AN OVERVIEW OF SURFACE WATER TREATMENT PROCESSES

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Reasons for Water Treatment

1. Remove turbidity – suspended particles
2. Remove disease-causing microorganisms
3. To protect public health
4. Provide potable and palatable water
5. To meet State or EPA SDWA primary MCLs and secondary MCLGs

Turbidity

<u>Physical Characteristic</u>

The cloudy appearance of water caused by the presence of suspended or colloidal matter.

- Suspended solids, colloidal in size.
- The property of water that causes light to be scattered or absorbed.
  - Problems
    - Taste
    - Odor
    - Hiding place for microorganisms
    - Interfere with disinfection

The reading is in NEPHLOMETRIC TURBIDITY UNITS or Ntu's

GWUDISW/GWDI

“Groundwater under the direct influence of surface water”

Shallow wells and springs which are recharged by surface water

GUDISW can contain the impurities that surface water contains, which
also means more complex treatment methods

Biological Characteristics of Water

Disease-causing organisms are called Pathogens.

Water-borne pathogens include:

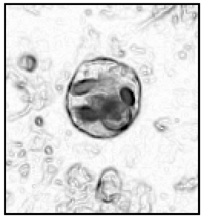
- Viruses – 0.02 to 0.25μ
  - Hepatitis A, Meningitis
- Bacteria - 0.5–2μ wide and 1-10μ long
  - Salmonella, Cholera, Typhoid
- Protozoa - 10-20μ up to 400-500 μ
  - Giardia, Cryptosporidiosis

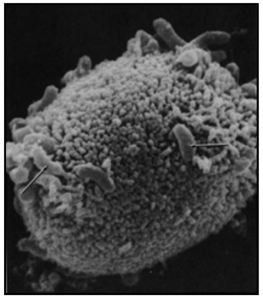
Waterborne Pathogens

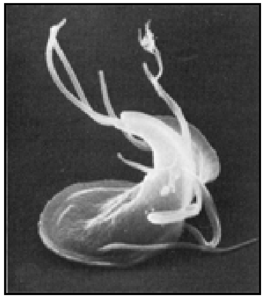
Diseases Caused By Waterborne Pathogens

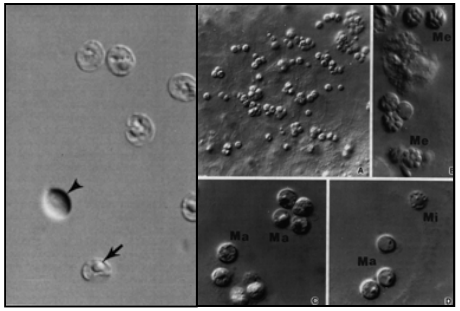
All Water Sources:
Typhoid
Paratyphoid (Types A & B)
Cholera
Dysentery
Hepatitis (Virus)

