Lecture 13

PARTICULATE MATTER REMOVAL (2)

Course: Water Reuse

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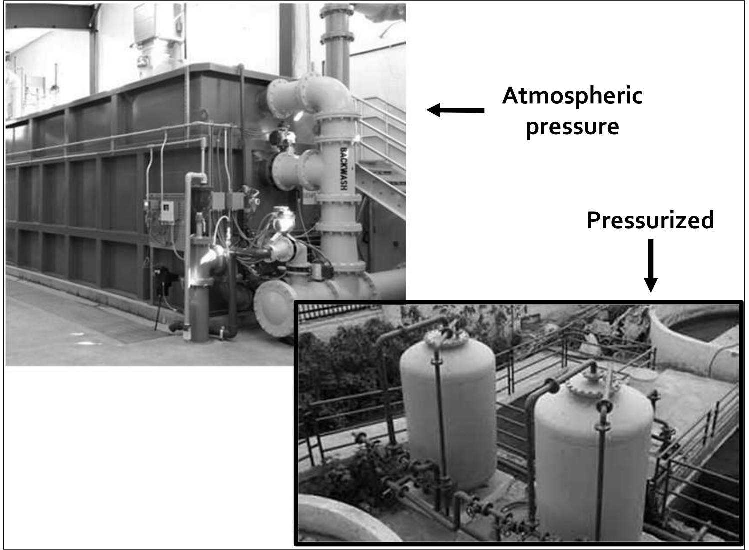


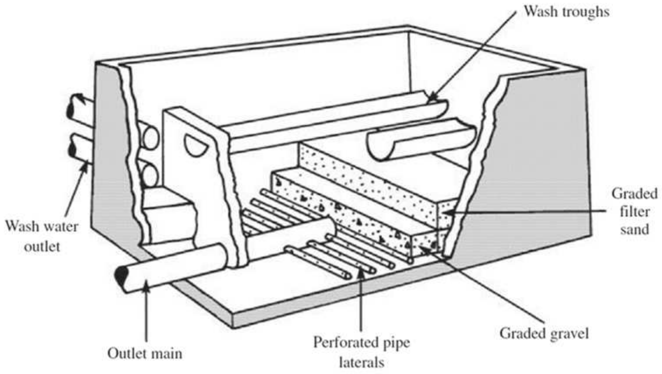
Atmospheric pressure

Pressurized

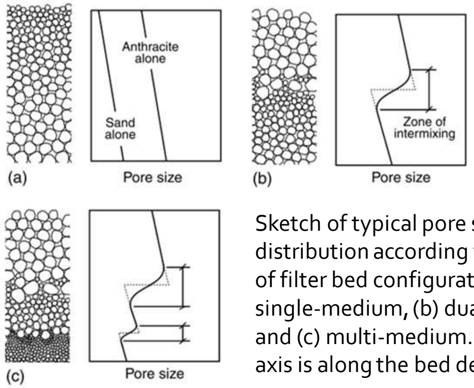
Gravity filter types

Slow sand filter	**Rapid sand filter**	**Dual media filter**
Loading rate: less than 10 m^3/m^2d. When top layers are clogged, they are removed, cleaned, and replaced. Large area, labor intensive, inexpensive.	Loading rate: 120-200 m^3/m^2d. Have graded (layered) sand. Cleaned by backwashing. After backwash the large particles settle first and fines settle on top. Most common.	Loading rate: 300-600 m^3/m^2d. Sand covered by coal which is bigger but settles slower during backwash. So top layer is not clogged. Designed to use more depth.

Schematic



Pore size



Sketch of typical pore size distribution according to the type of filter bed configuration (a) single-medium, (b) dual-medium, and (c) multi-medium. Vertical axis is along the bed depth.

TSS approximation

Settled secondary effluent

TSS, mg/L = (2.0 to 2.4) × (turbidity, NTU)

Filter effluent

TSS, mg/L = (1.3 to 1.6) × (turbidity, NTU)

Particle size

- Depending on the quality of the settled secondary effluent, chemical addition has been used to improve the performance of effluent filters, with respect to turbidity.
- Particles in the size range from 2-5 µm and 5-15 µm, which correspond to the appx sizes of Cryptosporidium and Giardia, are important with respect to disinfection.
- Particles larger than 10-15 µm are of importance because they are of sufficient size to shield microorganisms.

