University of Zambia

School of Engineering

Department of Civil and Environmental Engineering

CEE 4412: Environmental Engineering I

WASTEWATER MANAGEMENT

JMT

SEPTEMBER 2020

UNZA

Definition

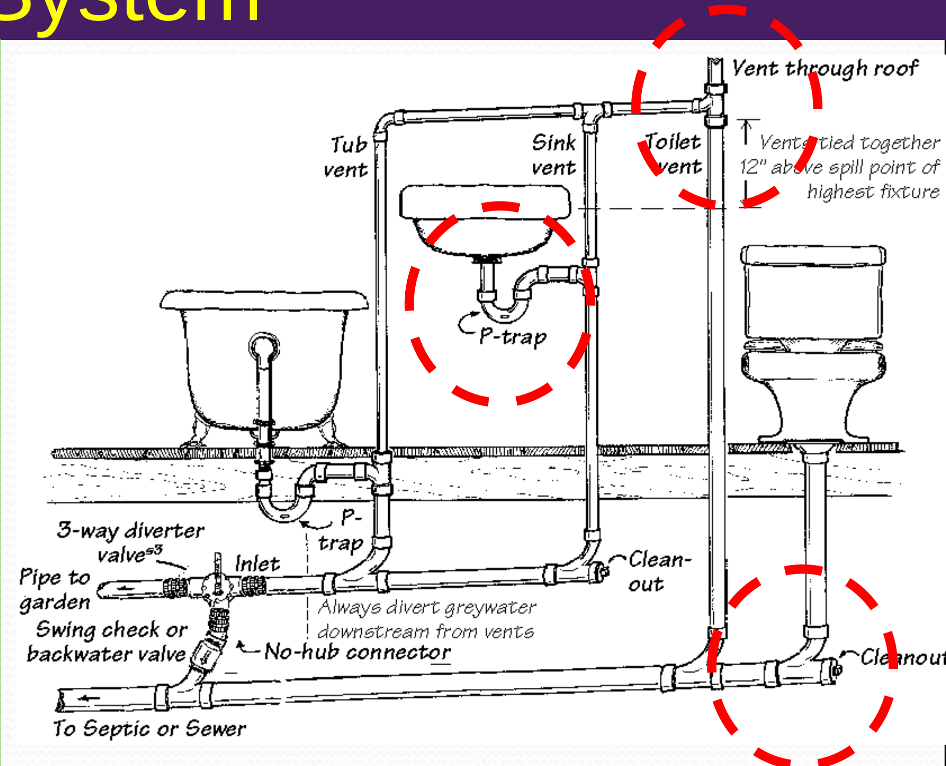
Off-site sanitation system

- System where wastewater is treated or/and disposed of on a site away from the point of generation
- In this case, wastewater is conveyed through a sewerage system which is the physical infrastructure for sewage conveyance (i.e. sewer pipes, pumps, force mains) to treatment/disposal site
- Off-site systems always require a sewerage systems

Elements of a Sewerage System

- Household or institutional plumbing systems (Plumbing fixtures)

- House connections to the community sewerage network (100-150mm pipes)



Elements of a Sewerage System

- Sewers and appurtenances such as manholes/inspection chambers and pumping stations

Elements of a Sewerage System

Types of Sewerage Systems

- Combined systems;
- Separate systems; and
- Small-bore sewers

Combined and Separate Sewerage systems

- Combined systems = Convey both wastewater and stormwater.

- Separate systems = Either convey stormwater or wastewater

Design Considerations

- Minimum velocity = 0.6m/s to promote self cleansing velocities in pipes

- Maximum velocity = 3m/s to avoid erosion of pipes – abrasion (due to grit)

- Q/Q_{full} = 0.5 – 0.7 to avoid pressurised flow characteristics

Small-bore Sewers

- Only transport the liquid constituent of the wastewater.
- Solids in a small-bore system are retained on site
- The liquid part is conveyed to the final point of discharge through small pipes which can be as small as 75mm.
- As there are no solids, there is no need for self-cleansing velocities. (0.3m/s is usually adopted; pipes gradient minimal (i.e., 1 in 200) thereby avoiding excessive excavations in most cases.

Small-bore Sewers Cont'

Small-bore sewers are appropriate:

- ❖ Where septic tanks already exist, but soakaways have failed or do not exist;
- ❖ Where pour-flush toilets are used, but on-site disposal of the effluent is impossible;
- ❖ Where sewerage is needed, but the normal conditions of sewer laying cannot be met without exceptional expense

O and M issues – Conventional and small bore sewers

- SB sewers designed to only carry the liquid part of the wastewater, therefore, there is need for efficient emptying of the septic tanks.
- In all systems, hydraulic jumps should be avoided
- Manholes to be provided at appropriate locations (Where connections are made and where direction is changing
- Minimum cover of 1m to be provided. Where too deep, concrete cover to be provided to withstand excessive pressure

Estimation of Flow Quantities

- Based on water supply. It is usually taken as 0.6 to 0.8 of water supplied

- Inflow from roofs and other sources are estimated based on local conditions

Quantification for Industrial Wastewater

- Dependant on processes

Wastewater Treatment

TREATMENT METHODS

- Conventional
  a) Trickling filters
  b) Activated sludge system

- Non – conventional
  c) Wastewater stabilisation ponds
  d) Oxidation ditches
  e) Aerated lagoons

Treatment Principles

- Physical
- Biological (aerobic vs anaerobic)
- Chemical (sometimes)