Surface Water Only:
Cryptosporidium
Giardia

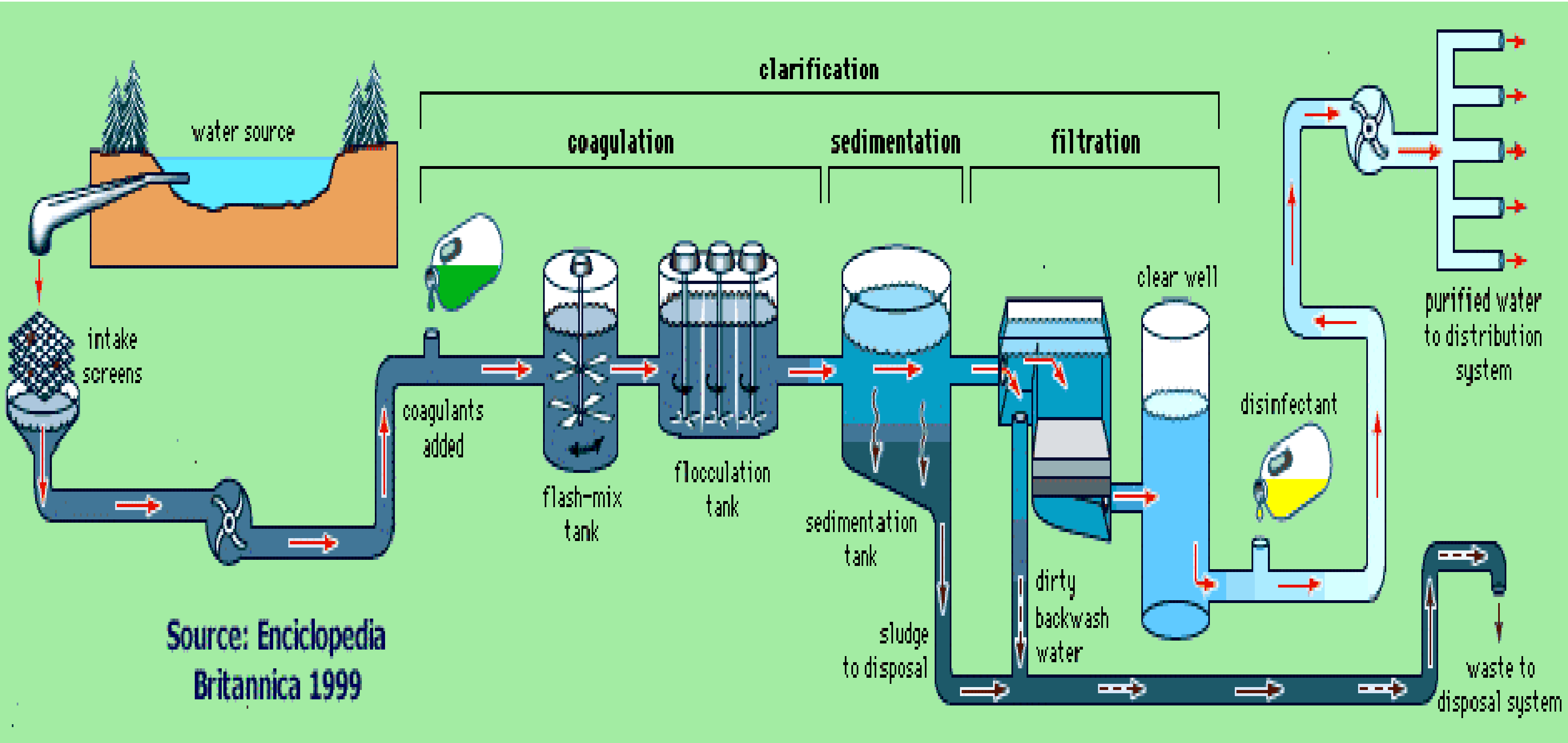

Dysentery


Cholera

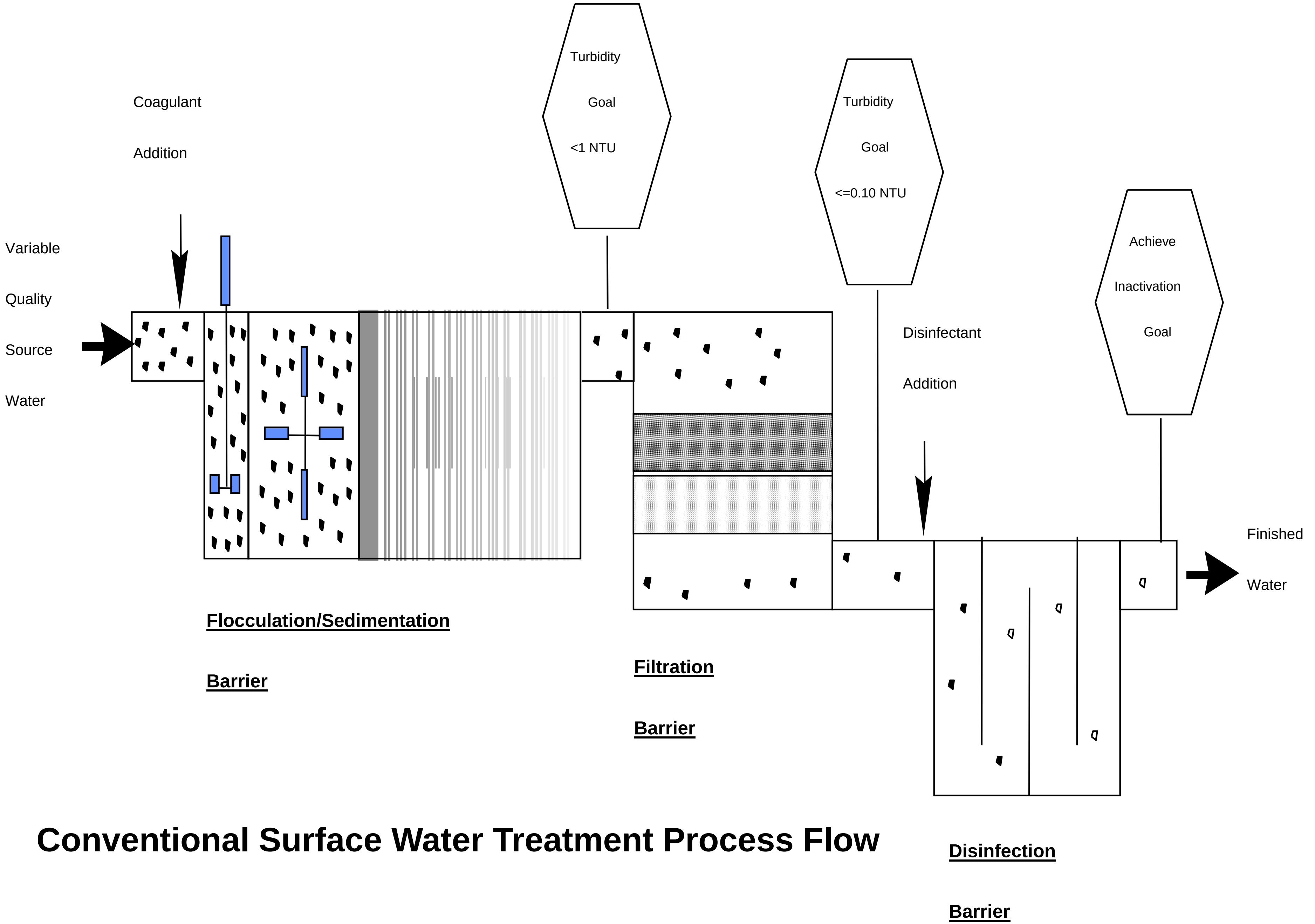

Giardia


Cyptosporidium

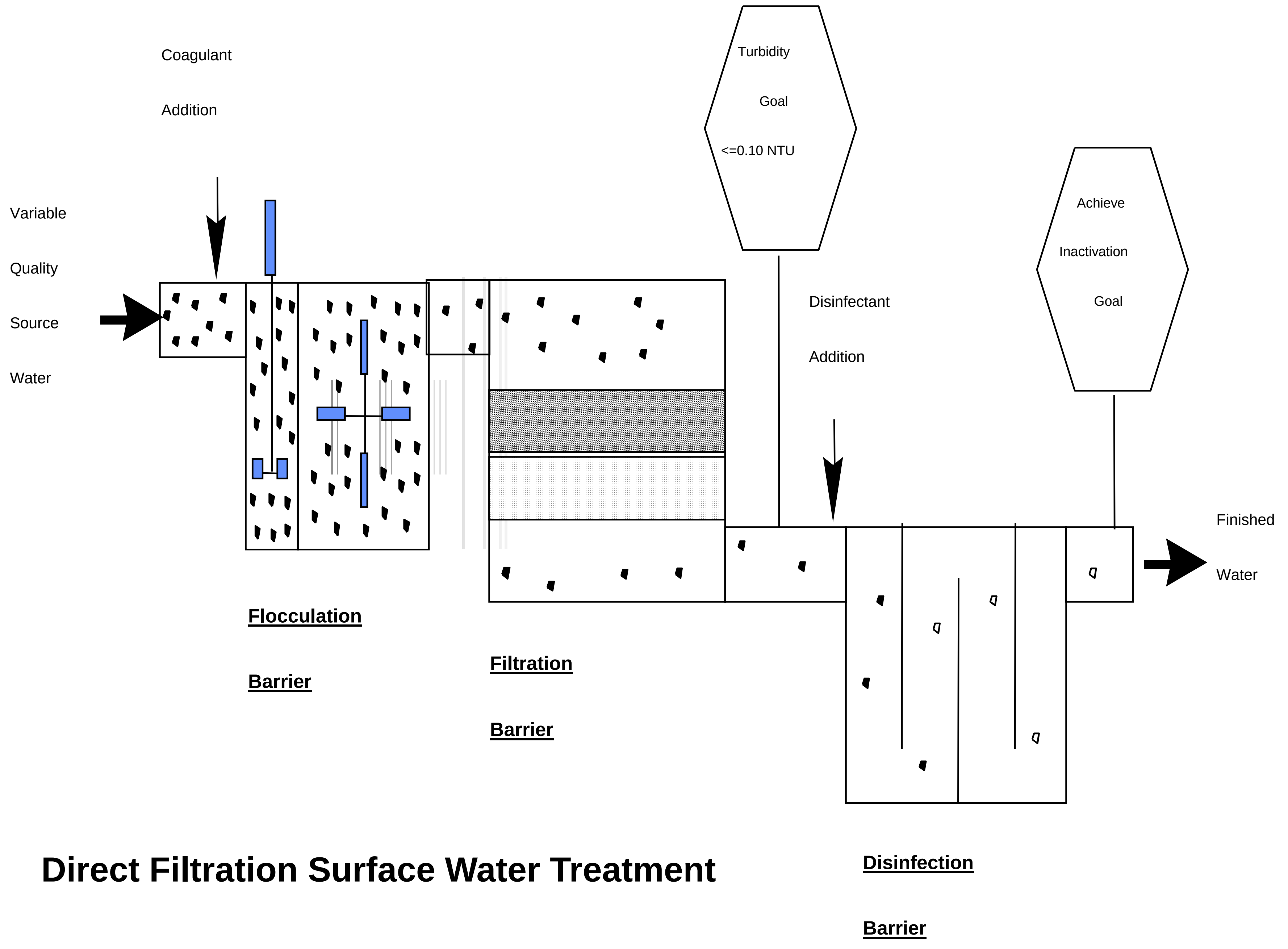
The protozoa that are found in surface water supplies form cysts and spores that protect them from cold temperatures and make them more difficult to kill with disinfectant chemical



Source: Enciclopedia Britannica 1999



Conventional Surface Water Treatment Process Flow

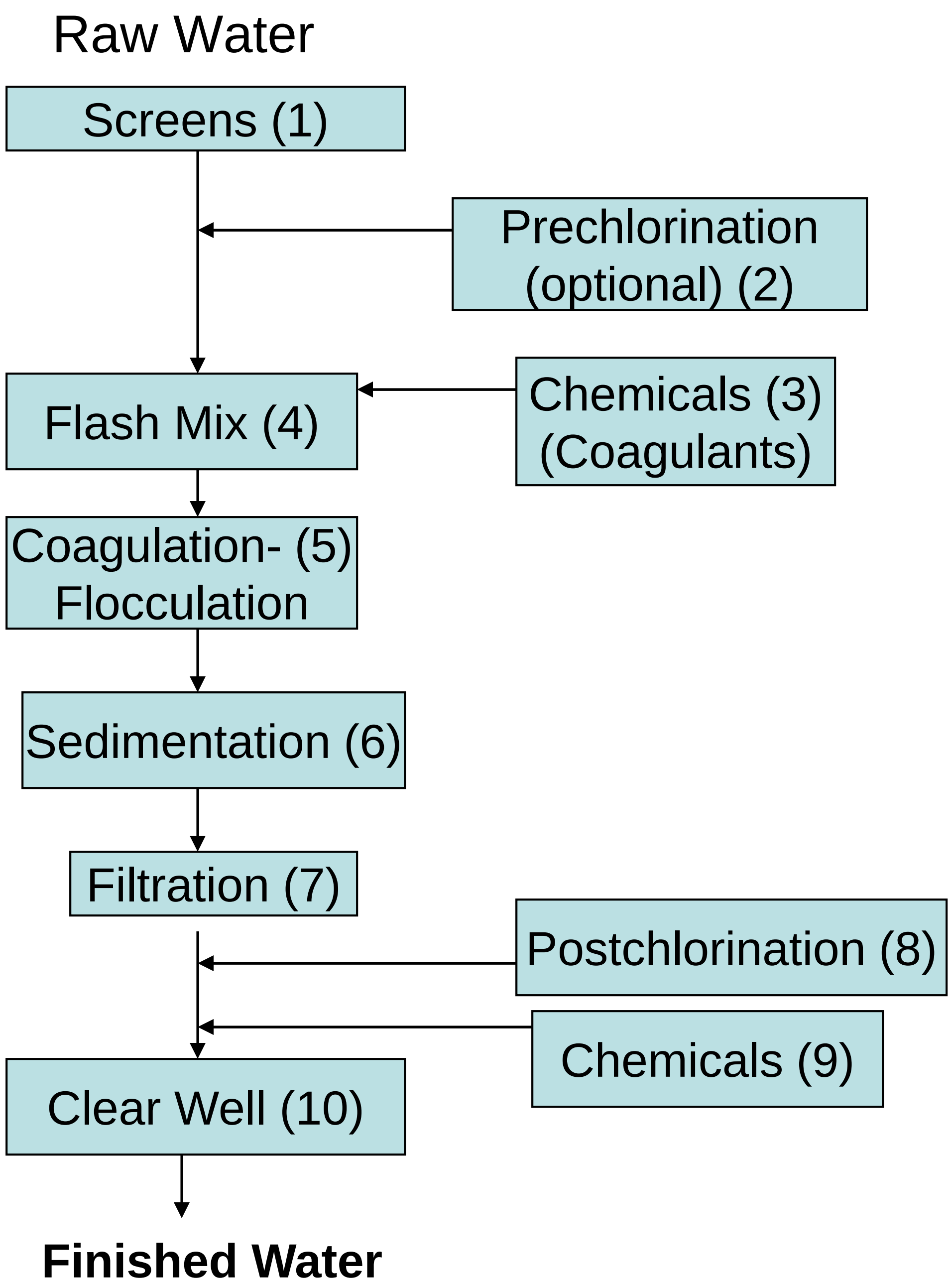


Direct Filtration Surface Water Treatment

Sources & Treatment of Water

Water quality problems	**Treatment**
1. Coliform or Microbiological Contamination	1. Disinfection: Chlorine, Chlorine Dioxide, Ozone; and Coagulation, Flocculation, Sedimentation, Filtration
2. Turbidity & Color	2. Coagulation, Flocculation, Sedimentation, Filtration & Disinfection
3. Odors (Organic Materials)	3. Clarification (Coagulation, Flocculation, Sedimentation, Filtration & Disinfection). Oxidation (Chlorine, Permanganate, Chlorine Dioxide), Adsorption (granular activated carbon)
4. Iron &/or Manganese	4. Sequestration (polyphosphates), Ion exchange, Permanganate & Greensand, Oxidation by Aeration, chlorine or Permanganate (filtration must follow any Oxidation)
5. Excessive Hardness (Calcium & Magnesium)	5. Ion Exchange Softening, Lime & Soda Softening
6. Dissolved Minerals (High Total Dissolved Solids)	6. Ion Exchange, Reverse Osmosis
7. Corrosivity (Low pH/alkalinity)	7. pH adjustment with chemicals, Corrosion inhibitor addition (zinc phosphate, silicate)

