WASTEWATER CHARACTERIZATION

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Outline

1. Introduction
2. Water Quality Criteria
3. Wastewater Characterization
    a. Source and flowrate
    b. Type of pollutant
    c. Measurement techniques
    d. Parameters
4. Wastewater Sampling

1. Introduction

Why Treating Wastewater?

- Domestic and industrial processes use and pollute water => wastewater
- Minimise effects of discharge on environment
- Remove pollutants for recycling and/or reuse of water

Objectives of Wastewater Treatment

- Ensure good water quality in natural environment
- Remove pollutants most efficiently and economically
- Avoid or minimise other environmental impacts like:
  - solid disposal
  - gas emission
  - odour creation
  - noise generation

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2. Water Quality Criteria

1. Traditional Approach

- Focus on point sources
- Mainly concerned with local effect
- Definition of maximum limits (BOD, SS, T, pH, nutrients etc.)
- Usually concentration limits and total flow rate limit

2. Water Quality Criteria

Modern Approach

- Classification of receiving water based on use:
  - A - drinking, environmentally sensitive
  - B - bathing, fish-life
  - C - navigation, fish-life, agricultural use
- Definition of stream quality standards for specific use

How to relate this to discharges?

- Estimating effects of non-point (diffuse) sources eg. storm water, irrigation run-off
- Set minimization targets and strategies (catchment management plans etc.)
- Focus on load (freight), not just concentrations
- Concerned with overall effects on receiving water body (creek, river, bay…)

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3. Wastewater Characterisation

What is (in) Wastewater?

1. Identify wastewater sources and flows
2. Specify likely key pollutants
3. Select suitable sampling strategies
4. Measure pollutant concentrations
5. Calculate pollutant loads
6. Identify main components to be removed

a. Sources and Flow Rates

- Essential step to identify problem area
- How to define sources & flows?
  1. Use "systems/mass balance" approach
  2. Utilize wastewater audits
  3. Anticipate future requirements
  4. **Reduce > Reuse > Recycle**
  5. Simple is better than complex
- Source reduction can drastically improve wastewater situation (tannery)

b. Types of Pollutants

- **Physical**: solids, temperature, color, turbidity, salinity, odor

- **Chemical**:
  - Organic : carbohydrates, fats, proteins, toxins…
  - Inorganic: alkalinity, N, P, S, pH, metals, salts…
  - Gaseous : H_2S, CH_4, O_2 …

- **Biological**: plants (algae, grass, etc.), microorganisms (bacteria, viruses)

c. Measurement Techniques

- Physical, chemical or biological methods
- Summary of basic methods in APHA (US): "Standard Methods for the Examination of Water and Wastewater"
- Many instrument methods in use (FIA)
- Good laboratory practice essential eg. dilution, weighing, filtration, standards

Flow Injection Analyser (FIA)

