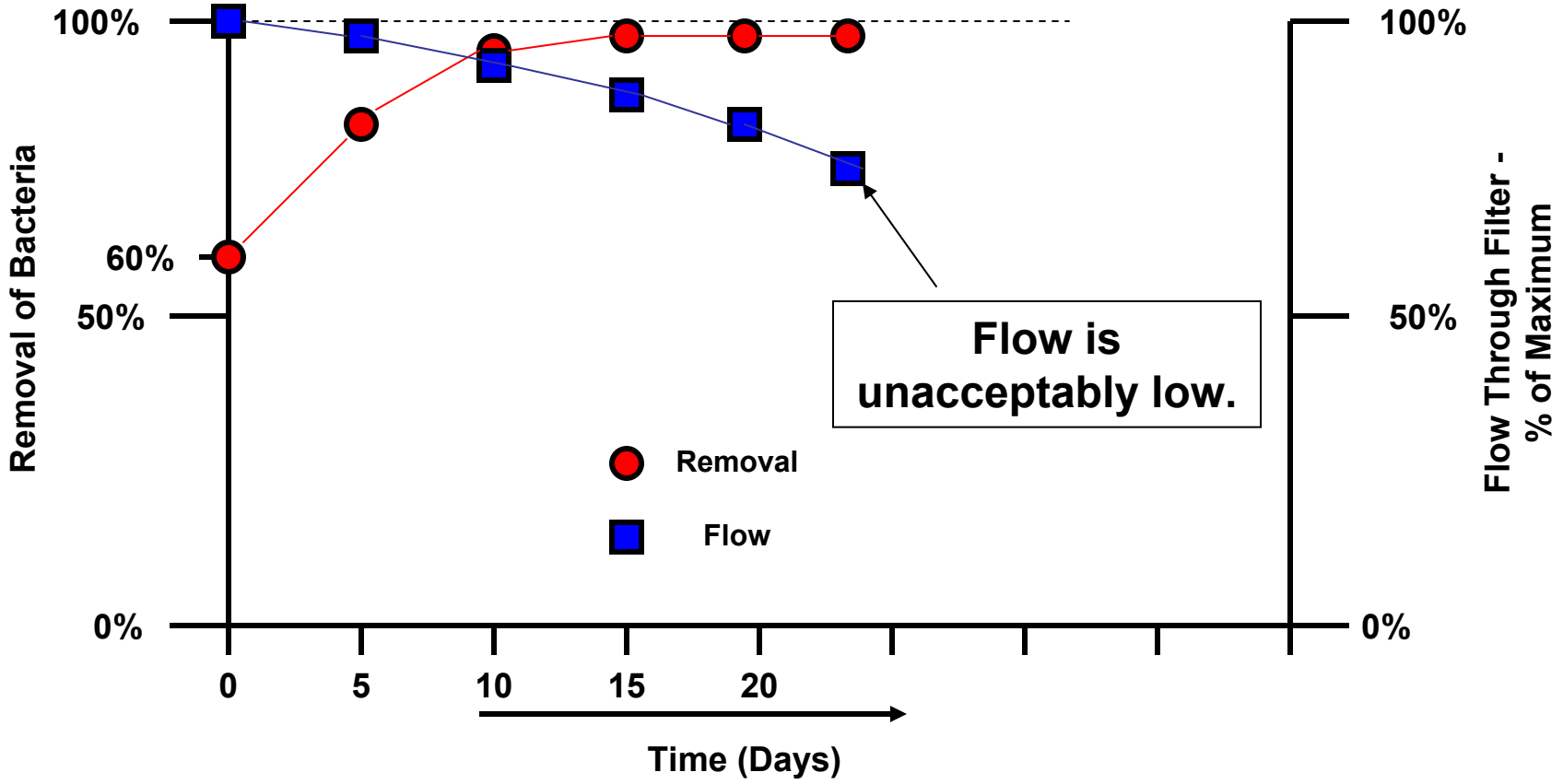


Cleaning the BSF will leave biolayer intact.

Typical Performance of a BSF Water Filtration Technology



Typical Performance of a BSF Water Filtration Technology



Cleaning and maintenance

TSSF: Up to 5 cm of the top sand must be removed each time the filter needs to be cleaned. Process is known as 'scraping'.

'Schmutzedecke' or 'surface biolayer' is removed and must be allowed to recover after each cleaning to restore effectiveness of bacteria and virus removal.

- **Cleaning requires a great deal of labour.**
- **Takes a long time to perform.**
- **Results in significant costs for replacement of the filtering media.**

BSF : Not scraped but cleaned-in-place.

'Surface biolayer' is left intact. Filter performance is never lost.

- **Media is manually cleaned without removal (clean in place).**
- **Media is never replaced – very low maintenance costs.**

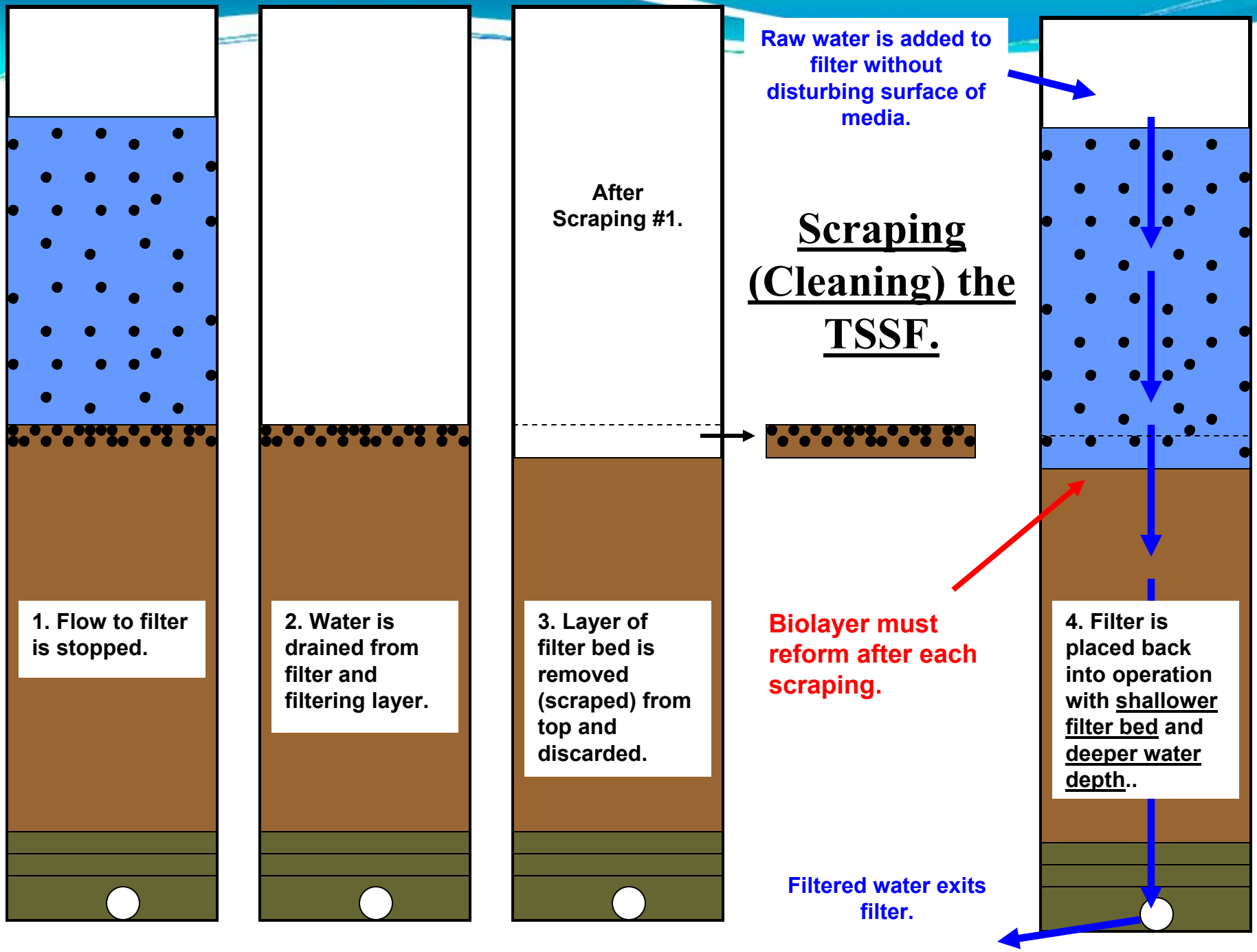
Normal Cleaning of TSSF.