Treatment Process



1. Removes leaves, sticks, fish & large debris
2. Kills most disease-causing organism & helps control taste & odor causing substances
3. Cause very fine particles to clump together into larger particles
4. Mixes chemicals with raw water containing fine particles that will not readily settle or filter out of the water
5. Gathers together fine, light particles (FLOC) to aid the sedimentation & filtration processes
6. Settles out larger suspended particles
7. Filters out remaining suspended particles
8. Kills disease-causing organisms & provides chlorine residual for distribution system
9. Controls corrosion
10. Provides chlorine contact time for disinfection. Stored water for high demand

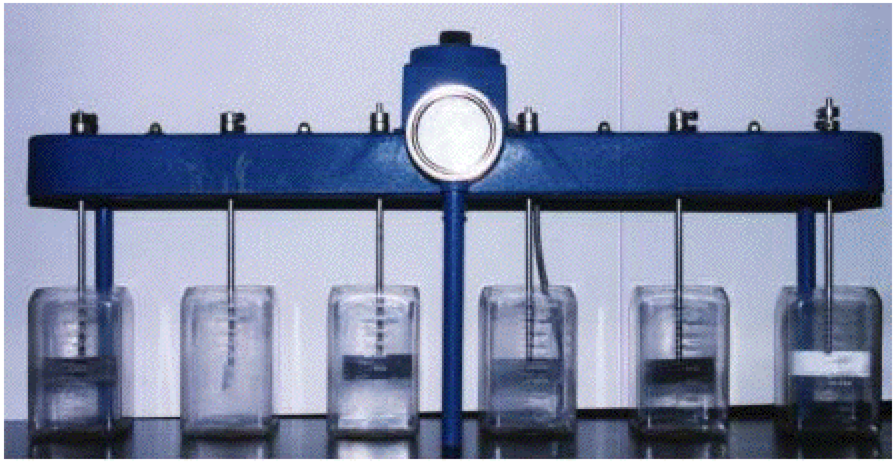
Coagulation and Flocculation

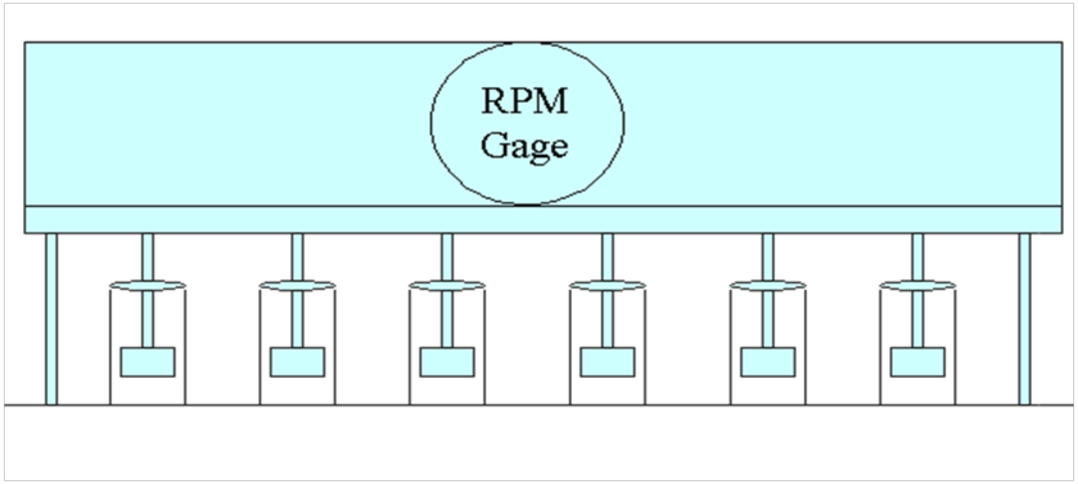
- The purpose of coagulation and flocculation is to remove particulate impurities, nonsettleable solids and color
- Nonsettleable particles in water are removed by use of coagulating chemicals

Chemical name	Chemical formula	Primary coagulant	Coagulant aid
Aluminum Sulfate	$Al_2(SO_4)_3 \cdot 14\ H_2O$	X	
Ferrous Sulfate	$FeSO_4 \cdot 7\ H_2O$	X	
Ferric Sulfate	$Fe_2(SO_4)_3 \cdot 9\ H_2O$	X	
Ferric Chloride	$FeCl_3 \cdot 6\ H_2O$	X	
Cationic Polymer	Various	X	X
Calcium Hydroxide	$Ca(OH)_2$	X (a)	X
Calcium Oxide	CaO	X (a)	X
Sodium Aluminate	$Na_2Al_2O_4$	X (a)	X
Bentonite	Clay		X
Calcium Carbonate	$CaCO_3$		X
Sodium Silicate	Na_2SiO_3		X
Anionic Polymer	Various		X
Nonionic Polymer	Various		X

(a) Used as primary coagulants only in water softening processes.

Jar Testing Apparatii





Jar Testing

- Common laboratory procedure used to determine the optimum operating conditions for water or wastewater treatment
- Allows adjustments in:
  - pH
  - variations in coagulant or polymer dose
  - alternating mixing speeds
  - testing of different coagulant or polymer types
- Simulates the coagulation and flocculation processes that encourage the removal of suspended colloids and organic matter which can lead to turbidity, odor and taste problems

