Glass Cullet as a Filter Media

Session Objectives

- Familiarize you with the terms and properties of filtration media
- Share some insights
- Answer questions (or at least try...)

Topics of Discussion

- What is filtration?
- What role does media play?
- Required properties of the media
- Research support

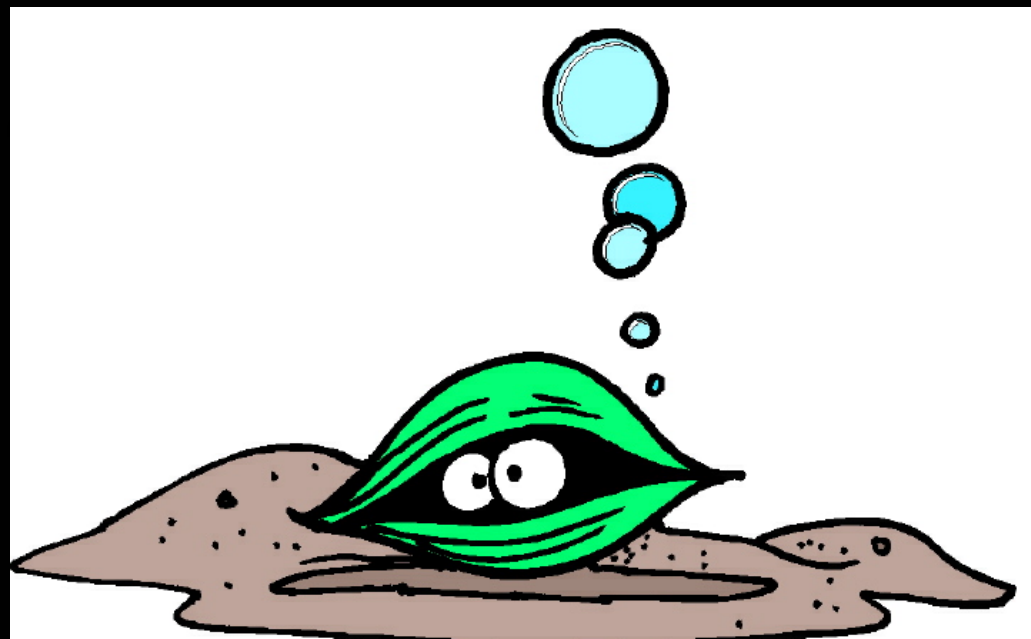
What is filtration?

- Goal: Modify the concentration (usually reduce) of chemical or physical constituents of fluid to achieve certain desired characteristics, specifically:
  - Total Suspended Solids (TSS): Fluid Clarity
  - Nitrates & Nitrites
  - Ammonia
  - Microbial reduction (a little)

What role does media play?

- Mechanical separation -> “Netlike”

- Biological reduction ->

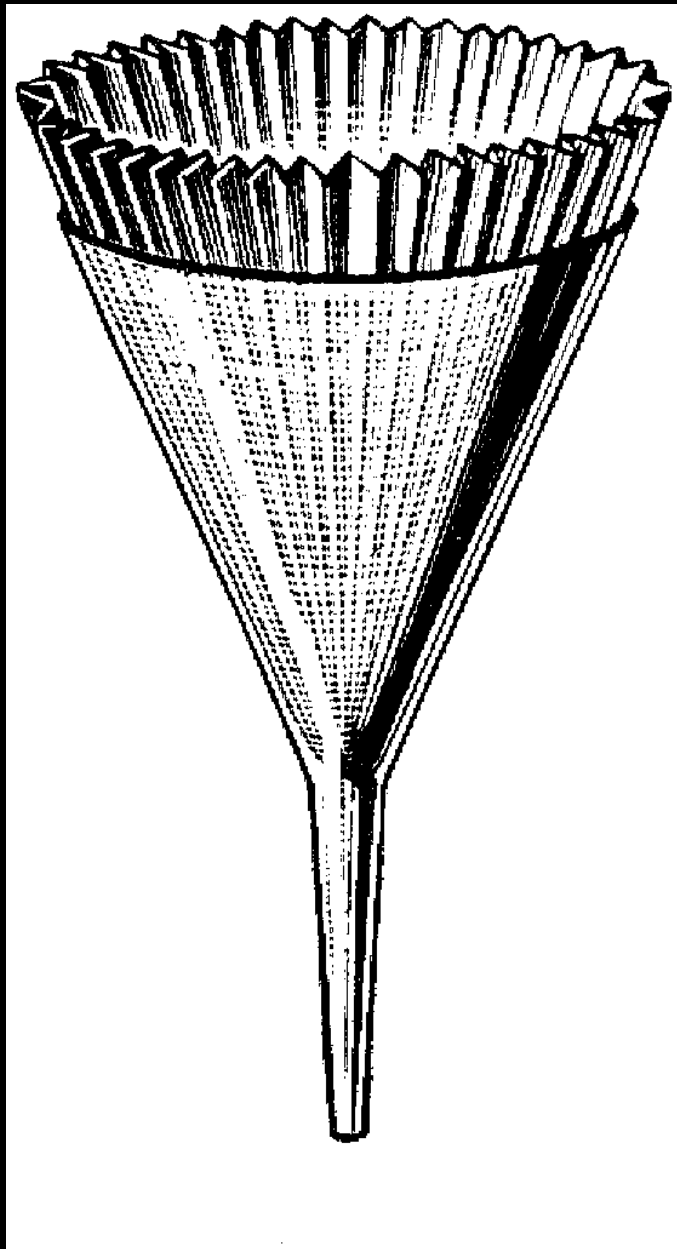


What role does media play?