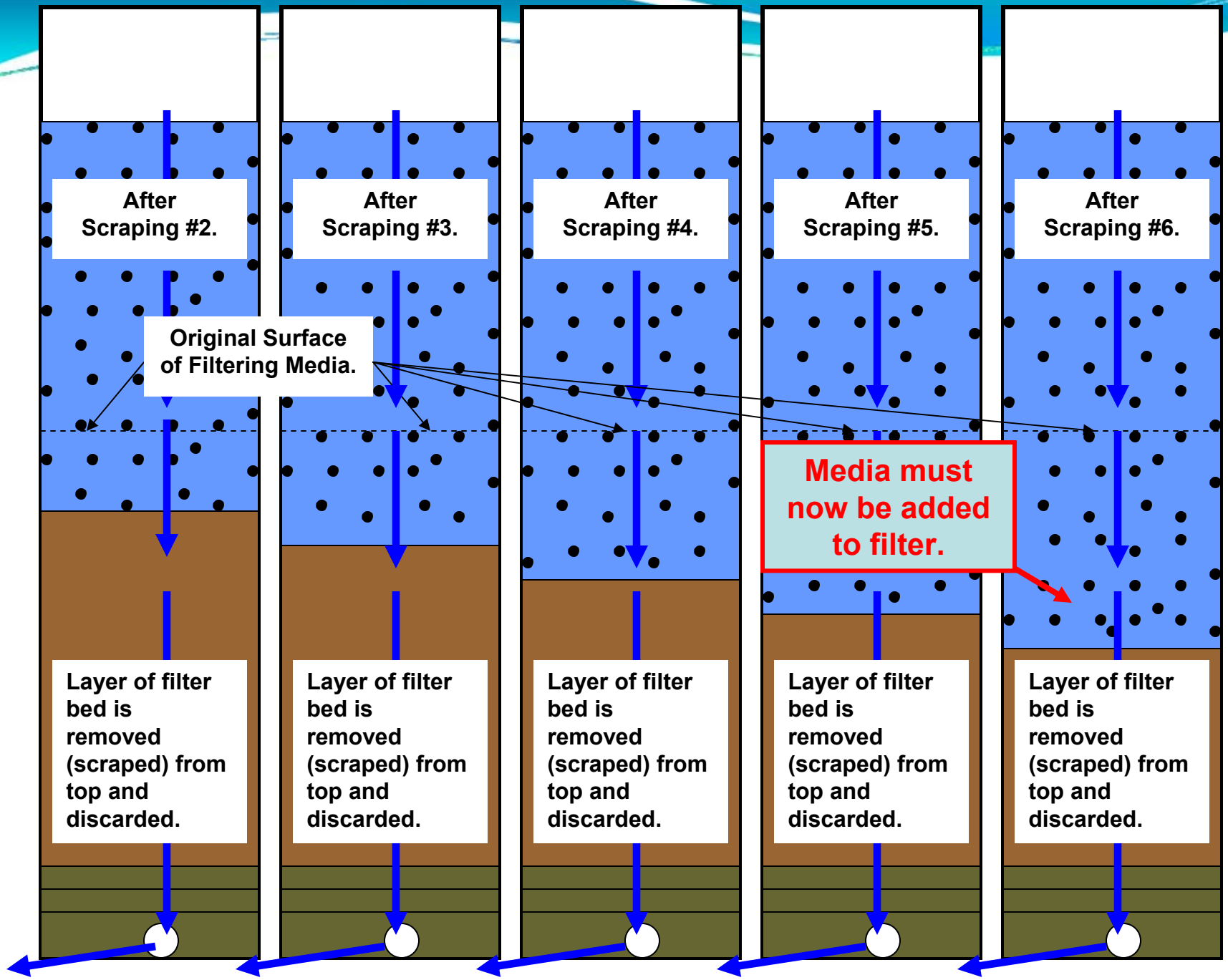
1. Filter is drained.
2. Up to 5 cm of media (including biolayer) is removed and discarded.
3. Filter is placed into operation. Biolayer will take several days to reform.

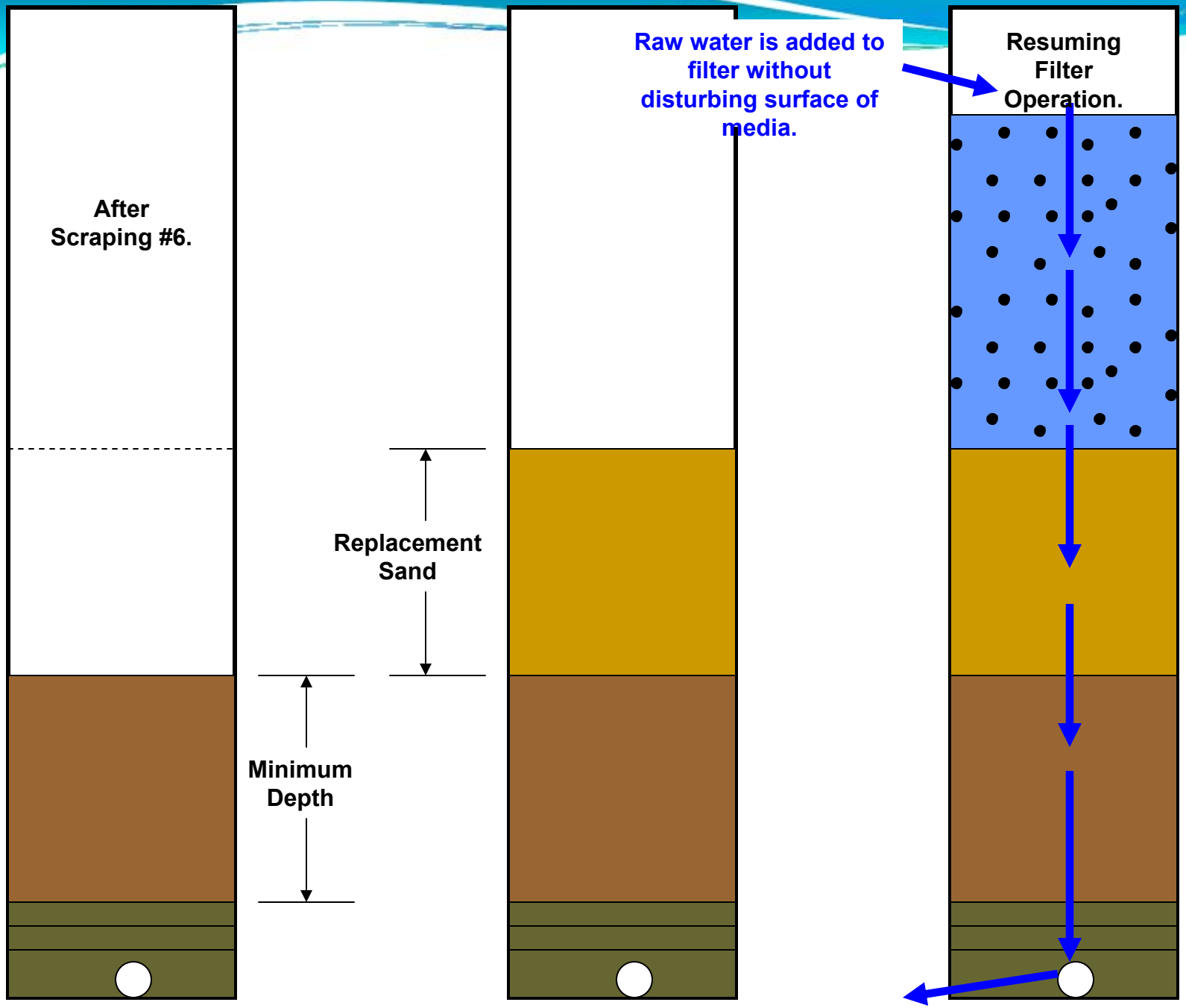
Entire cleaning process can take days to perform.

Ultimately new media will be added to filter.

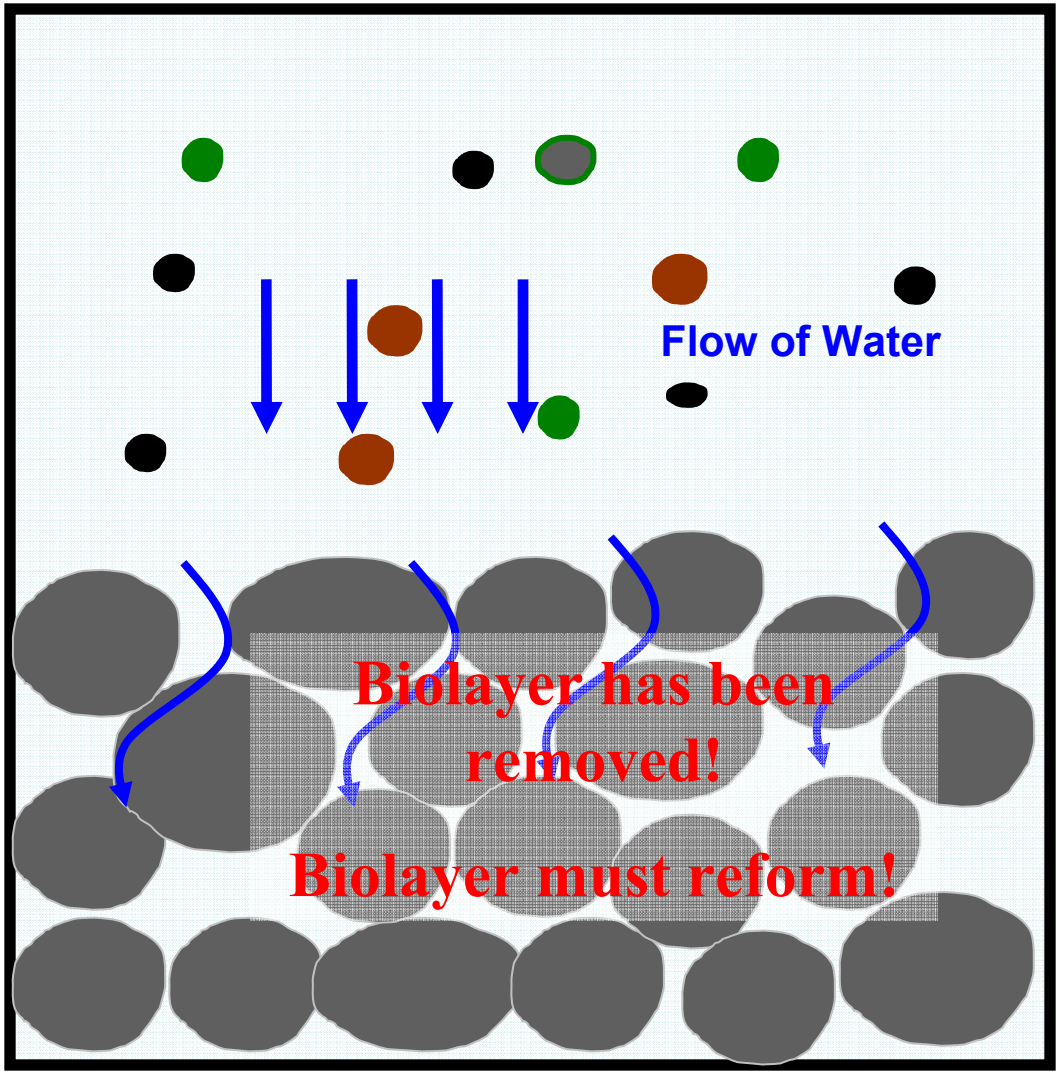
Scraping (Cleaning) the TSSF.