Sitting of Treatment Plants

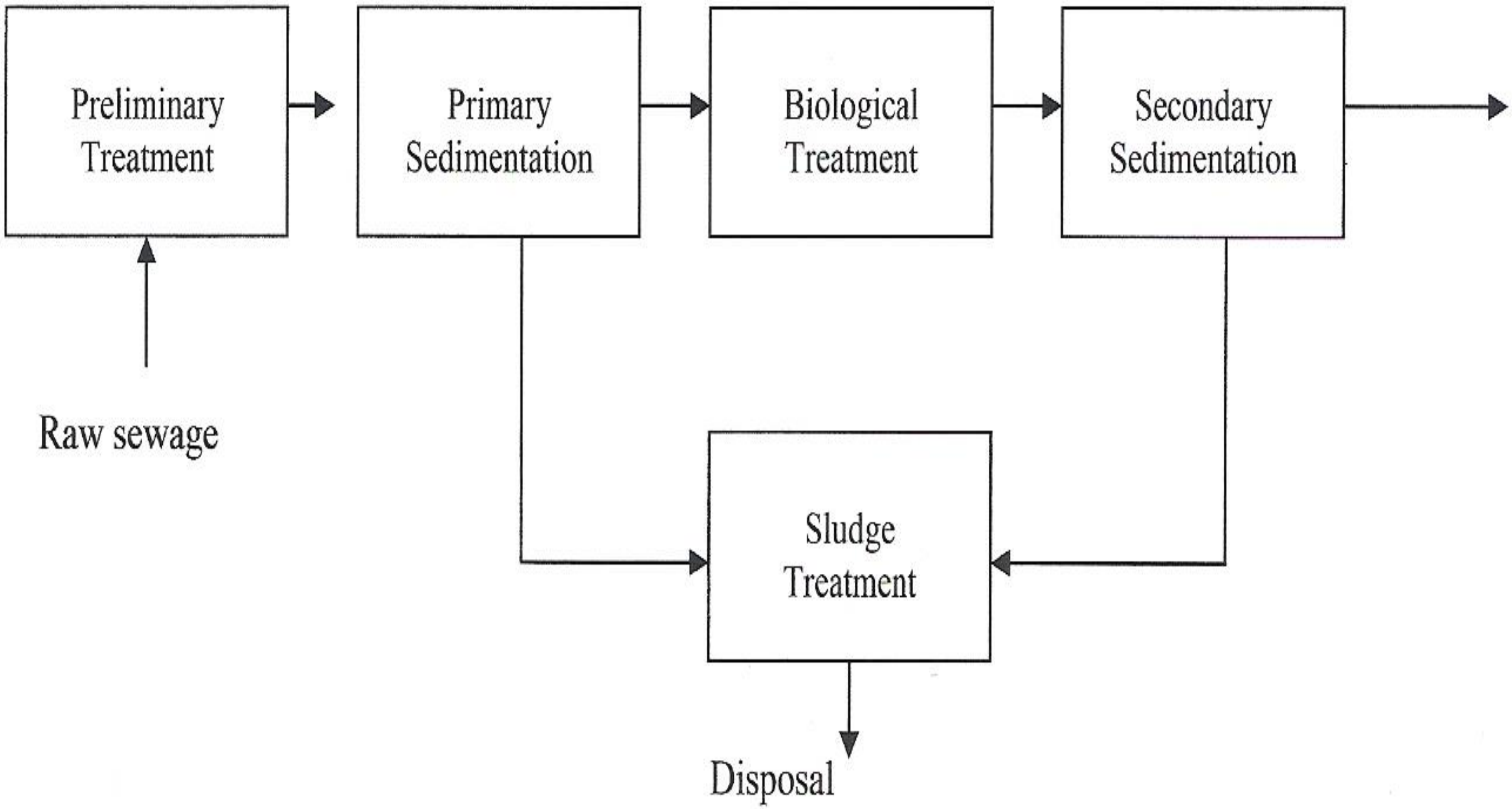
- ❖Free from floods
- ❖Suitable shape and gradient to permit gravitational flow
- ❖Sufficient land for future expansion
- ❖Leeward of prevailing winds
- ❖At least 500m from nearest dwellings

Conventional Treatment Systems

STAGES

- Preliminary treatment
- Primary sedimentation (Treatment)
- Biological treatment
- Secondary sedimentation
- Sludge treatment

Flow Diagram Of Conventional Treatment



Preliminary Treatment

- Screening
- Communition
- Grit removal

❖Screening

❖Screening is the process for the removal of bigger inorganic objects (Rugs, wood, metals, plastics etc) from the wastewater.

❖If absent or not effective, the following might occur:-

a. Blockages in sludge pipes
b. Damage to pumps
c. Formation of scum in digesters (Due to inorganics)
d. Complications to the ultimate disposal of sludge

