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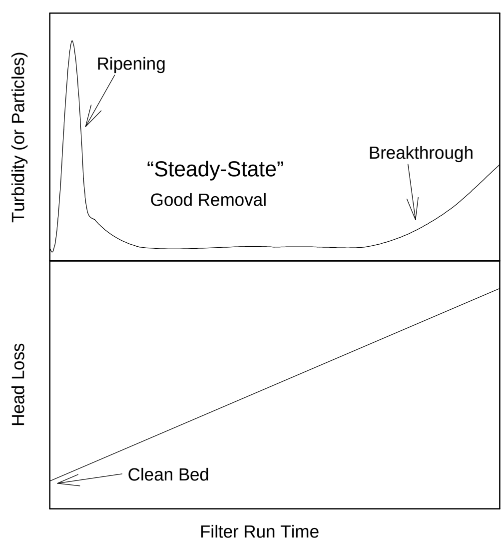
CEE 371
Water and Wastewater Systems

Lecture #19
Drinking Water Treatment: Granular Media Filtration (cont.)
Reading: Chapter 7, pp.217-225

FILTRATION PERFORMANCE

- *Performance determined by measuring:*
- Filtered water quality (extent of particle removal)
- Increased resistance to fluid flow caused by particle deposition (head loss)



from John Tobiason

Filter Run Length

- Duration of filter run (i.e., hours) between backwashes; determined by:
  - exhaustion of available head (i.e., 5 - 10 ft by gravity)
  - breakthrough of particles or turbidity (i.e., >0.1 to 0.3 ntu)
  - allowed operation time (i.e., 24 hrs or other time)
- *Run length affects frequency of backwashing and water production*
- Water production as Unit Filter Run Volume (UFRV):
  - UFRV = (Volume filtered per run per unit area of filter media)
  - UFRV = [(Filter Rate) x (Run Length)] / Filter Area
  - (i.e., 2,000 - 20,000 gallons per square foot per run)
  - (or 40 - 400 cubic meters per square meter per run)
  - i.e., 24 hrs @ 4 gpm/ft^2, UFRV=24 x 60 x 4 = 5760 gal/ft^2
- Production also expressed as % of water used for backwashing per day (i.e., 2 to 5 % is common)

from John Tobiason

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PARTICLE REMOVAL (DEPOSITION) MECHANISMS

(dp = particle diameter; dc = media diam.; V_0 = filtration rate)

- ***STRAINING*** (a physical mechanism)
  - particles larger than pores
  - important in membrane and DE filtration
  - important when $d_P/d_C > 0.2$
  - not dominant in granular media (depth) filtration
- ***DIFFUSION*** $[\sim (d_p\, d_c\, V_0)^{-2/3}]$
  - important for sub-micron size particles (d_p < 1-2 μm)
  - transport rate increases as dp decreases
- ***INTERCEPTION*** $[\sim (d_p / d_c)^2]$
  - important for larger size particles (d_p > 1-2 μ m)
  - finite size of particle results in transport to collector surface as fluid streamlines constrict
- ***SEDIMENTATION (GRAVITY)*** $[\sim (d_p^2 (\rho_p - \rho_w)/V_0]$
  - important for larger, denser particles
  - importance increases as filtration velocity decreases

from John Tobiason

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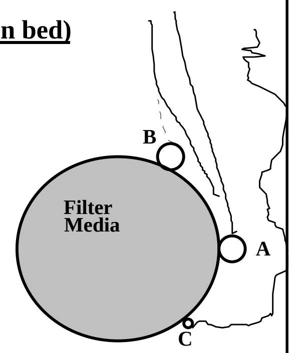
Particle Removal as a Two Step Process

:

- *Transport* from flowing fluid to collector surface
  - (physical processes)
- *Attachment* to original media or deposited particles
  - (chemical effects - MUST HAVE GOOD COAGULATION)

PARTICLE REMOVAL (clean bed)

TRANSPORT
- Interception (A)
- Sedimentation (B)
- Diffusion (C)