After Scraping #2.
After Scraping #3.
After Scraping #4.
After Scraping #5.
After Scraping #6.
Original Surface of Filtering Media.
Media must now be added to filter.
Layer of filter bed is removed (scraped) from top and discarded.
Layer of filter bed is removed (scraped) from top and discarded.
Layer of filter bed is removed (scraped) from top and discarded.
Layer of filter bed is removed (scraped) from top and discarded.
Layer of filter bed is removed (scraped) from top and discarded.


After
Scraping #6.
Replacement
Sand
Minimum
Depth
Raw water is added to
filter without
disturbing surface of
media.
Resuming
Filter
Operation.

TSSF After Cleaning (Scraping)

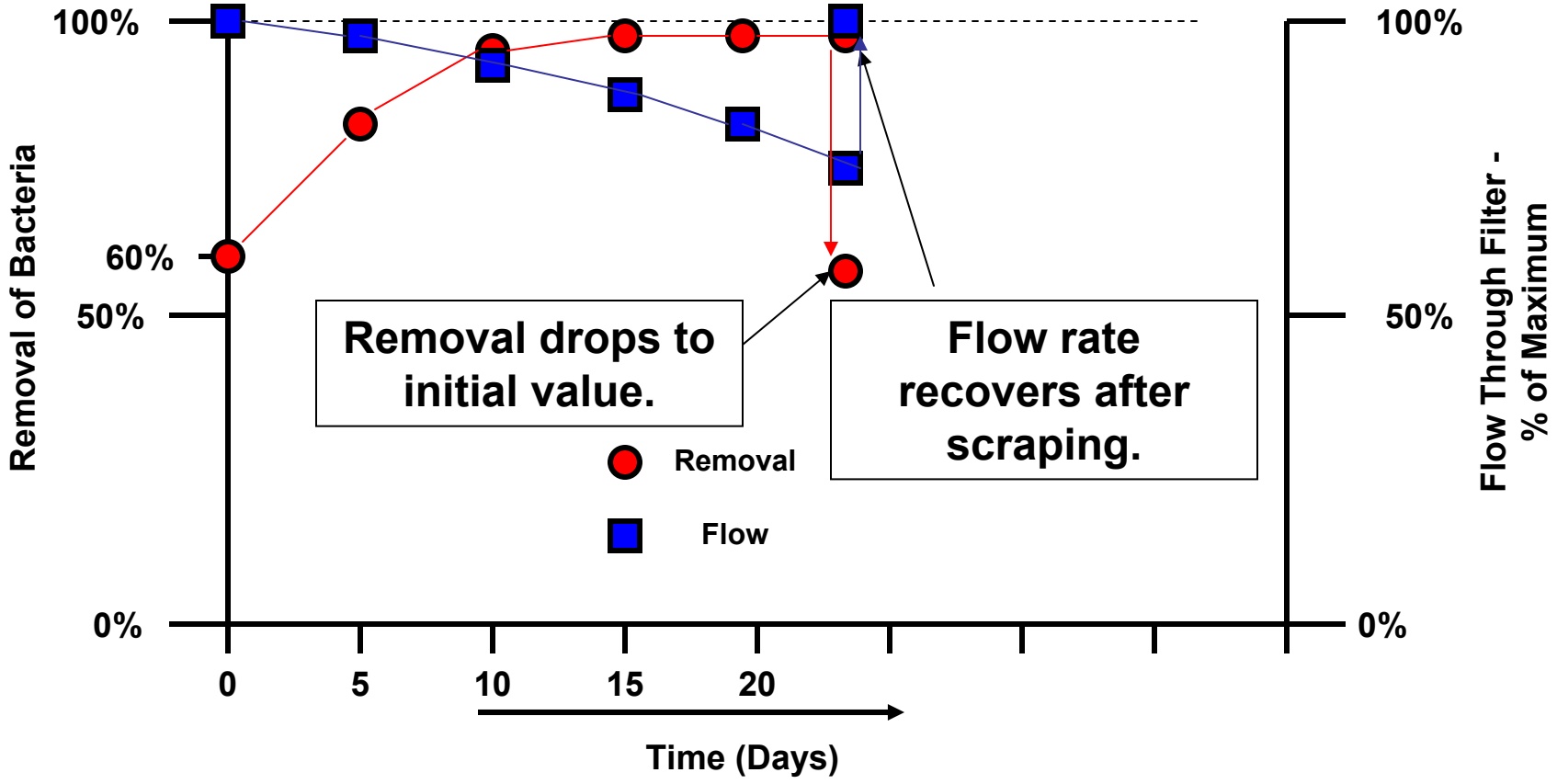


Media particle without surface biofilm.

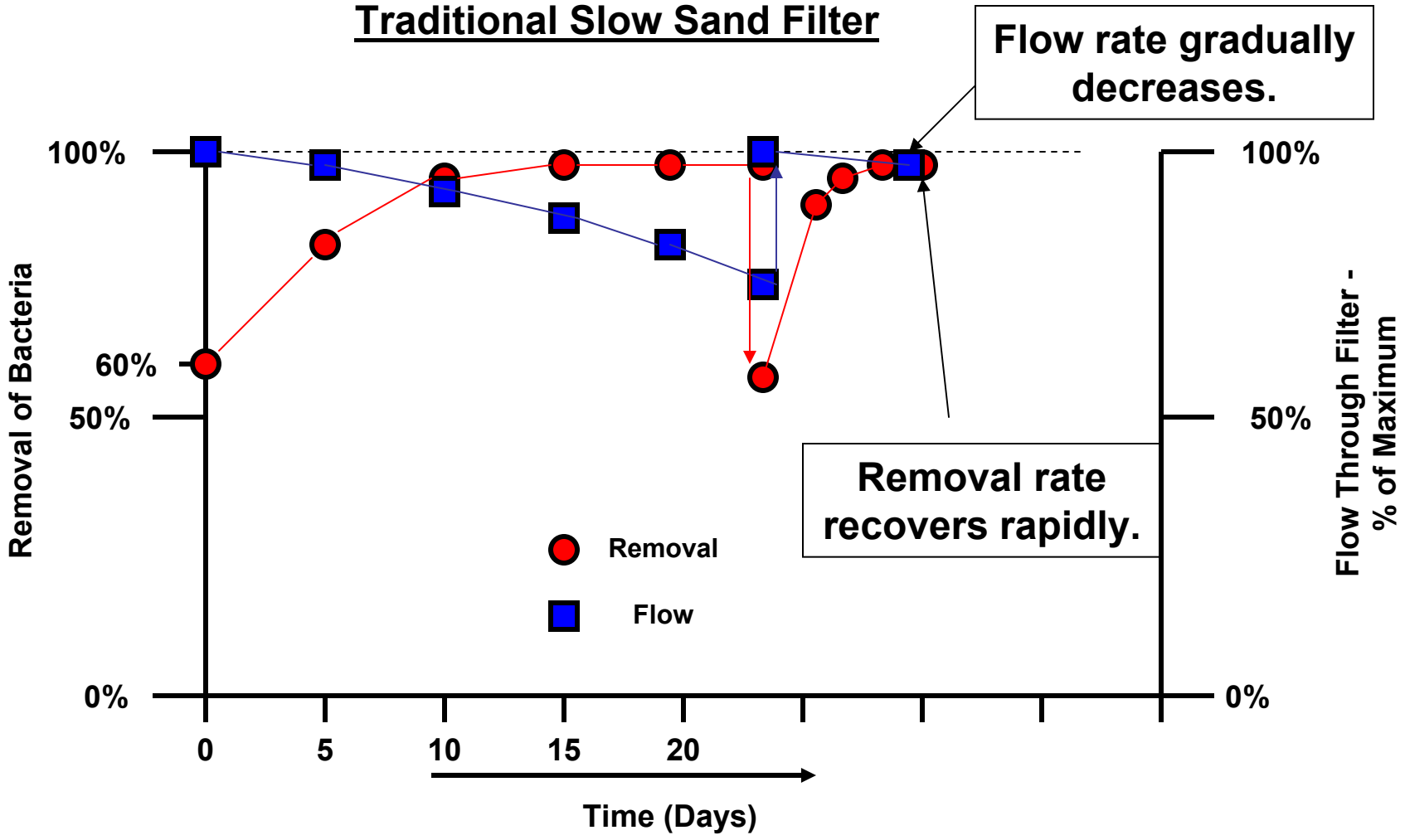
Other mineral and organic particles or flocs of particles.

Also includes large living organisms such as algae, helminthes and the cysts of parasites.