- Let’s look at the Netlike or straining properties first...

Commonplace Straining Examples

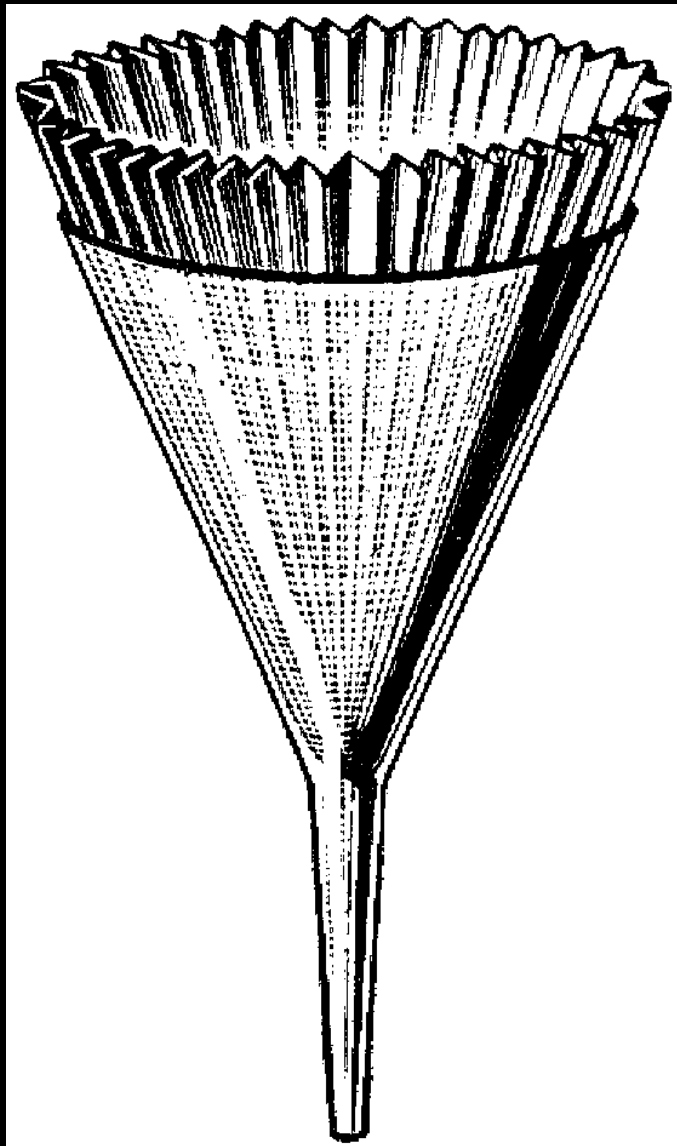
- The media provides a “net” to hold back particles larger than a set size, passing particles *smaller* than the opening size



Commonplace Straining Examples

- Clarity improvement:
  - Coffee & automotive filters
- Chemical modification:
  - “Brita”® pitcher & faucet filters
- Gross solids removal:
  - Liquids passed through a cheesecloth