Screens

TYPES

- ❖ Hand raked – 20 to 40cm bars
- ❖ Mechanical raked

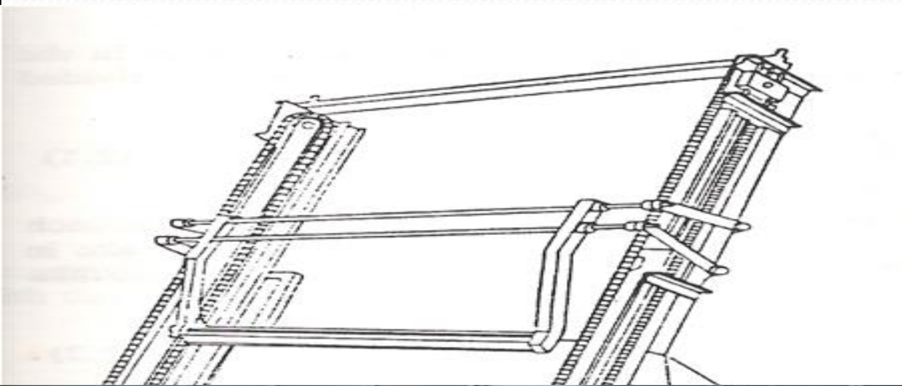
FOR EFFECTIVE OPERATION OF SCREENS

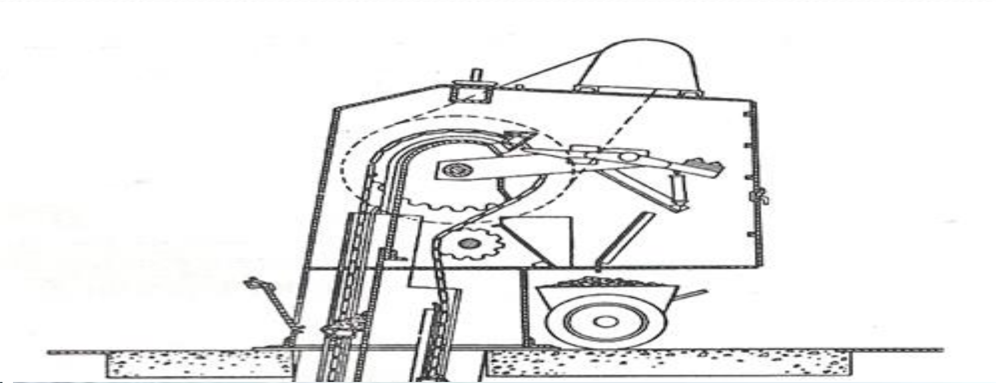
- ❖ Frequent removal of screenings
- ❖ Effective disposal of screenings
- ❖ The approach velocity (0.3 - 0.6m/s)




HAND RAKED BAR SCREEN

Mechanically/Automatically Raked Screens

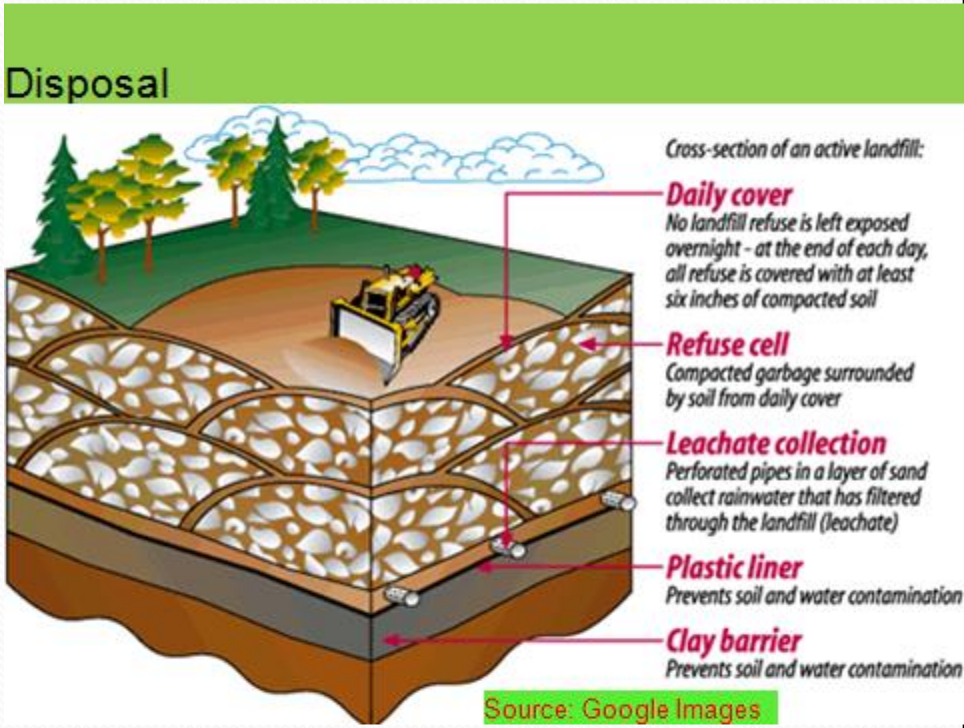




eening device (Metcalf and Eddy, 1991).

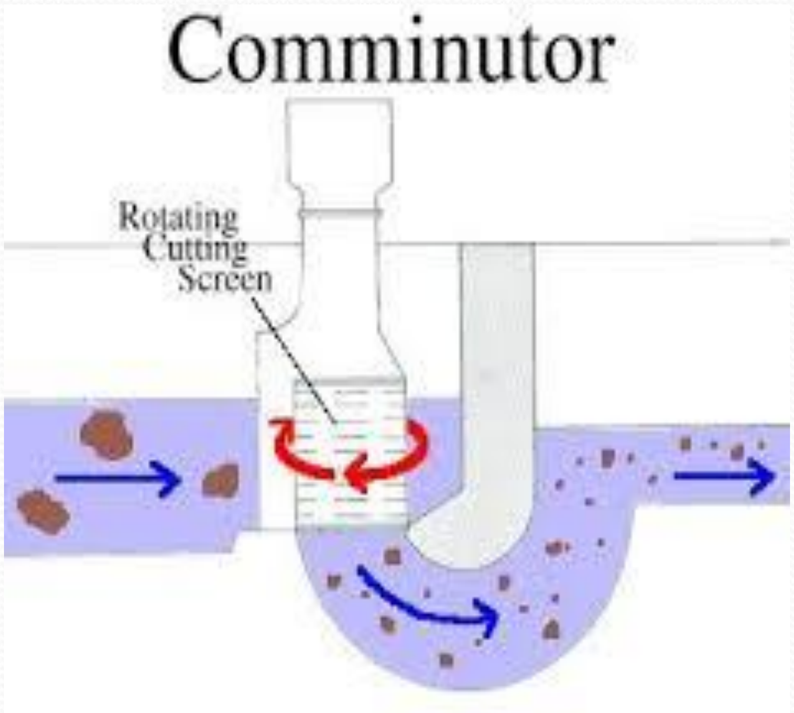
Disposal Of Screenings

❖Burying/incineration/Engineered Landfill.