Typical Performance of a Traditional Slow Sand Filter



Typical Performance of a Traditional Slow Sand Filter



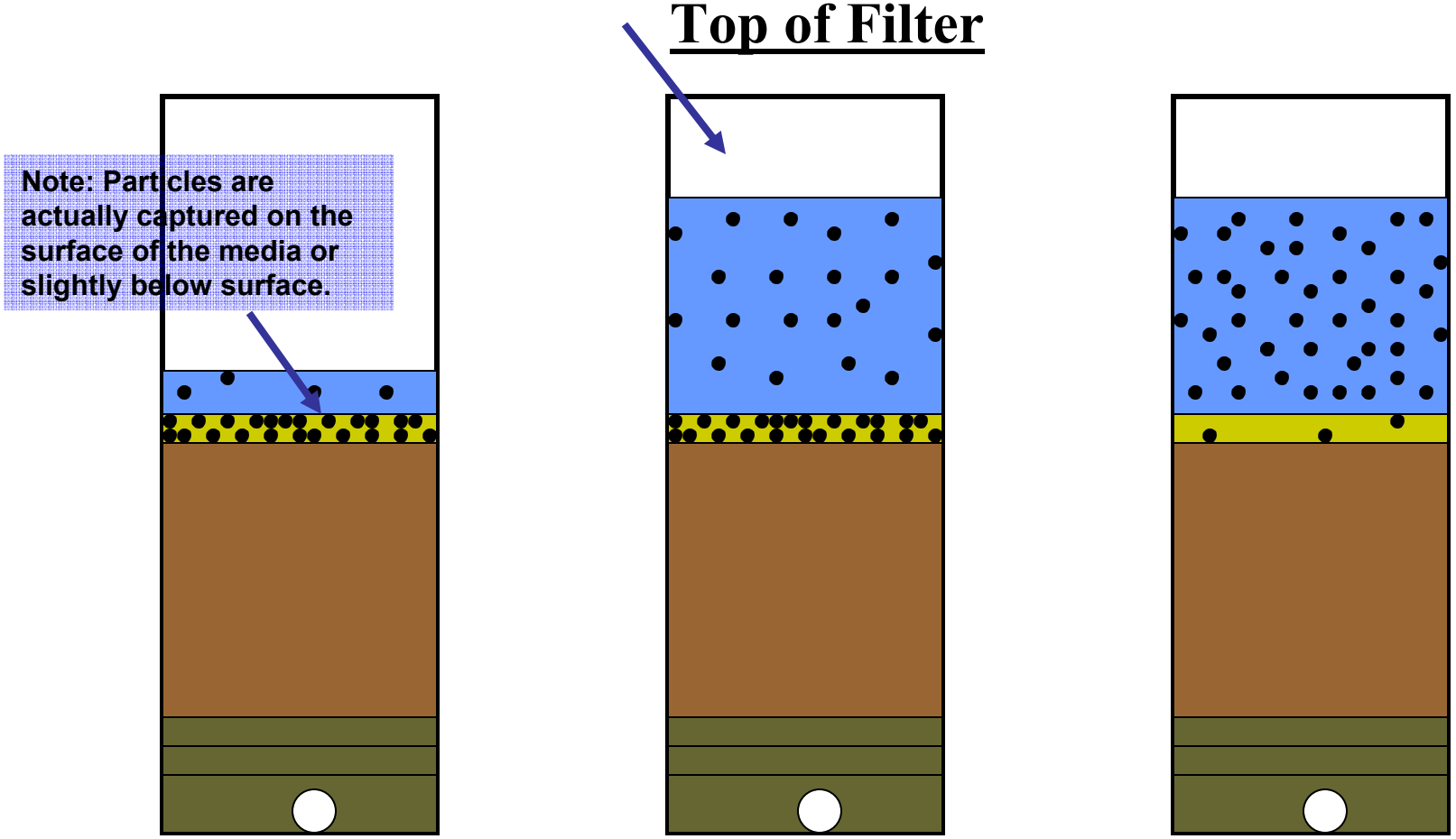
Normal Cleaning of BSF.

1. Untreated water is added to top of filter.
2. Surface of media is agitated to suspend captured particles.
3. Water containing captured particles is removed.
4. Biolayer is not removed and does not need to reform.

Entire cleaning process takes less than 10 minutes.

No media is removed or needs to be replaced.

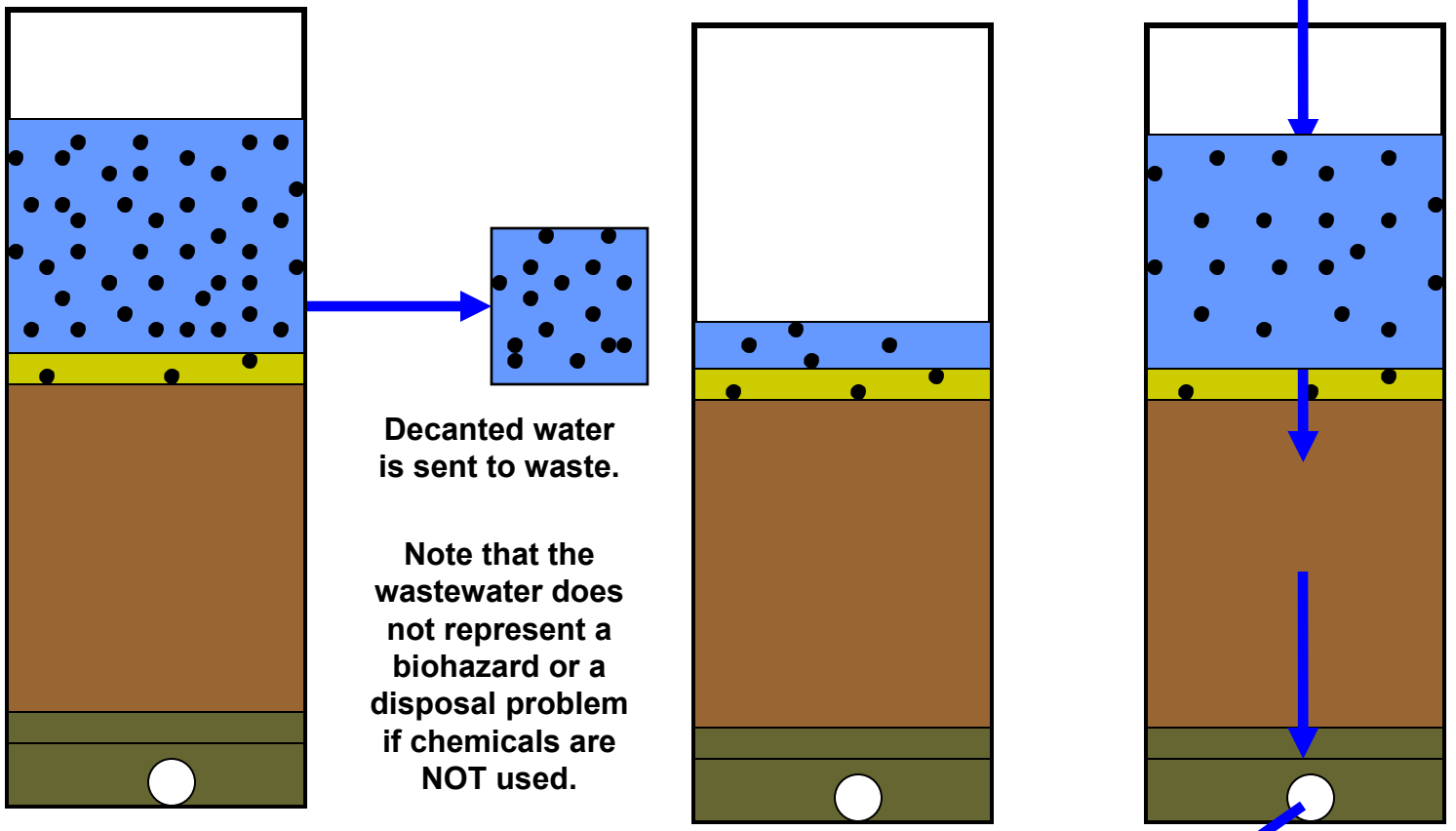
Normal Cleaning the BSF – Raw Water Added to Top of Filter



Water level in filter is at the paused depth – could be at any depth.

Untreated water is added until there is at least 0.2 to 0.3 m of depth above top layer of media.

Surface of top layer of media is agitated. This action suspends most of the captured particles.



Water containing all of the captured media is decanted from filter surface.

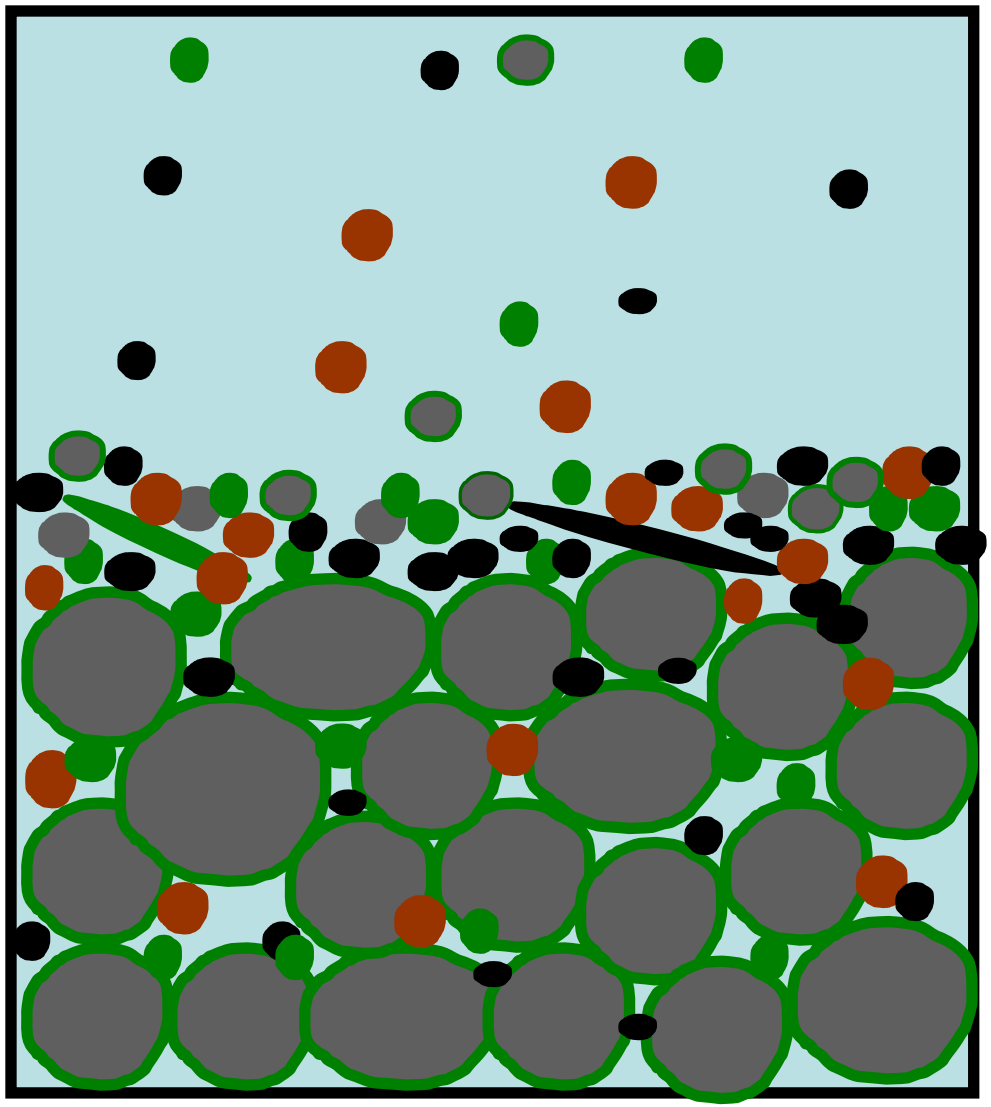
Decanted water is sent to waste.