- colorimeter
- Fluorimeter
- biosensors

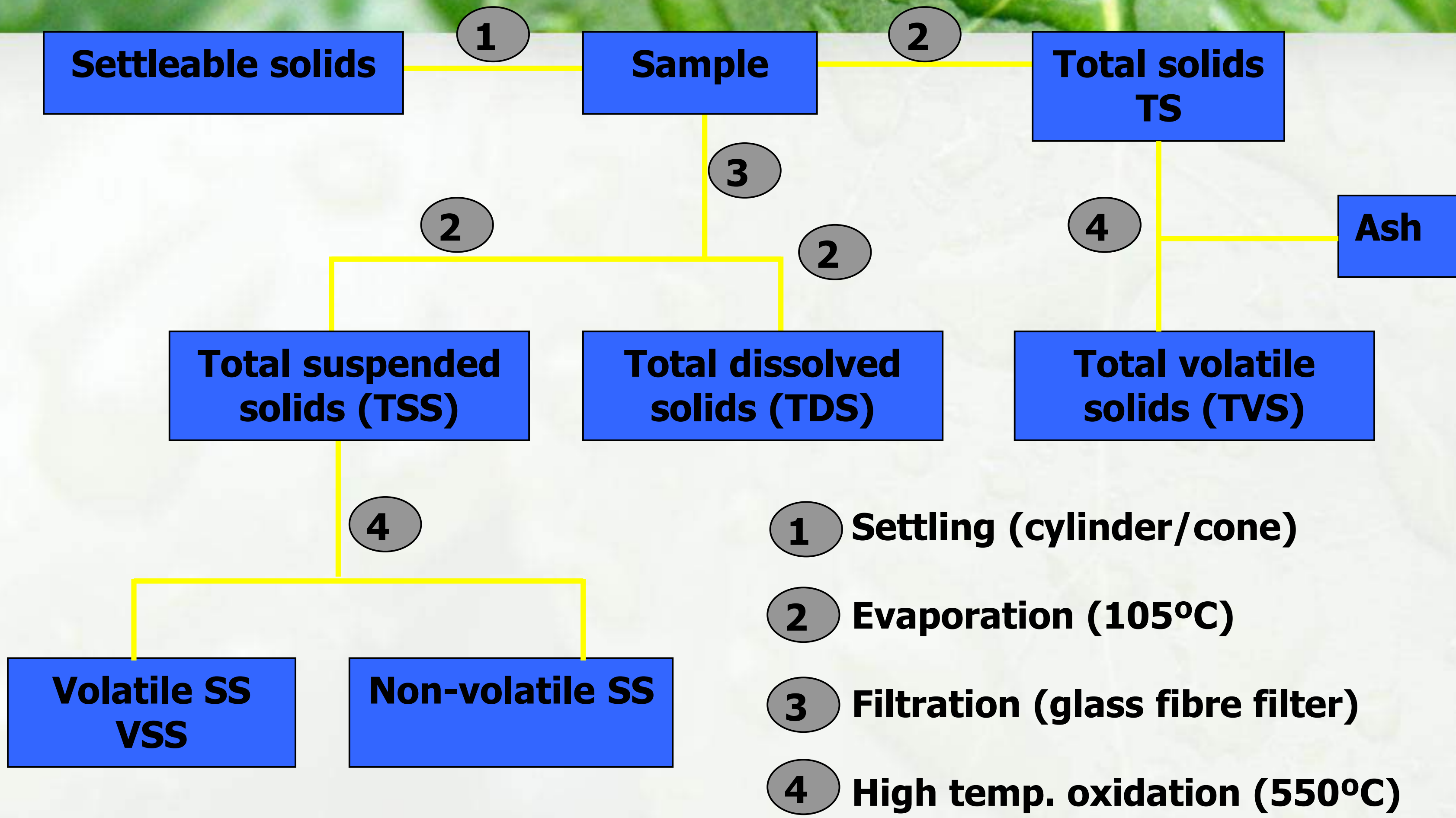
d. Measurement Parameters

1. Solids
2. Odor
3. Temperature
4. Salinity
5. Color and turbidity
6. Carbohydrate
7. Protein
8. Flow terms

1. Solids

- Solids separated by filtration into non/soluble and by high temperature oxidation into non/volatile
- Solids often form large percentage of total organic material
- Solids degradation often slow due to mass transfer limitations
- Sources: food processing, abattoirs rural industries (piggeries etc.), domestic

Solids Fractions



Practical Exercises: Solids

In solids analysis, the following measurements were obtained:

- Sample size: 50 mL
- After filtration/evaporation:

  12 mg filter cake, 2.5mg solids in filtrate
- After high temperature oxidation:

  2.0 mg filter cake

What is TSS, VSS and TS in the sample? mg/ml

Answer

TSS : 12 mg / 50 ml = 0.24 mg/ml

VSS : (12 – 2.0 mg) / 50 ml = 0.2 mg/l

TS : (12+2.5) mg /50 ml = 0.29 mg/l

2. Odour

- Often very small amounts cause nuisance (eg. H_2S approx. 10 ppb)
- Physical/chemical measurement difficult
- Olfactometry uses human odor panels
- Olfactometer determines dilution necessary until no odor detected

3. Temperature

- Industrial WW often elevated temperature
- Affects treatment performance of many treatment systems
- Gas eg. O2 solubility is lower at higher temperature
- Effluent temperature usually specified in license limits

4. Salinity

- Affects ecosystems in receiving waters
- Reduces O_2 solubility
- Restricts reuse applications (eg. irrigation)
- Critical for downstream water utilization

5. Colour & Turbidity

- Colour of WW & biological treatment:
  - light brown-gray => fresh, aerob
  - dark brown-black => old, anaerob
- Soluble dyes (stains) also cause coloring, very difficult to remove (e.g textile)
- Turbidity measures light-transmission
  - Caused by colloidal or suspended matter
  - Can be correlated with suspended solids

6. Organic Matter

- Largest component group in most ww: 75 % of TSS, 40 % of TDS (domestic ww)
- Composition highly industry dependent
- Types:
  - carbohydrates
  - proteins
  - oil & grease
  - organic toxins (priority pollutants, eg.pesticides)
  - others eg. surfactants, dyes etc.
- Mostly biodegradable, some very slowly

a. Carbohydrates

- Composition: C, H, O
- Soluble: sugars, alcohols, acids (VFA) *rapidly biodegradable*
- Insoluble: starches, cellulose, fibres (*relatively) slowly biodegradable*
- Sources: sugar mills, breweries, dairy factories, canneries etc.

b. Proteins

- Composition: C, H, O, N (16%), S, P
- Solubility varies with protein type and ww conditions (eg pH, salt conc.)
- Quite *rapidly biodegradable* to amino acids except when insoluble
- Anaerobic degradation creates H_2S and other sulphur components => odor
- Sources: dairy factories, meat processing (abattoirs), food processing

c. Oil & Grease

- Composition: C, H, O
- Hydrophobic substances: grease, fat, oil
- Mostly insoluble, floating, easily adsorbed on surfaces
- *Slowly biodegradable*, even when hydrolysed to glycerol and fatty acids
- Sources: meat processing, food production, chemical factories

d. Toxics (Priority Pollutants)

- Organic toxic chemicals, pesticides, herbicides, solvents, etc.
- Inorganic substances eg. Heavy metals (Cd, Cr, Pb, Hg, Ag etc.)
- Normally very low effluent limits
- Sources: chemical factories, metal manufacturing, tanneries, agriculture, etc.

