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761-Sediment Removal

The most misunderstood concept in Hemodialysis Water System Design

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Objectives

- Distinguish between adequate sediment filtration and ineffective filtration.
- Define the best Preventative Maintenance program for the existing equipment.
- Create and implement that Preventative Maintenance program.

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- SEDIMENT -

– What Is Sediment?

- SEDIMENT -

- www.dictionary.com
- **sediment**. (sĕd'ə-mənt) Geology Solid fragmented material, such as silt, sand, gravel, chemical precipitates, and fossil fragments, that is transported and deposited by water, ice, or wind or that accumulates through chemical precipitation or secretion by organisms, and that forms layers on the Earth's surface.

- SEDIMENT -

- www.merriam-webster.com/dictionary/sediment

- **sediment.**
- 1. the matter that settles to the bottom of a liquid.
- 2. material deposited by water, wind, or glaciers.

- SEDIMENT -

- www.urbandictionary.com

- noun; a large sum of cash awarded to the plaintiff whose case is upheld by Judge Joe Brown.

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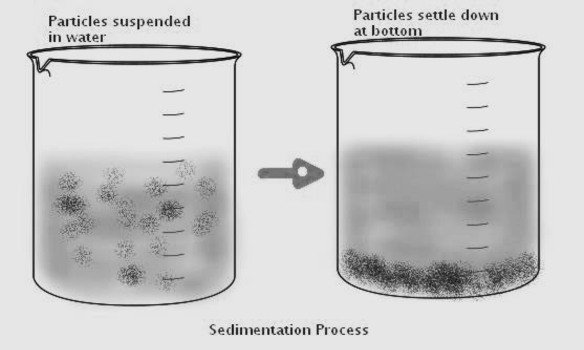
- SEDIMENT -

- For this presentation, sediment is defined as the settable, solid matter that is transported by water in the hemodialysis water treatment system



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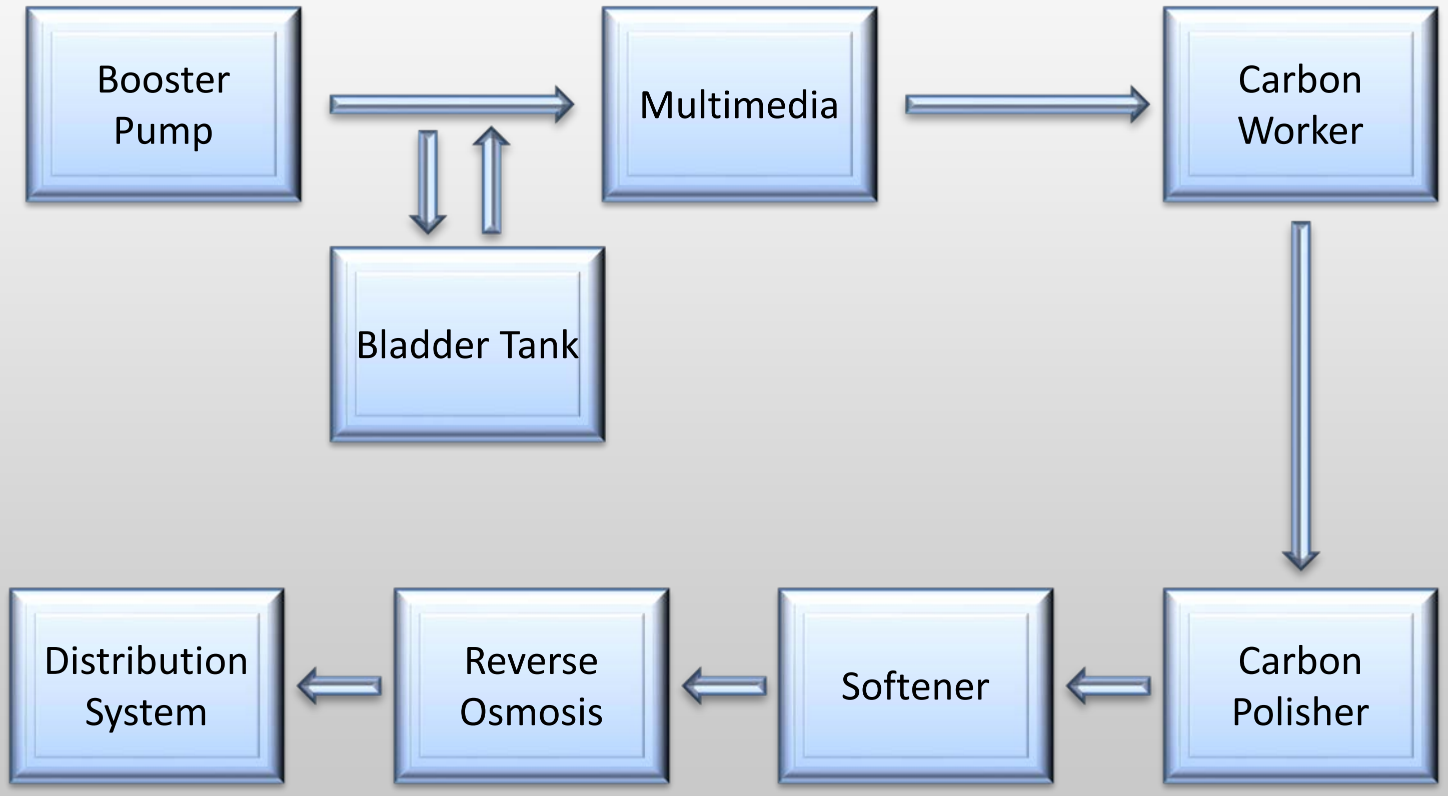
Traditional Water Treatment System



Three Sources of Sediment

1. Incoming municipal water
2. Carbon fines
3. Biological growth in situ

Why is sediment still a problem Today? (2018)

Out-of-sight

Out-of-mind

Nanotechnology is a hot new development field today

New discoveries are being made daily because:

No longer

Out-of-sight

Out-of-mind

When we can see things, then we can understand what is happening and solve problems

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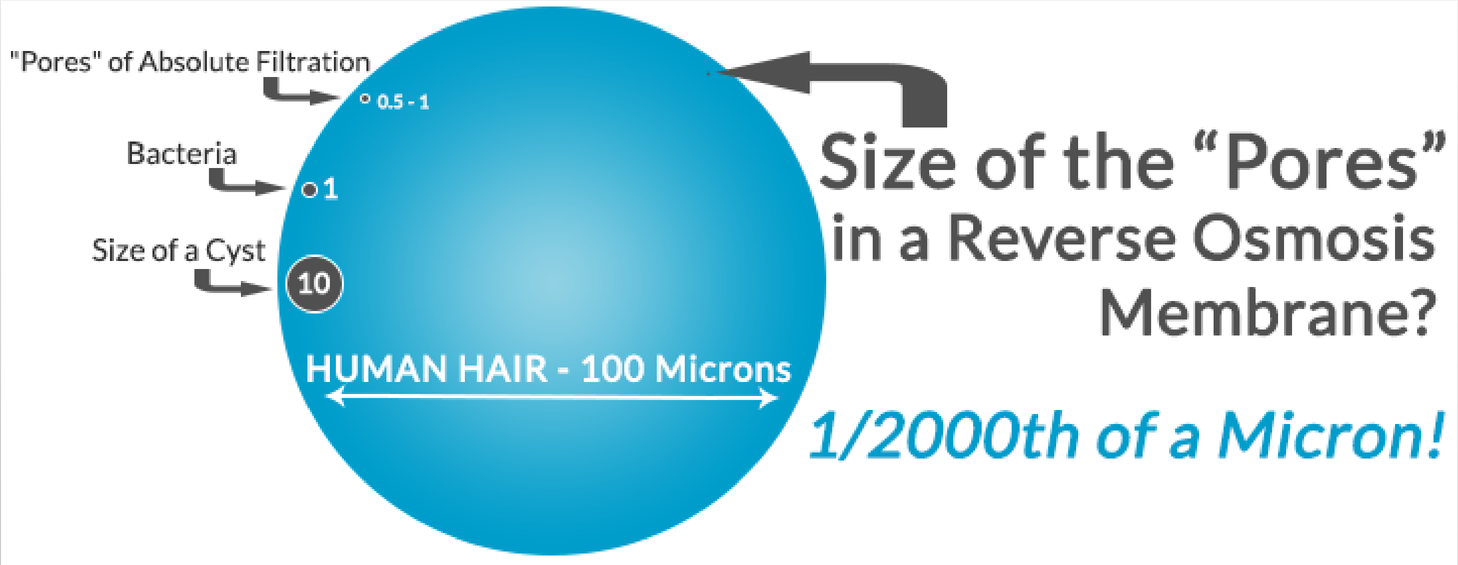
We are going to explore sediment on a nanometer scale

- 1mm = 1M/1,000 = 10^{-3} M
- 1 µm (micron)=1 mm/1,000 = 10^{-6} M
- 1 nm= 1µm/1,000 = 10^{-9} M

To get comfortable with nm:

1. Hair grows at about 1 nm per second
2. Nails grow at about 0.5 nm per second



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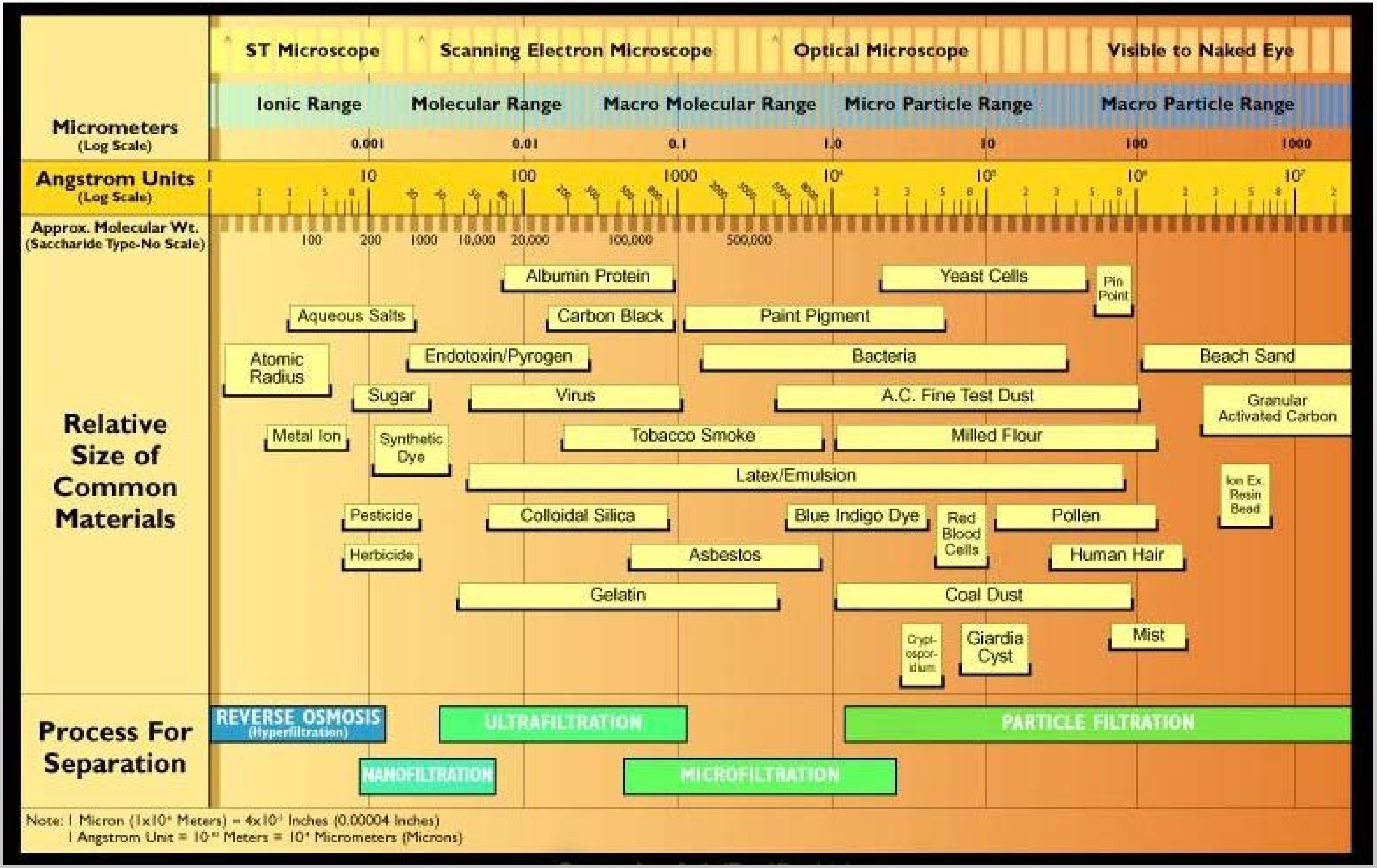
Filtration Spectrum



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Municipal Water Particle Distribution Chart

From Frederick Ayisi Sarpong's, Master Thesis *Particles in drinking water, Lulea, Sweden* at Lulia University of Technology in 2007