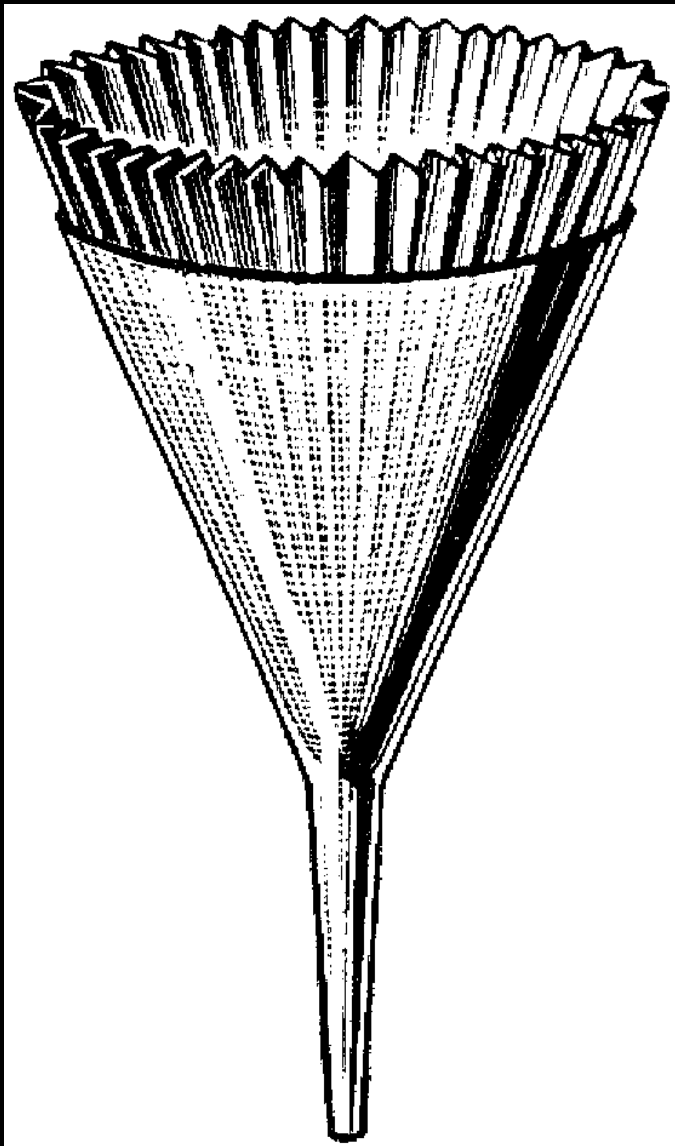
This is all MECHANICAL separation



Commonplace Straining Maintenance

- Coffee filters
  - Only good for one use
- “Brita”® pitcher, automotive & faucet filters
  - Must be replaced as a single component
- Liquids passed through a cheesecloth
  - Must shake out, wash or rinse cloth

With non-disposable systems, this is the backwash cycle

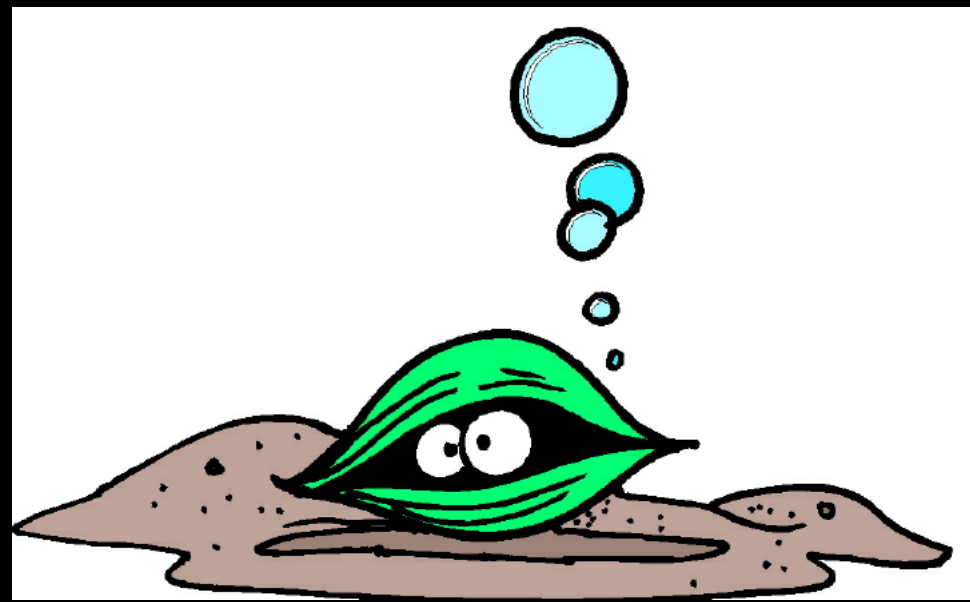


Mechanical / Straining / Netlike => Large Scale (Municipal)

- Mostly in water filtration applications
- Requires backwashing to remove trapped particles
- Seeks to AVOID biological growth
  - Potability
  - Off-Tastes

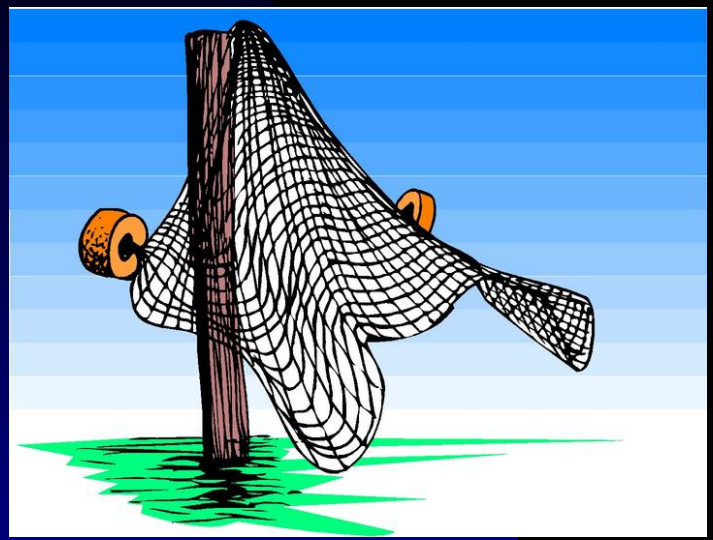
Biological / Clamlike

- More often in wastewater treatment applications
- Use a specific biology (typically widely diverse colonies of microorganisms) to absorb or convert (through consumption) undesirable components
- Should not be backwashed, lest the “bugs” get washed away
- Media **SURFACE** Provides a home for the “bugs”