Practical Exercises: Composition

- What main components would you expect in a cheese factory wastewater?
- What are the main concerns when considering treatment of an electroplating wastewater stream?
- Why should storage of raw wastewater be avoided if at all possible?
- What precautions should be taken if storage is necessary?

Measurement of Organic Content

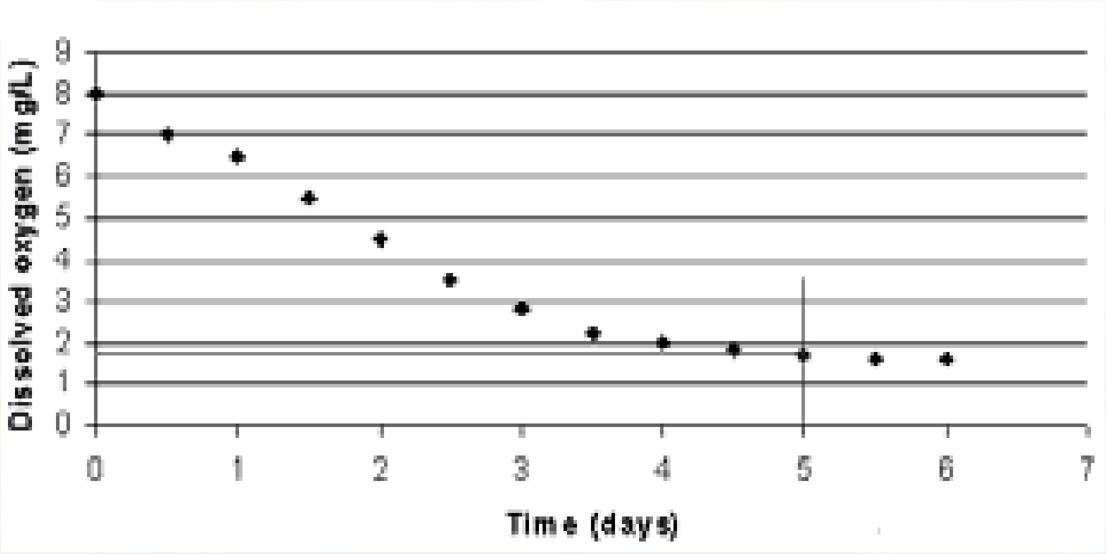
- Mostly overall content measured:
  - Total organic carbon: TOC
  - Biochemical oxygen demand: BOD
  - Chemical oxygen demand: COD
- BOD & COD most commonly used for design and effluent specifications

a. Biochemical Oxygen Demand (BOD)

- Measures **oxygen** required for biological oxidation of organics
- BOD: oxygen uptake by microorganism during aerobic growth in ww sample
- Standard BOD: 5 day incubation @ 20°C
- Samples require a series of dilutions to achieve suitable oxygen consumption

BOD Example

This result was obtained for a BOD test on a wastewater sample. The sample was diluted by a factor of 20 prior to the test.



What is the BOD5 ?

BOD5 = (8 - 1.7)*20

= **126 mg/L**

Practical Concerns with BOD Test

- Only partial degradation of organics
- Cannot be used for mass balancing
- Very high (>1000mg/L) and very low (<10mg/L) values often unreliable
- Industrial wastewater can contain inhibitors, leading to low BOD results

b. Chemical Oxygen Demand (COD)

- Also measures oxygen required, but for **chemical** oxidation of organics
- COD: chemical oxidants used for oxidation of organics to CO_2, H_2O & NH_3
- Standard COD: $K_2Cr_2O_7^{2-}$ /H_2SO_4 @ 145°C
- During oxidation dichromate is used up and remaining oxidant is measured spectrophotometrically to determine oxidant used

8. Wastewater Flow Terms

- Equivalent person (EP): average wastewater amount produced per person
- Typically 1 EP equivalent to 200-250 l/d per person for domestic households
- Average Dry Weather Flow (ADWF): average flow over 7 days without rain
- Peak Dry Weather Flow (PDWF): maximal flow during day (1.5-3 x ADWF)

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4. Sampling & Measurements

- On-line measurements where possible
- Appropriate sampling crucial to achieve relevant results
- Sampling schedule based on expected (or measured) variance over time
- Automatic sampling often essential