Communition

- The cutting of bigger sewage solids into smaller pieces
- Improves plant efficiency by increasing surface area of organics
- Satisfactory performance depends on servicing of the machine especially the cutting teeth



Source: Google images

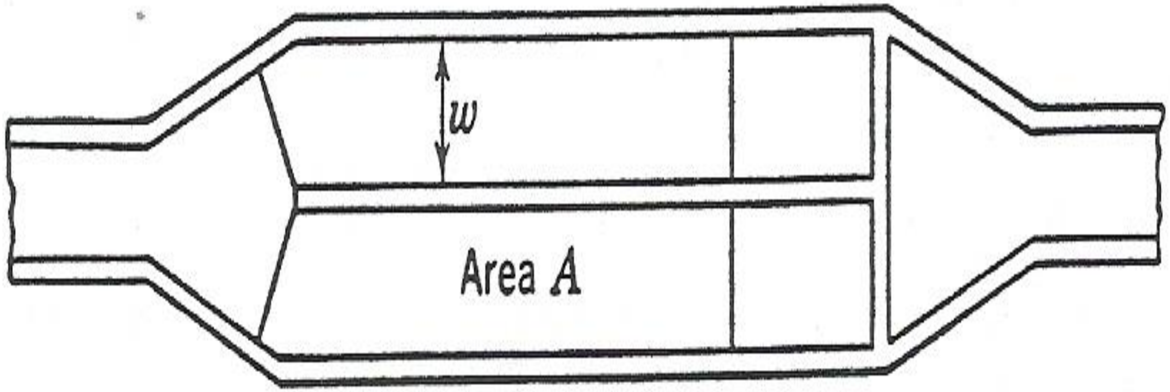
Grit Removal

- The removal of dense inert particles from the sewage
- Grit should be removed early in the treatment process because it is:
  - Abrasive and will rapidly wear out pumps and other equipment
  - Settles in pipes and channels causing blockages/clogging
  - Settles in digesters and settling tanks resulting in more frequent cleaning and maintenance

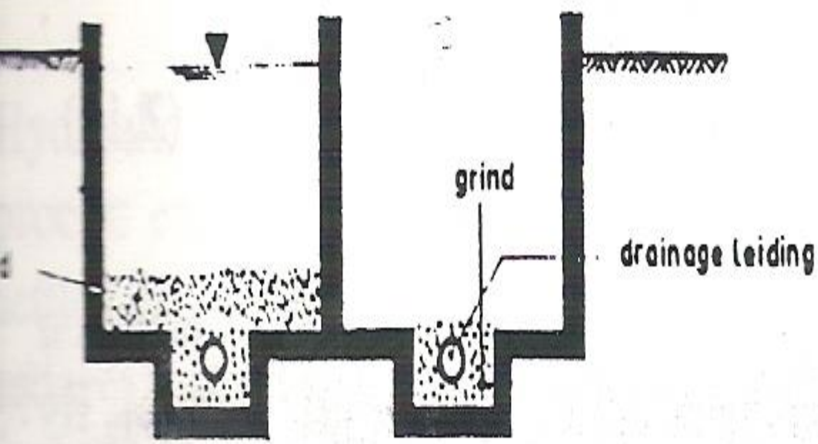
Grit Channels

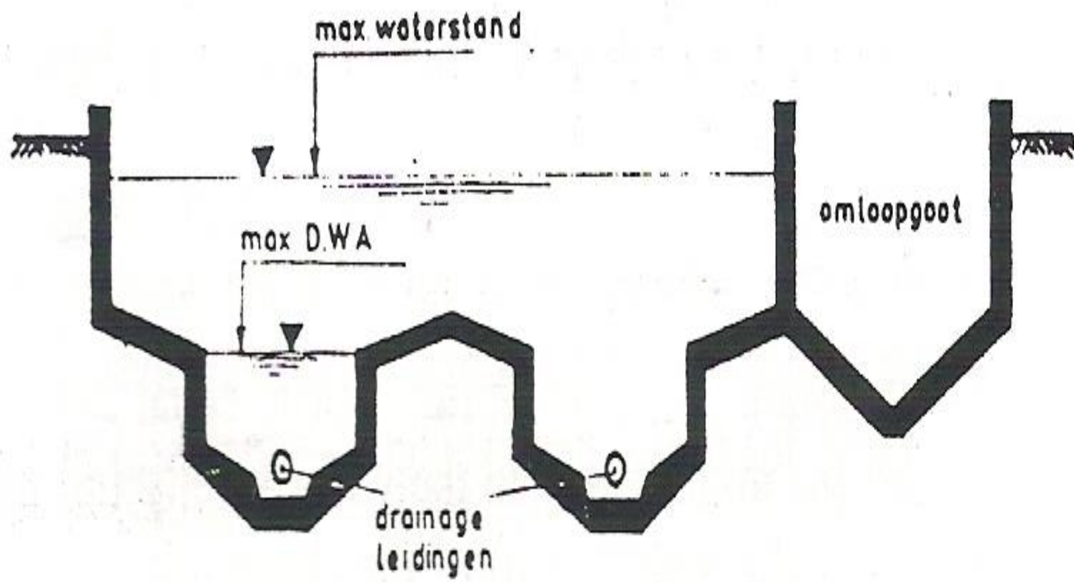
- Grit is removed in
  - ✓ Constant velocity channels
  - ✓ Tanks with spiral currents