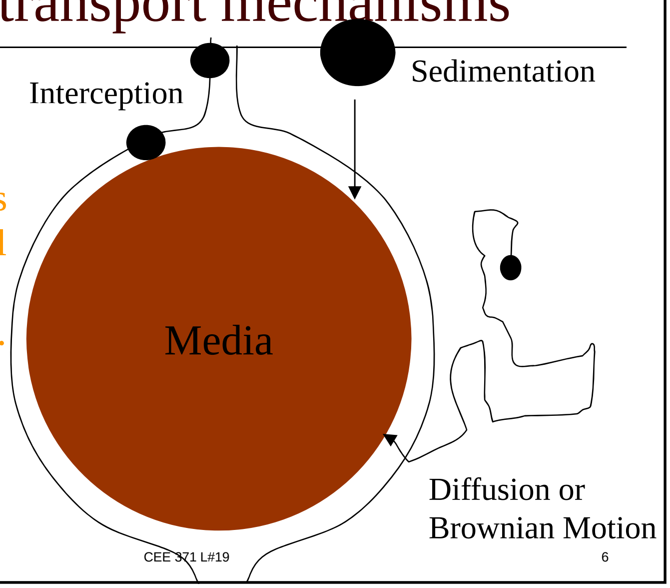


ATTACHMENT
- Chemical Effects
- Short Range Surface Interaction Forces

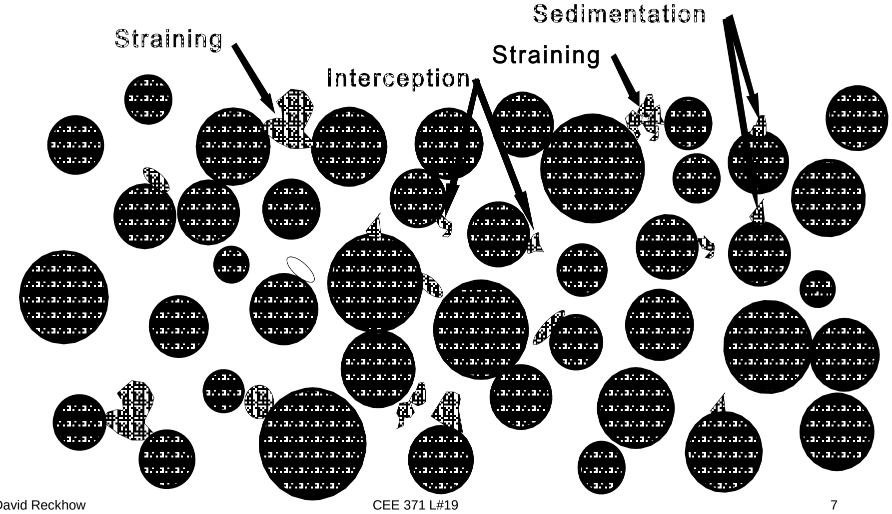
from John Tobiason

Filtration transport mechanisms

In addition, particles must be able to stick. This requires chemical destabilization (i.e. coagulation).



Deposition in a Filter



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HEAD LOSS DEVELOPMENT

- *HEAD LOSS*: **Energy lost during fluid flow due to friction at surfaces (water is viscous!)**
  - **Total ΔH = Initial Δ H (Δ H_0) + Δ H due to deposited particles**
  - ***Constant rate filtration*:**
    - **transfer of head loss from control valve to filter over time**
  - ***Declining rate filtration:***
    - ***flow decreases as H increases***
- ***Clean Bed Head Loss: Carmen-Kozeny equation***

$$\frac{\Delta H}{L} = \frac{36k(1-\varepsilon)^2 \nu V_0}{\varepsilon^3 d_c^2 g}$$

  - ***where ε = porosity, ν=kinematic viscosity, V_0 = filtration rate, d_c = mean media diameter, ΔH=clean bed head loss, L = bed depth, k= constant (4-5)***
- ***Clean bed head loss increases:***
  - ***as temperature decreases (viscosity increase)***
  - ***linearly as bed depth (L) and loading rate (V_0) increase***
  - ***as square of media diameter decrease***
  - ***as porosity decreases (uniformity coefficient increases)***