Removal efficiency

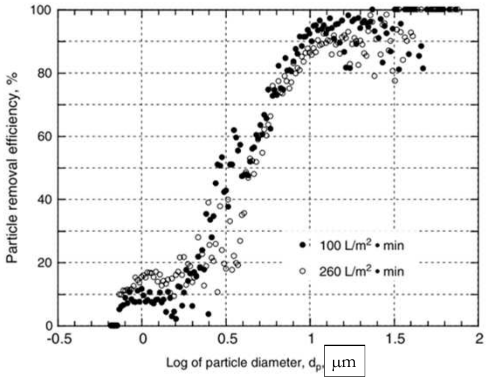


Figure 8-15
Particle size removal efficiency for a depth filter for effluent from an activated sludge plant.

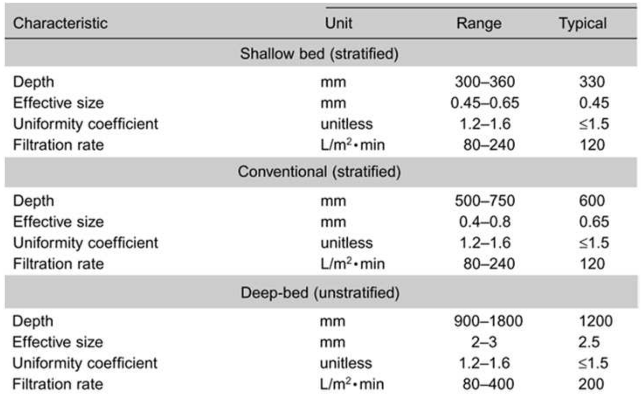
Selection of medium

- Selection of a filter media involves the effective size, d_{10} ; uniformity coefficient, UC; the 90 percent size; the specific gravity; solubility; hardness; and depth of the various materials used in the filter bed.
- The d_{90} is used to determine the required backwash rate for depth filters.
- To avoid intermixing of dual-media particles during backwash:

$$\frac{d_1}{d_2} = \left(\frac{\rho_2 - \rho_w}{\rho_1 - \rho_w}\right)^{0.667}$$

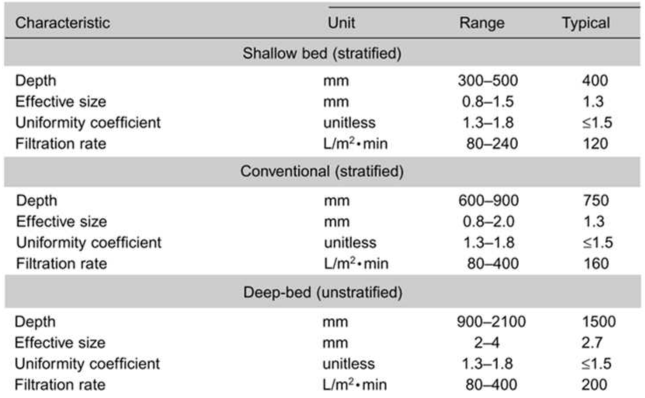
where d_1, d_2 = effective size of filter medium
ρ_1, ρ_2 = density of filter medium
ρ_w = density of water

Mono-media filter: sand



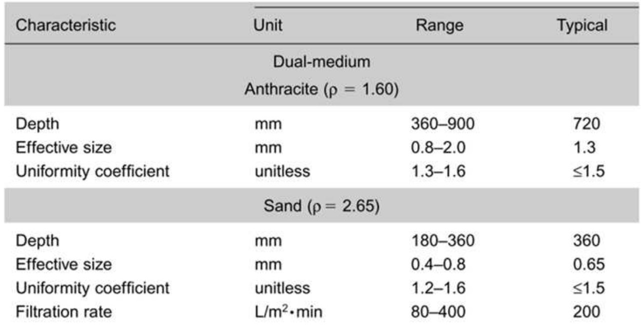
Characteristic	Unit	Range	Typical
Shallow bed (stratified)			
Depth	mm	300–360	330
Effective size	mm	0.45–0.65	0.45
Uniformity coefficient	unitless	1.2–1.6	≤1.5
Filtration rate	L/m²•min	80–240	120
Conventional (stratified)			
Depth	mm	500–750	600
Effective size	mm	0.4–0.8	0.65
Uniformity coefficient	unitless	1.2–1.6	≤1.5
Filtration rate	L/m²•min	80–240	120
Deep-bed (unstratified)			
Depth	mm	900–1800	1200
Effective size	mm	2–3	2.5
Uniformity coefficient	unitless	1.2–1.6	≤1.5
Filtration rate	L/m²•min	80–400	200