Grit Channels - Examples



Plan





Effective Performance

- Effective performance of grit removal will depend on
  - Degritting Rate
  - Flow rate (about 0.3m/s)

Grit Disposal

- Washed, Buried or used in construction works

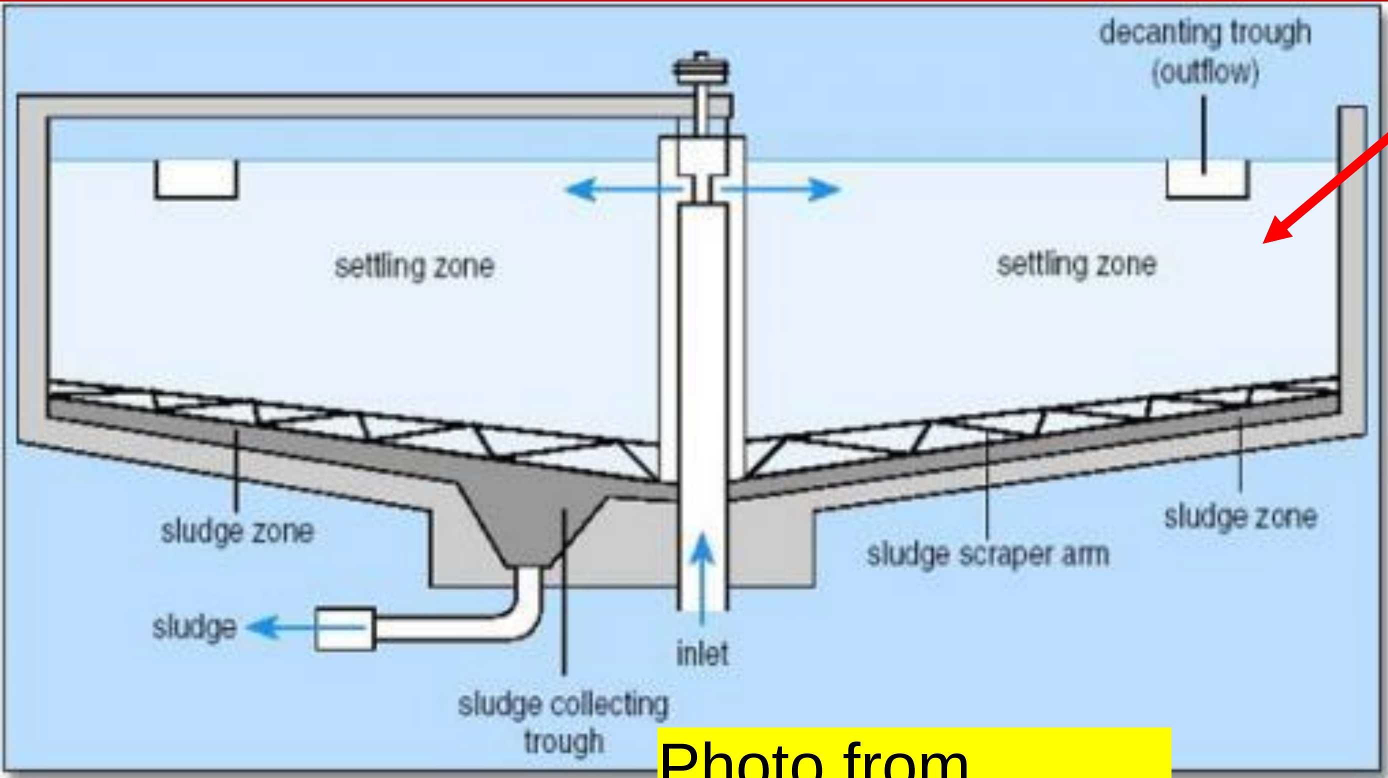
Primary Treatment

PRIMARY SEDIMENTATION

REASONS FOR PRIMARY SEDIMENTATION

- To reduce "Strength" of sewage
- To remove Solid organic matter (including some colloidal particles)
- To prevent the solids from blocking the biological filters (ponding)

Sedimentation tank Cross Section



Source: Google images

Photo from CWWTP

Primary Sedimentation Cont’

- EFFICIENCIES
  - ✓ Total suspended solids removal 50 -70%
  - ✓ BOD removal 25 - 40%

- PARAMETERS FOR ENHANCED OPERATION
  - Flow rates which affect
    - ✓ Retention times
    - ✓ Hydraulic surface loading rates upon which the efficient operation of the tanks is based (design parameters)