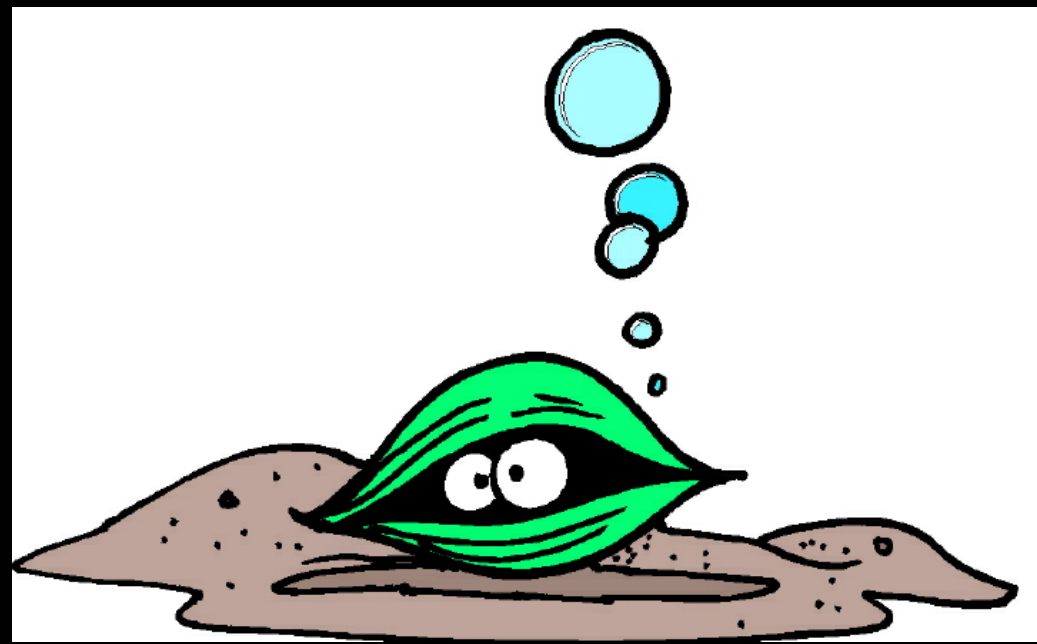


The Role of Media, then is...

Either mechanical separation -> “Netlike”



or Biological reduction/ separation



Or Both!

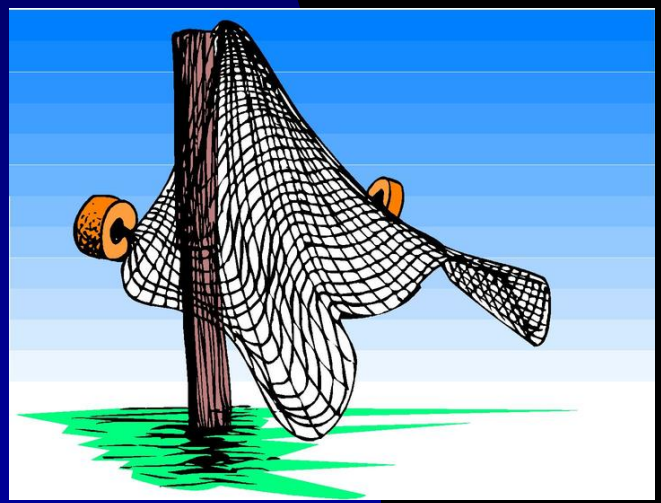
Rick Stryker, PE

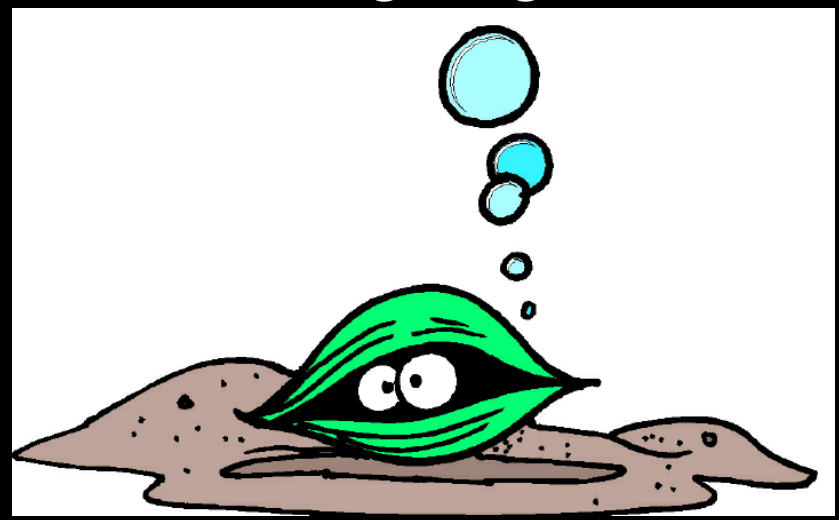
The chain of design thought ...

The properties of the media are determined by the intended function of the filter.

The function that the filter is to perform is based on the:

A. Characteristics of the stuff coming in, and
B. Desired characteristics of the stuff going out





There is no “one size fits all” setup.

What are the properties of interest for filter media?

- Hardness
- Chemistry
- Shape
- Particle size / distribution (gradation / sieve analysis)
- Individual particle density

What are the properties of interest for filter media?

- Hardness
  - Specifications and regulations usually require “Of sufficient hardness and soundness...”
    - For filter media – It shouldn’t crush, powder, compact, or deform under its own load or the hydrostatic load of the carrier fluid

What are the properties of interest for filter media?

- Chemistry
  - The media cannot be reactive with the fluid which is being filtered, the constituents being removed, or with the biology it is supporting

What are the properties of interest for filter media?