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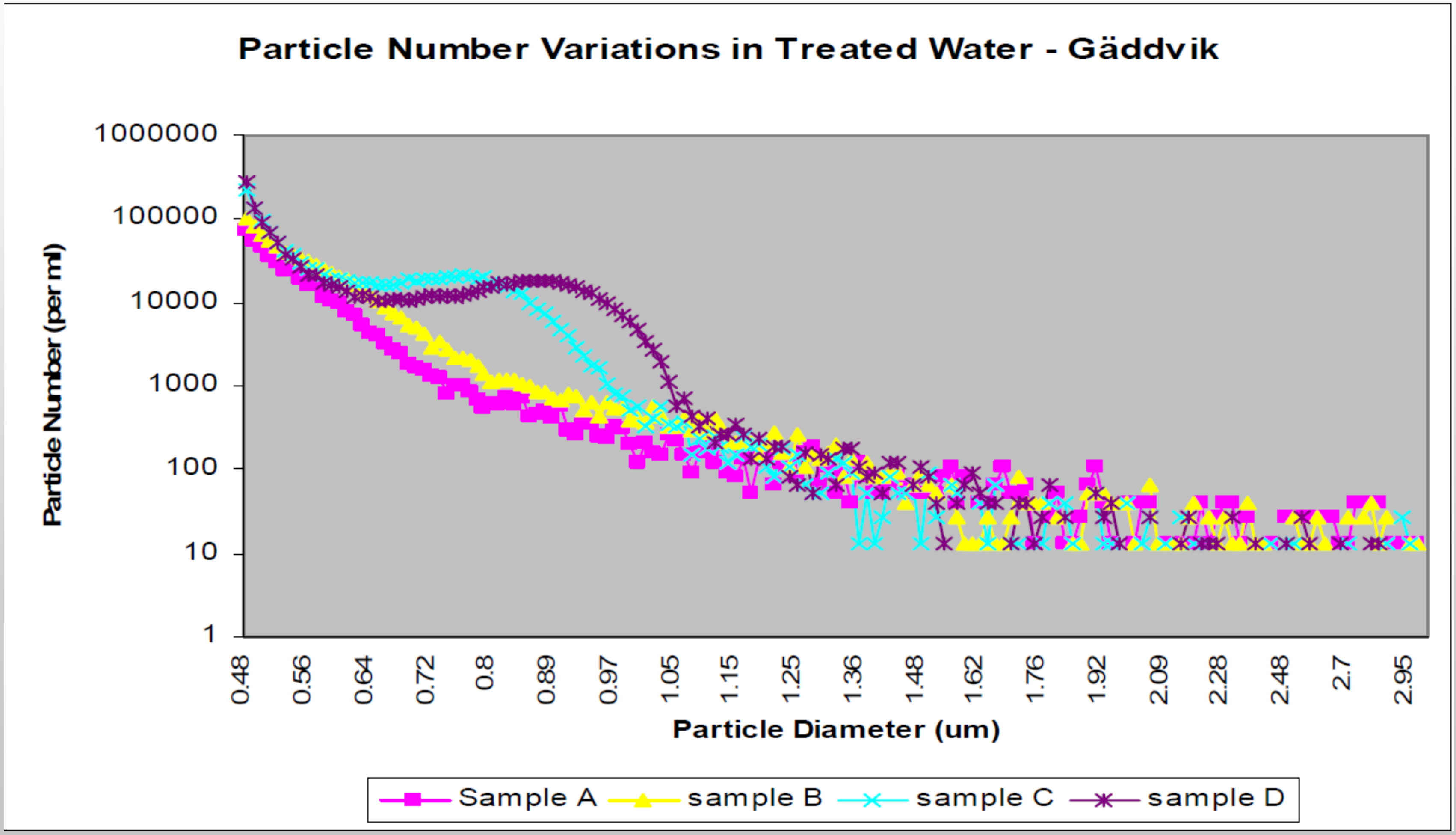
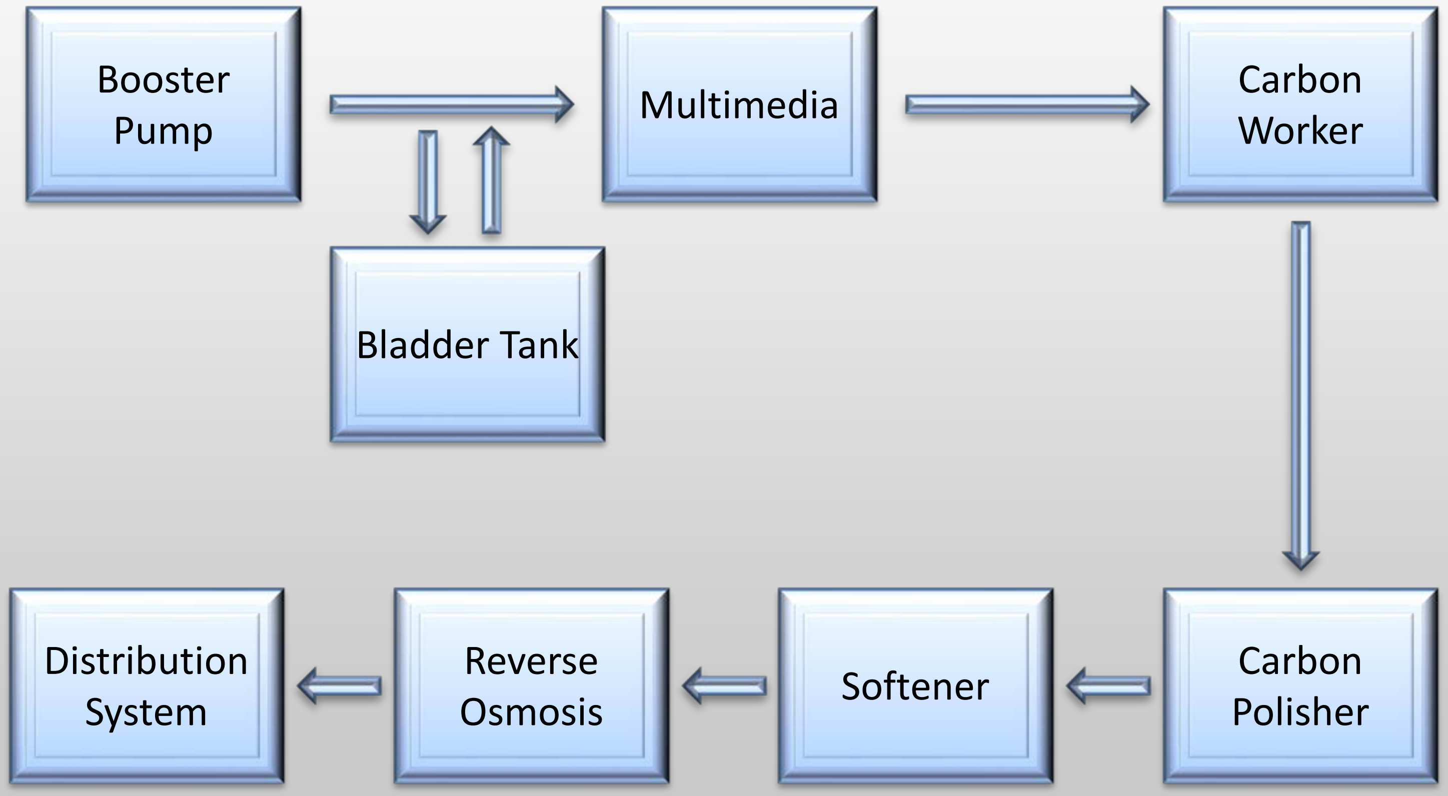


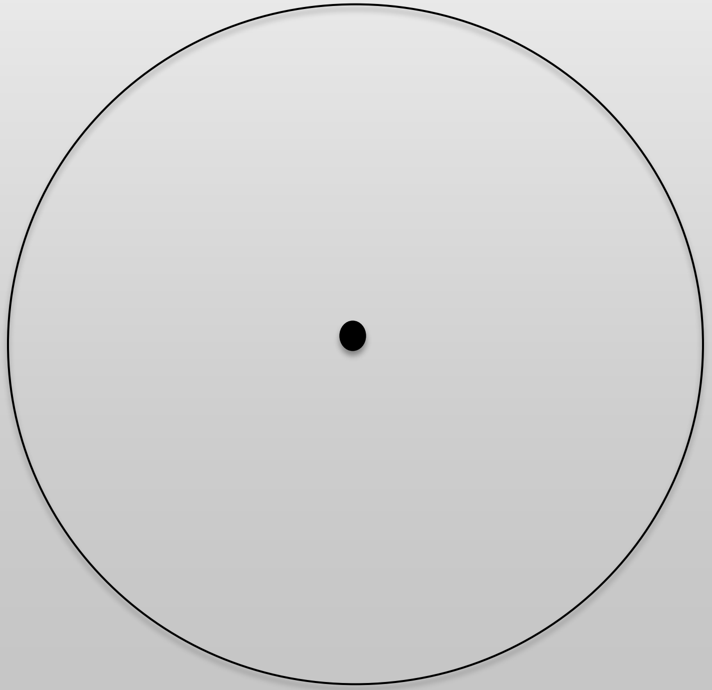
Sediment In Influent Water

99.9% of particles smaller than 1 micron (1,000 nm)

Traditional Water Treatment System

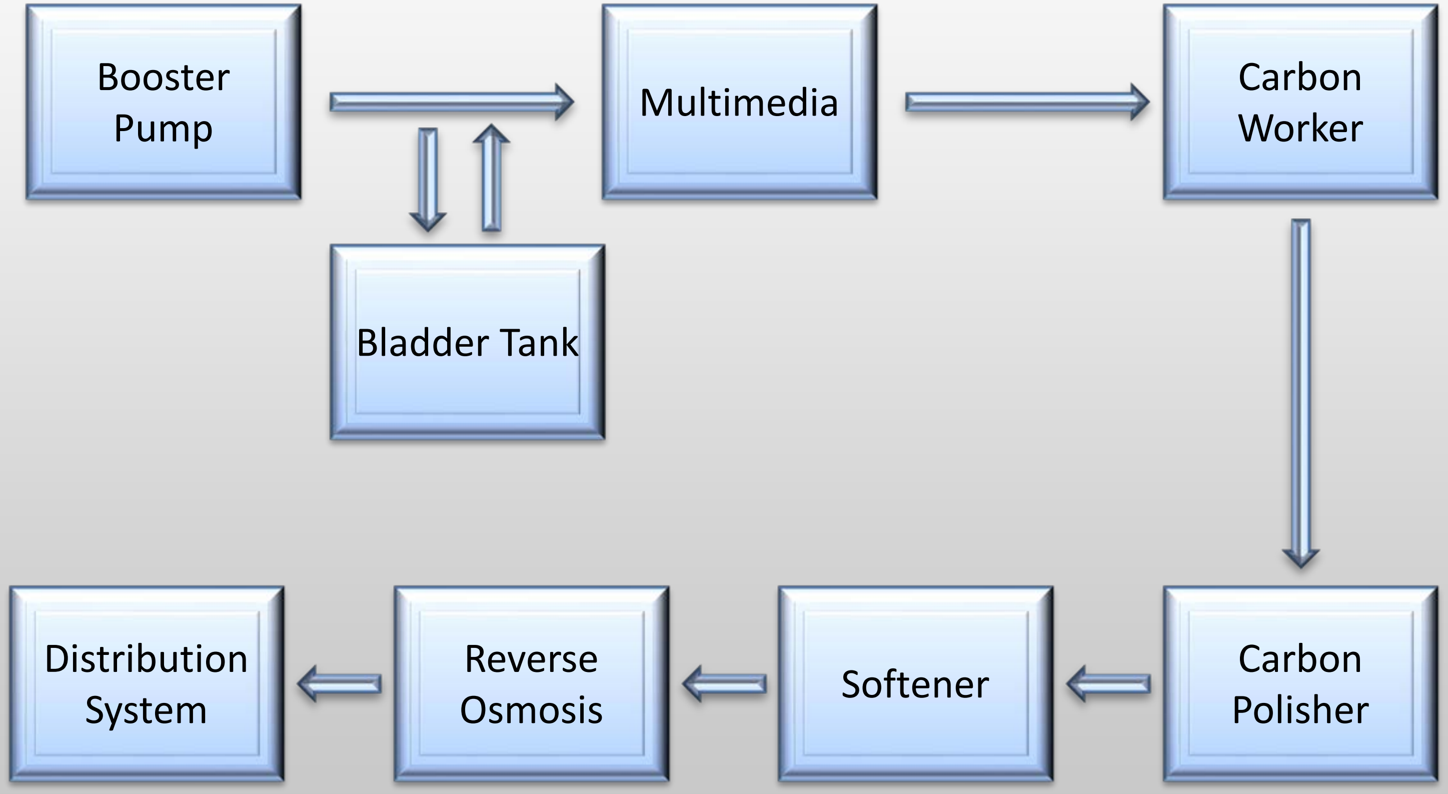


- Multimedia Filter filters down to 40,000 nanometers!
- Sediment Passing Through Multimedia Filter



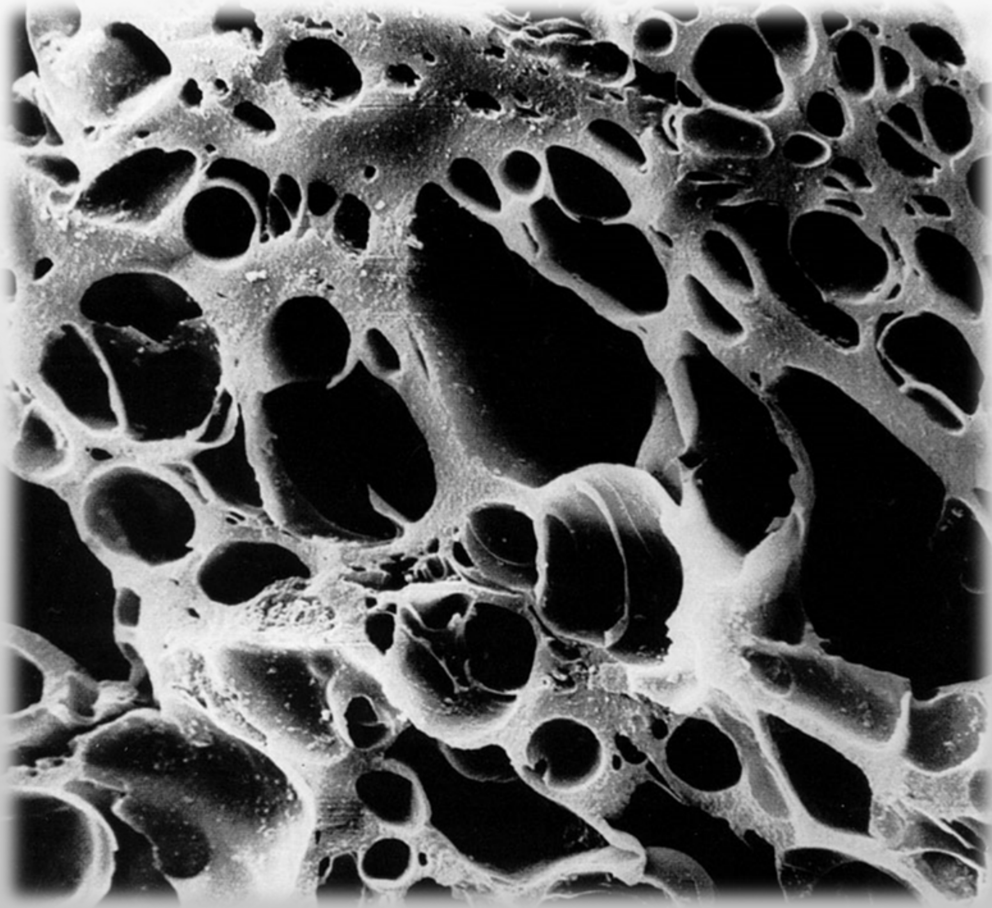
Reason why I have led a 15-year campaign against multimedia filters for hemodialysis

Traditional Water Treatment System



Coal-based, acid-washed 12x40 GAC(Granulated Activated Carbon) is an excellent sediment filter

GAC Pore Size



On the nanometer scale the carbon structure is like a gigantic sponge, giving it the ability to trap sediment from 1,000 nanometers down to the smallest particle sizes.