Note that the wastewater does not represent a biohazard or a disposal problem if chemicals are NOT used.

All water is decanted. Note that captured particles cannot penetrate below top layer of media.

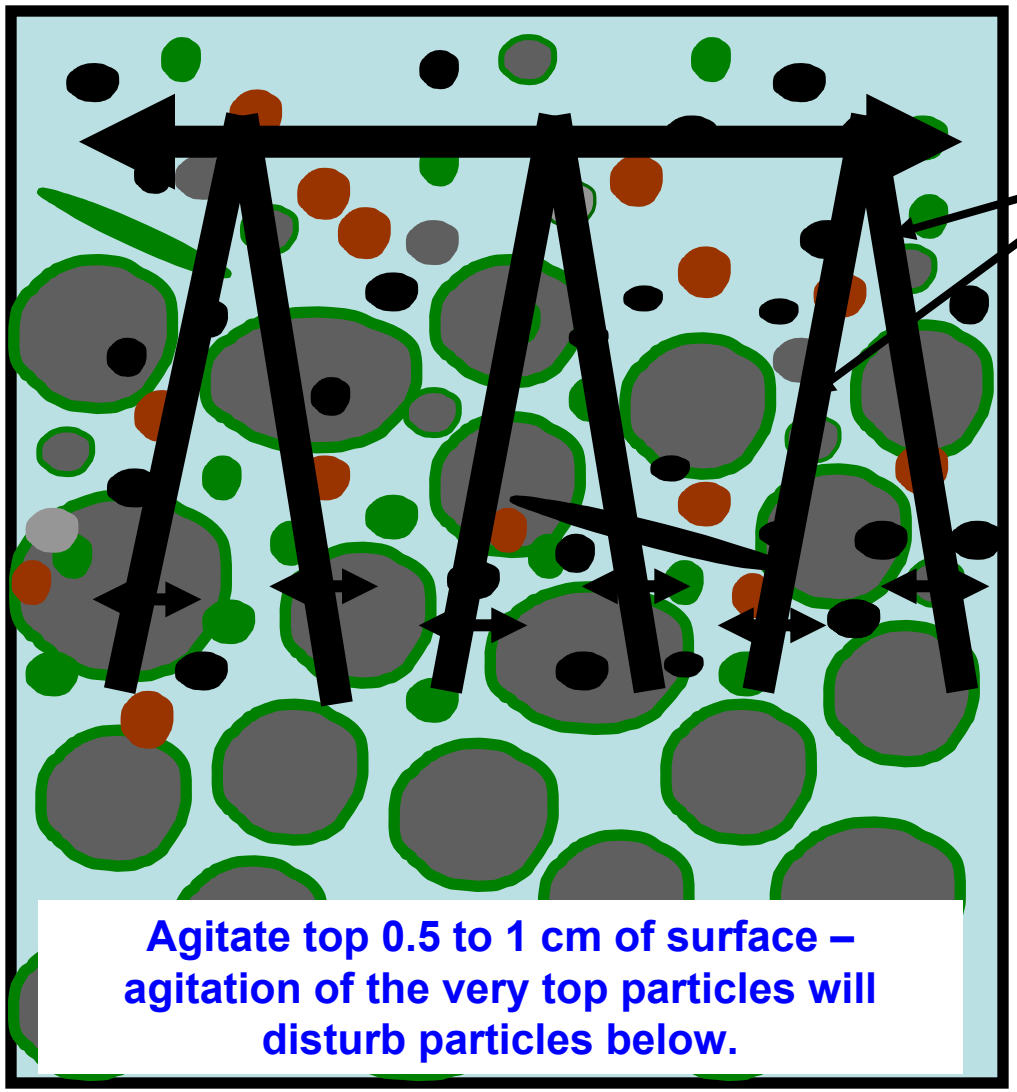
Filter can be put into production immediately after backwashing.

Normal Cleaning the BSF.



If the water in the filter has been lowered to the paused depth (5 cm) additional untreated water should be added from the top through the diffuser.

Normal Cleaning the BSF.



Agitate top 0.5 to 1 cm of surface – agitation of the very top particles will disturb particles below.

Wire 'fingers' or real fingers used to agitate very top of filtering media where the particles restricting flow are located.

Surface agitation should NOT be confused with 'harrowing' used to extend period between cleanings of TSSF. Harrowing a BSF will seriously impair performance.

Note on Harrowing.

The purpose of 'harrowing' a TSSF is to extend the period between scrapings. Harrowing the surface of a TSSF (using a device that resembles a rake) is used to remove the organic accumulation on the surface of the media. The fingers of the 'harrow' might penetrate the surface of the media (less than 5 cm) with some mixing. Because the flow through a TSSF is continuous and the flowing water contains ample oxygen the now deeper layer of media containing significant organic matter is always aerobic. Eventually, the TSSF will need to be scraped. Harrowing a TSSF is an accepted practice.

A BSF is designed to be operated on an intermittent flow basis – on demand. When the flow is stopped oxygen can only reach the biolayer by diffusing through the paused water. If a BSF was harrowed the media particles coated with a biofilm and much of the organic accumulation on the media surface would be mixed into the surface of the media similar to a harrowed TSSF.

Note on Harrowing – cont'd.

Unfortunately, oxygen cannot reach the now buried organic matter – biofilm or other organic material and this region will likely become anaerobic when the flow through the filter is stopped. The expected effects are:

- By-products of anaerobic decomposition are created causing some objectionable odor, color and taste. By-products of anaerobic decomposition might impair viability and performance of the biolayer. The ability of the filter to remove bacteria and viruses might be impaired.

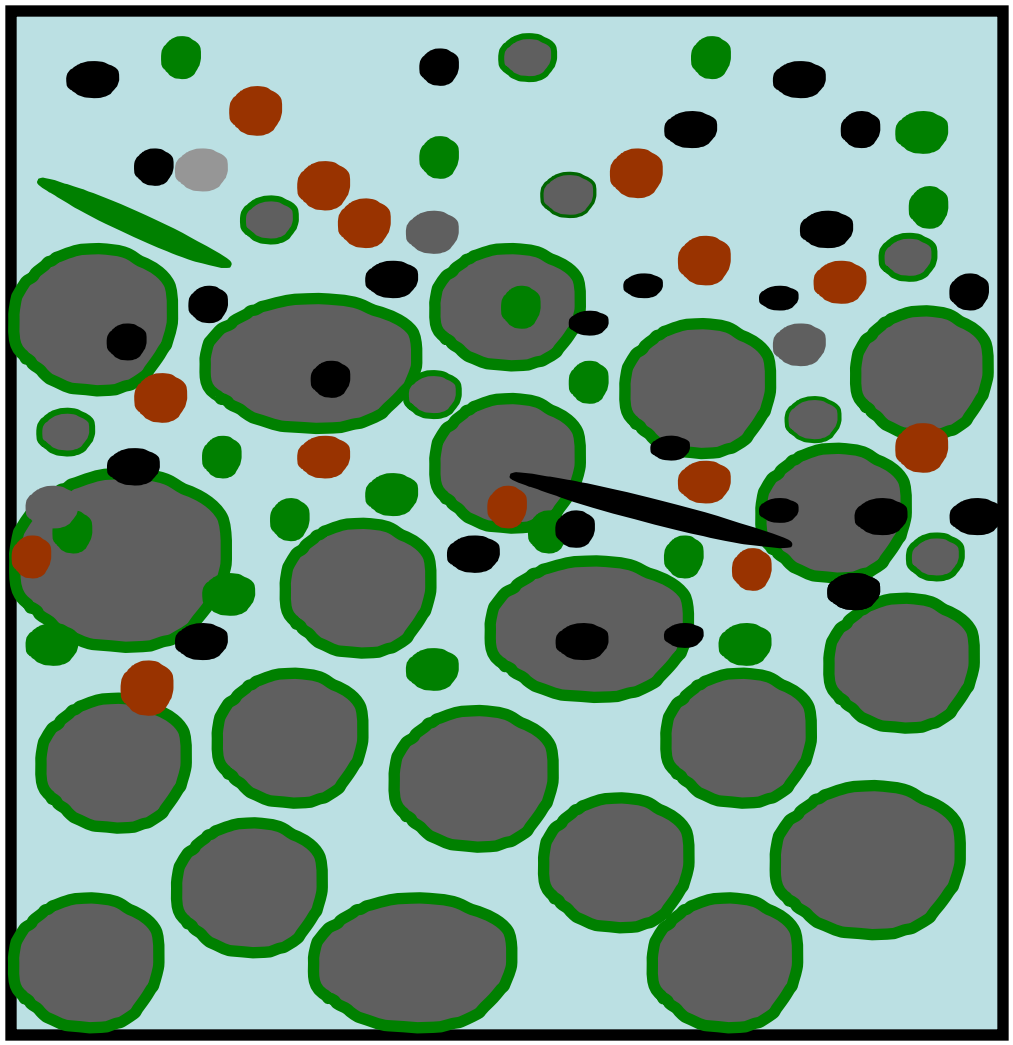
- Colonization of the organic matter with bacteria typical of human digestive systems (which can survive in both aerobic and anaerobic conditions). The effect of this can be recontamination of the water after passing through the surface biolayer. These bacteria will not survive as they are pushed further into the filter provided the filter was constructed using media that was not contaminated. Continuous operation of the BSF would not be possible – in fact it would appear the only one volume of pore spaces in the media could be treated at a time. It would appear that the filter required a 'rest' to do its job.