- Shape - Minerals
  - Ideally, perfect spheres (for mechanisms described next)
  - Realistically found as angular, oblong or irregular
  - Flat (planar across 2 dimensions) is ok, but platy (planar across all 3 dimensions) is not

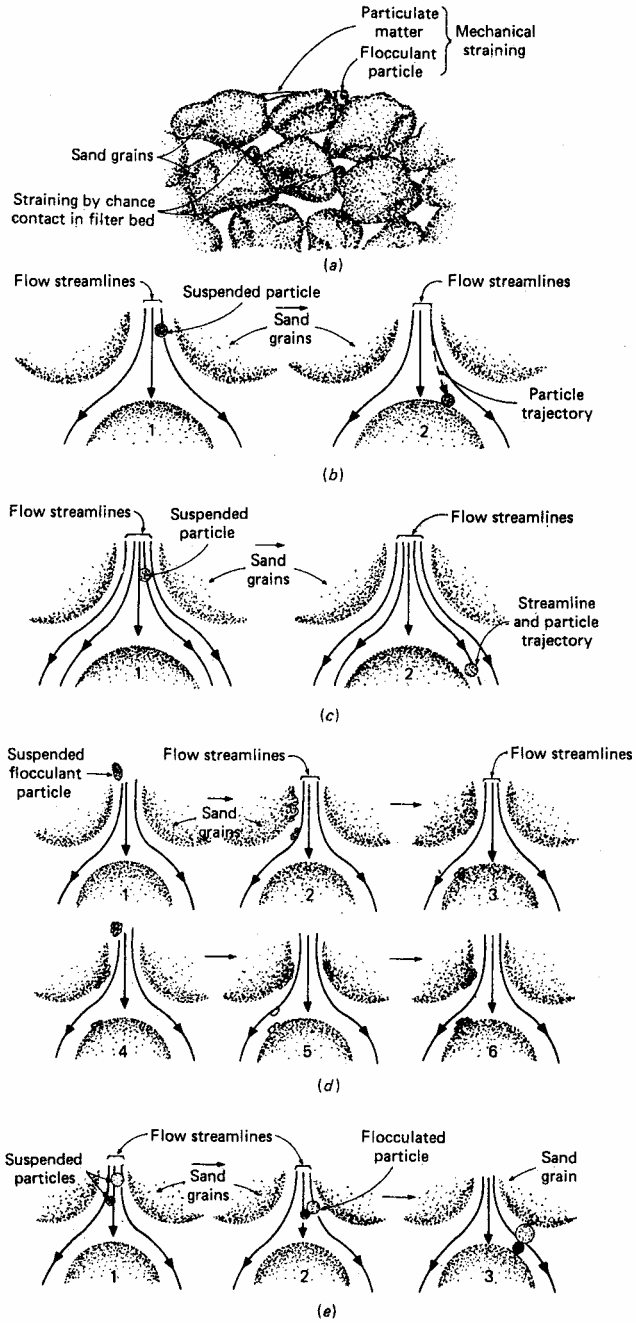


FIGURE 6-30

Filtration Mechanisms

a. Straining
b. Sedimentation
c. Interception
d. Adhesion
e. Flocculation

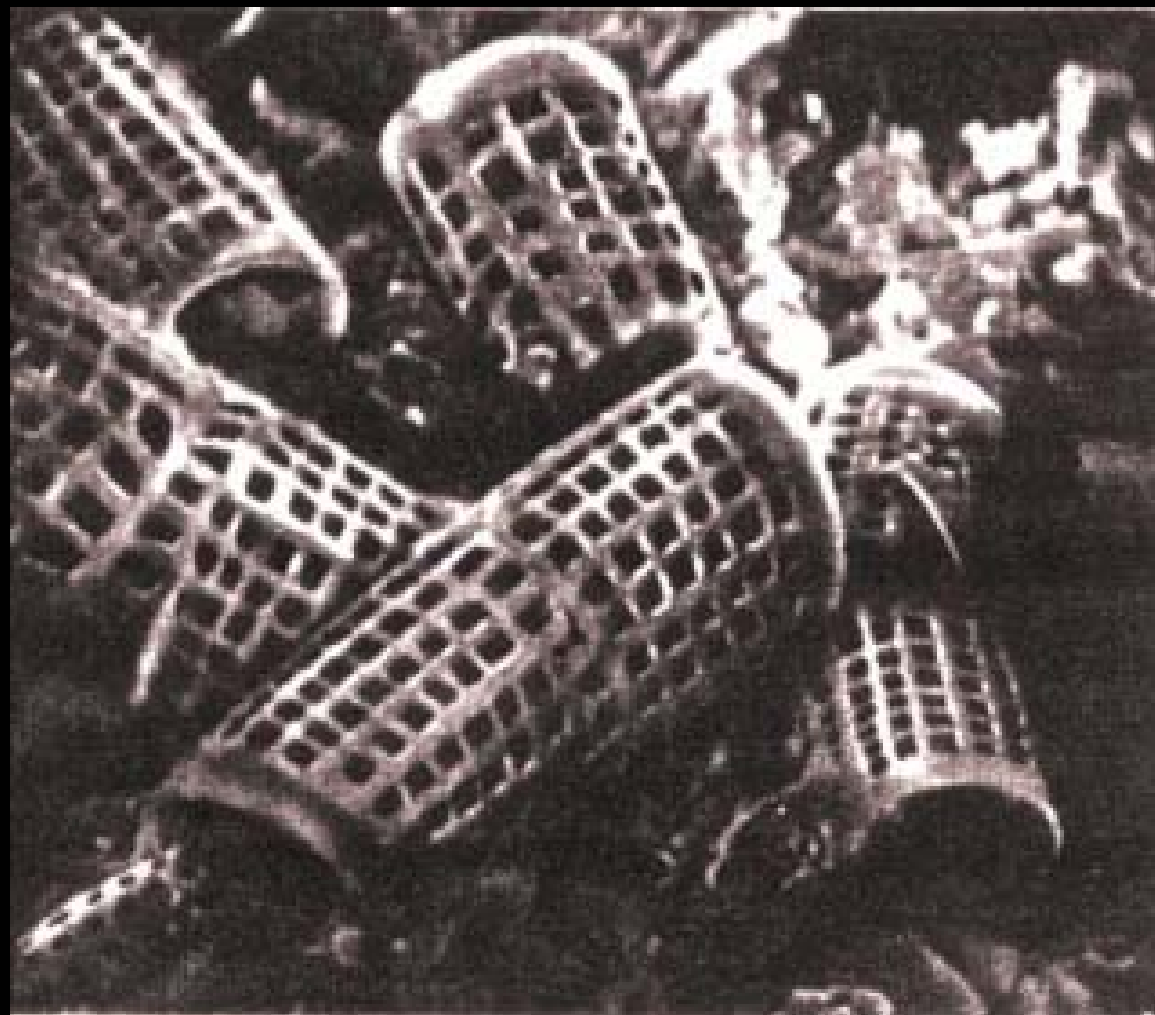
Illustration from
Wastewater Engineering
Metcalf & Eddy