Mono-media filter: anthracite



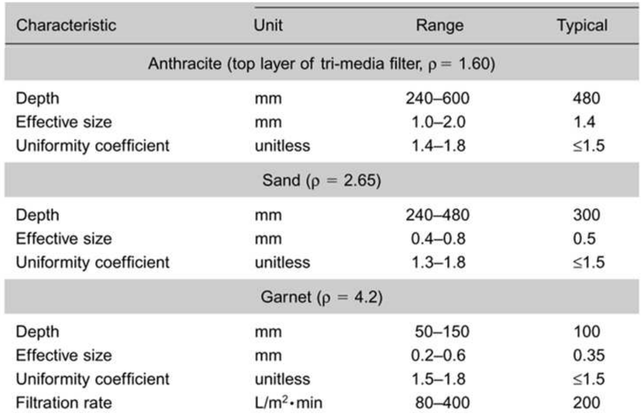
Characteristic	Unit	Range	Typical
Shallow bed (stratified)			
Depth	mm	300–500	400
Effective size	mm	0.8–1.5	1.3
Uniformity coefficient	unitless	1.3–1.8	≤1.5
Filtration rate	L/m²•min	80–240	120
Conventional (stratified)			
Depth	mm	600–900	750
Effective size	mm	0.8–2.0	1.3
Uniformity coefficient	unitless	1.3–1.8	≤1.5
Filtration rate	L/m²•min	80–400	160
Deep-bed (unstratified)			
Depth	mm	900–2100	1500
Effective size	mm	2–4	2.7
Uniformity coefficient	unitless	1.3–1.8	≤1.5
Filtration rate	L/m²•min	80–400	200

Dual media filter: anthracite + sand

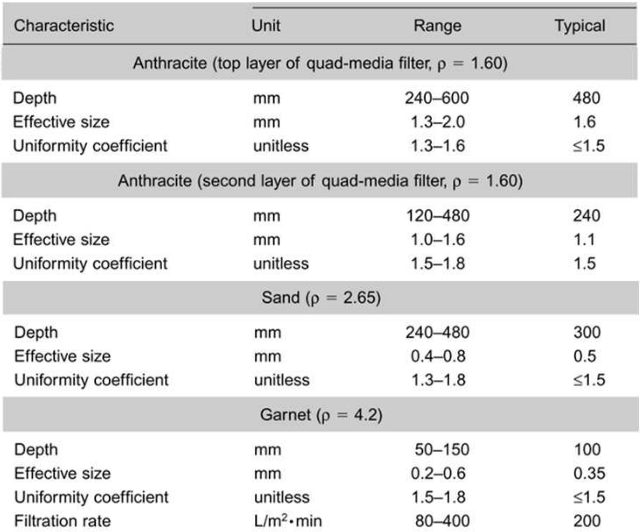


Characteristic	Unit	Range	Typical
Dual-medium Anthracite (ρ = 1.60)			
Depth	mm	360–900	720
Effective size	mm	0.8–2.0	1.3
Uniformity coefficient	unitless	1.3–1.6	≤1.5
Sand (ρ = 2.65)			
Depth	mm	180–360	360
Effective size	mm	0.4–0.8	0.65
Uniformity coefficient	unitless	1.2–1.6	≤1.5
Filtration rate	L/m²•min	80–400	200

Tri-media filter

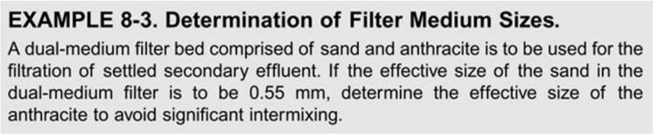


Characteristic	Unit	Range	Typical
Anthracite (top layer of tri-media filter, $\rho = 1.60$)			
Depth	mm	240–600	480
Effective size	mm	1.0–2.0	1.4
Uniformity coefficient	unitless	1.4–1.8	≤1.5
Sand ($\rho = 2.65$)			
Depth	mm	240–480	300
Effective size	mm	0.4–0.8	0.5
Uniformity coefficient	unitless	1.3–1.8	≤1.5
Garnet ($\rho = 4.2$)			
Depth	mm	50–150	100
Effective size	mm	0.2–0.6	0.35
Uniformity coefficient	unitless	1.5–1.8	≤1.5
Filtration rate	L/m²•min	80–400	200