Note on Harrowing – cont'd.

- Destruction of the biolayer after each harrowing requiring that the biolayer reform, a process that might require several days.
- Requirement to frequently remove upper levels of media for thorough cleaning.
- Eliminate the practicality to treat very turbid water, use of coagulants or water containing higher concentrations of iron or other particles.

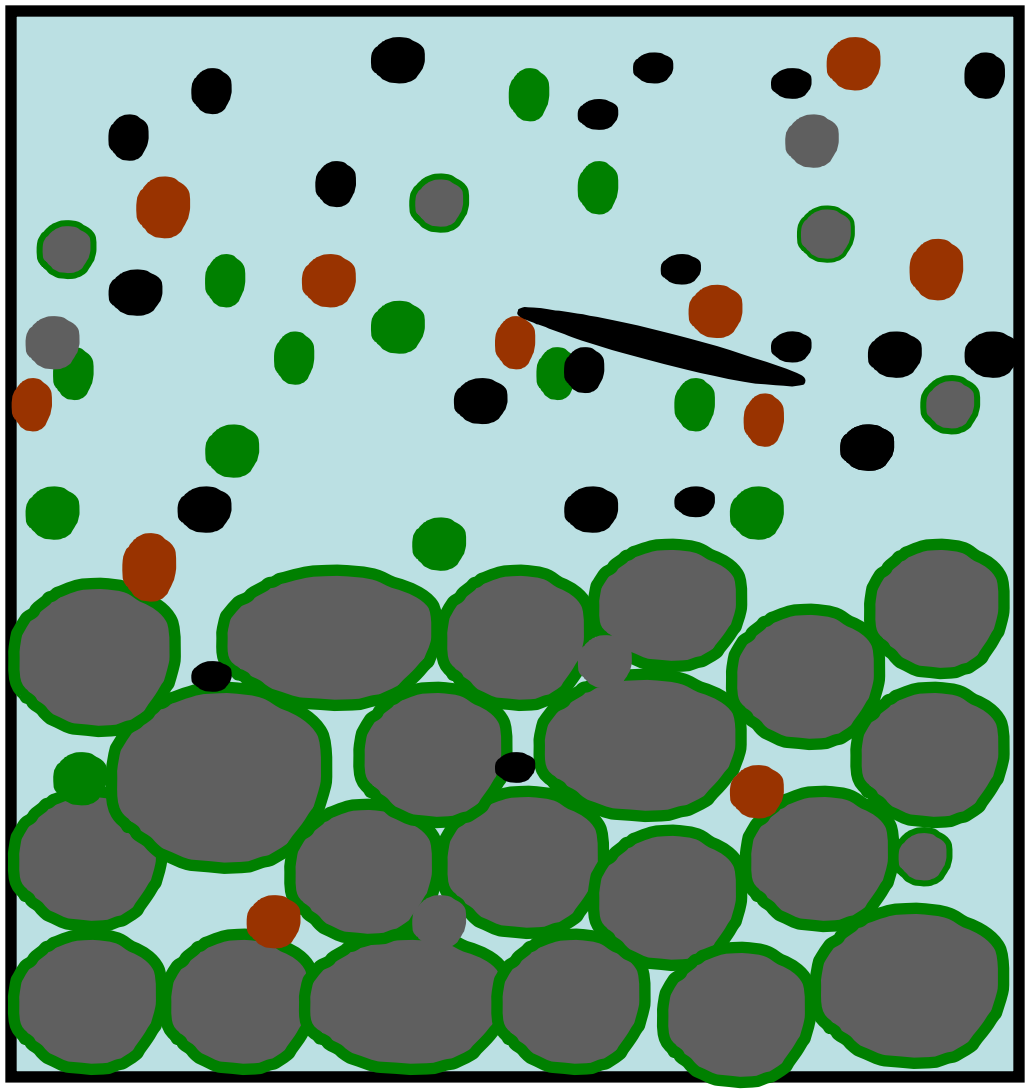
It is obvious that BioSand Filters should NOT be harrowed! They should be cleaned.

Normal Cleaning the BSF.



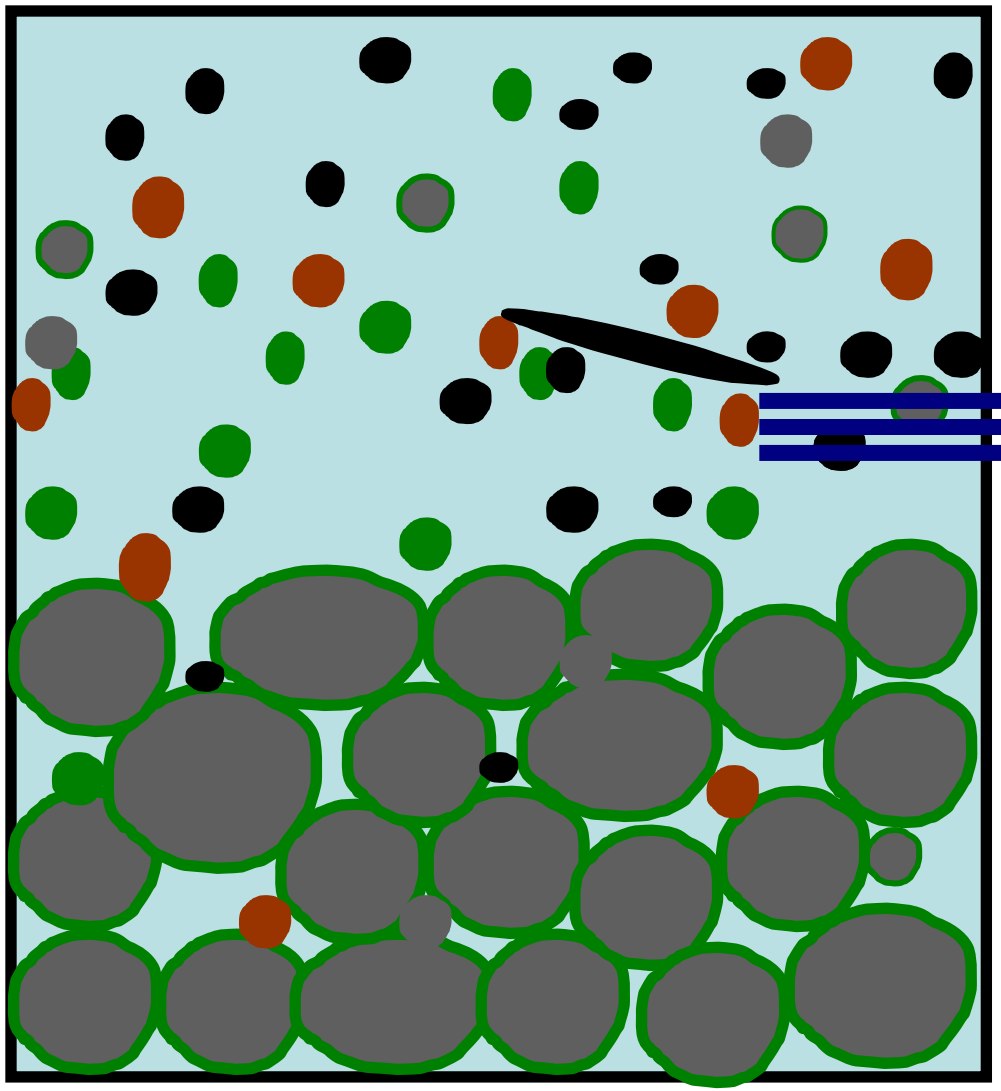
Agitation will continue until most of the particles are suspended in water above the media. This will take ½ minute or so.

Normal Cleaning the BSF.