What are the properties of interest for filter media?

- Shape – Exception
  - Diatomaceous Earth

Magnified 7,000x

(and then some with the overhead!)

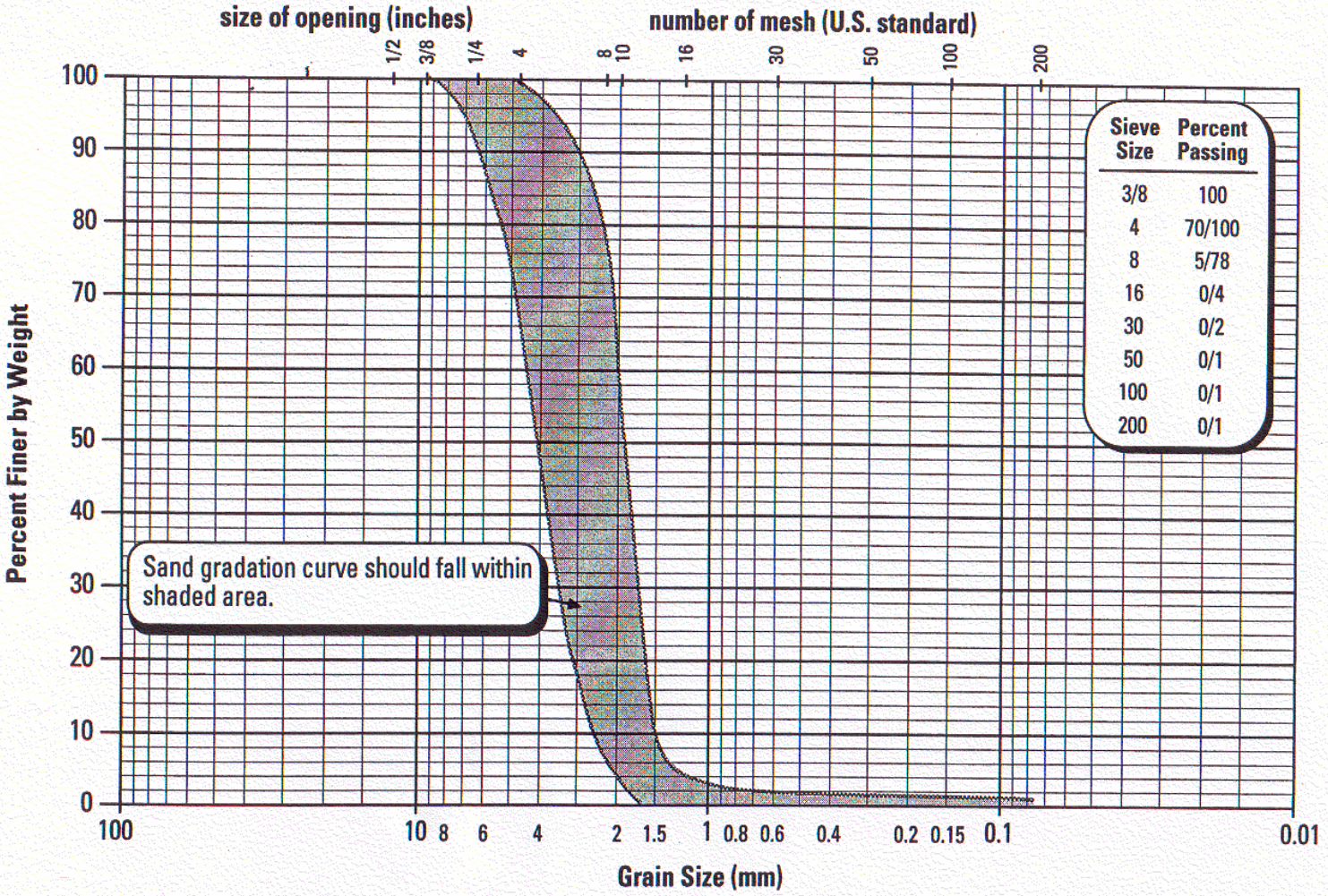


What are the properties of interest for the media?