Carbon media are fantastic sediment filters, but with one problem –

Releasing the sediment that they collect

They are backwashed in an attempt to remove the sediment. Unfortunately because the sediment is captured physically by trying to pass through a pore smaller than it is, it gets lodged into its resting place.

Backwashing:

1. Introduces sediment to the bottom of the bed
2. Expands the media by 50% to ensure sediment reaches all of the media
3. Tumbles the GAC in a turbulent stream
4. Causes scouring of the GAC due to its abrasiveness
5. Does a very good job of producing carbon fines
6. Requires forward rinsing after backwashing in an attempt to remove the generated carbon fines
7. Does a very poor job at releasing the debris because during the tumbling the water is not flowing through the GAC in the reverse direction to that which fixed it in place

The carbon fine particle size distribution is very large as the scouring process that produces the fines is not controlled and is subject to many contributing factors such as:

- the abrasiveness of the carbon,
- the hardness of the carbon,
- the fragility of the carbon (the structure of the grain),
- the temperature of the water, etc.

Net result of backwashing:

1. Effectively changes the incoming sediment to carbon fines
2. Much of the sediment is not backwashed out, decreasing the efficacy over time
3. Carbon bed releases sediment in an exponentially decreasing manner for long periods of time. This can be up to several hours

Wang Leilei at the College of Environmental Science and Engineering, at Hohai University in China documented particle emissions after GAC bed filter backwashing as part of a study and report, *Particle size distribution and property of bacteria attached to carbon fines in drinking water treatment* report.

His observations are interesting.

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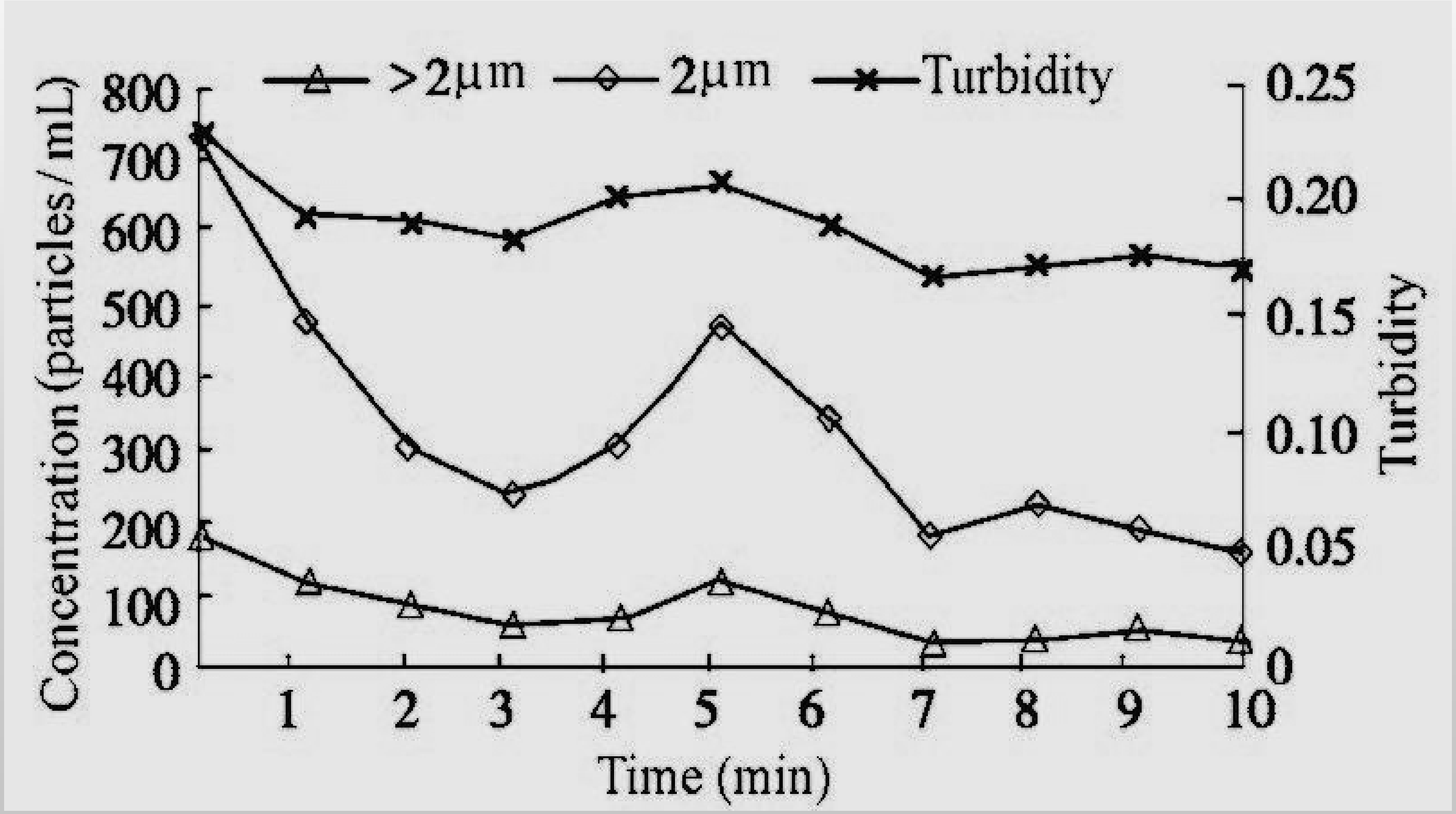
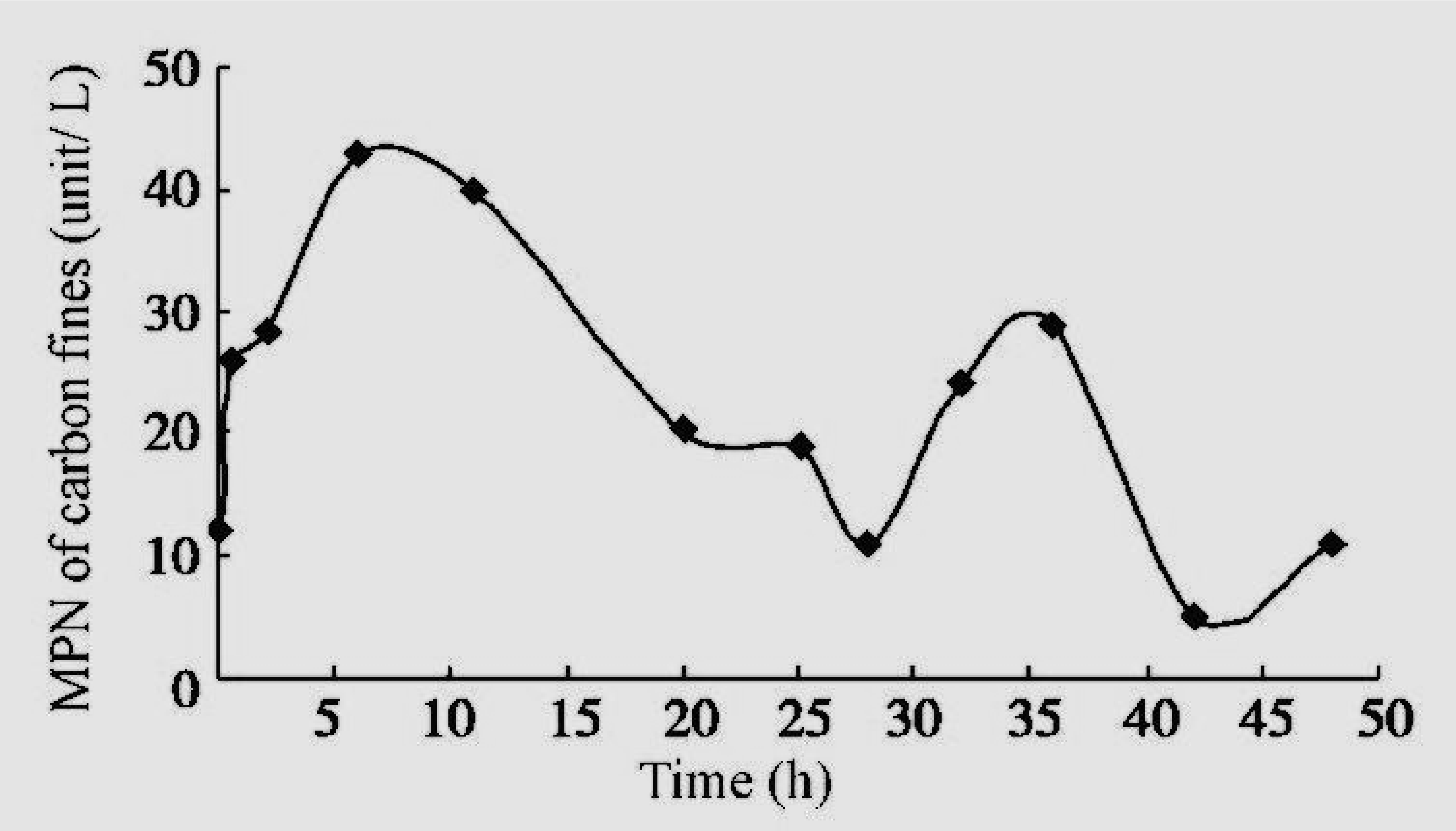
Three very important observations were recorded:

- Total sediment particle emission for 10 hours after GAC bed backwashing
- Carbon fines emission for 50 hours after GAC bed backwashing
- Carbon fines typically were 0.2 to 0.5 µm