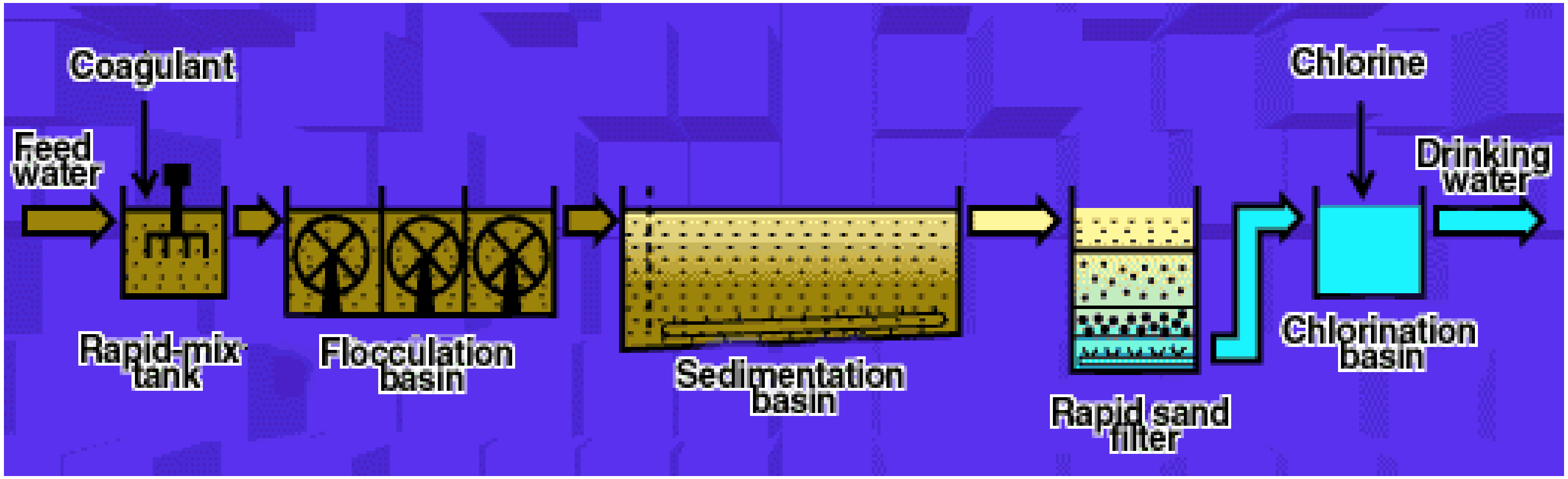
Flash Mix

1. Methods of Mixing

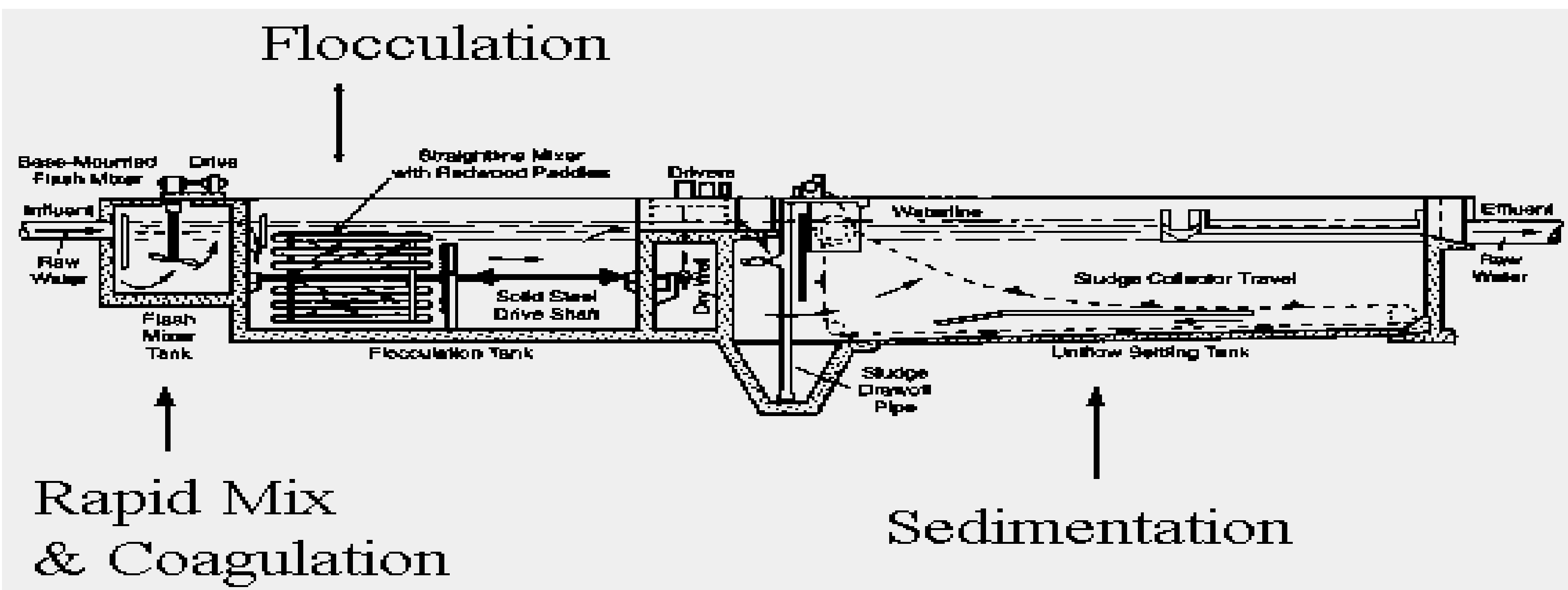
- Coagulation takes place in a matter of seconds
- It is important that chemicals used for coagulation be added and disperse quickly
- Accomplished in a unit/process called FLASH MIX/RAPID MIX

2. There are various methods used for this process:

- Hydraulic mixing uses flow energy in the system
  - Baffles or throttling valves
  - Sufficient water velocity causes turbulence
- Mechanical mixing
  - Paddles, Turbines or Propellers
- Diffuser & grid systems
  - Perforated tubes or nozzles used to uniformly disperses the coagulant into the water being treated
- Pump blender
  - Directly and forcibly pumps the coagulant through defuser piping



Conventional Filtration



Flocculation

1. Follows flash mix and takes place in a basin or series of basins that steady reduce mixing energy
   - Too little agitation will prevent floc formation
   - Too much agitation will destroy the floc (floc shear
   - Velocity in the flocculation basin should be 1 ft/sec

2. Objective is to create a floc of sufficient size, density & toughness; ~0.1mm to 3mm in size for settling and removal

3. Detention Time
   - direct filtration: 5 – 20 min
   - conventional filtration: 30 min.

4. Basin configuration
   - Generally rectangular in shape
   - usually 2-3 stages with decreasing mixing energy

Paddle-Wheel Flocculators

Sedimentation

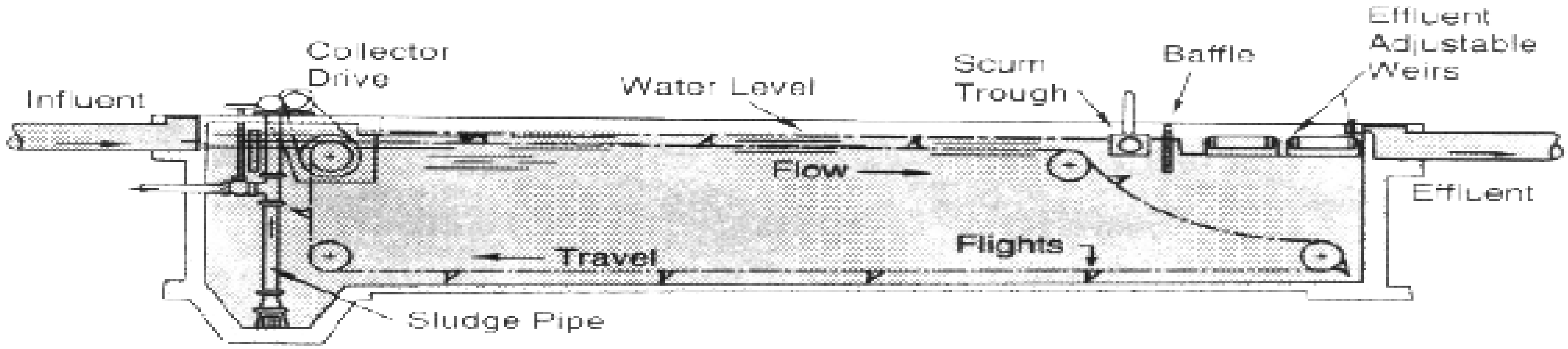
A typical sedimentation basin can be divided into four zones:

INLET ZONE: should provide a smooth transition, have a perforated baffle to evenly distribute the flocculated water evenly over the entire cross-section of the basin to reduce short-circuiting

SETTLING ZONE: the largest portion of the basin; provides a calm region that allows the floc to settle; detention times ~3 hours, velocities from 0.01to 0.03 fps, usually 8 to 12 ft deep, surface loading rates around 800 gpd/ft^2

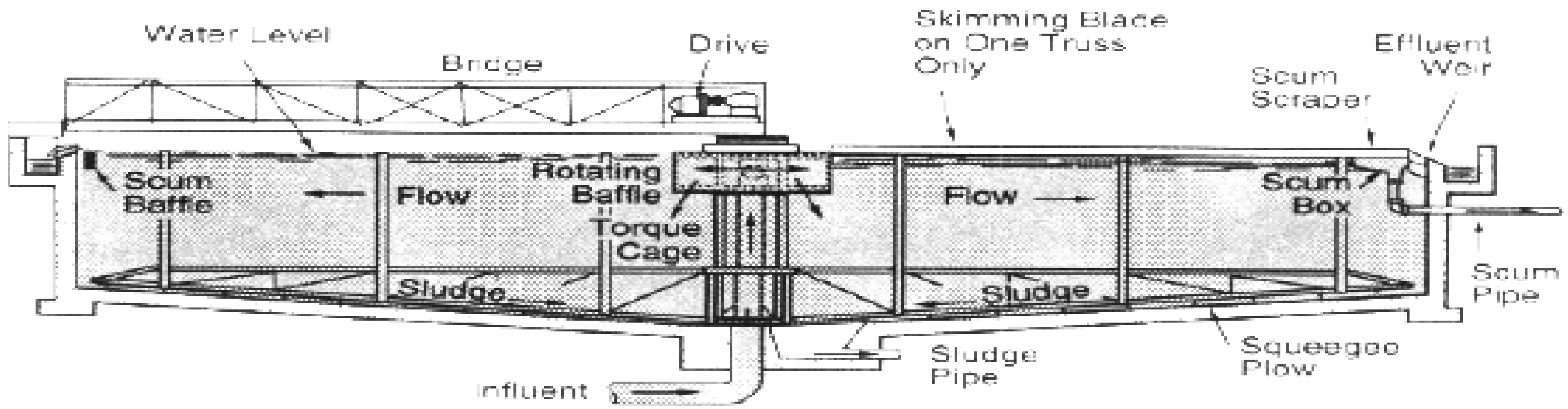
SLUDGE ZONE: located at the bottom of the basin for the temporary storage of the settled particles; also allows for compaction of the sludge

OUTLET ZONE/EFFLUENT: provides a smooth flow transition from the sedimentation basin to the next treatment process (usually filtration)

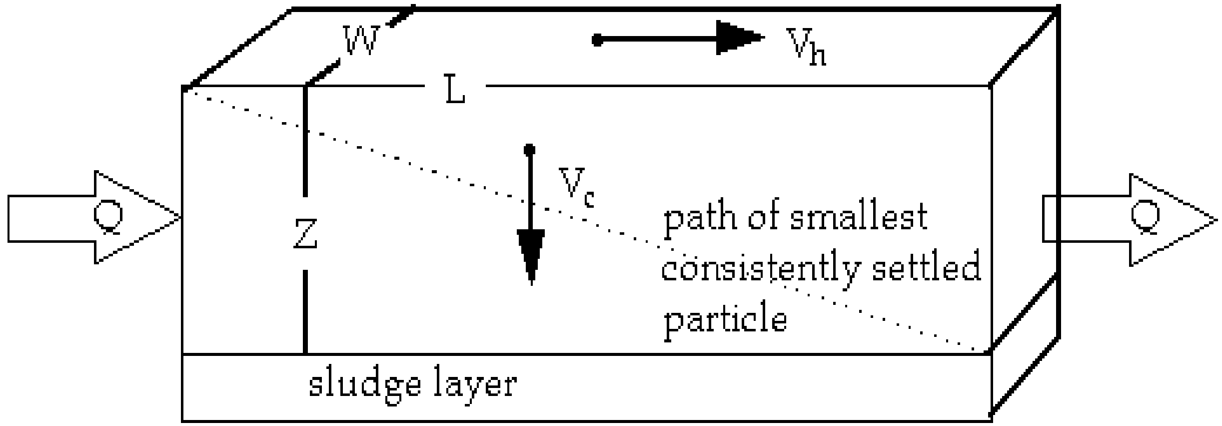


Rectangular Sedimentation Basin

Courtesy of FMC Corporation, MHS Division



Circular Sedimentation Basin


W
V_h
L
V_c
Q
Z
Q
path of smallest
consistently settled
particle
sludge layer

Filtration

1. The purpose is to remove particulates, impurities and floc
2. Conventional filtration is preceded by coagulation, flocculation and sedimentation
3. Direct filtration does not include the sedimentation process
4. Filtration is a physical and chemical process
5. Turbidity removal is based on the following factors:

- Chemical characteristics of the water being treated (source water quality)
- Nature of suspension (physical & chemical characteristics of the suspended particles in the water
- Types and degree of coagulation, flocculation & sedimentation
- Filter type and operation

    - Gravity filtration (sand, dual media & mixed media)
    - Single media (sand)
    - Diatomaceous Earth
    - Slow sand

Filter Anatomy

Filter boxes can be rectangular, square, round, or as the outer segment of a ring. Depth and surface dimensions will vary depending on the volume of water to be filtered.

