

**The Islamic University of Gaza
Faculty of Engineering
Civil Engineering Department**

**Environmental Engineering
(ECIV 4324)**

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Water Treatment Part D

Filtration

Filtration is widely used for removing small flocs or precipitated particles. It may be used as the primary turbidity removal process such as direct filtration of raw water with low turbidity. It is also used for removal of pathogens, such as Giardia lamblia and Cryptosporidium.

TYPES OF GRANULAR FILTRATION

Granular media filtration can operate at either a high hydraulic loading rate (5–15 m/h) or a low rate (0.05–0.2 m/h). (The units on the hydraulic loading rates are really $\text{m}^3/\text{m}^2\text{-h}$, which reduces to m/h.) In both processes, the influent water is driven by gravity flow through a bed of granular material, and particles are collected within the bed.

Filtration Mechanisms

There are four basic filtration mechanisms:

SEDIMENTATION : The mechanism of sedimentation is due to force of gravity and the associate settling velocity of the particle, which causes it to cross the streamlines and reach the collector.

INTERCEPTION : Interception of particles is common for large particles. If a large enough particle follows the streamline, that lies very close to the media surface it will hit the media grain and be captured. into media grains.

Filtration Mechanisms

BROWNIAN DIFFUSION : Diffusion towards media granules occurs for very small particles, such as viruses. Particles move randomly about within the fluid, due to thermal gradients. This mechanism is only important for particles with diameters < 1 micron.

INERTIA : Attachment by inertia occurs when larger particles move fast enough to travel off their streamlines and bump into media grains.

Filter Materials

Sand: Sand, either fine or coarse, is generally used as filter media. The size of the sand is measured and expressed by the term called effective size. *The effective size*, i.e. D_{10} may be defined as the size of the sieve in mm through which ten percent of the sample of sand by weight will pass. The uniformity in size or degree of variations in sizes of particles is measured and expressed by the term called *uniformity coefficient*. The uniformity coefficient, i.e. (D_{60}/D_{10}) may be defined as the ratio of the sieve size in mm through which 60 percent of the sample of sand will pass, to the effective size of the sand.

Types of Filter

Slow sand filter: They consist of fine sand, supported by gravel. They capture particles near the surface of the bed and are usually cleaned by scraping away the top layer of sand that contains the particles.

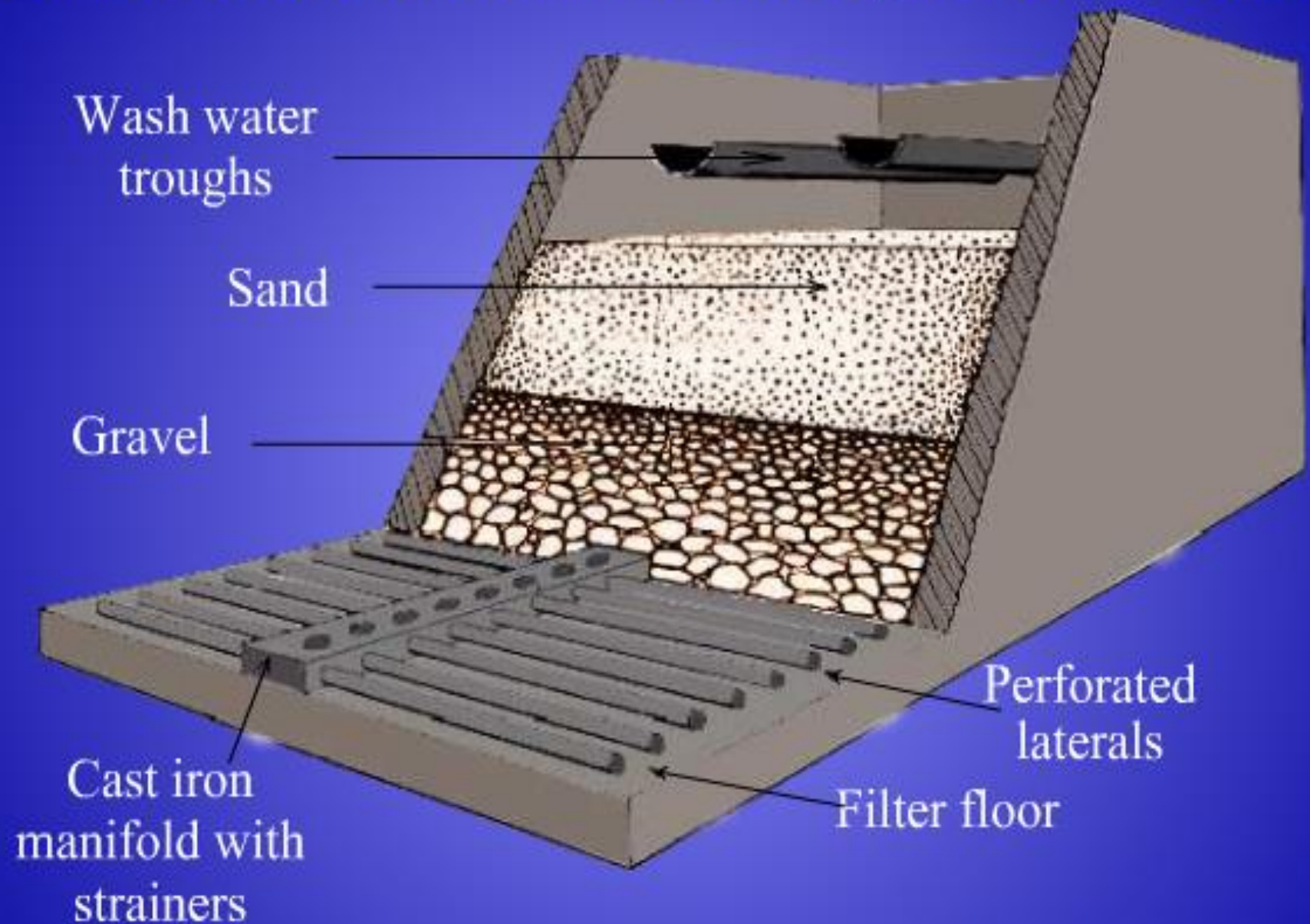
Rapid-sand filter: They consist of larger sand grains supported by gravel and capture particles throughout the bed. They are cleaned by backwashing water through the bed to 'lift out' the particles.