Changes of Particle Concentration And Turbidity In Initial GAC-filtered Water



Changes of Particle Concentration And Turbidity In Initial GAC-filtered Water



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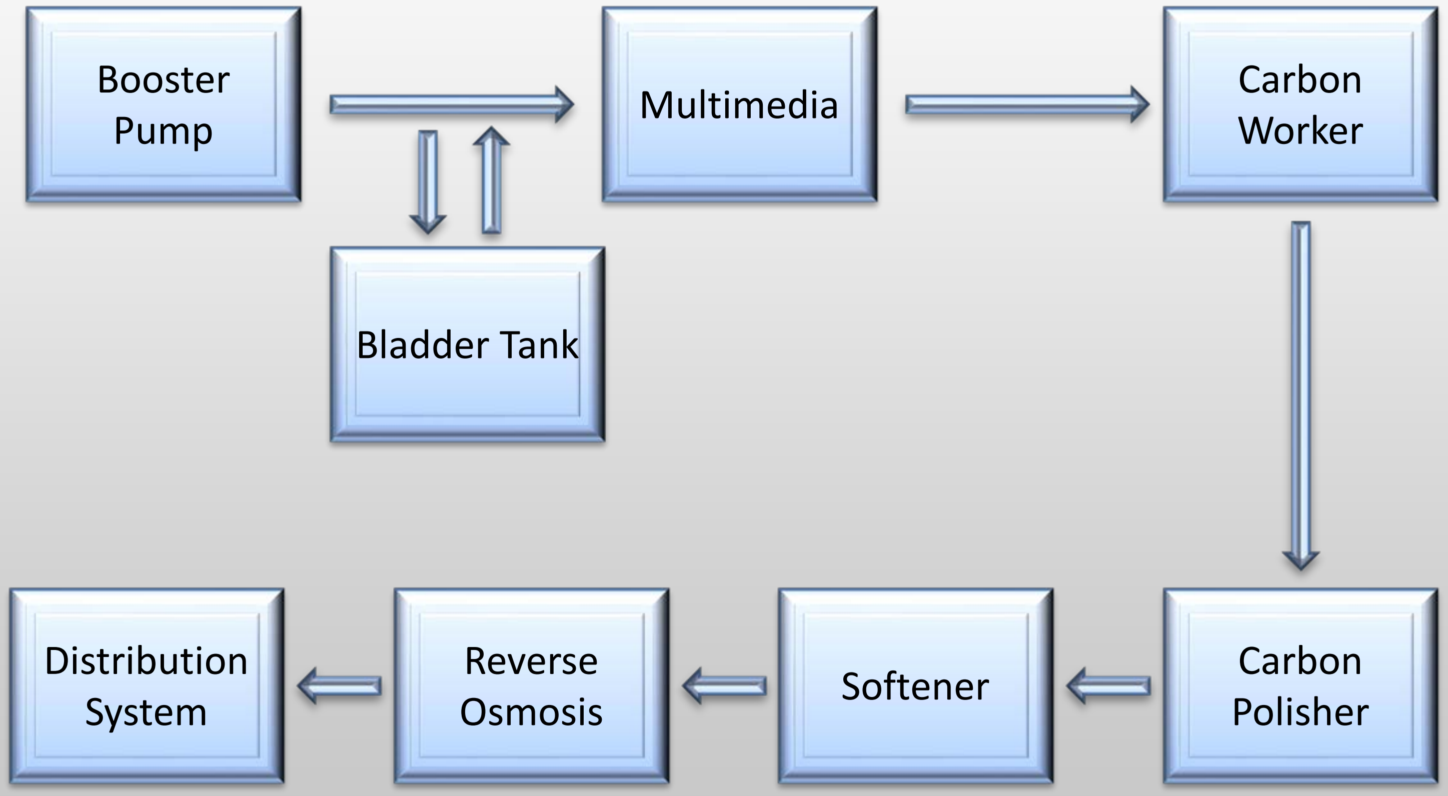
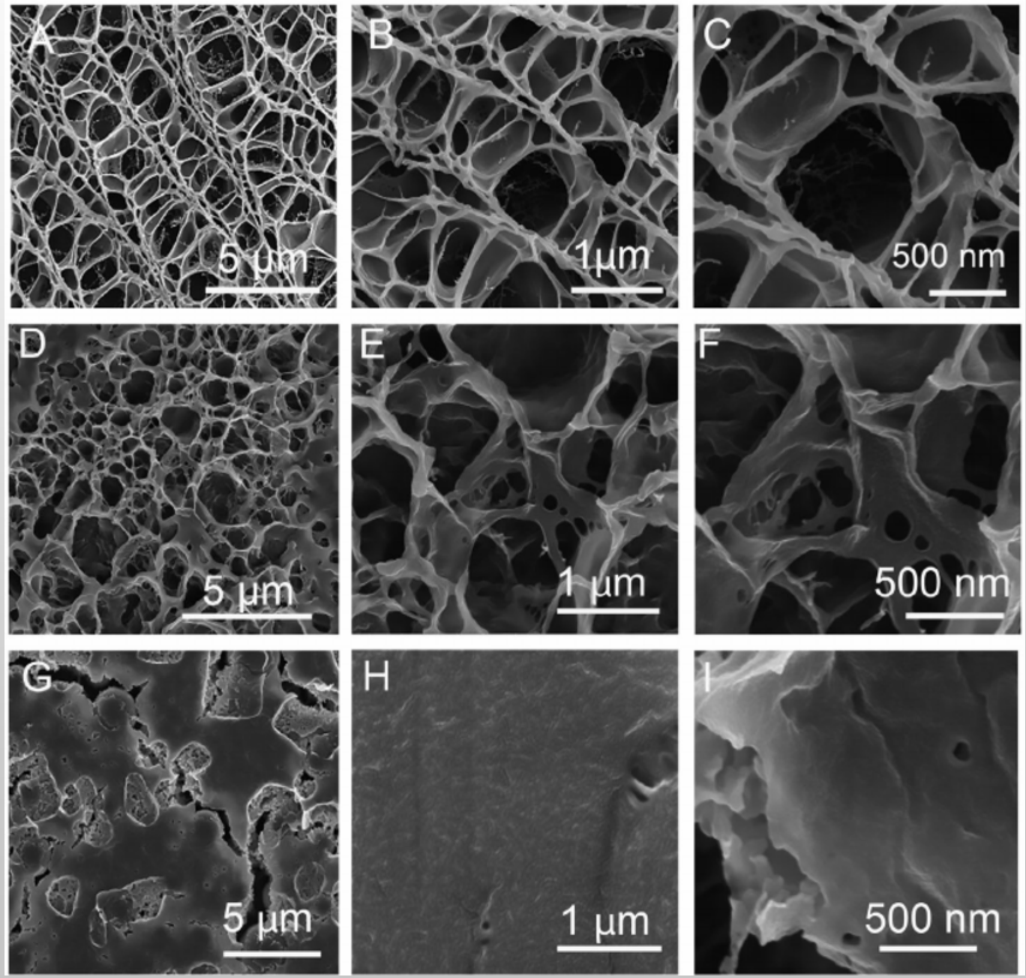
Traditional Water Treatment System



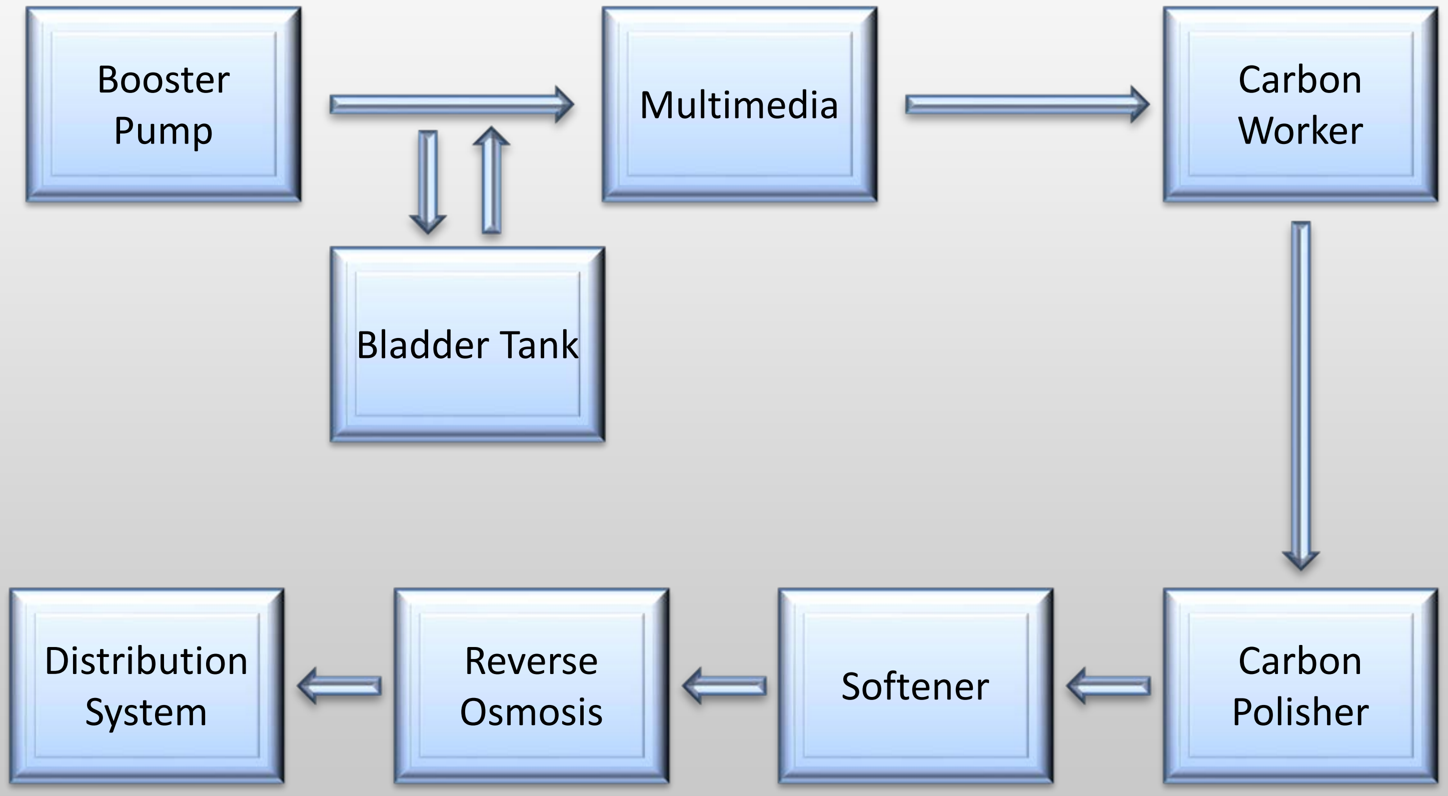
Softener Beads:

1. are about 1,500,000 nanometers in diameter
2. are very porous
3. are consistent as to pore size
4. don't trap sediment.

Softener Media



Traditional Water Treatment System



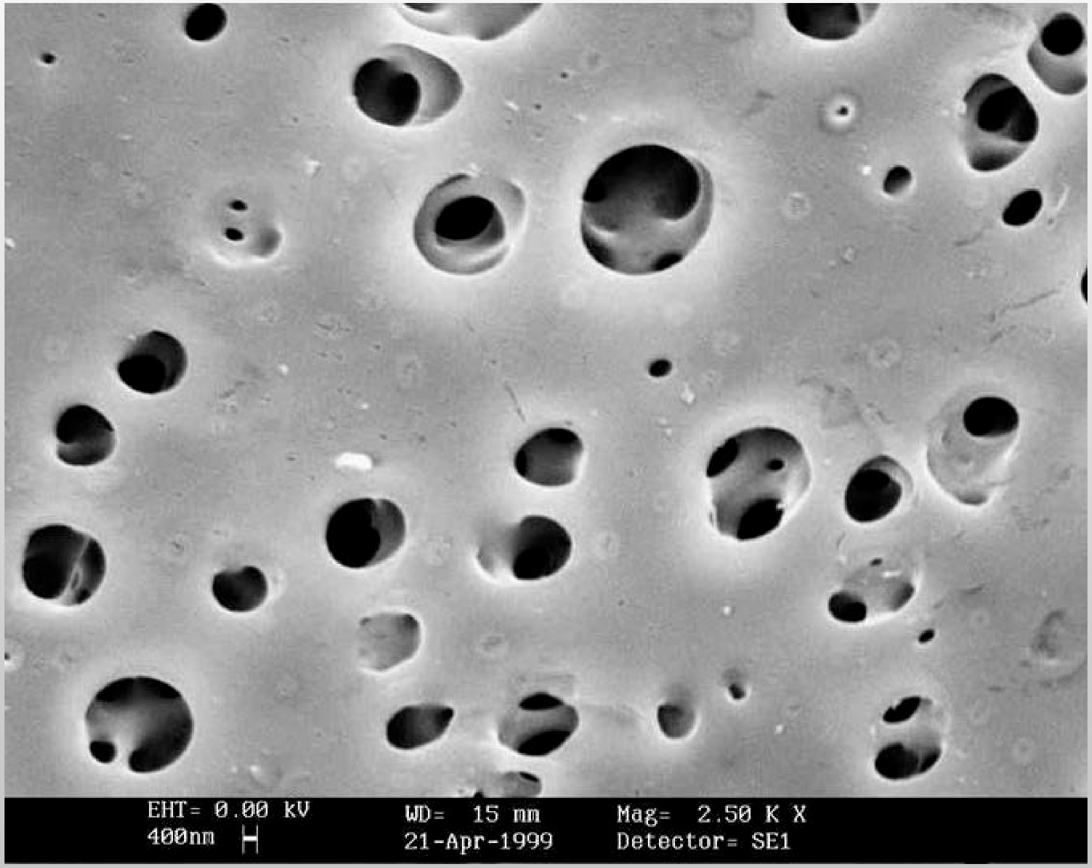
RO Pre-filter

First water treatment component on RO machine

1. Typically dual 2 ½" x 20" cartridge depth filters.
2. Filters typically rated at 5 micron (5,000 nm) nominal.
3. Nominal means 90% of particles sized at the nominal value are retained by the filter.

- The depth filters are effective for the larger sizes of carbon fines above 1,000 to 5,000 nanometers in size. If left in service long enough they will build a cake that will filter down to less than 1,000 nanometers size
- But, they are usually changed out before that happens
- Thus, all particles usually found in the water system pass through the RO depth filter onto the RO membranes
- The RO membrane pore size is approximately 1 nm
- Therefore, no measurable quantity of sediment gets past the RO membranes

RO Membrane Pore Size



Does that mean that all of the sediment goes down the concentrate stream from the membrane?

That depends.

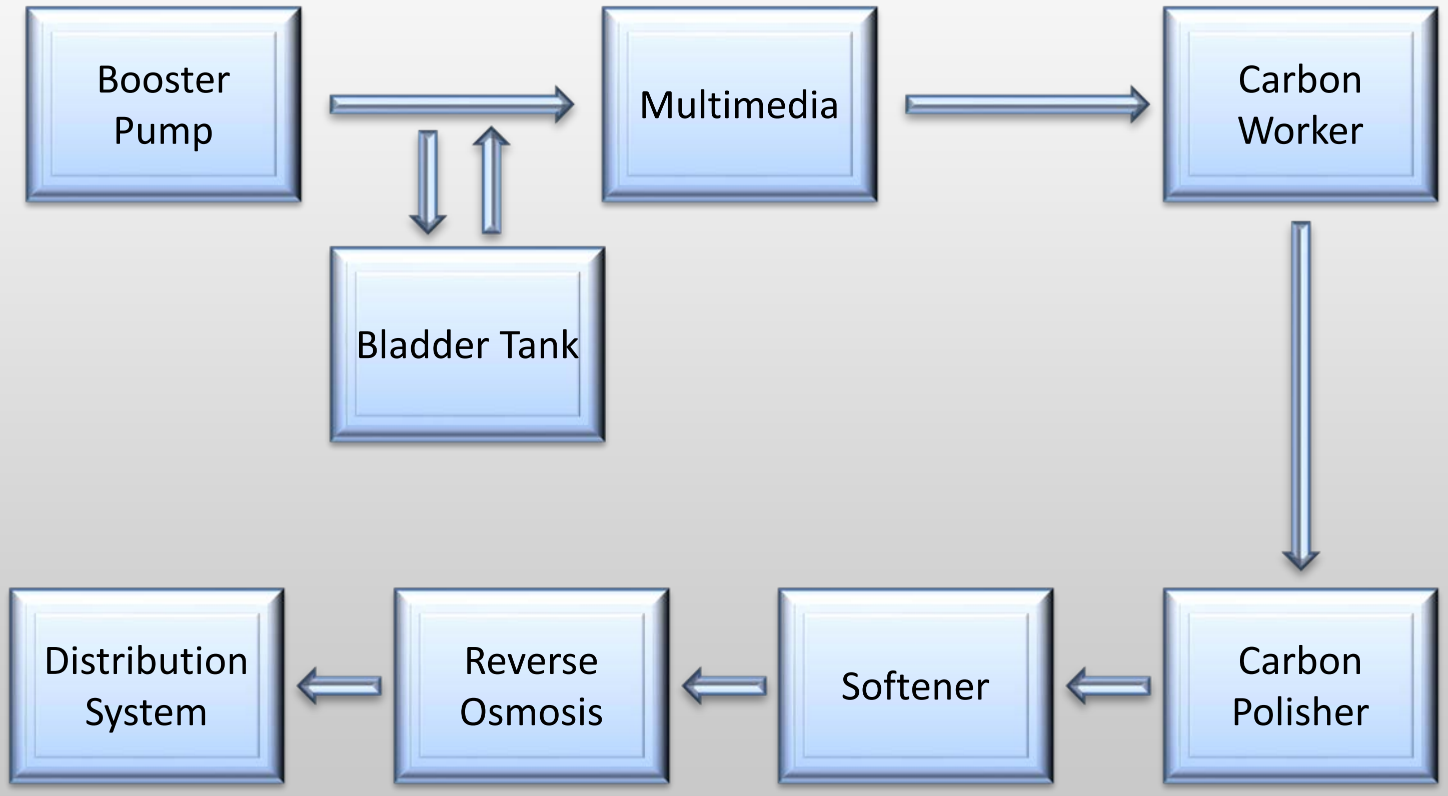
Remember we have three types of sediment:

1. Incoming municipal water
2. Carbon fines
3. Biological growth in situ

Let's talk about the third sediment:

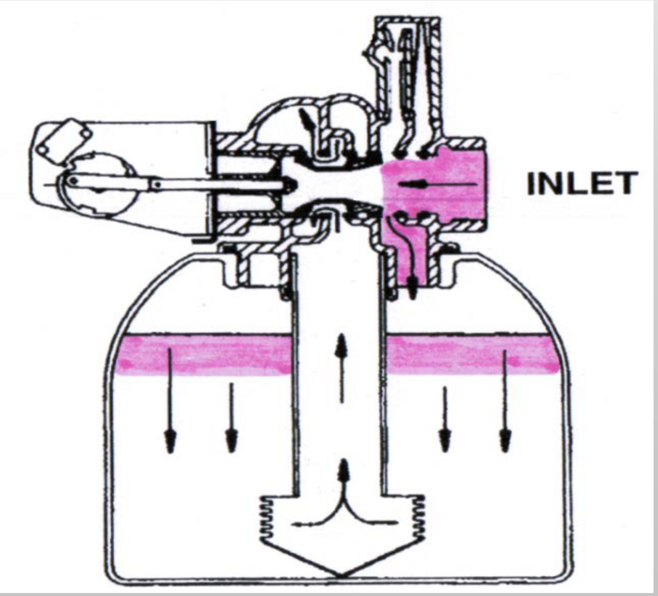
Biological Sediment

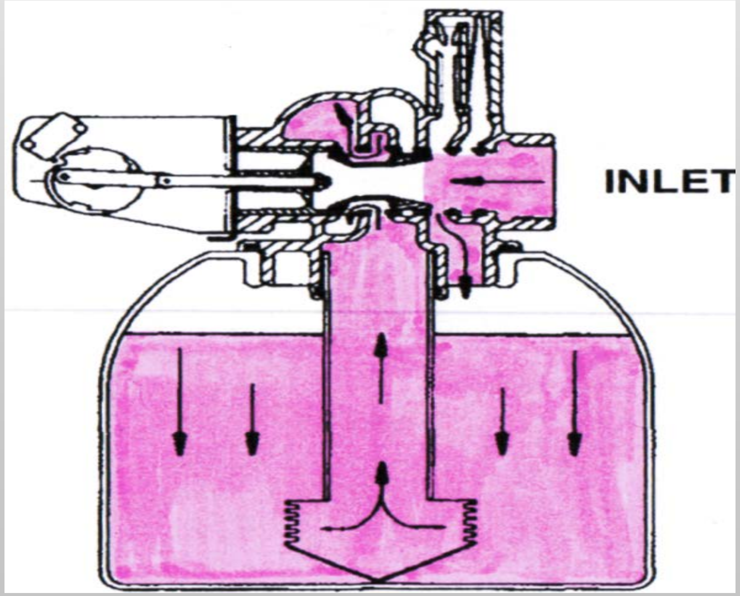
Traditional Water Treatment System



- Influent water from the municipality is chlorinated: ***(no live bacteria)***
- Can we say no live biological organisms? ***No – cysts such as giardia and cryptosporidium can survive municipal chlorination***
- Is there dead organic material? ***Yes.***

This biological sediment is filtered out in the carbon bed (except that which enters the bottom of the bed during backwash and is subsequently sloughed off in the following service cycle).





The carbon beds do an excellent job of removing the incoming chlorine from the water:

1. If there is any free residual chlorine, it is removed on contact with the GAC (by chemical reaction).

2. The combined chlorine (chloramines) are adsorbed by the GAC. This is a time dependent process that typically takes less than one minute.

3. To ensure that the process has adequate time, the AAMI standard is a minimum of 5 minutes for the worker carbon filter and 10 minutes for worker and polisher filters.

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4. for the majority of the time that the water is flowing through the worker carbon bed and for all of the time that the water is flowing through the polisher bed, the water is chlorine free
5. no chlorine = bacteria growth opportunity
6. Some bacteria love to eat carbon, carbon beds make a perfect nursery
7. No protection against biological growth after GAC filters

The bacteria

- typically are above 200 nanometers in size
- pass through the 1,000 nanometer softener media pores
- land on the RO membrane surface which appears to be perfect for attaching to
- once attached by a layer of polysaccharide slime, they form colonies, if they have food to survive

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Continues

- and they do have lots of food from the carbon fines which are constantly being fed to them as well as the influent organic material which passes through the system by frequent backwashing of the carbon filters
- eventually they clog up the membrane pores if the membranes are not cleaned regularly
- once a biological colony is established, it cannot be removed – only controlled (the colony's gelatinous cover protects the bacteria under it from biocides)

Bio Fouled Membrane

Traditional RO System 50 years ago used RO water storage tanks for a couple of reasons:

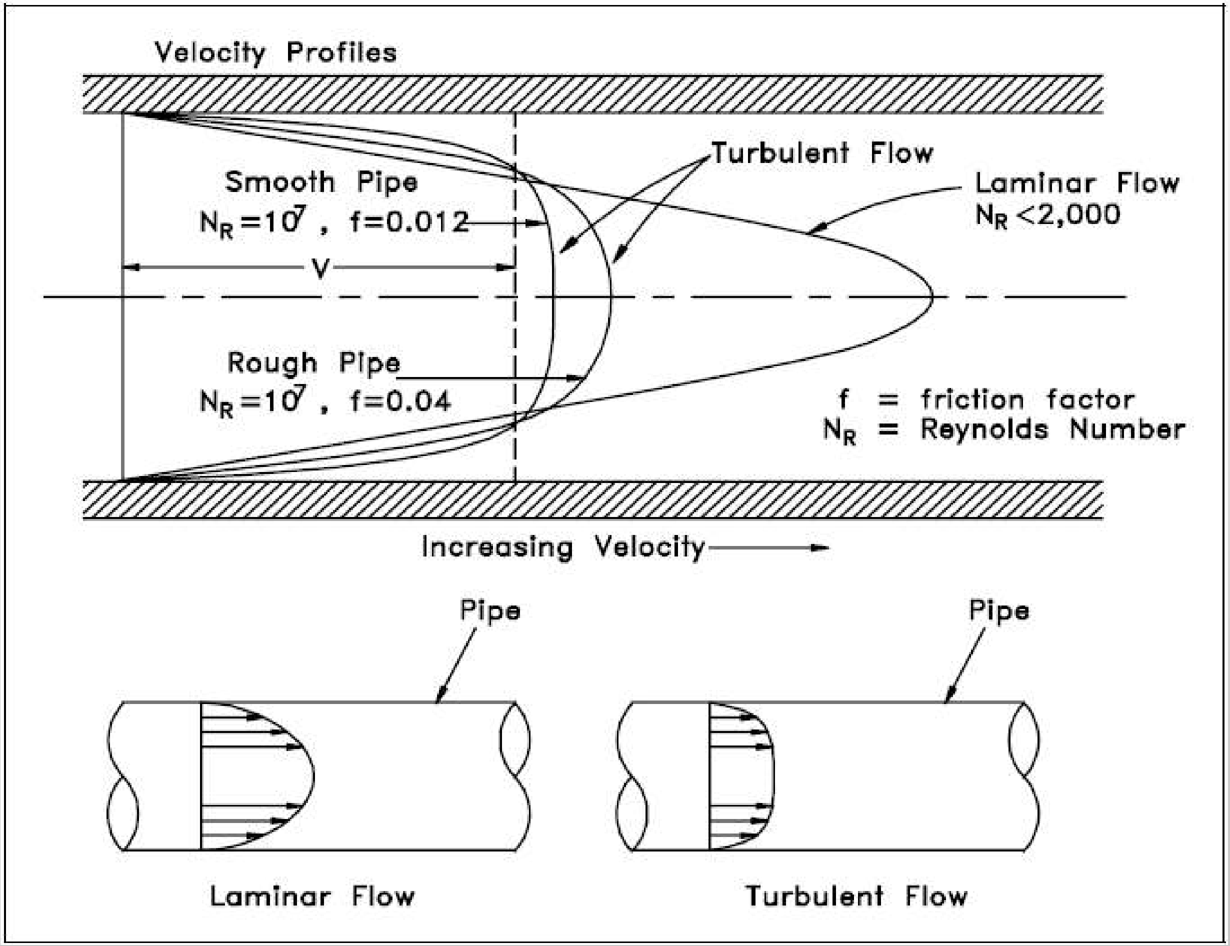
- As a buffer for RO maintenance or machine breakdown
- RO membranes were thought to work best on a 50% on-off cycle

In doing so, added components in addition to the storage tank needed to be added to the system. Each component was a bacterial venue.

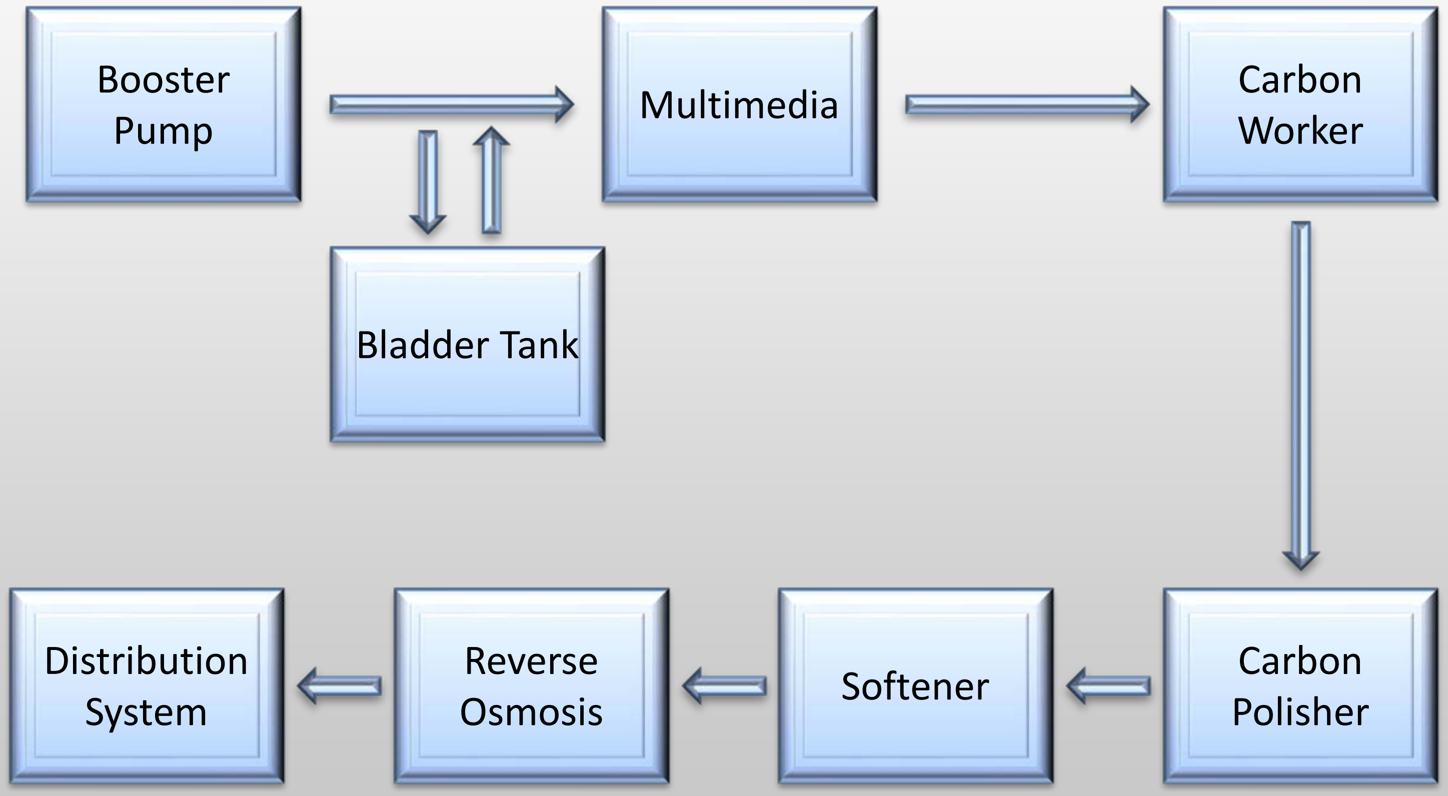
Traditionally piping after the RO, including the patient water loop, was constructed using PVC80 pipe and fittings that are glued together.