Composite Sampling

- Reduces analysis costs and levels out concentration fluctuations
- Composite samples should be taken proportional to flow
- Individual samples can be collected and composited later
- Ensure appropriate sample conservation/ storage from sampling time until analysis

THANK YOU

Lagoons

- Like most natural environments, conditions inside facultative lagoons are always changing.
- Lagoons experience cycles due to variations in the weather, the composition of the wastewater, and other factors.
- In general, the wastewater in facultative lagoons naturally settles into three fairly distinct layers or zones.
- Different conditions exists in each zone, and wastewater treatment takes place in all three

Lagoons…

- The top layer in a facultative lagoon is called the aerobic zone, because the majority of oxygen is present there.
- How deep the aerobic How deep the aerobic zone is depends on loading, climate, amount of sunlight and wind, and how much algae is in the water.
- The wastewater in this part of the lagoon receives oxygen from air, from algae, and from the agitation of the water surface (from wind and rain, for example).
- This zone also serves as a barrier for example). This zone also serves as a barrier for the odors from gases produced by the treatment processes occurring in the lower layers.

Wastewater treatment

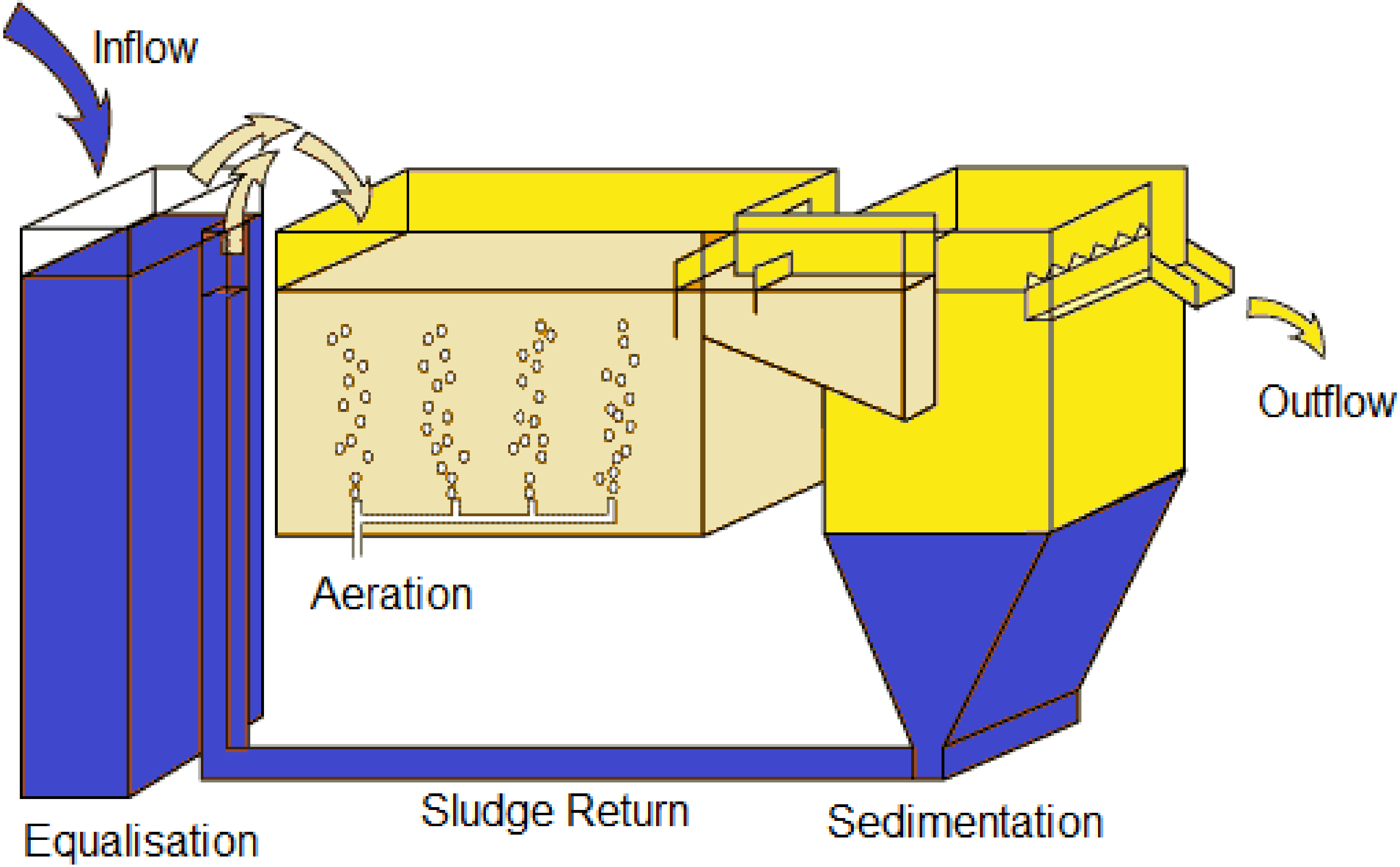
Primary treatment :