Characteristic	Unit	Range	Typical
Anthracite (top layer of quad-media filter, $\rho = 1.60$)			
Depth	mm	240–600	480
Effective size	mm	1.3–2.0	1.6
Uniformity coefficient	unitless	1.3–1.6	≤1.5
Anthracite (second layer of quad-media filter, $\rho = 1.60$)			
Depth	mm	120–480	240
Effective size	mm	1.0–1.6	1.1
Uniformity coefficient	unitless	1.5–1.8	1.5
Sand ($\rho = 2.65$)			
Depth	mm	240–480	300
Effective size	mm	0.4–0.8	0.5
Uniformity coefficient	unitless	1.3–1.8	≤1.5
Garnet ($\rho = 4.2$)			
Depth	mm	50–150	100
Effective size	mm	0.2–0.6	0.35
Uniformity coefficient	unitless	1.5–1.8	≤1.5
Filtration rate	L/m²•min	80–400	200

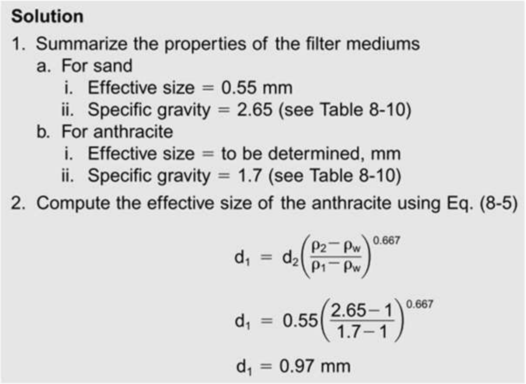
Example



EXAMPLE 8-3. Determination of Filter Medium Sizes.

A dual-medium filter bed comprised of sand and anthracite is to be used for the filtration of settled secondary effluent. If the effective size of the sand in the dual-medium filter is to be 0.55 mm, determine the effective size of the anthracite to avoid significant intermixing.

Answer



Solution

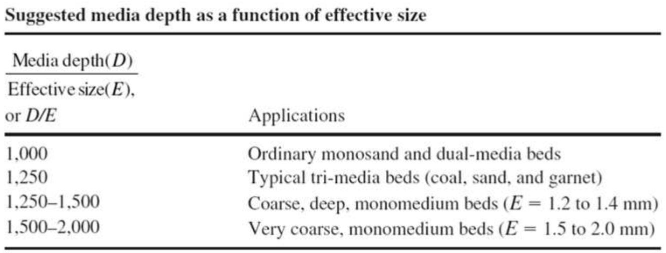
1. Summarize the properties of the filter mediums
   a. For sand
      i. Effective size = 0.55 mm
      ii. Specific gravity = 2.65 (see Table 8-10)
   b. For anthracite
      i. Effective size = to be determined, mm
      ii. Specific gravity = 1.7 (see Table 8-10)
2. Compute the effective size of the anthracite using Eq. (8-5)

$$d_1 = d_2\left(\frac{\rho_2 - \rho_w}{\rho_1 - \rho_w}\right)^{0.667}$$

$$d_1 = 0.55\left(\frac{2.65 - 1}{1.7 - 1}\right)^{0.667}$$

$$d_1 = 0.97 \text{ mm}$$

Suggested depth

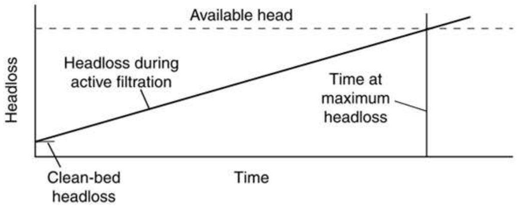


Suggested media depth as a function of effective size

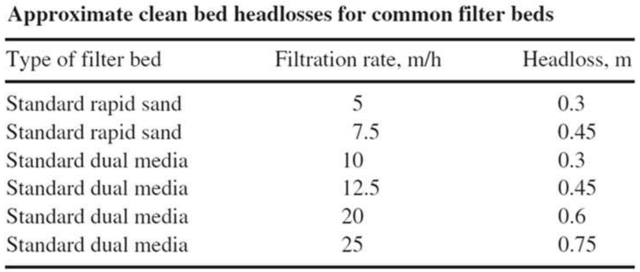
Media depth(*D*) / Effective size(*E*), or *D*/*E*	Applications
1,000	Ordinary monosand and dual-media beds
1,250	Typical tri-media beds (coal, sand, and garnet)
1,250–1,500	Coarse, deep, monomedium beds (*E* = 1.2 to 1.4 mm)
1,500–2,000	Very coarse, monomedium beds (*E* = 1.5 to 2.0 mm)