The **rate of flow controller** maintains a constant flow of water throughout the filter run. As the filter media becomes clogged the rate of flow controller opens a valve on the effluent line that compensates for the head loss through the filter.

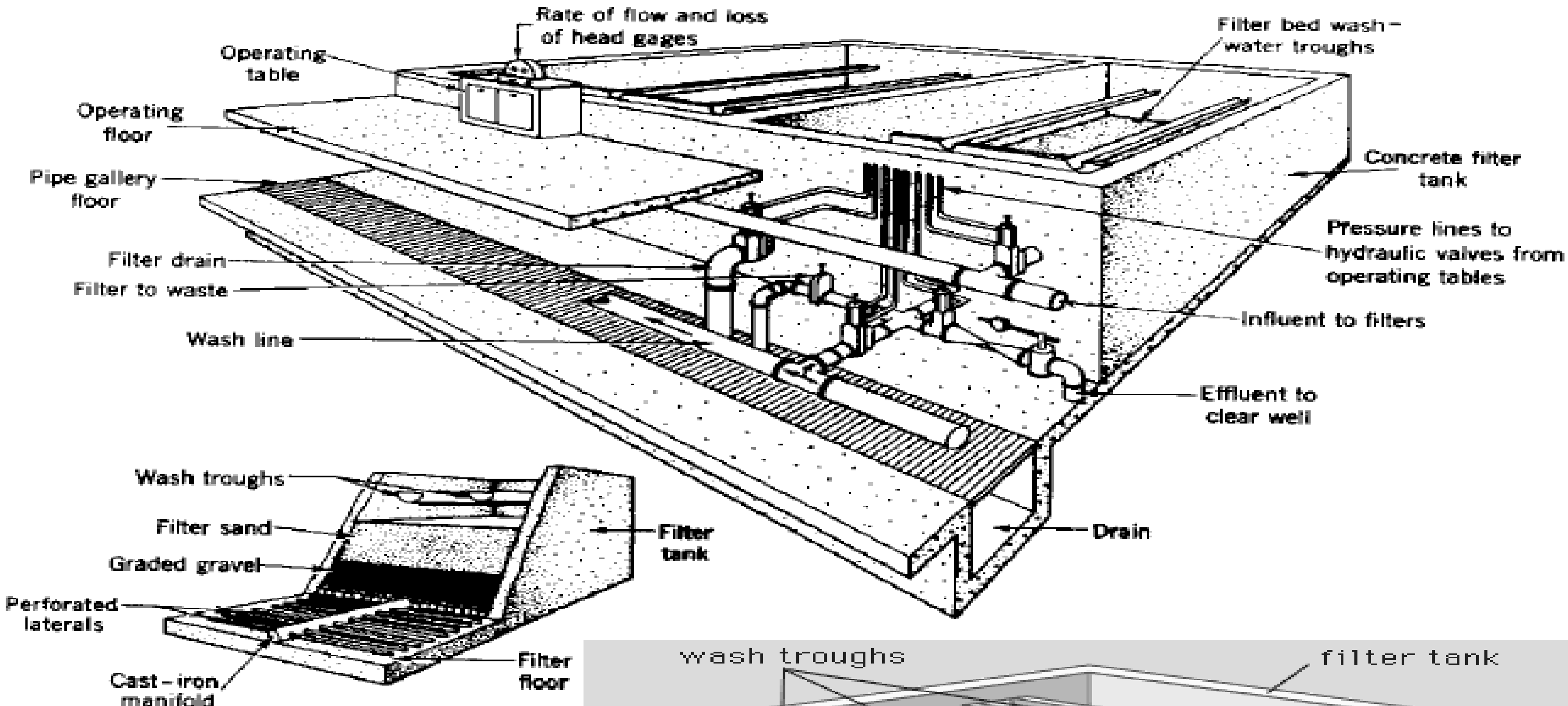
A **loss of head gauge** indicates when the filter is in need of backwashing. The loss of head is determined by the difference between the level of water in the filter and the level of a column of water that represents the pressure in the effluent line.

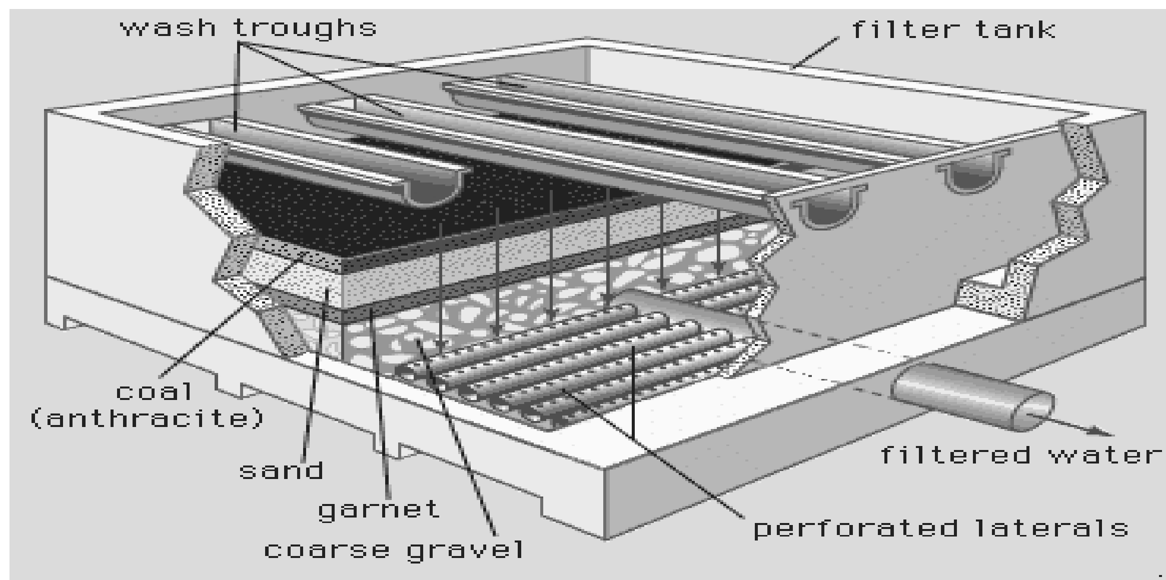
The **under drain** serves 3 basic functions. It supports the filter media, collects the filtered water, and evenly distributes the backwash water throughout the filter.

Backwash troughs collect backwash water and transport it out of the filter. The rim of the troughs should be 24-28 inches above the filter media (32-36 inches for anthracite).

Surface washers are used during the backwash cycle to agitate and break up the top layer of the sand where most of the dirt is trapped. This step helps reduce the amount of backwash water needed for a filter by reducing the time it takes to properly clean the filter.

A **backwash valves & pump** to supply backwash water to the filter; capable of supplying at least 15 gpm/ft^2 of filter area. Enough backwash water must be available to run the backwash for 7-15 minutes on average.