Septic tank : lower the total organic loading, and separate the solids from the liquid

Secondary treatment:

Constructed wetland: convert the dissolved or suspended material into a useful form separated from the water

Aerobic Suspended Growth Systems(s32)



Process Description

The aerobic conversion of the organic matter occurs in three steps:

- **Oxidation**

- **COHNS + O_2 + BACTERIA → CO_2 + NH_3 + END PRODUCTS+ ENERGY**

  (Organic matter)

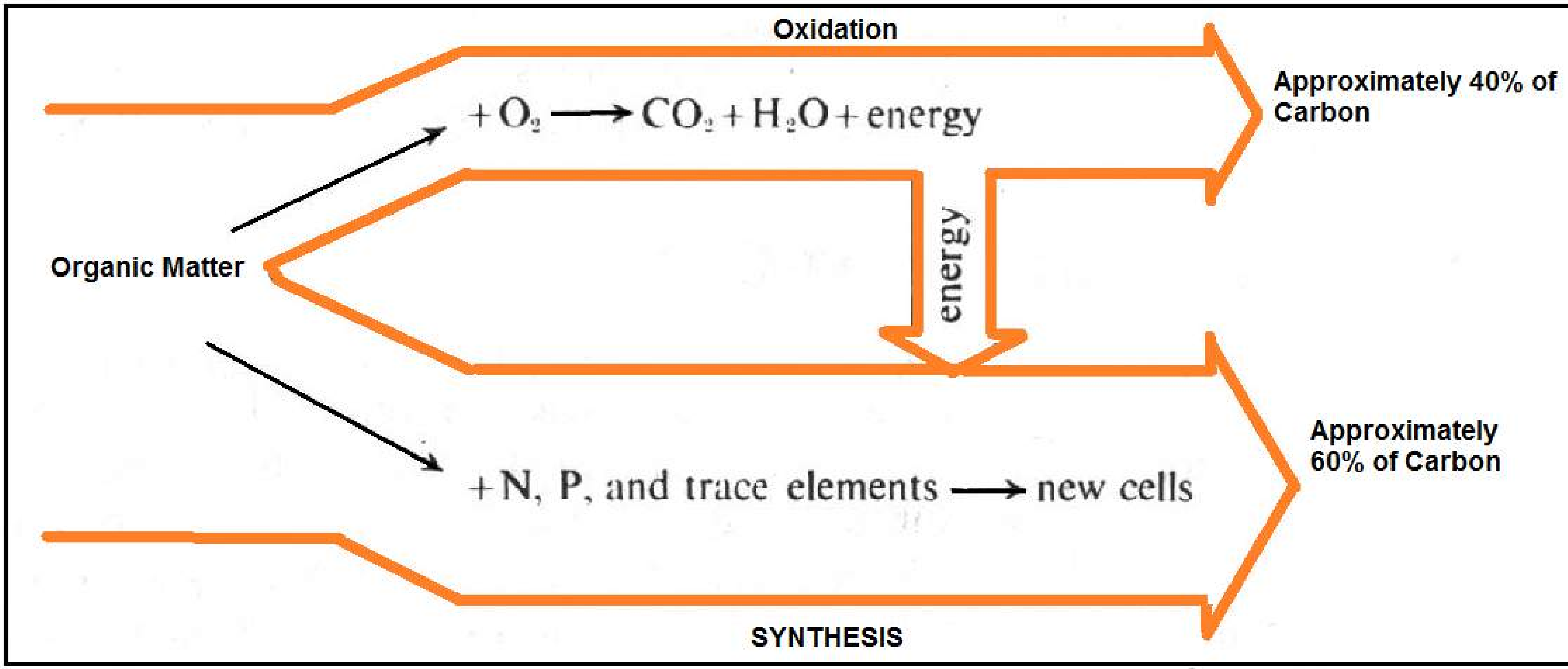
- **Synthesis of new cells**

- **COHNS + O_2+ BACTERIA + ENERGY → $C_5H_7NO_2$**
  (new cells)

- **Endogenous respiration**

- **$C_5H_7NO_2$ + 5O_2 → 5 CO_2+ NH_3+ 2H_2O + ENERGY**

Pathways for the breakdown of organic matter



Extended Aeration System

External substrate is completely removed.