- The PVC80 pipe surface is perfect for bacteria to attach to – it wets easily
- Improperly glued fittings in the loop created large incubation sites for bacteria
- PVC80 has a low wall boundary velocity ideal for bacteria colonies

Flow Velocity In The Pipe



Traditional Water Treatment System



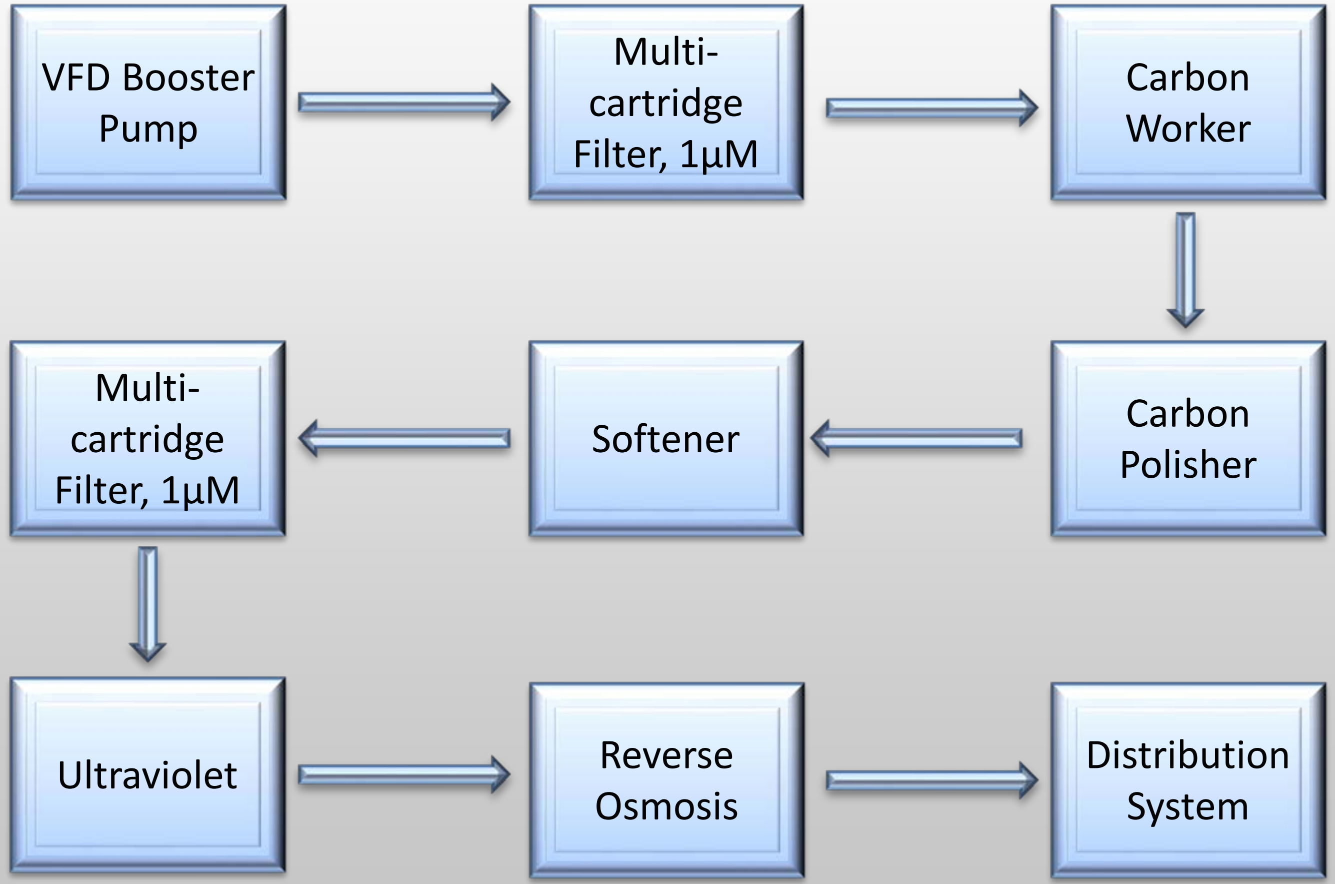
Since the early days of hemodialysis, through ignorance and not recognizing the importance of the hemodialysis water treatment process, bio-meds have been saddled with an almost impossible task of maintaining these systems.

It has been through much hard work that bio-meds have been as successful as they have in keeping the water treatment systems operational.

- Today, the water treatment system is getting the attention it deserves.
- Improving the efficiency of removing the sediments in the hemodialysis water treatment system must be recognized.

How Do We Better Control The Sediment

New Water Treatment System



The multimedia filter must go. It is a “crime against nature” to use it in hemodialysis systems:

- it gives false security that removes sediment
- it wastes vast amounts of water
- it wastes natural resources
- It has high operating cost
- takes up space

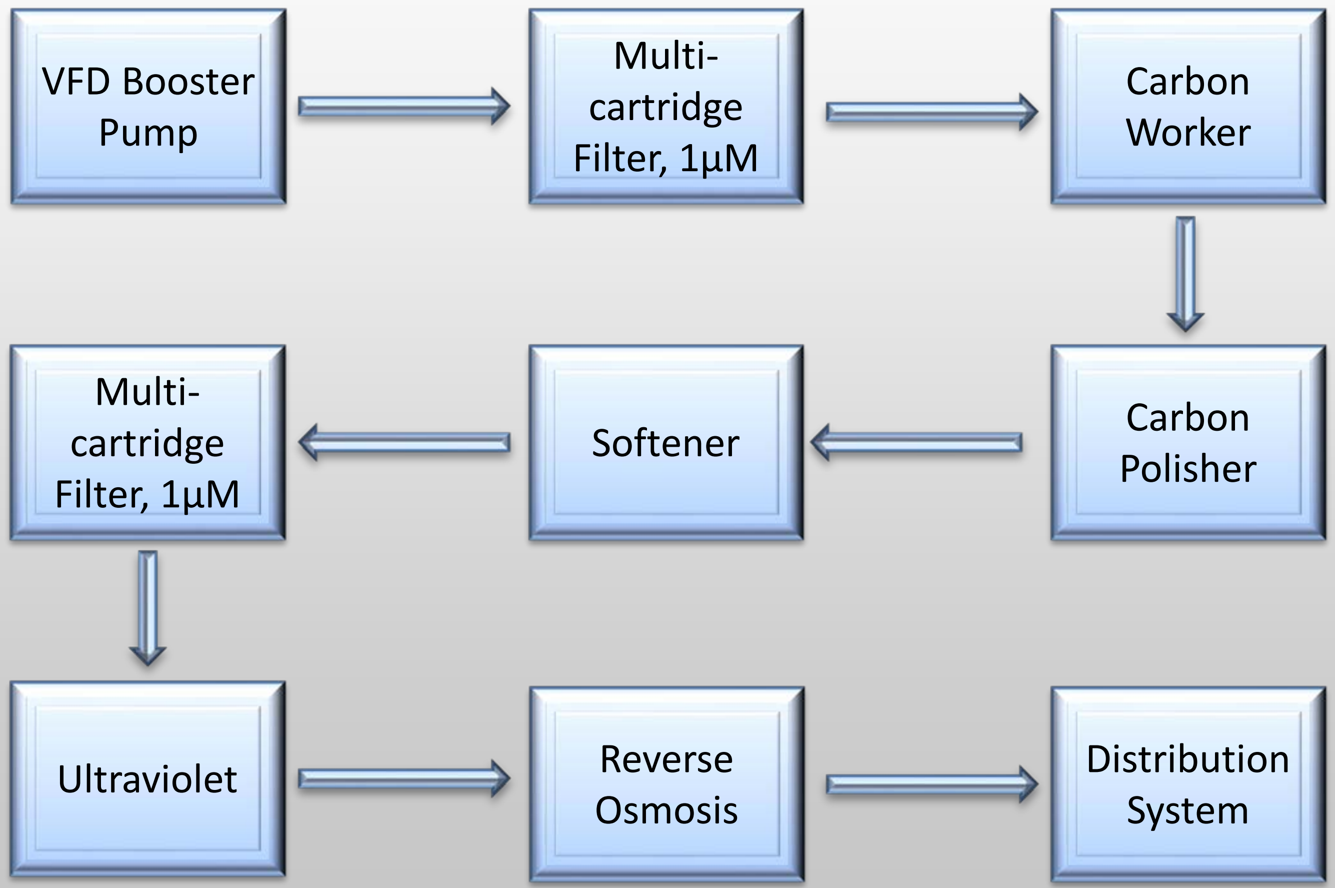
In its place a multi-cartridge filter must be used that:

- is adequately engineered to ensure proper sediment removal
- has proper flow velocity (it is critical to the efficacy of the filter)
- incorporates 1-µm depth cartridge filters
- is fed by a Variable Frequency Drive (VFD) pump

It is extremely important not to change the cartridge filters until the pressure drop increases at least 10 psi over the initial pressure drop:

- the longer the cartridge filters are used the more efficient they become.
- they will filter sediment down into the nanometer range once a cake builds up on the surface.
- do not change out the cartridge filters quarterly unless the delta pressure drop has increased over 10 psi.

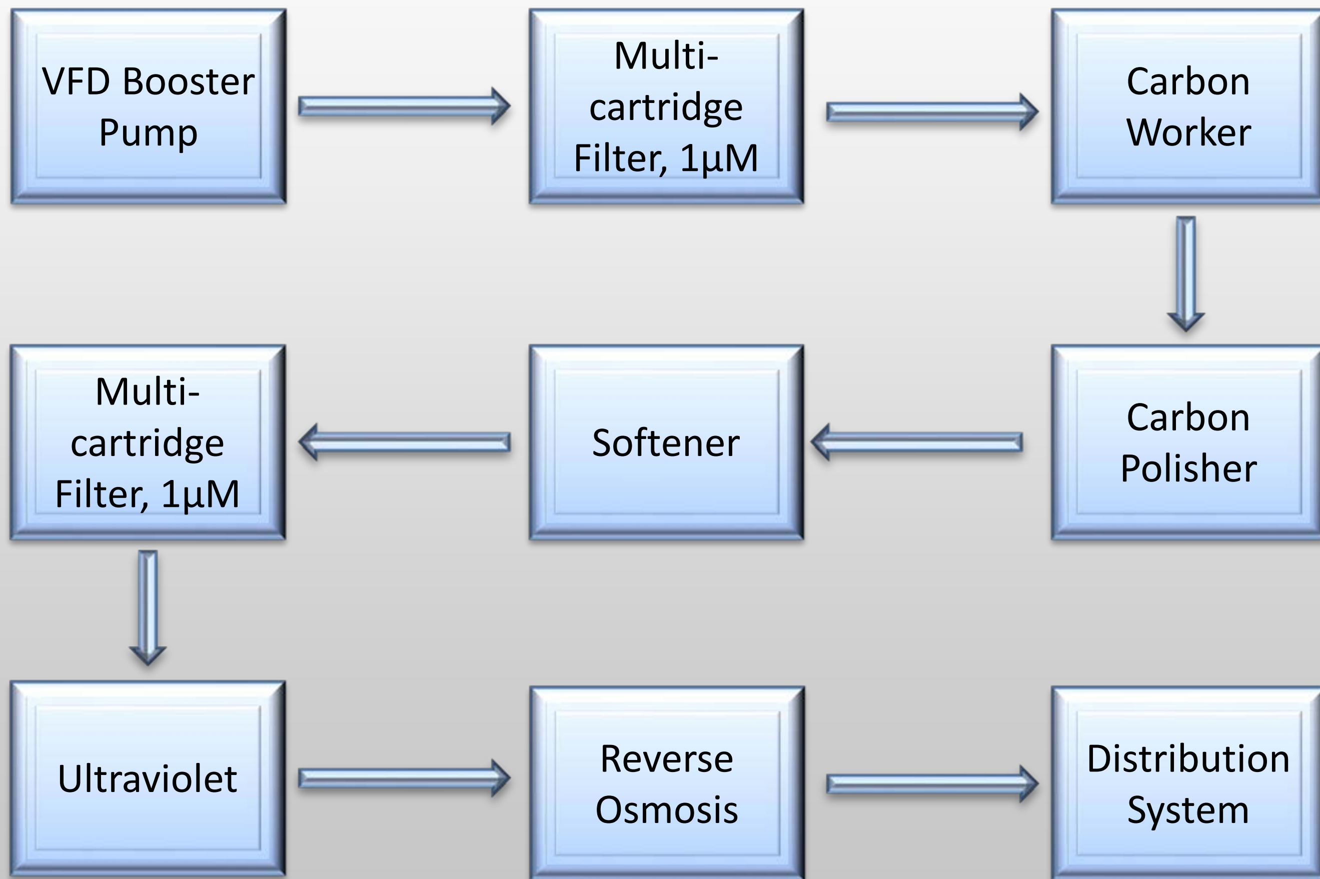
New Water Treatment System



Second, reduce or stop backwashing of carbon filters

- Backwashing of carbon tanks is unnecessary if the inlet sediment filter is adequate
- The goal of backwashing once a month or once a quarter is an excellent sustainability goal
- Using only enough carbon to meet the 10-minute EBCT is also prudent. Extra carbon is a waste of resources, generates more carbon fines, and does not provide any benefit