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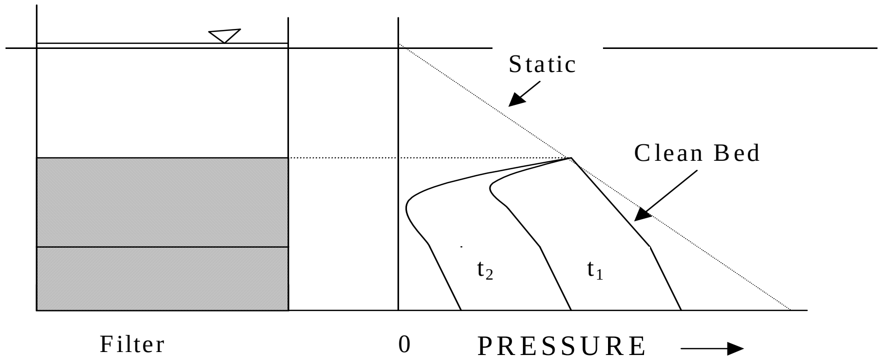
Illustrationof Headloss Development



-Head loss caused by particles can reduce pressure significantly
-If pressure too low, precipitation of dissolved gases can occur
-Referred to as "air binding"

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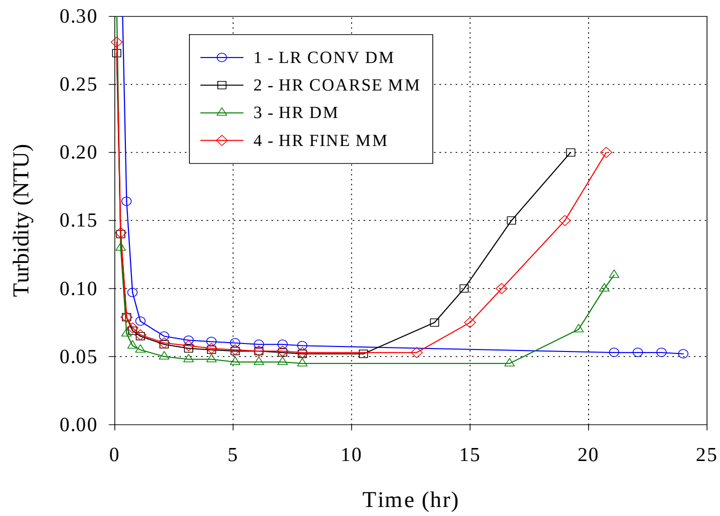
Typical Filter Performance

LR=low rate = 10 m/hr, HR=high rate = 20 m/hr



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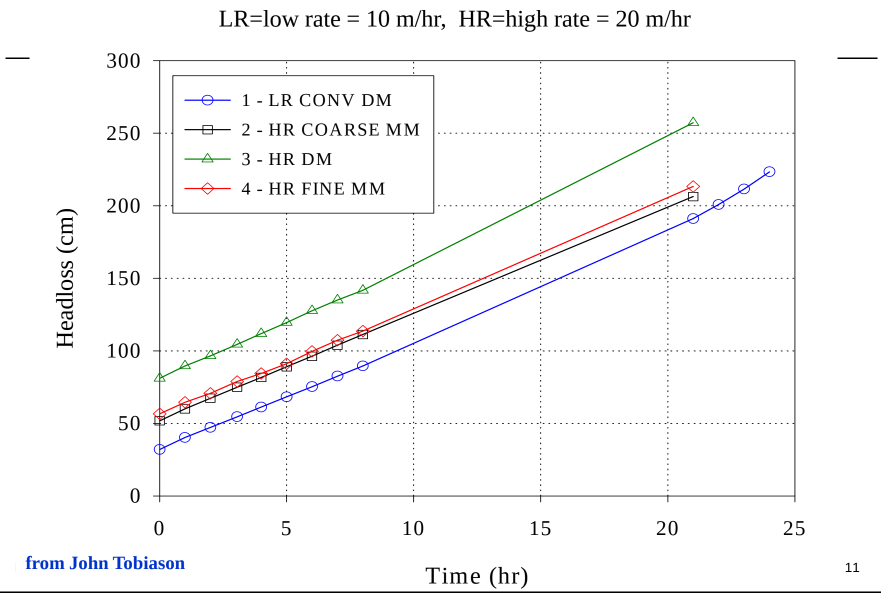
Typical Filter Performance