Table / 8.18

Comparison of Typical Ranges for Design and Operating Parameters for Slow Sand Filtration and Rapid Filtration Some filters are designed and operated outside of these ranges.

Process Characteristic	Slow Sand Filtration	Rapid Filtration
Filtration rate	0.08–0.25 m/h (0.03–0.10 gpm/ft ²)	5–15 m/h (2–6 gpm/ft ²)
Media diameter	0.15–0.30 mm	0.5–1.2 mm
Bed depth	0.9–1.5 m (3–5 ft)	0.6–1.8 m (2–6 ft)
Required head	0.9–1.8 m (3–6 ft)	1.8–3.0 m (6–10 ft)
Run length	1–6 months	1–4 days
Pretreatment	None required	Coagulation
Regeneration method	Scraping	Backwashing
Maximum raw-water turbidity	10 NTU	Unlimited with proper pretreatment

Cross sectional view of a Rapid Sand Filter



Principles of Slow Sand Filtration

- In a slow sand filter impurities in the water are removed by a combination of processes: sedimentation, straining, adsorption, and chemical and bacteriological action.
- During the first few days, water is purified mainly by mechanical and physical-chemical processes. The resulting accumulation of sediment and organic matter forms a thin layer on the sand surface, which remains permeable and retains particles even smaller than the spaces between the sand grains.