Auto oxidation (internal substrate is used)

Net growth = 0

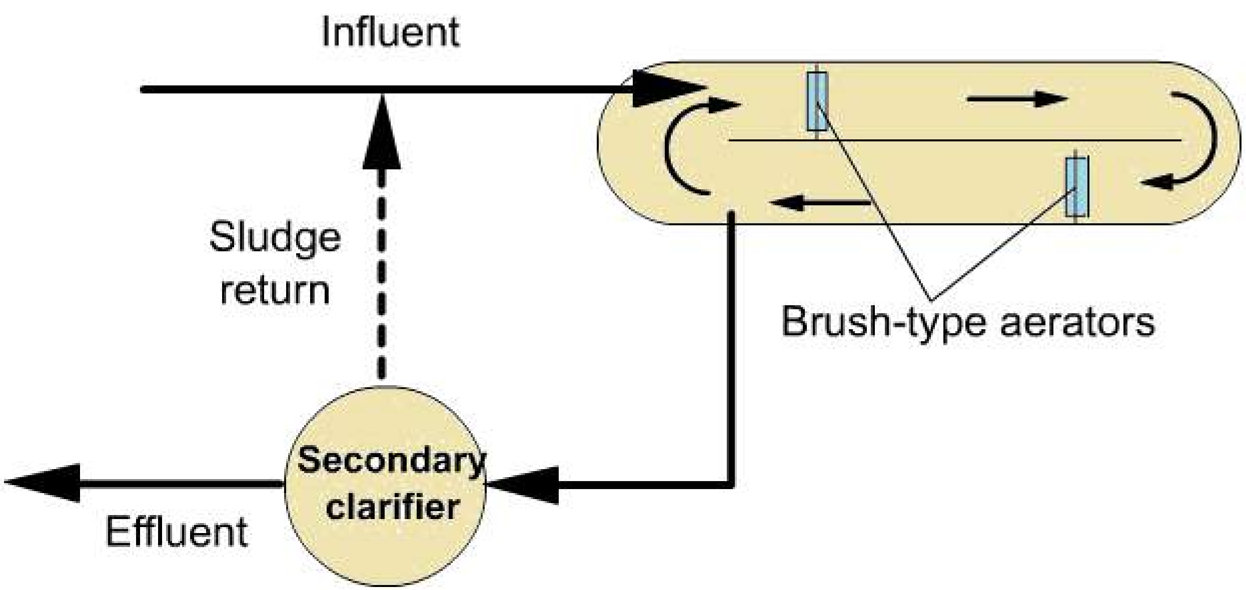
Advantages

- **Sludge production minimal**
- **Stabilized sludge → No digesters are required**
- **Nutrient requirement minimal**

Disadvantages

- High power requirement
- Large volume of aeration tank
- Suitable for small communities