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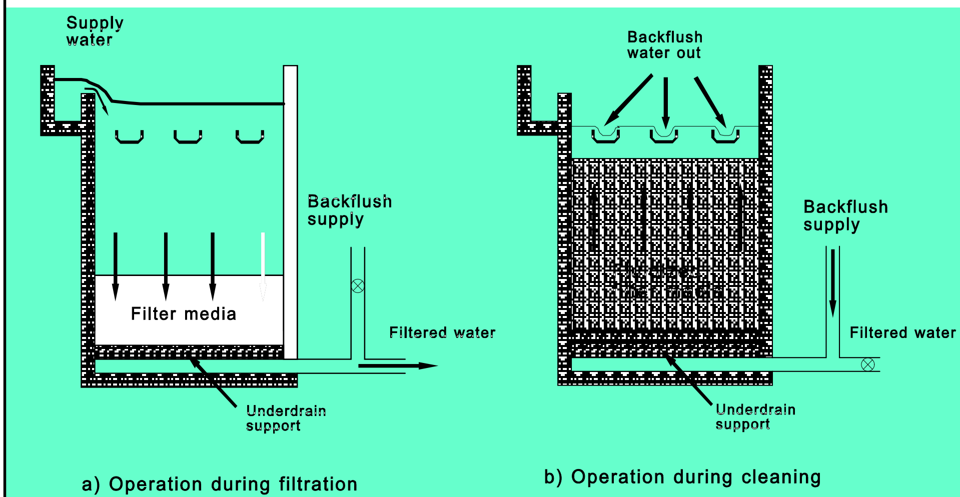
Filter Operation



Filter Backwashing

- Granular media filters backwashed at end of filter run (head loss, breakthrough, time) to remove deposited particles.
- *Typically occurs in upflow direction to fluidize and expand filter media.*
- Methods include water only wash with surface washing, or sequencing/combining of air and water washes.
- *Hydraulic shear & media collisions remove deposited particles.*
  - Collapsed pulse backwashing (Amirtharajah) - subfluidization water velocity and appropriate air flow - yields best media cleaning
- Backwash hydraulic loading rate and duration varies with media, water temperature, water quality and coagulation/clarification practices.
  - Must use higher backwash rate in warm water conditions to achieve same expansion as obtained with colder water (water viscosity decreases as temperature increases).

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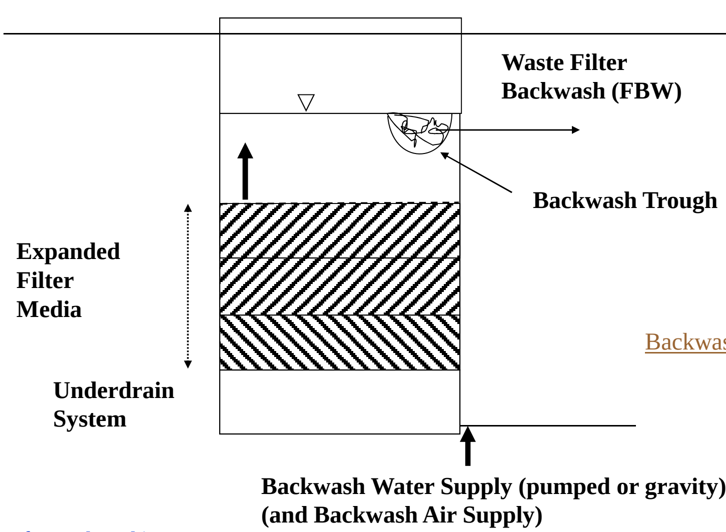
Backwashing of Granular Media Filter



Backwash Video

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Filter Backwashing (cont.)

- **Filter backwash (FBW) produced at high rate for short time:**
- ***Typical water backwash rates: 14-22 gpm/ft^2 (34-54 m/hr) (rate often varied within the backwash: low, high, low)***
- **Duration of 10-20 minutes (wider range not uncommon).**
- ***Typical waste filter backwash volume produced*:**
  - **150 - 300 gallons/ft^2 per filter run**
  - **2 to 5% of finished water production overall**
- **For plants with only a few filters, rate of filter backwash production from one filter can be a large fraction of, or exceed, overall plant production rate (BW at 4-10 times filtration rate).**

from John Tobiason

Air scour blowers

3 Feb 09

DSCN6204

Waste Filter Backwash Water

- **Waste FBW Processing Options:**
  - **Discharge to sanitary sewer**
  - **Discharge to receiving water (treatment, permits)**
  - **Recycle with or without treatment within plant**
- ***Waste FBW Recycling:***
  - ***Recent US EPA regulation – location, reporting***
  - ***Concern over potential to impair finished water quality***
  - ***Impact of recycle depends on water quality and flow control***

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- To next lecture

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