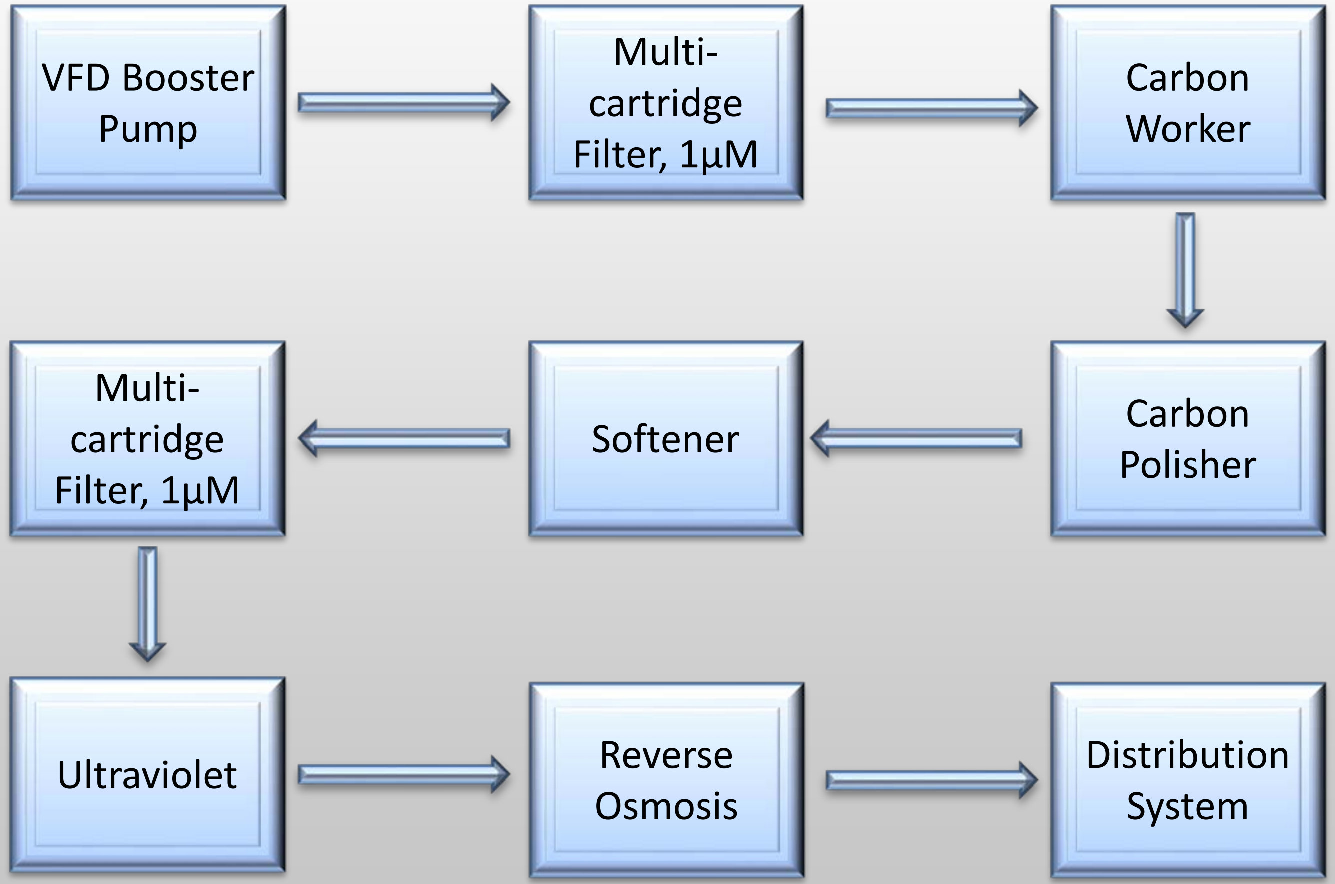
New Water Treatment System



Third, add a multi-cartridge filter (same size and same cartridge filters as inlet filter) after carbon filters.

- The rules for its maintenance are identical to those of the inlet sediment filter.
- This is critical to ensure that any biological growth on the RO membranes will starve due to lack of food.

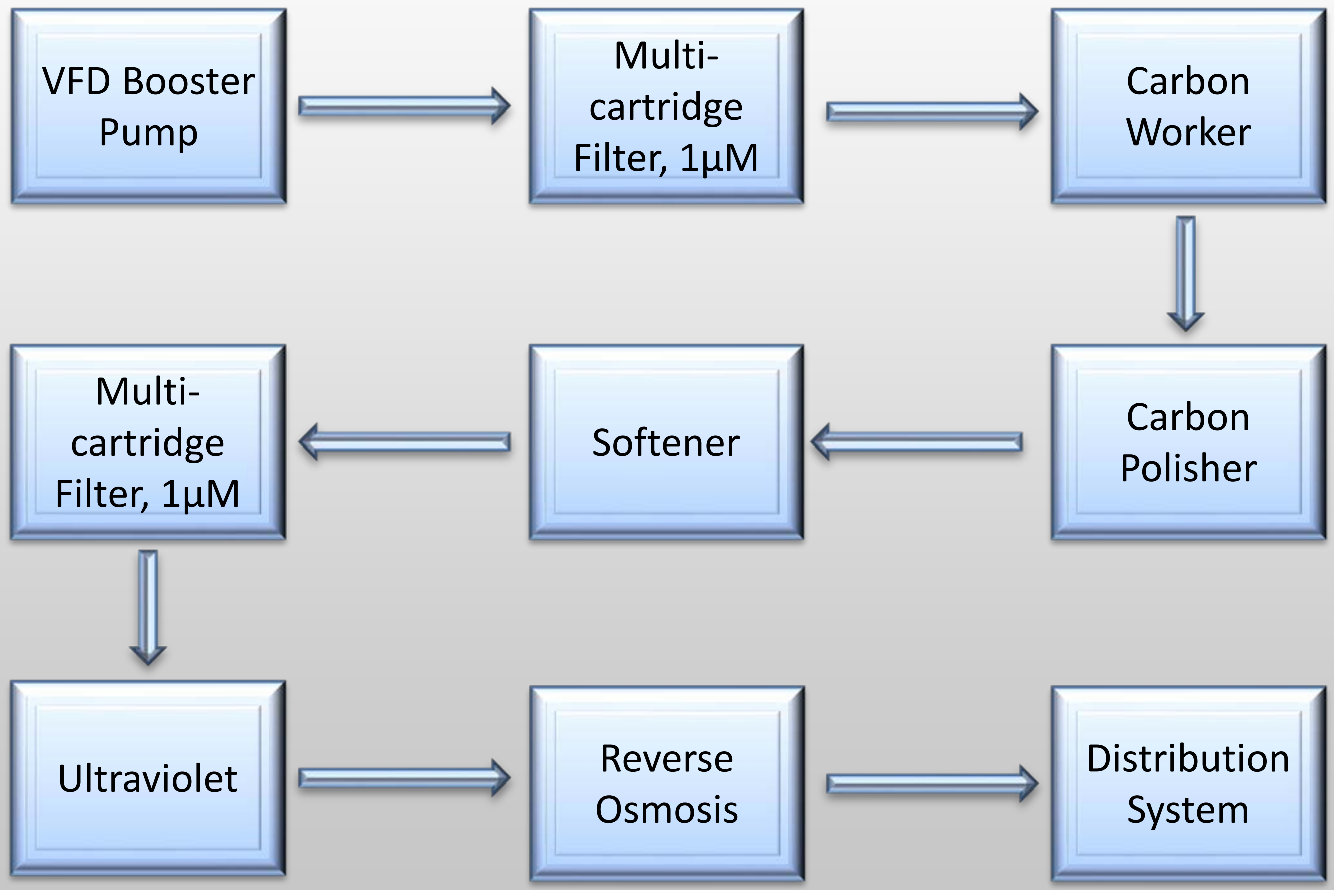
New Water Treatment System



Fourth, add an ultraviolet (UV) sterilizer before the RO machine

- The UV light will sterilize (not kill) the bacteria passing through the sterilizer.
- Those bacteria that attach to the RO membrane will not be able to form colonies.

New Water Treatment System



- Fifth, use pleated 0.35-µm absolute cartridge filters in the RO sediment filter. Change out these filters quarterly (or after an increase of 10 psi if sooner). It is better to replace absolute filters more often than to leave them in too long as they will collapse and cease to filter the water. If frequent changes are necessary, it is a sign that the pre-RO sediment filter is not performing adequately.

- Sixth, use the RO in direct feed mode. Today the RO machines, membranes as well as the rest of the water treatment equipment are reliable enough to provide constant flow to the patient water loop. In the past, water tanks were incorporated into the water treatment system in order to have a buffer when a piece of equipment failed.

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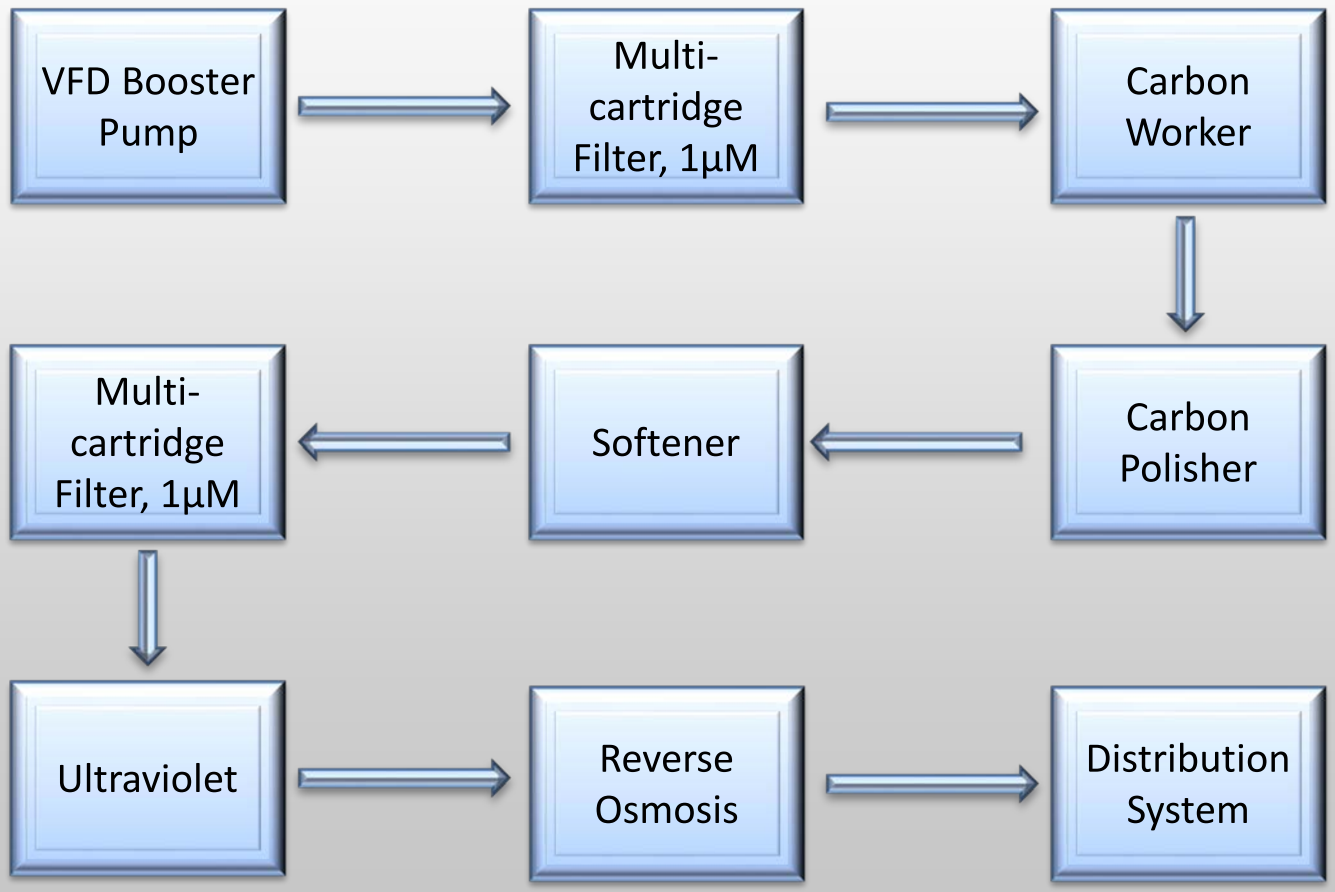
New Water Treatment System



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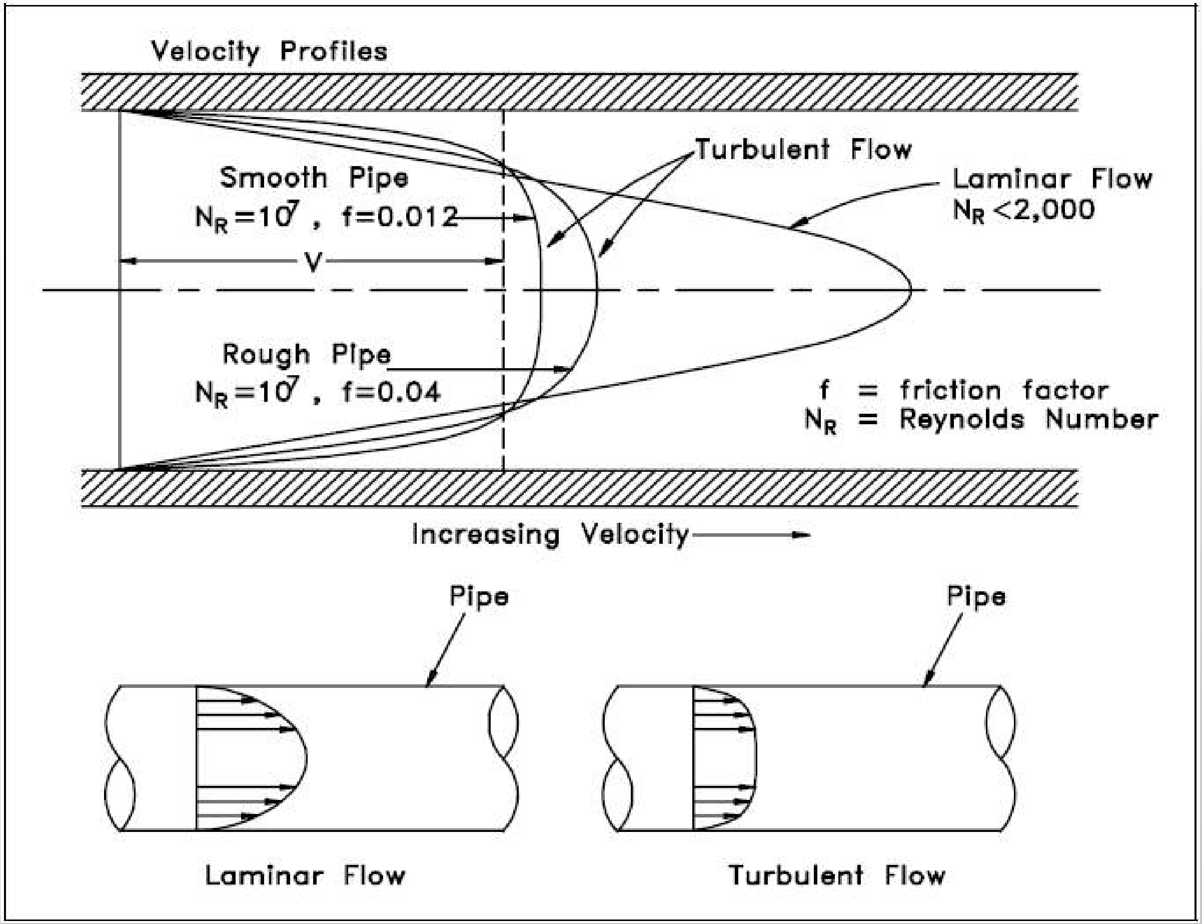
Seventh, and last, use Teflon tubing for post-RO patient water loop.