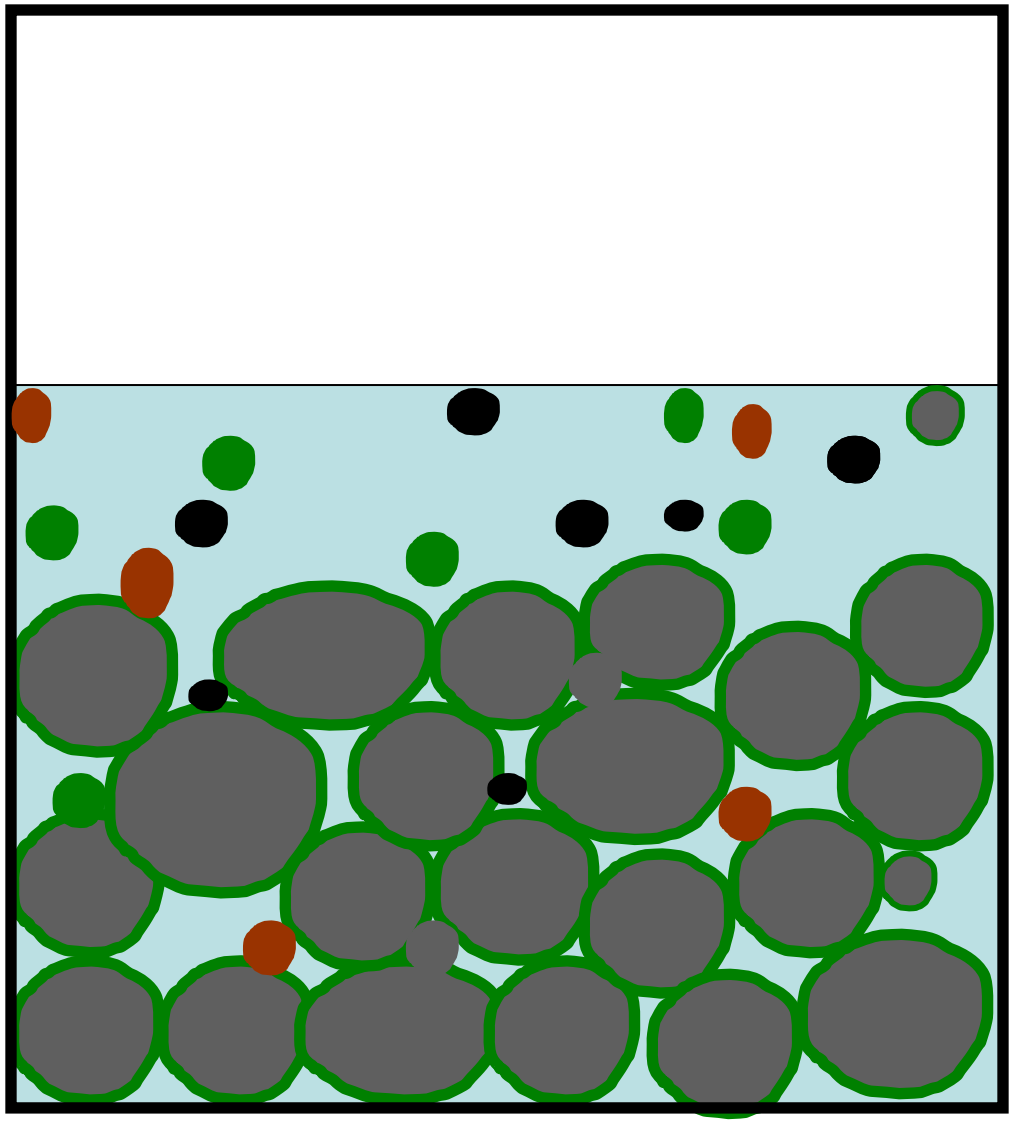
When the agitation is stopped, the media particles coated with a biofilm will settle back into place. The previously captured particles will remain suspended in water above top of media.

Normal Cleaning the BSF.



Decant water containing suspended particles.

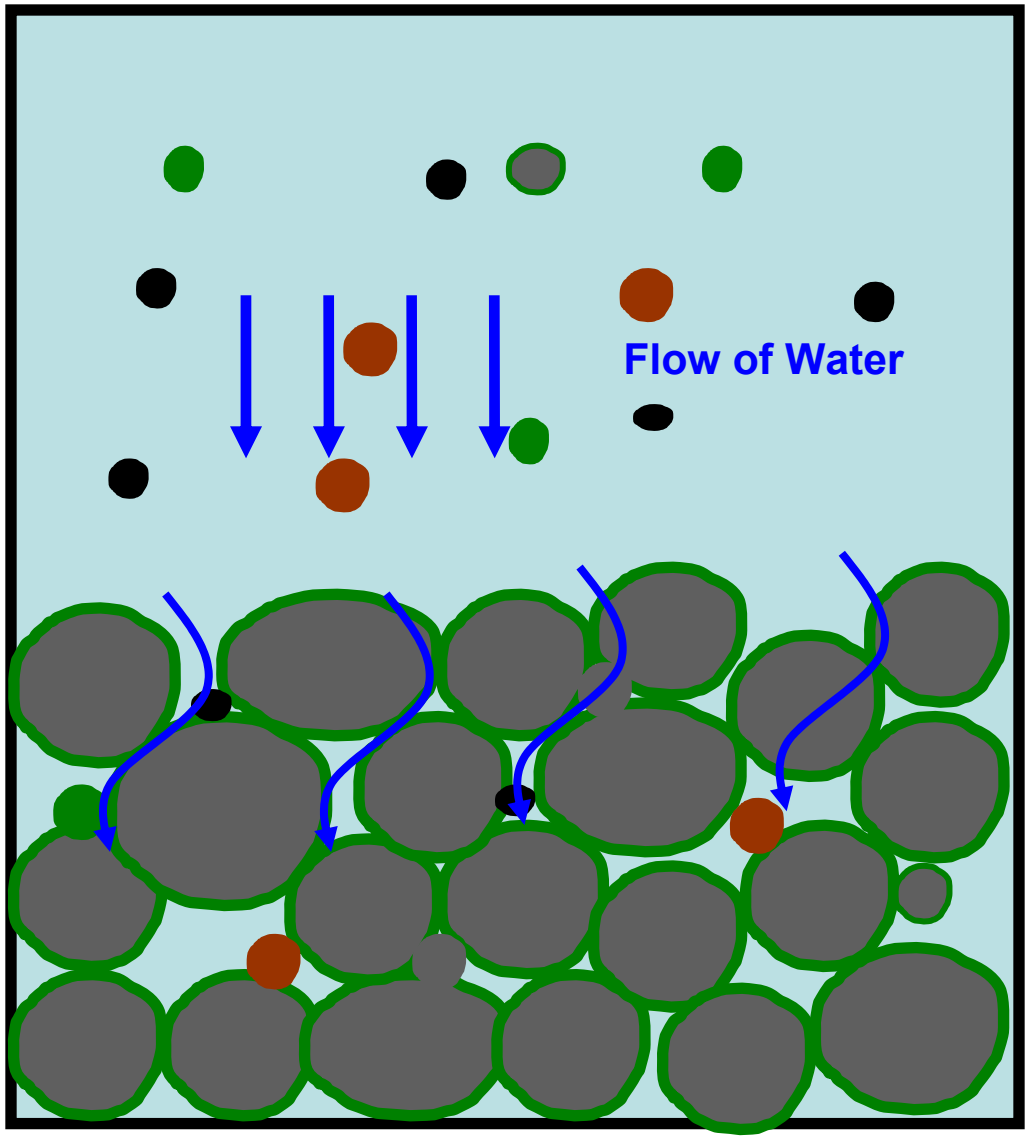
Normal Cleaning the BSF.



Decant is complete.

Diffuser is replaced.

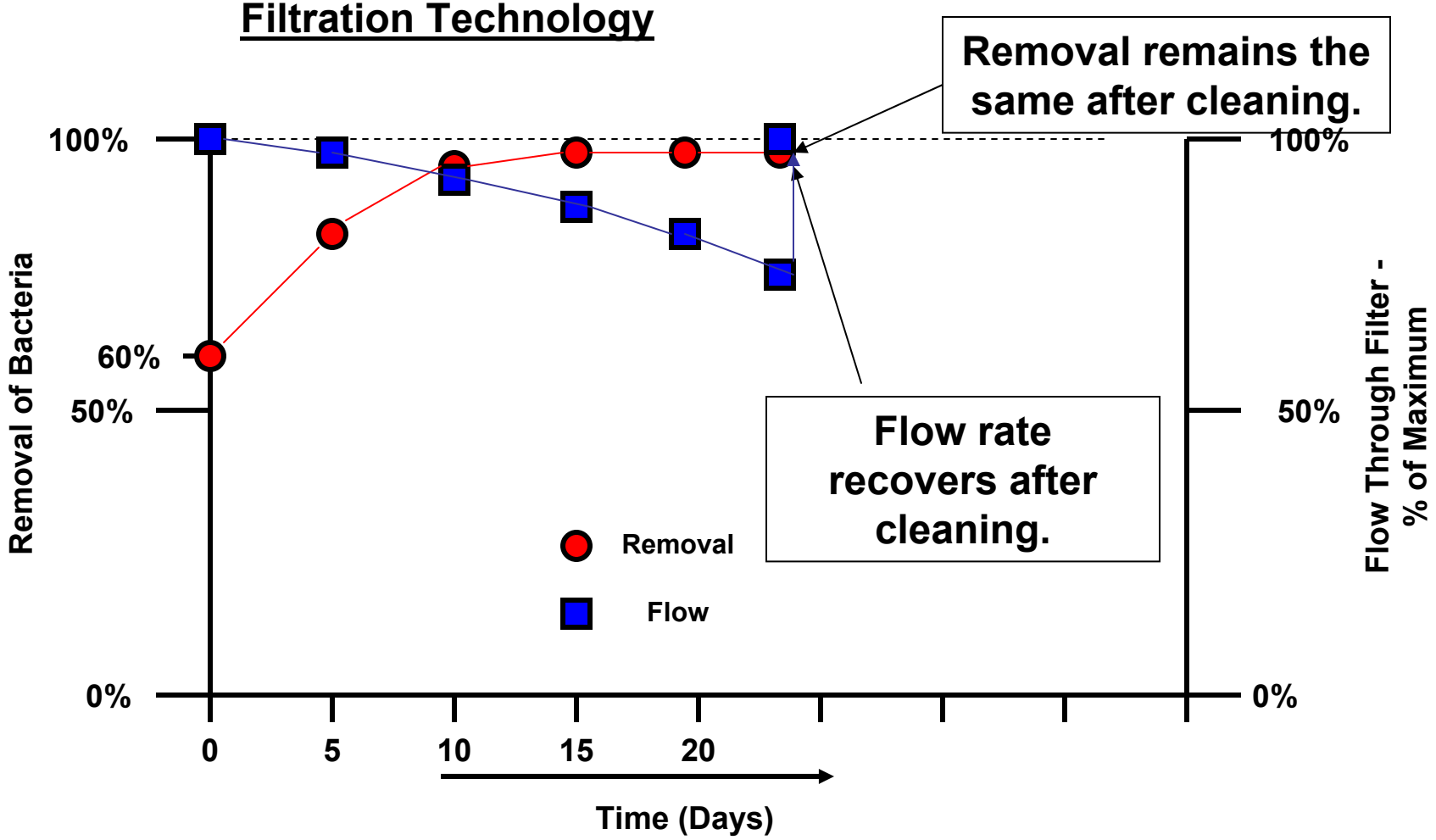
Normal Cleaning the BSF.