Design Considerations

Design surface loading rates and retention times for clarifiers

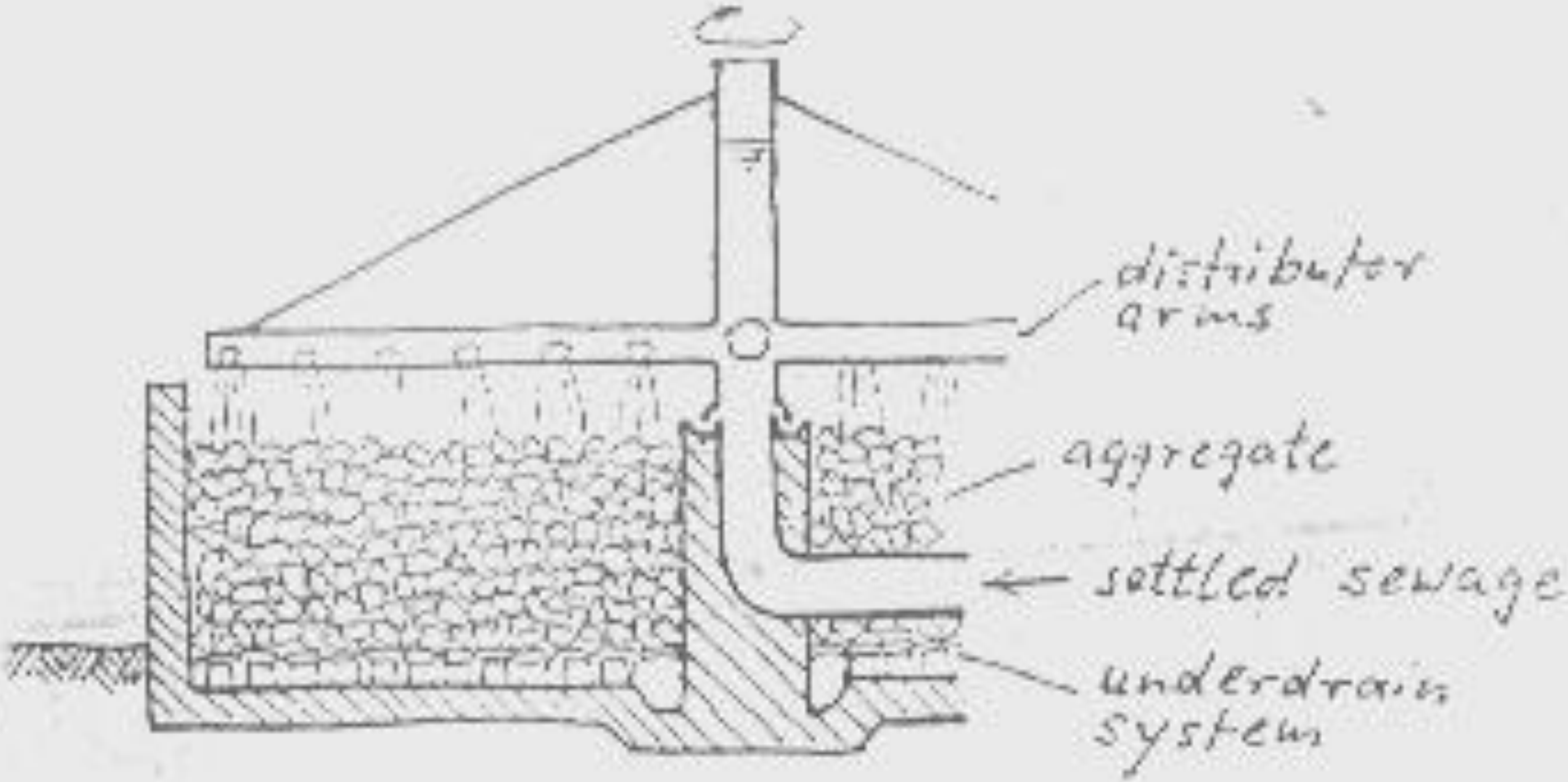
TYPE	S.L.R(m/d)	RETENTION TIME(h)
PRIMARY	24 - 32	1.5 - 2.5
SECONDARY	32 - 40	1.0 - 1.5