- Individual particle density
  - Each particle has to be stable and not float in the fluid being filtered

Sand Gradation Range for Recirculating Sand Filter Media Loaded up to 5 gpd/ft^2* (D_{10} = 1.5 to 2.5 mm C_u = 1 to 3)

* Follow complete Recirculating Sand Filter design criteria.



Note: To ensure the sand consolidates sufficiently, keep it wetted while placing.

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Why “sand?”

It’s the traditional material – Adheres to the six word deadly phrase:

WE’VE ALWAYS DONE IT THIS WAY!

Why not something new?

It’s the traditional material – Adheres to the deadly seven-word phrase:

WE’VE NEVER DONE IT THIS WAY BEFORE!

What are the properties of interest for filter media? Revisited

- Hardness
- Chemistry
- Shape
- Particle size / distribution (gradation / sieve analysis)
- Individual particle density

What does all of this have to do with glass?

It has EVERYTHING to do with filter efficiency.

We’ve been describing all of the best properties of processed, sorted, post-consumer glass

What are the properties of interest for glass cullet?

- Hardness
  - Glass Compressive strength => 150,000 psi
  - Glass Tensile strength varies inversely with size
    - ½" diameter rod => 8,000 psi
    - Fibers ($5x10^{-5}$ in) => 3,000,000 psi

1. It takes a lot of work to make cullet, and
2. It's not likely to change size or shape under field application

What are the properties of interest for glass cullet?

- Chemistry
  - Chemically inert – Only reactive with a short list of acids

And if these are passing through the filter, you have MUCH larger problems than the sand dissolving...

What are the properties of interest for glass cullet?

- Shape – Glass Cullet
  - Angular to blocky
  - Often slightly curved

What are the properties of interest for glass cullet?

- Particle size / distribution (gradation / sieve analysis)
  - Related to idea that we need space for the fluid to pass with its load of stuff we want to remove
  - May require space for biology to live AND
  - May require space for AIR for that biology

What are the properties of interest for glass cullet?

- Particle size / distribution - continued
  - Catch-22
    - Spaces which are too small will deny biology oxygen by holding water or filling the pores
    - For a straining filter, it will catch very large particles, giving rise to much backwashing
    - Spaces which are too big will allow offending material to pass but flow won't be a problem

What are the properties of interest for the media?

- Individual particle density
  - Glass particles (in sizes appropriate for filter media) has a specific gravity of about 2.5 (more than twice the unit weight of water)

Most importantly...

WHAT'S PennDoT HAVE NOT A THING TO DO WITH THIS ?!?!?

AASHTO #57
4.5 < E_s < 10.5
1.1 < C_u < 2.3

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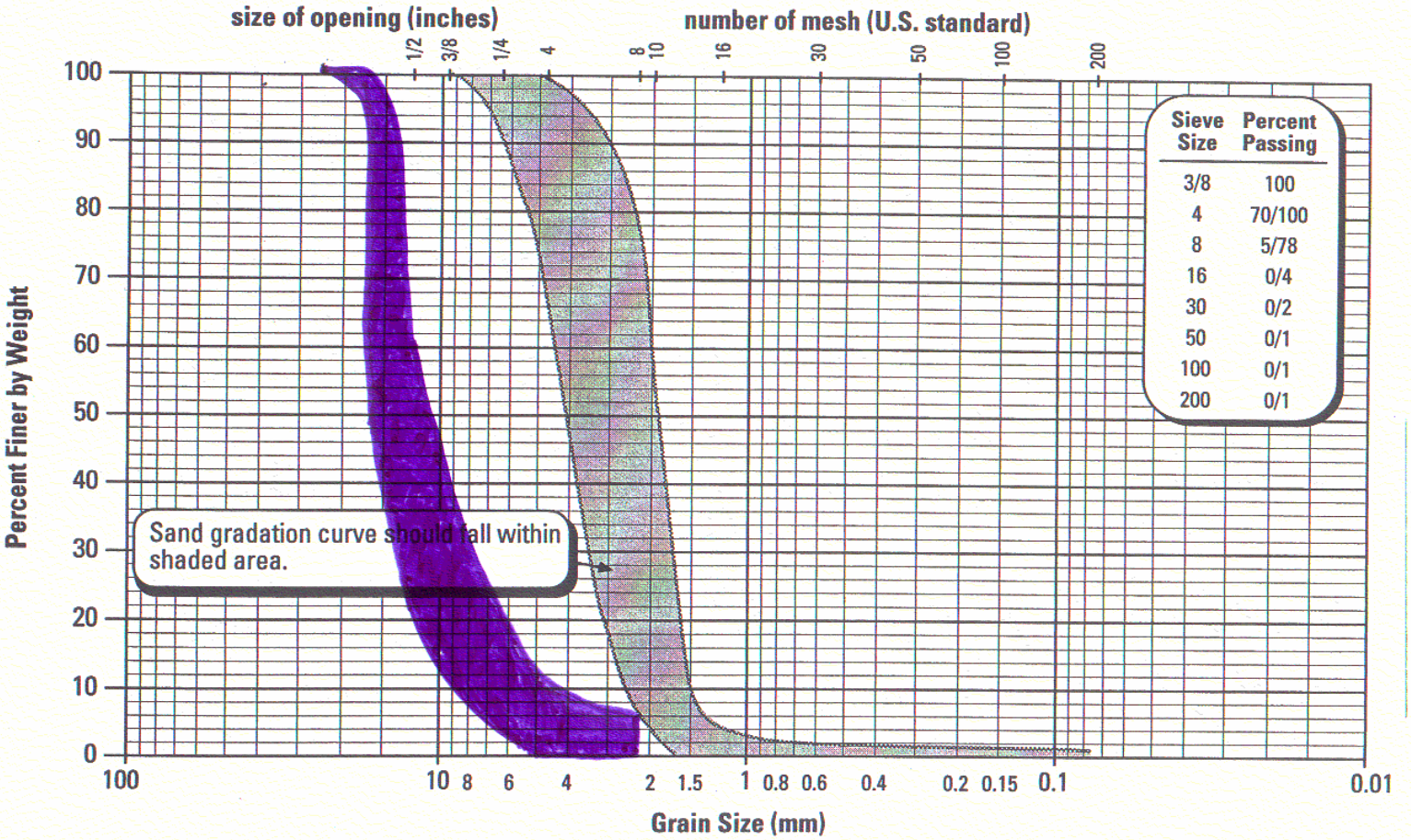