Oxidation ditch – Pasveer Ditch


Influent
Sludge
return
Brush-type aerators
Secondary
clarifier
Effluent

Attached Growth systems

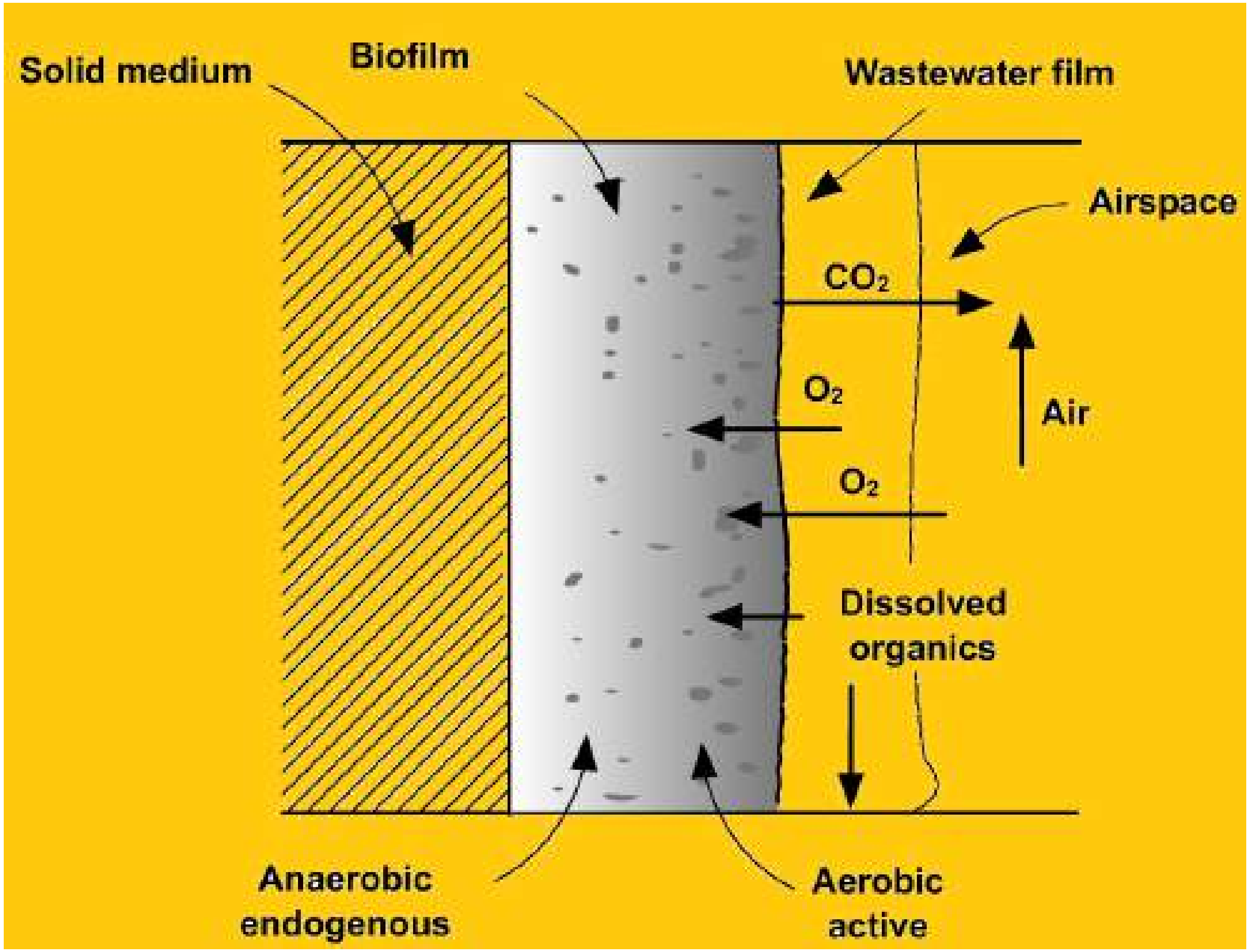
Aerobic

- Trickling filters
- Rotating biological contactors

Anaerobic

- Anaerobic filters
- Denitrification systems

System biology - Heterogeneous microbes



Rate of organic matter removal

1. Wastewater flow rate
2. Organic loading rate
3. Rate of diffusivity of food and oxygen into the biofilm.
4. Temperature