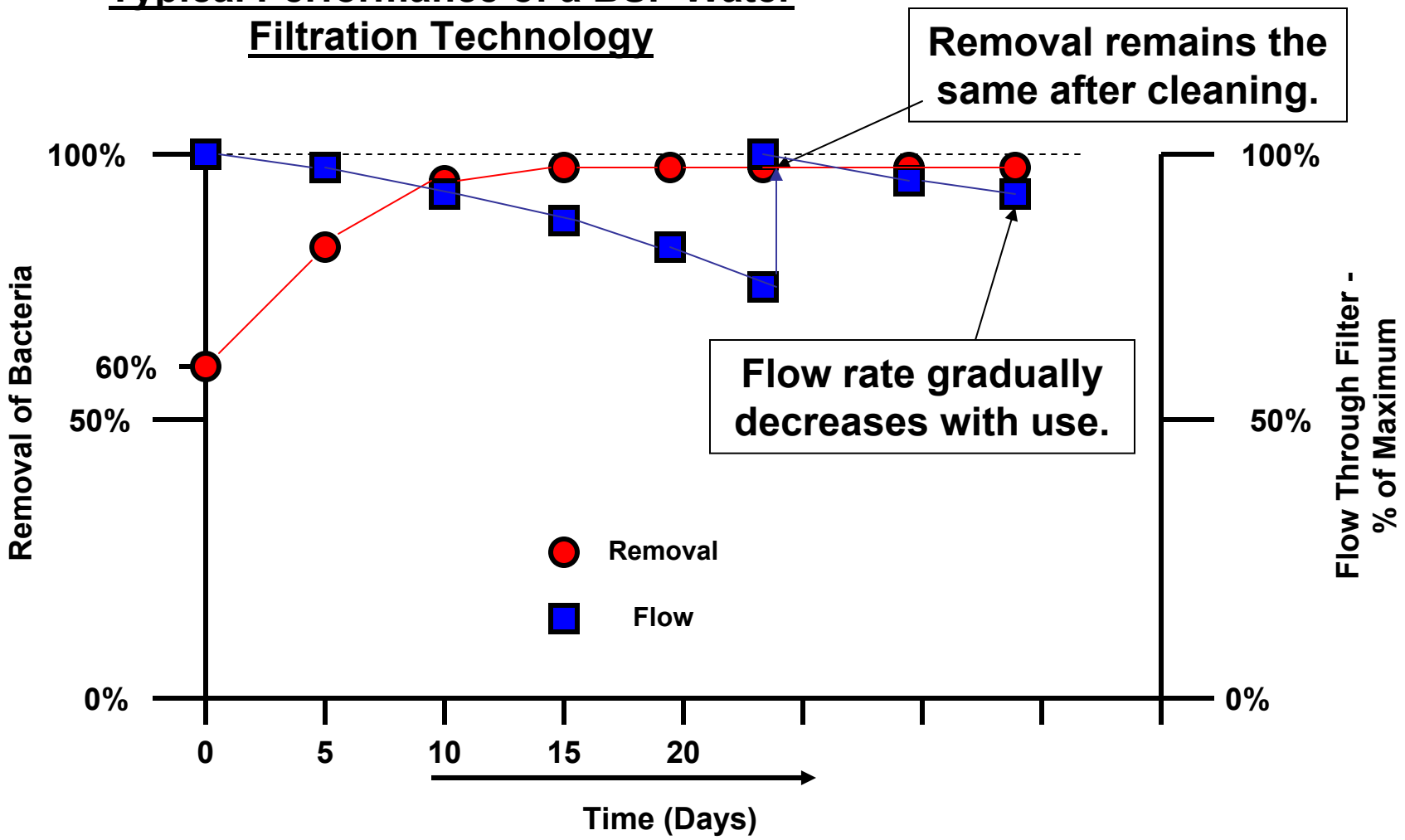
Resume filtration of water.

Biolayer has NOT been removed and does not need to reform!

Typical Performance of a BSF Water Filtration Technology



Typical Performance of a BSF Water Filtration Technology



Note: Unlike other water filtration technologies, cleaning of the BSF produces very little waste water. Normal cleaning may be performed with untreated water.

BSF technology requires very little energy to operate (energy efficient).

Use of chemicals:

Treatment of water using BSF treatment technology may be enhanced by using very small quantities of chemicals (coagulants). Waste water may be reclaimed if necessary.

In contrast the TSSF technology CANNOT be used with chemicals because of the cost of cleaning.

Other filtration methods, rapid sand and pressure sand, are used with large scale settling basins or clarifiers and use very large amounts of chemicals.

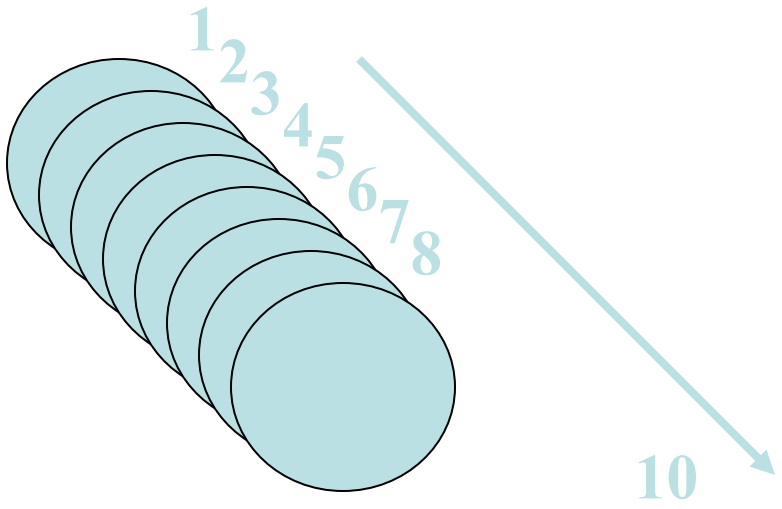
BSF water treatment technology is environmentally friendly.

Filter Capacities

BioSand Water Filters **have been constructed with capacities ranging from 10 Litres per hour to 30,000 Litres per hour.**

Several *BioSand Water Filters* may be combined to achieve desired treatment system capacities.

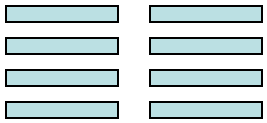
LHPF technology is recommended for most community scale applications. See www.purefilteredwater.com.



BioSand Water Filters may be operated in <u>parallel</u> to achieve desired capacities.

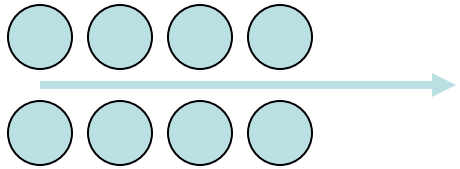
<u>Stacks of filters.</u>

Where space is a problem!



(Like an automobile parkade or multi-floor building.)

Additional filters may be added as required – Modular Design.



Summary of Advantages of BSF Water Treatment Technology.

1. Provide effective treatment for a wide variety of water quality problems.
2. Small scale compared to 'traditional slow sand filtration' – simple to construct – low capital cost.
3. Operate as required – can be used to treat very small to very large volumes of water (small to large communities that may be remotely located – LHPF option available).
4. Simple operation (use local operators) that may be manual or fully automated – inexpensive operation.
5. Simple to use with other water treatment technologies.
6. Inexpensive to clean and maintain – low maintenance costs.

7. Environmentally friendly – minimum use of chemicals.
8. Produce very little waste water or waste products.
9. Energy efficient – require very little energy to operate and maintain.
10. Can be designed and constructed using locally available manufacturers and materials.
11. Expected service of more than ten years before significant maintenance costs will be incurred. Life expectancy of installations is in excess of twenty years – long life expectancy – a sustainable technology.
12. Water treatment plant production capacity is easily increased to meet future increases in demand for potable water – as communities grow in population.

Note:

1. The BSF technology is patented and owned by the company Pure Filtered Water Ltd. of Calgary, Alberta, Canada. See web site: www.purefilteredwater.com.
2. Access to the original concrete version of the BSF technology for humanitarian purposes was granted by David Manz, co-owner of Pure Filtered Water Ltd., to not-for-profit agencies with the expectation that they would observe and respect the design, operation and cleaning principles described in the web site: www.manzwaterinfo.ca.
3. The ONLY organization that has been granted a license by Pure Filtered Water Ltd. to manufacture and produce plastic versions of the BSF is International Aid, Michigan, USA (distributed as the HydrAid Water Filter). See web site: www.hydraid.org.

Thank you!