Biological Treatment

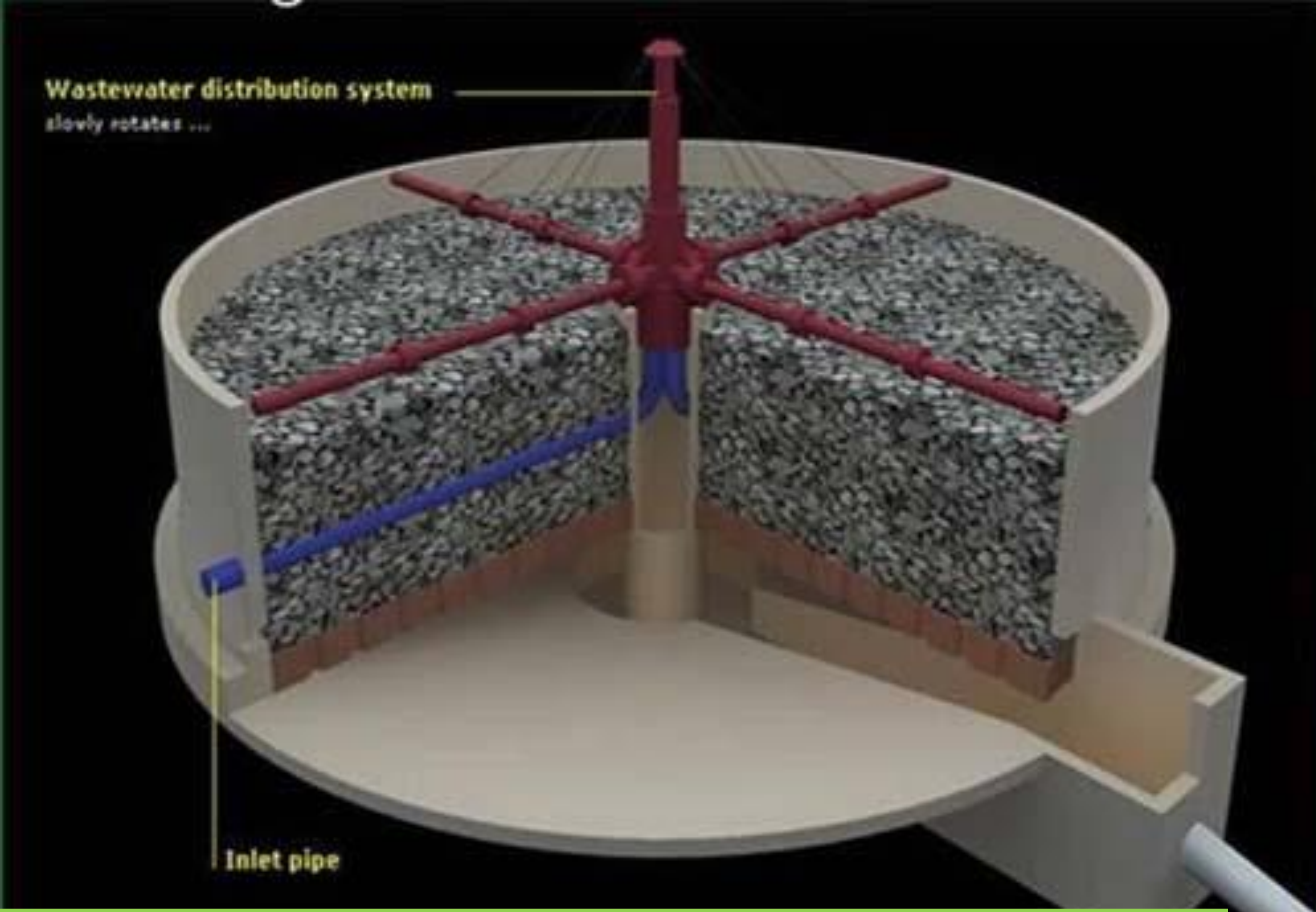
- Trickling Filters (fixed film process)

- Activated Sludge (Suspended film process)

What is a Trickling Filter (Percolating Or Bio -Filter)