Head loss

- As the filtration bed is used, the pores gradually get blocked and the head loss increases
- There is a turbidity spike at the beginning of every run (after backwash) because of the opening of the pores (ripening phase)



Approximate head loss

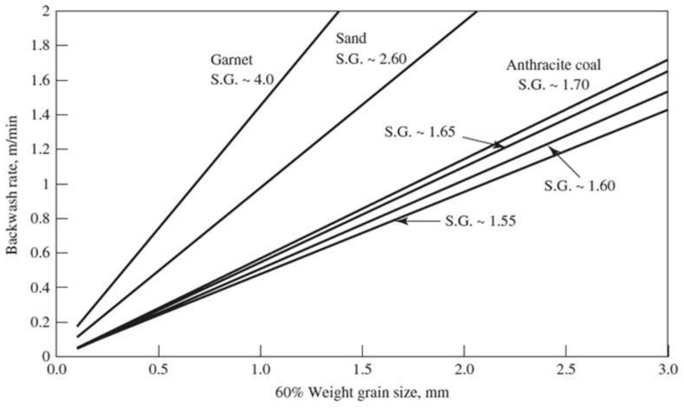


Approximate clean bed headlosses for common filter beds

Type of filter bed	Filtration rate, m/h	Headloss, m
Standard rapid sand	5	0.3
Standard rapid sand	7.5	0.45
Standard dual media	10	0.3
Standard dual media	12.5	0.45
Standard dual media	20	0.6
Standard dual media	25	0.75

Dual media filter video

`Video clip inserted`



Guide for backwash rate, water temperature = 10°C. S.G. = specific gravity.

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Possible problems

Problem	Description/control
Turbidity breakthrough[b]	Unacceptable levels of turbidity are recorded in the effluent from the filter, even though the terminal head loss has not been reached. To control the buildup of effluent turbidity levels, chemicals and polymers have been added to the filter. The point of chemical or polymer addition must be determined by testing.
Mudball formation	Mudballs are an agglomeration of biological floc, dirt, and the filtering medium or media. If the mudballs are not removed, they will grow into large masses that often sink into the filter bed and ultimately reduce the effectiveness of the filtering and backwashing operations. The formation of mudballs can be controlled by auxiliary washing processes such as air scour or water surface wash concurrent with or followed by water wash. To avoid the formation of mudballs and the buildup of grease (see below) wastewater filters should be backwashed at least once per day, even though longer runs may be possible.

[b] Turbidity breakthrough does not occur with filters that operate continuously.

Possible problems

Problem	Description/control
Buildup of emulsified grease	The buildup of emulsified grease within the filter bed increases the headloss and thus reduces the length of filter run. Both air scour and water surface wash systems help control the buildup of grease. In extreme cases, it may be necessary to steam clean the bed or to install a special washing system.
Development of cracks and contraction of filter bed	If the filter bed is not cleaned properly, the grains of the filter bed filtering medium become coated. As the filter compresses, cracks develop, especially at the sidewalls of the filter. Ultimately, mudballs may develop. This problem can be controlled by adequately backwashing and scouring.
Loss of filter medium or media (mechanical)	In time, some of the filter material may be lost during backwashing and through the underdrain system (where the gravel support has been upset or the underdrain system has been installed improperly). Loss of the filter material can be minimized through the proper placement of washwater troughs and underdrain system. Special baffles have also proven effective.

Possible problems

Problem	Description/control
Loss of filter medium or media (operational)	Depending on the characteristics of the biological floc, grains of the filter material can become attached to it, forming aggregates light enough to be floated away during the backwashing operations. The problem can be minimized by the addition of an auxiliary air and/or water scouring system.
Gravel mounding	Gravel mounding occurs when the various layers of the support gravel are disrupted by the application of excessive rates of flow during the backwashing operation. A gravel support with an additional 50 to 75 mm (2 to 3 in.) layer of high density material, such as ilmenite or garnet, can be used to overcome this problem.

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