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How do others address this?

- **New Hampshire: 0.25mm <Es< 2.0mm, and sets limits of max and min particle size**
- **New York: 0.25mm < Es <1.0mm,**

  Cu < 4.0
- **New Jersey: Refers to NJDoT standard *SIZING* for coarse aggregates**

How do others address this?

- **Maine: Refers to EPA Onsite Wastewater Treatment and Disposal Systems, 625/1-80/012...**
- **EPA document: 0.3mm < Es <1.5mm, Cu <4.0 (prefer <3.5)**
- **Ohio: 0.4mm < Es < 1.0mm, Cu < 3.0**
- **Maryland: 0.25mm < Es < 0.5mm, Cu <3.5**

Research Support for Recycled Materials for Media

- EPA – Small Flows Clearing House
  - Tire Chips in Soil Absorption Systems
  - Crushed Glass as a Filter Media for the Onsite Treatment of Wastewater
  - Sand Filter Wastewater Treatment Facilities for Small Communities
  - Evaluation of the Use of Crushed Recycled Glass Filter Media in a Recirculating Granular Media Filter

Research Support for Recycled Materials for Media

- EPA: 2002 Onsite Wastewater Disposal Manual: 0.25mm < Es < 1.00 mm, Cu < 4

"Many types of media are used in packed bed filters. Washed, graded sand is the most common medium. Other granular media used include gravel, anthracite, CRUSHED GLASS, expanded shale and bottom ash from coal-fired plants...."

Research Support for Recycled Materials for Media

- EPA: 2002 Onsite Wastewater Disposal Manual:

"Crushed glass has been studied successfully (Darby et al '96, and Emerick et al '97), and it was found to perform similarly to sand of similar size and uniformity."

Research Support for Recycled Materials for Media

- EPA: 2002 Onsite Wastewater Disposal Manual:

"ISF filter design starts with the selected media. The media characteristics determine the necessary filter area, dose volumes, and dosing frequency. Availability of media for a specific application should be determined before completing the detailed design. The sand or gravel selected should be durable with rounded grains. Only washed material should be used. ... Other granular media that have been used are bottom ash, expanded clay, expanded shale, and crushed glass. These media should remove BOD and TSS similar to sand and gravel for similar effective sizes, uniformity, and grain shape."

Research Support for Recycled Materials for Media

- Clean Water Center (Washington State)
  - Cullet for Pool Filter Media (GL-98-1)
  - Cullet for Septic Filters (GL-97-2)
  - Cullet as a Slow Sand Filter Medium (GL-95-4)
  - Recycled Glass in Onsite Wastewater Filters (BL-GL-04-03-01)

Research Support

The data supports it.

When properly sorted, graded, and free from different / foreign material, glass cullet is an excellent granular media for fine media filtration applications, in either filtration mode intended.

An exercise in logic ...

Question	Answer
What are common SYMPTOMS of sand mound failure?	Breakout, ponding, house backup.
What is the common cause for the failure?	Malfunctioning bed.
Why do beds fail?	They lose their permeability: clogging.
What's the bed clogged with?	Suspended solids (sometimes) Anaerobic biomat (more often)

An exercise in logic ...

Question

Answer

Why does the mat form?

Intrinsic microbes flourish in saturated, *oxygen free* conditions

There was air in there when we started, where'd it go?

With limited pore space, capillary action becomes a predominant force between the granules: We've made a giant sponge!

So what can we do?

Install media which performs as required:

1. **Provides surface area for AEROBIC colonies,**
2. **Devoid of pore-filling fines,**
3. **Individual particles are sufficiently large and uniform in size to allow gravity, not capillary action, to dominate.**