Principles of Slow Sand Filtration

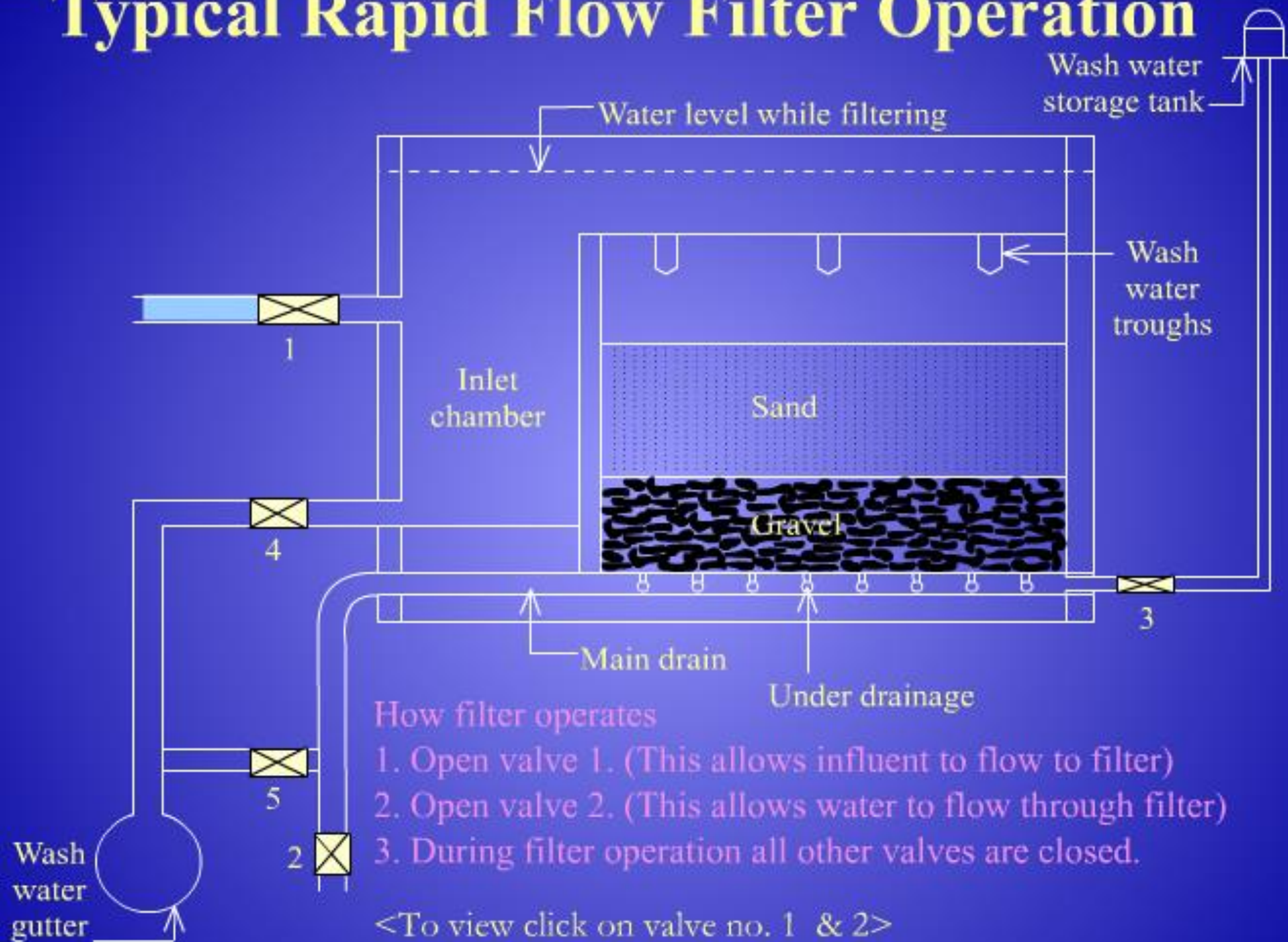
- As this layer (referred to as “Schmutzdecke”) develops, it becomes living quarters of vast numbers of micro-organisms which break down organic material retained from the water, converting it into water, carbon dioxide and other oxides.
- Most impurities, including bacteria and viruses, are removed from the raw water as it passes through the filter skin and the layer of filter bed sand just below. The purification mechanisms extend from the filter skin to approx. 0.3-0.4 m below the surface of the filter bed

Principles of Slow Sand Filtration

- When the micro-organisms become well established, the filter will work efficiently and produce high quality effluent which is virtually free of disease carrying organisms and biodegradable organic matter.

They are suitable for treating waters with low colors, low turbidities and low bacterial contents.

Typical Rapid Flow Filter Operation



Filter Materials

Gravel: The layers of sand may be supported on gravel, which permits the filtered water to move freely to the under drains, and allows the wash water to move uniformly upwards.

Other materials: Instead of using sand, sometimes, anthrafilt is used as filter media. Anthrafilt is made from anthracite, which is a type of coal-stone that burns without smoke or flames. It is cheaper and has been able to give a high rate of filtration.

Clean Water Headloss

Several equations have been developed to describe the flow of clean water through a porous medium. Carman-Kozeny equation used to calculate head loss is as follows:

$$h = \frac{f (1-\alpha) L v_s^2}{\phi \alpha^3 d_g}$$

$$h = \frac{f_p (1-\alpha) L v_s^2}{\phi \alpha^3 d_g g}$$

$$f = 150 \frac{(1-\alpha)}{N_g} + 1.75$$

$$N_g = \frac{\phi d v_s \rho}{\mu}$$

where, h = headloss, m

f = friction factor

α = porosity

ϕ = particle shape factor (1.0 for spheres, 0.82 for rounded sand, 0.75 for average sand, 0.73 for crushed coal and angular sand)

L = depth of filter bed or layer, m

d = grain size diameter, m

v_s = superficial (approach) filtration velocity, m/s

g = acceleration due to gravity, 9.81 m/s^2

p = fraction of particles (based on mass) within adjacent sieve sizes

d_g = geometric mean diameter between sieve sizes d_1 and d_2

N_g = Reynolds number

μ = viscosity, N -s/m²