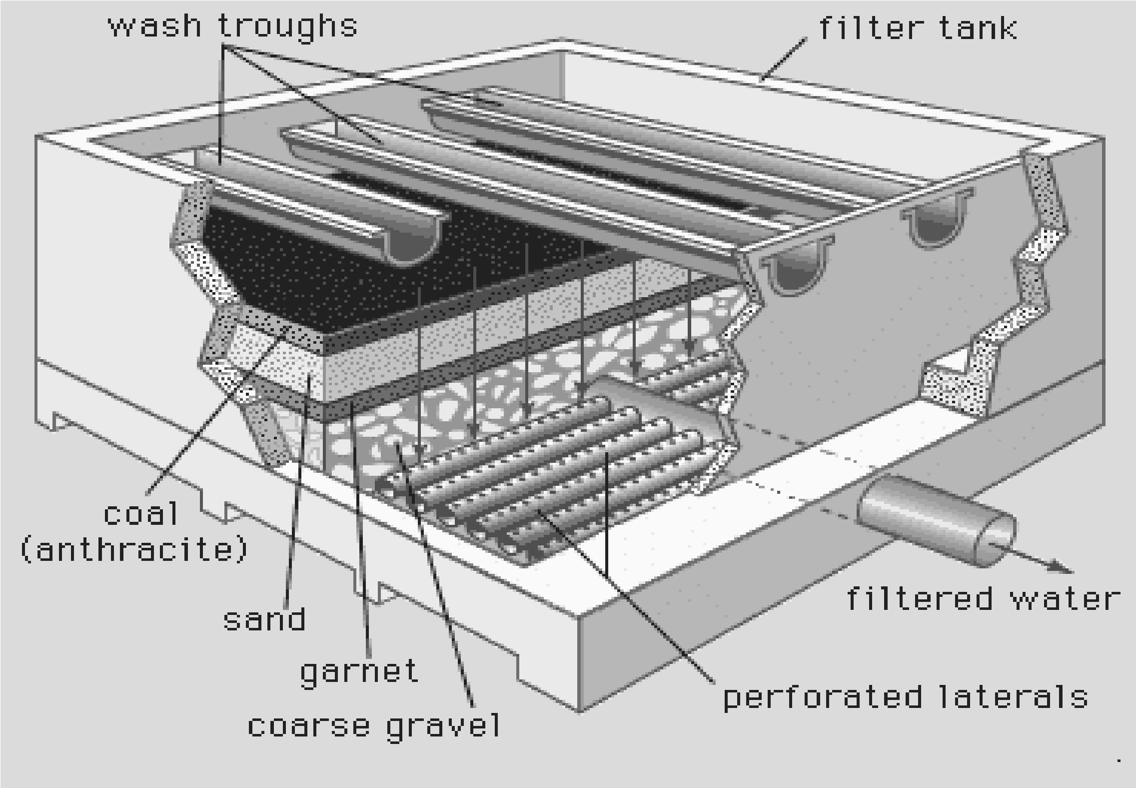




Source: Enciclopedia Britannica, 1999

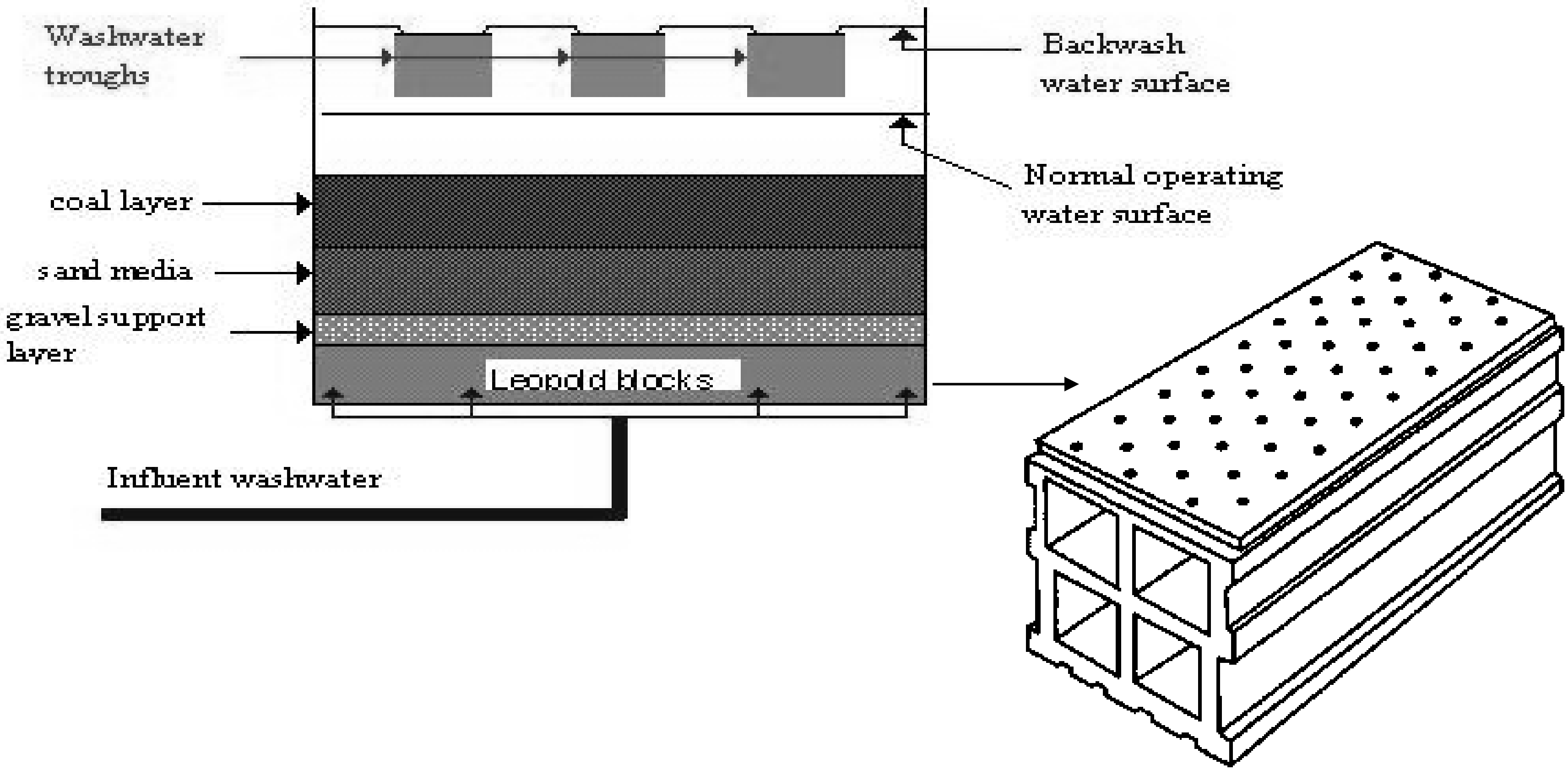
Gravity Filtration

1. The water level above the media forces the water through the filter media
2. Filter media configurations:
   - Single media: sand or anthracite coal or granular activated carbon
   - Dual media: sand & anthracite coal
   - Multi- or mixed media: sand, anthracite coal and garnet
3. Filtration rates (hydraulic loading): 2 to 10 GPM/ft^2
4. Includes rapid sand filters and high rate filters