- Teflon is slippery (hydrophobic) - bacteria cannot easily attach to it

Flow Velocity In The Pipe



Seventh, and last, use Teflon tubing for post-RO patient water loop.

- Teflon is slippery (hydrophobic) - bacteria cannot easily attach to it
- Teflon can be, and should be, heat disinfected frequently

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Seventh, and last, use Teflon tubing for post-RO patient water loop.

- Teflon is slippery (hydrophobic) - bacteria cannot easily attach to it

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Heat disinfection is the best method for eliminating organic sediment in the water treatment system

Quick Look Into The Future

So far, all of this is where we are today:

- Available technology
- How we should be applying it

No let's take a quick look at what is most likely to be the next tools in bio sediment reduction/elimination.

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Quick Look Into The Future

Looking into my crystal ball I see two more future innovations:

- Heat disinfection of RO membranes
- Nanometer texturing of RO membranes

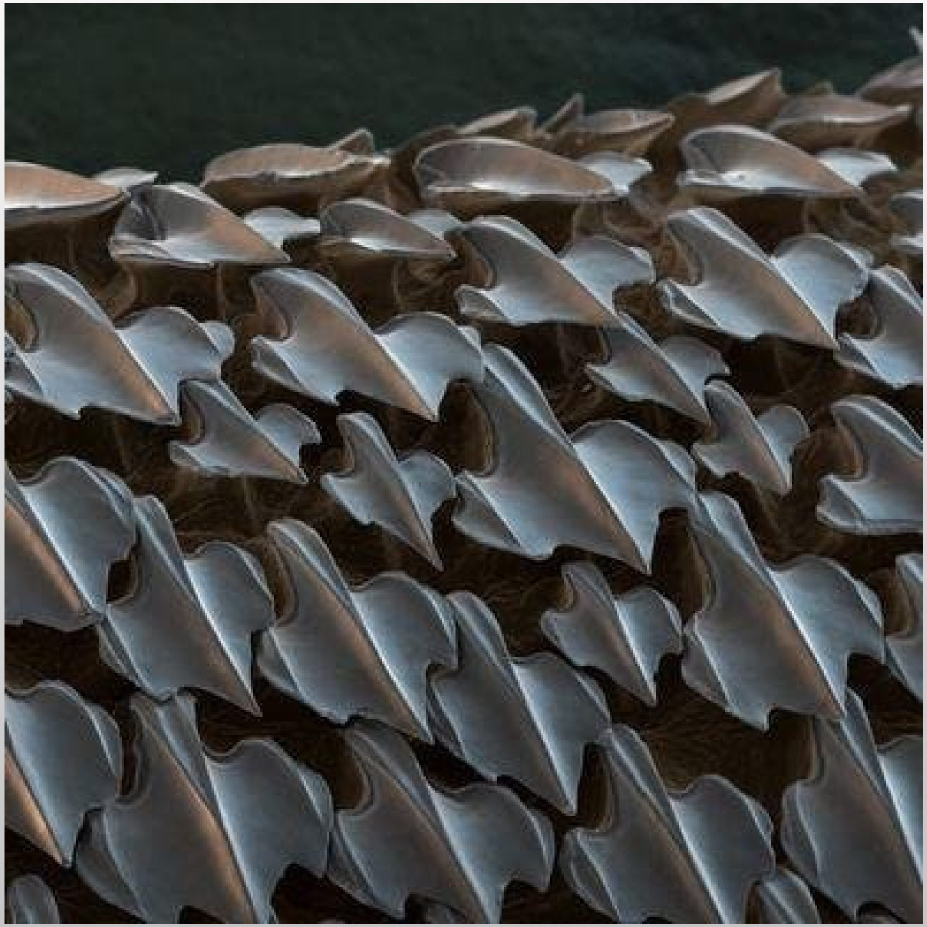
Heat Disinfection of RO Membranes

When heat disinfectable RO membranes are used, the complete purified water side of the RO can then be disinfected by heat, virtually eliminating any bio sediment developing.

Texturing of RO Membranes

- For many years scientists have noted that the skin on sharks appear to be free from or resistant to biofouling?
- They wanted to know why
- Looking at shark's skin on a nanometer scale they found out

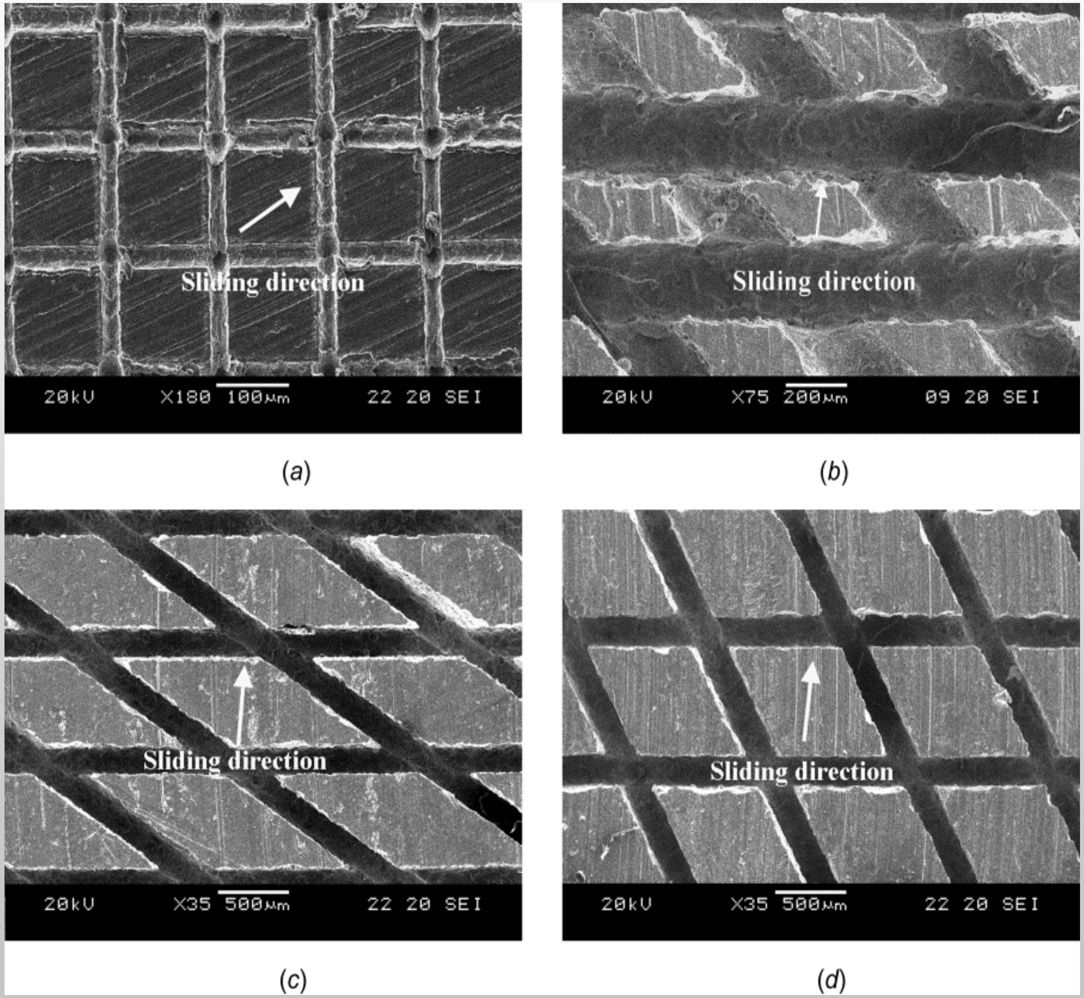
Texturing of RO Membranes



Texturing of RO Membranes

- The micro scales did not give microorganisms an easy surface to attach to
- So they decided to try to mimic skin surface

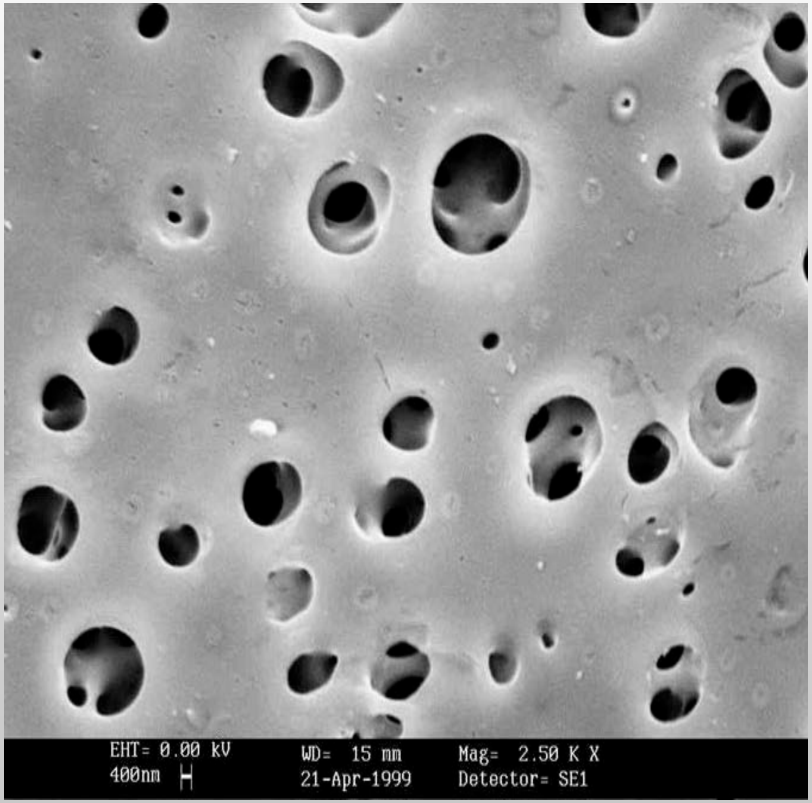
Texturing of RO Membranes

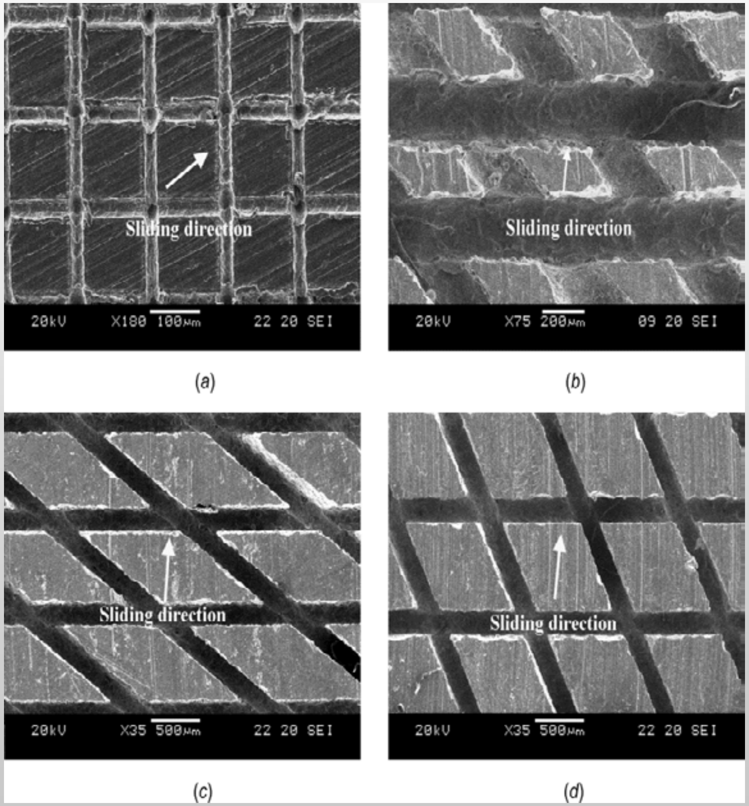


Texturing of RO Membranes

- 97% bio growth reduction on textured surface compared to smooth copper surface in hospital tests
- The RO membrane surface appears to be perfect for bacteria to attach to –
- It is super smooth even on the nanometer scale

Texturing of RO Membranes





In Summary

Today's water treatment systems can be a significant improvement over traditional water treatment systems if operated correctly and taking advantage of the benefits they offer.

Biomeds must follow corporate protocols in all of the areas that have just been reviewed.

Yes, they are not free to arbitrarily change those protocols.

Does that mean that bio-meds just passively sit on the sideline and say, “it’s not my problem”?

No.

Bio-meds have the responsibility to:

- understand how their water treatment systems function
- identify how to improve their water treatment systems
- know how to maintain their water treatment systems
- know how to troubleshoot and identify problems
- to communicate with their management issues that arise with their water treatment systems

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- If Bio-Meds do that, then they have done their job to advise their management and it is then with their management to help them do their job better.
- Unless you do that, saying that you must follow protocol is a “cope out”, a failure of responsibility, and a failure of opportunity.
- They can build a machine that will follow protocol.

A Good Bio-Med Will Not Be Replaced With A Machine

Patients Need Good Bio-Meds!

Question & Answer

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Supplementary Resources

- Please use this as your last slide to direct your audience to additional reading materials not cited in your presentation that may be of interest to them based on your presentation.