Picture Of A Trickling Filter

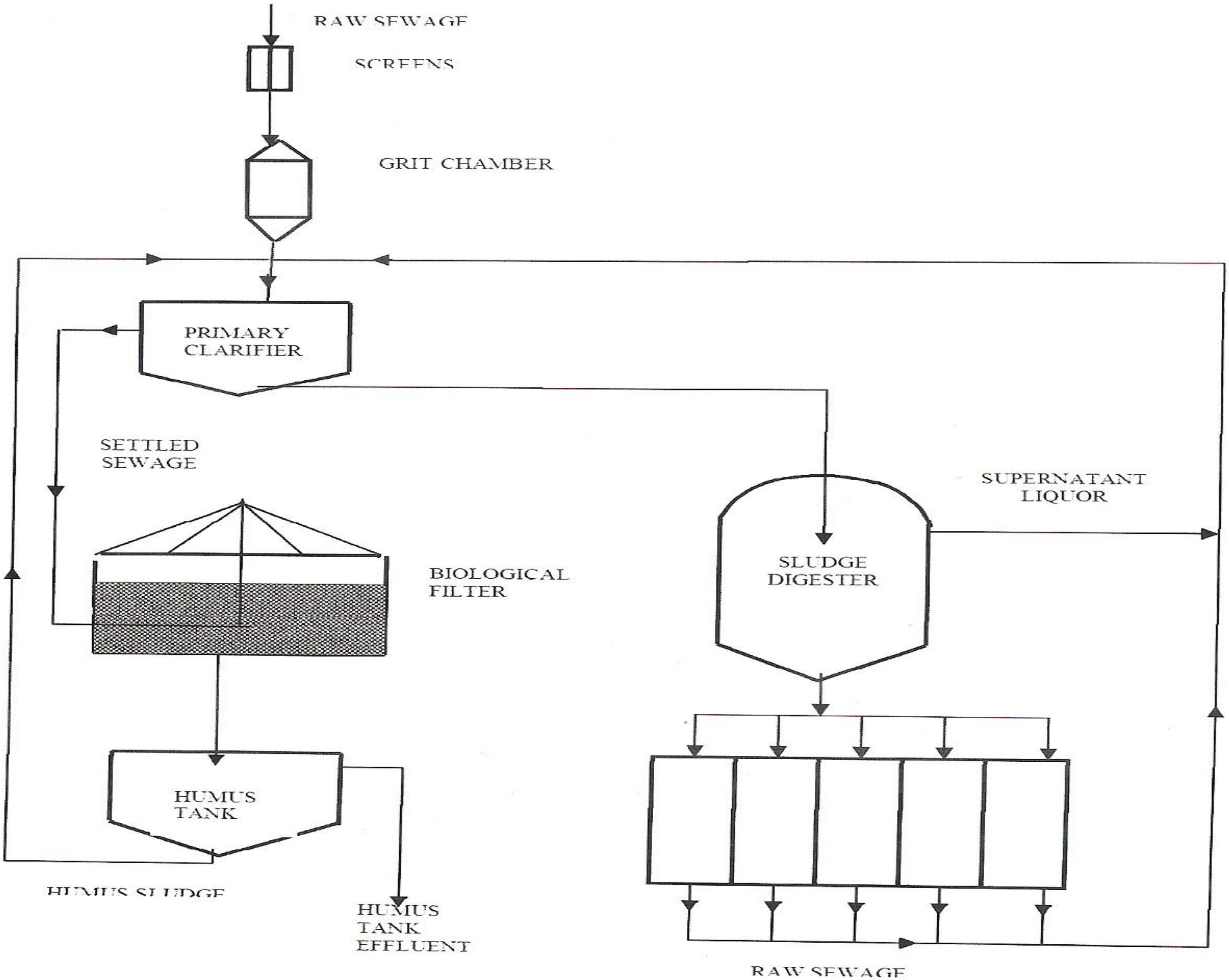


INSIDE A TRICKLING FILTER

Components

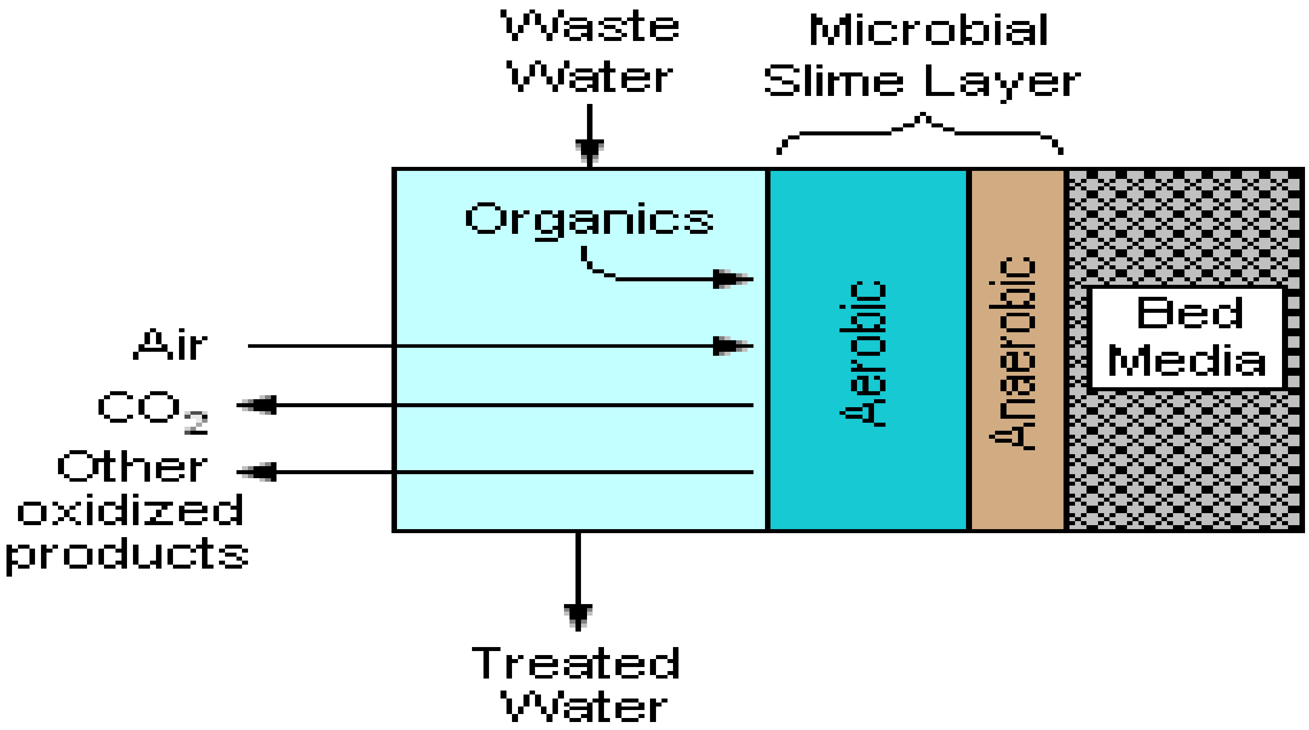
- ❖Containment structure
- ❖Media (Crushed stones 60mm dia or sythentic)
- ❖Underdrain system
  - ✓ to support the media,
  - ✓ to collect and transport the filter effluent, and
  - ✓ to convey the air through the filter
- ❖Filter feed (and recirculation system) and
- ❖Post filter clarifiers (Secondary sedimentation tanks)

Synthetic Media


RAW SEWAGE
SCREENS
GRIT CHAMBER
PRIMARY CLARIFIER
SETTLED SEWAGE
SUPERNATANT LIQUOR
SLUDGE DIGESTER
BIOLOGICAL FILTER
HUMUS TANK
HUMUS SLUDGE
HUMUS TANK EFFLUENT
RAW SEWAGE

Treatment Mechanism

Microorganism + soluble/Colloidal organic matter + O_2 = More microorganisms + energy + CO_2 + H_2O+ other waste products (e.g. Nitrates)



Treatment Mechanism Cont'

- SLOUGHING = In biological terms is shedding or casting off of dead skin

Important parameters in the design/operation of biofilters

- Volumetric (Organic) loading rate Lv
- Surface (Organic) loading rate SLR
- Hydraulic surface loading rate HSLR

Design Criteria

Volumetric Organic Loading Rate

$$L_v = \frac{Load(KgBOD/d)}{V_f(m^3)}(Kg/m^3.d)$$

Design Criteria Cont'

Organic Surface Loading Rate

$$SLR = \frac{Load(KgBOD/d)}{A_f(m^2)}(Kg/m^2.d)$$

Design Criteria Cont'

Hydraulic Surface Loading Rate

$$HSLR = \frac{FlowrateQ_i + Q_r}{A_f\,(m^2)}\,(m^3/d)$$