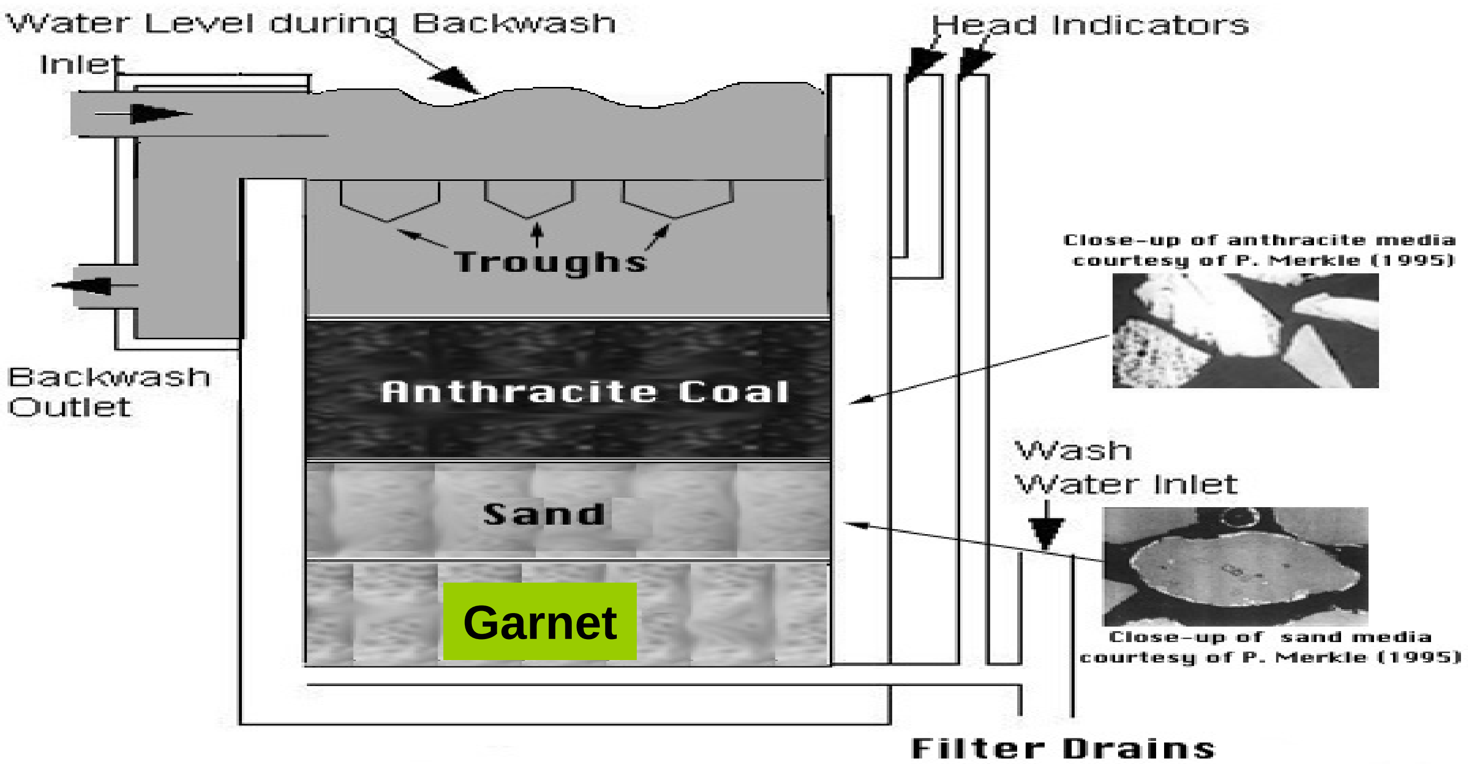


Source: Enciclopedia Britannica, 1999

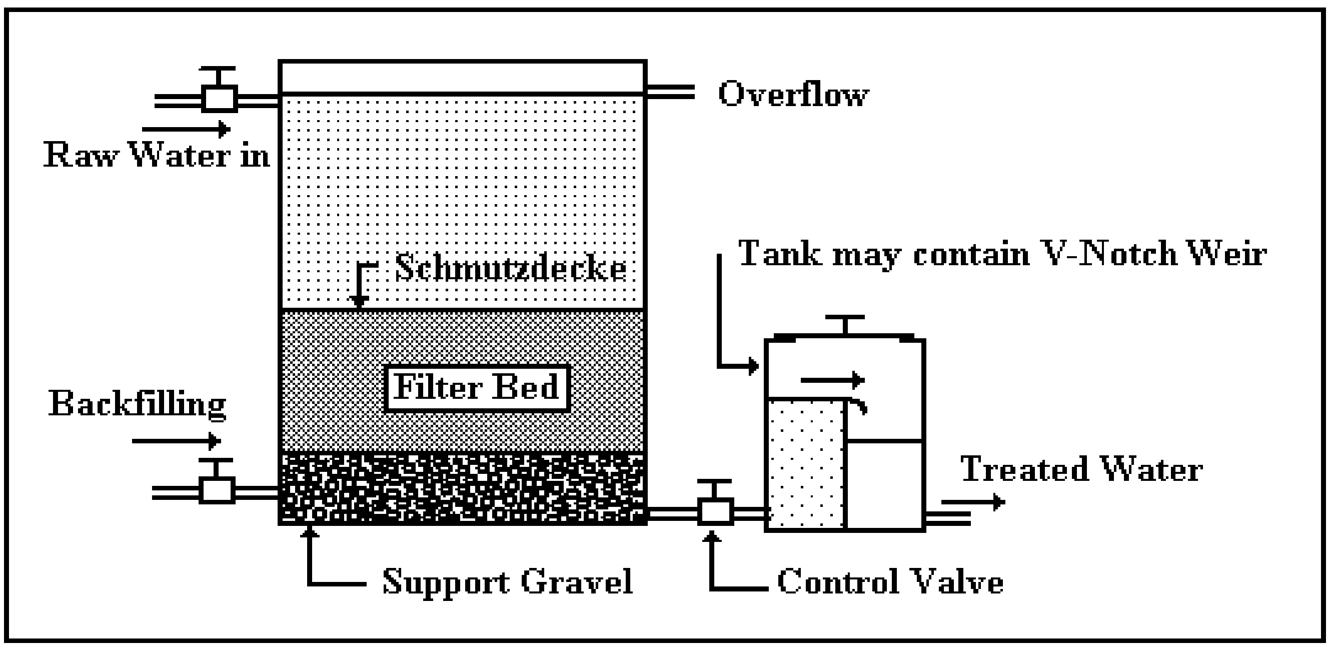
Dual-media filters use a filter bed of both anthracite coal and silica sand. There is usually 12-18 inches of coal on top of 8-12 inches of sand. The upper layer of the lighter and coarser anthracite has voids about 20% larger than the sand, resulting in a larger to smaller grading of the media in the direction of flow. Dual media filters have a filter rate of **3-5 gpm/ft^2**. After backwashing, the filter media separates with the heavier sand falling to the bottom and the lighter coal on top. The larger floc particles are trapped in the surface of the coal layer while the finer particles are held in the sand. This creates deeper particle penetration into the filter bed and allows higher filtration rates.



Multi-media filter beds using coal, silica sand and garnet sand provide the highest filtration rate of any gravity filter. Filter rates for multi-media filters are **5-8 gpm/ft².** Garnet sand has a specific gravity of about 4.2, which is greater than coal (1.6) or silica sand (2.6). A multimedia filter bed will consist of 4-6 inches of garnet sand on the bottom, 8-10 inches of silica sand in the middle, and 12-18 inches anthracite coal on top. Because of the difference in specific gravities, separation of the different media occurs after backwashing with little intermixing. A typical mixed media filter has particle sizing gradually decreasing from about 0.7 mm at the top to 0.2 mm at the bottom. In addition to gravity filters, mixed media is are used in pressure filters.

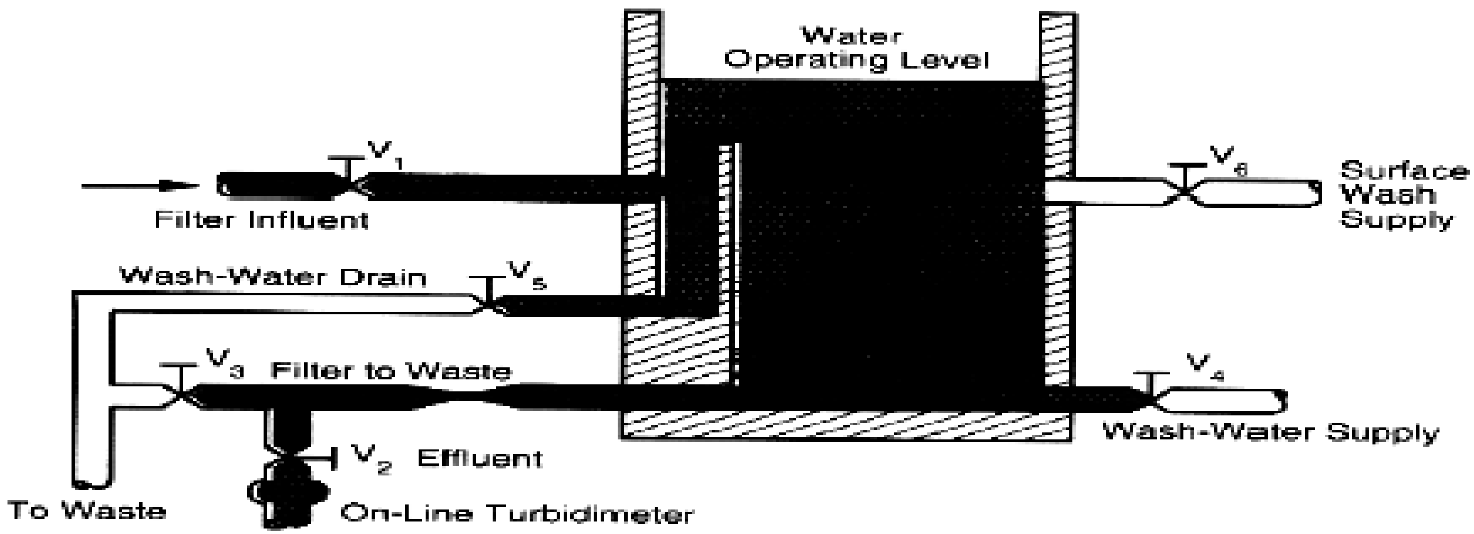


Slow sand filters were the first type of gravity filter used for water treatment. They consist of a box and under drain that is filled with about 3.5 ft of filter sand. Suspended material collects on the surface of the filter bed and forms a layer known as a smutzdecke. When the filter gets clogged it is taken out of service and cleaned by scraping the top inch or so of sand off of the filter bed. This material must be replaced after several cleanings to restore the original media depth. After a filter is cleaned, it must be filtered to waste for several days before it can be put back in service. Because of this, a system must have two filters to provide continuous service. The filtration rate of a typical slow sand filter is about **0.015-0.15 gpm/ft^2.**



Filter Backwash

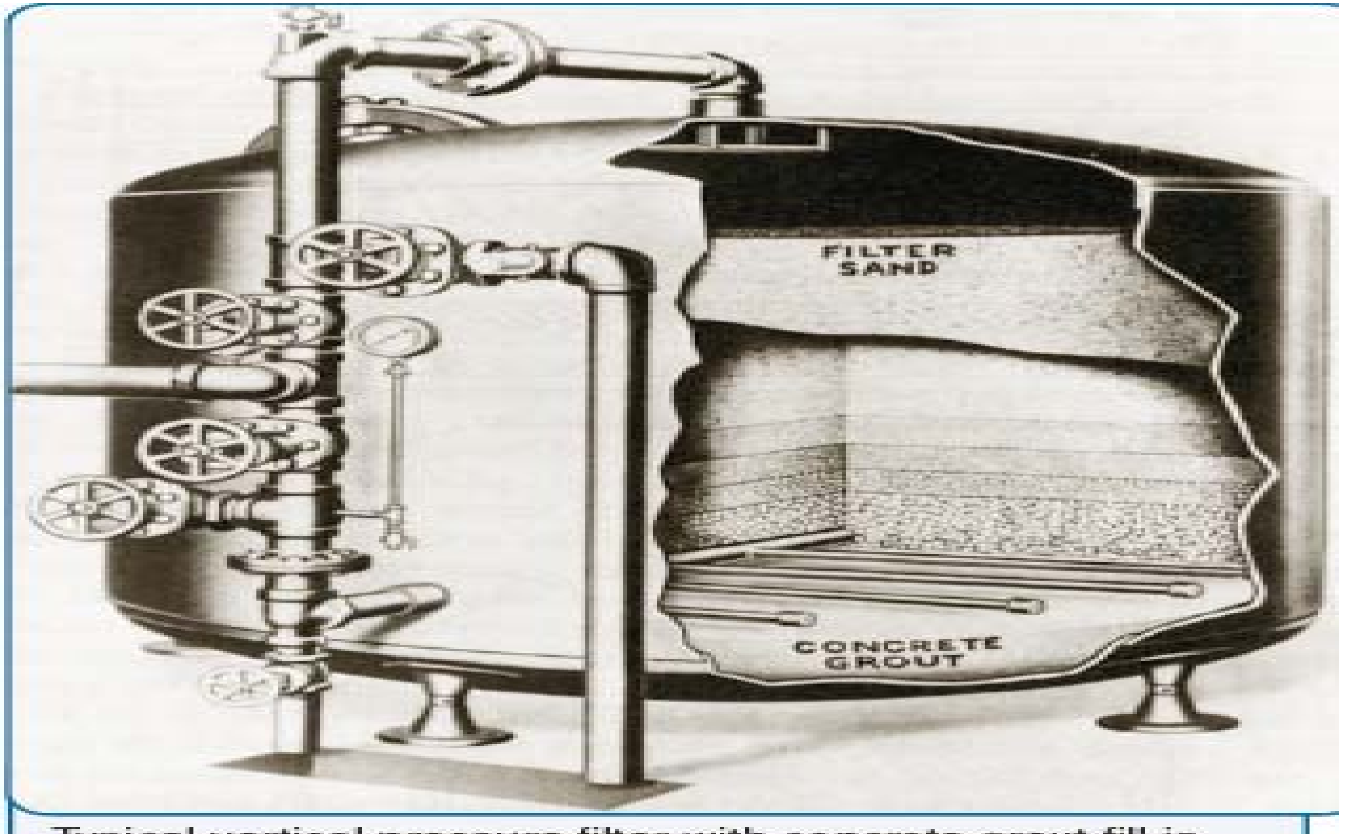
When a filter has been in operation for its optimum number of hours or its head loss reaches a predetermined pressure the filter is taken out of service and backwashed. The proper procedure for backwashing filters is very important. This is a typical procedure for backwashing a sand filter. However, the operator should always follow manufacturer's instructions to avoid possible damage to the under-drain or media bed.



Valve Position During Filtration

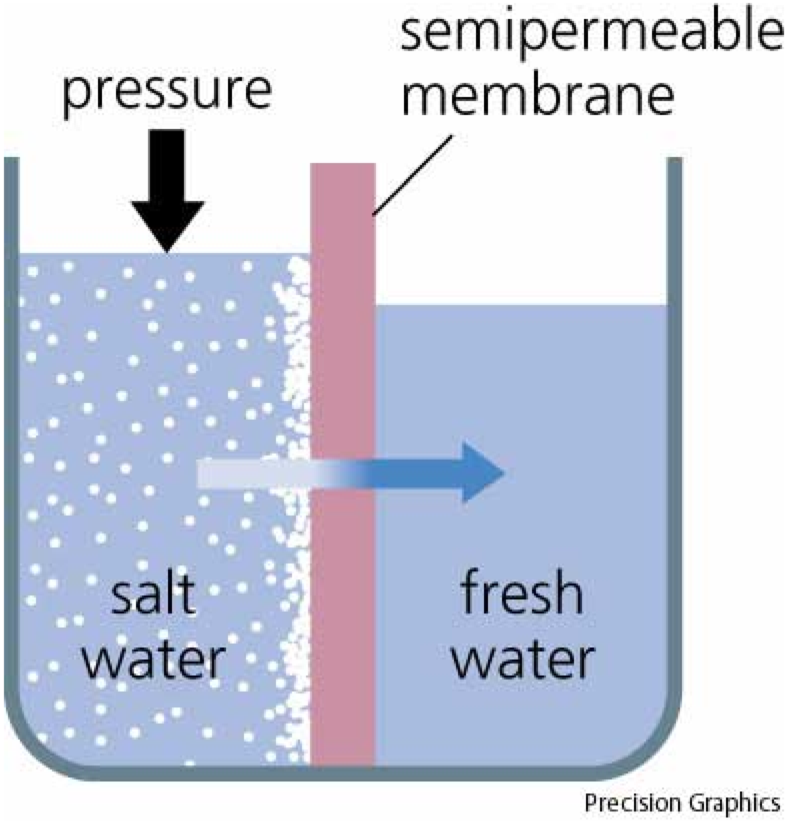
Valve	*Filtering*	*Backwashing*	*Filtering to Waste*
V_1 — Influent	Open	Closed	Open
V_2 — Effluent	Open	Closed	Closed
V_3 — Filter to Waste	Closed	Closed	Open
V_4 — Wash-Water Supply	Closed	Open	Closed
V_5 — Wash-Water Drain	Closed	Open	Closed
V_6 — Surface Wash Supply	Closed	Open	Closed

Pressure filters operate under the same principles as gravity filters except the influent is forced through the filter under pressure. Pressure filters are steel cylinders that use sand or other media to remove particulates. They must be backwashed when the media gets clogged with solids. This is usually accomplished by manually operating the filter valves to reverse the flow through the filter bed. Pressure filters have about the same filter rate as gravity filters with the same type of media. Diatomaceous earth is another type of media that may be used instead of sand in some pressure filters.



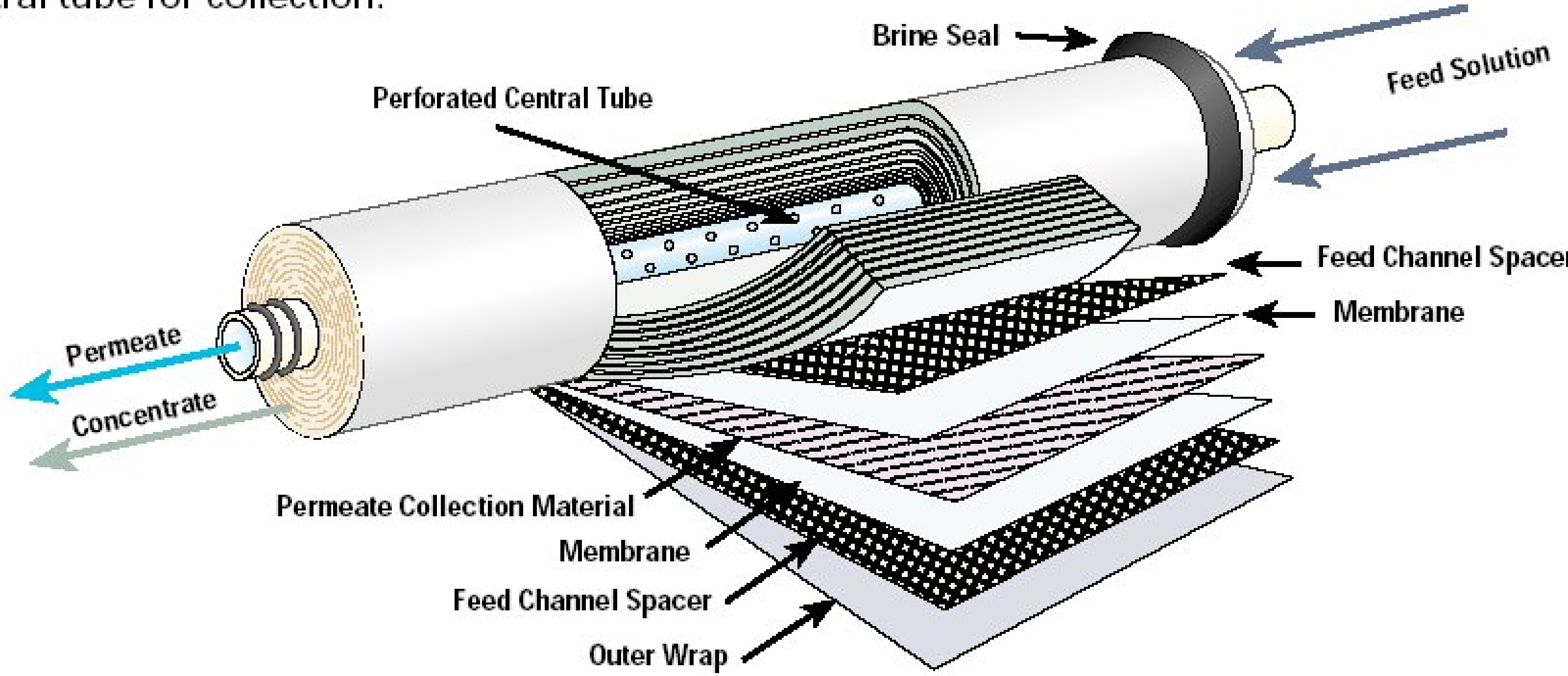
Typical vertical pressure filter with concrete grout fill in bottom, pipe headers, lateral under drains, gravel support bed, and filter sand, (Courtesy of Infilco Degremont, Inc.) illustration from *Handbook of Public Water Systems*, second edition, HDR Engineering, Inc

Reverse osmosis (RO or R/O) is a common treatment technology that produces high purity water. The process works by forcing water under great pressure against a semi-permeable membrane, where contaminate exclusion occurs. With contaminate exclusion, water molecules form a barrier that allows other water molecules to pass through while excluding most contaminants.



Reverse Osmosis Membranes

The spiral membrane is constructed of one or more membrane envelopes wound around a perforated central tube. The permeate passes through the membrane into the envelope and spirals inward to the central tube for collection.



The illustration above represents a simplified spiral-wound membrane element. Recovery can be as high as 90% and systems may be capable of chemical cleaning in place (CIP).