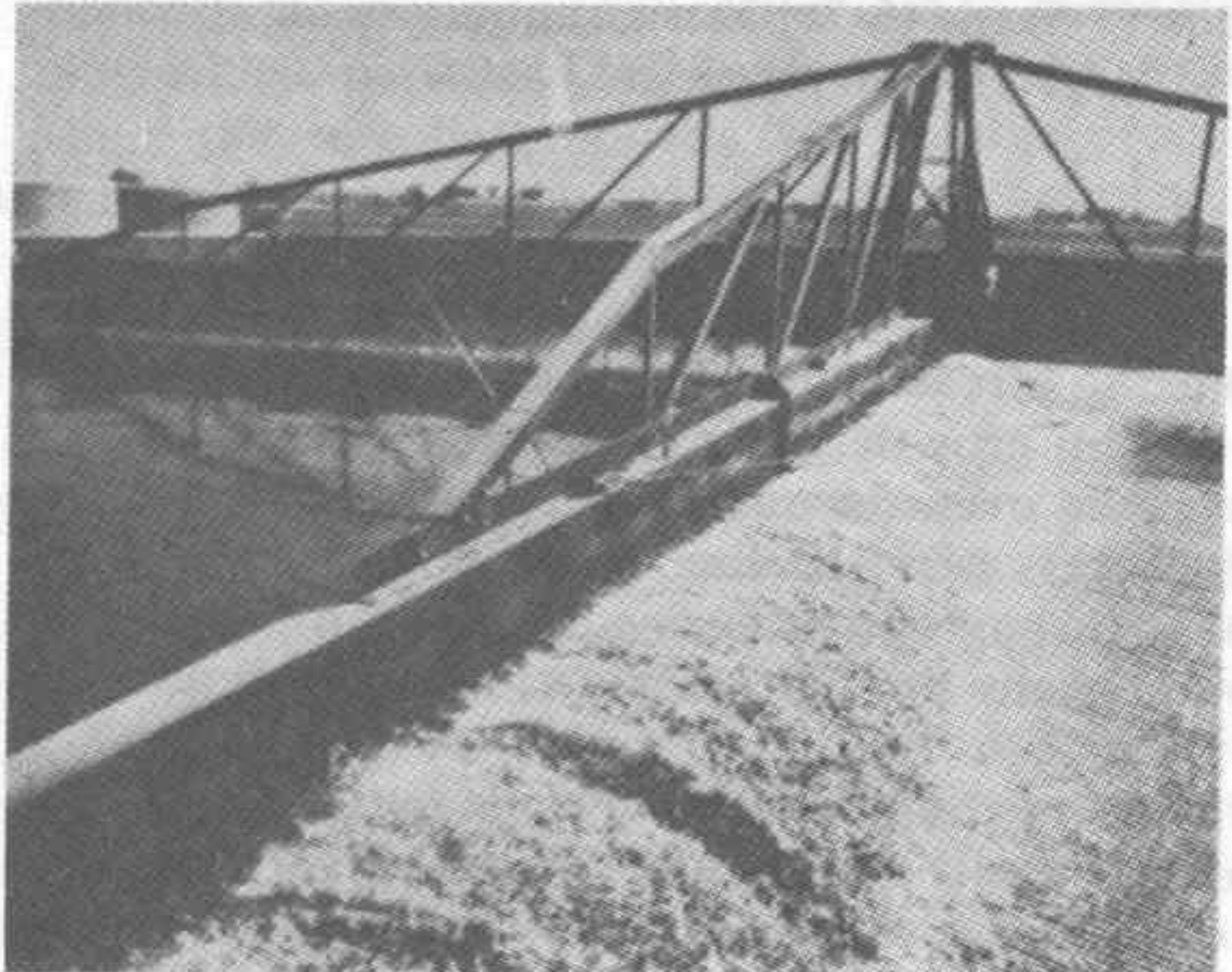
Trickling Filters

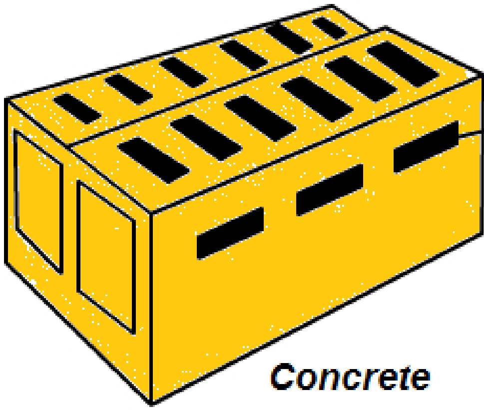
T.F → Reactor in which randomly packed solids forms provide surface for microbial growth.

- system for wastewater distribution

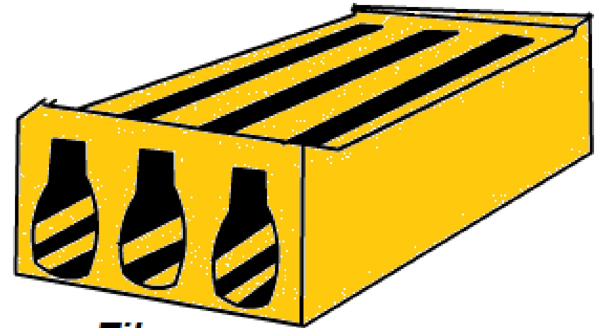
Specific surface area and porosity

Specific surface area: The amount of surface area of the media that is available for bio film growth





Concrete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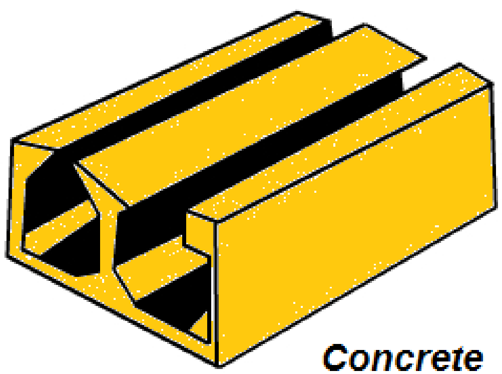
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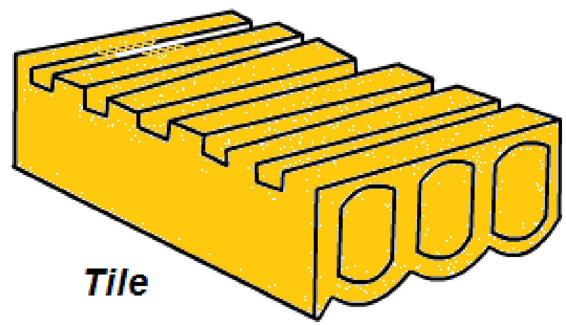
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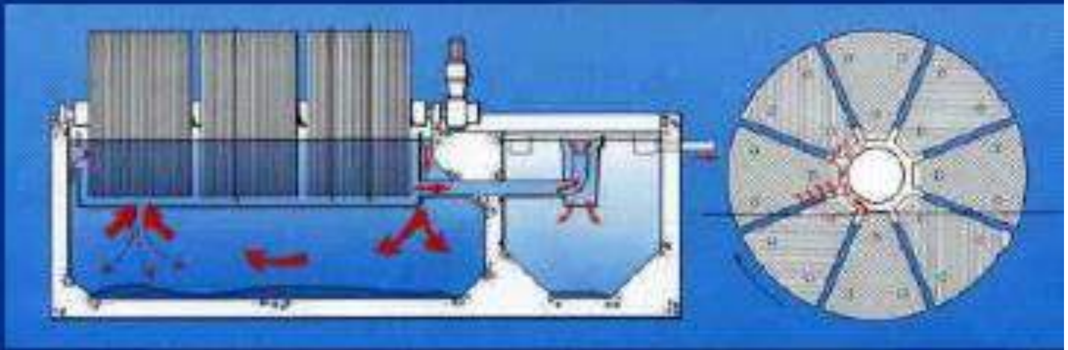
Item	Low-rate filter	Intermediate-rate filter	High-rate filter
Hydraulic loading m3/m2.d	1 - 4	4 - 10	10 - 40
Organic loading Kg/m3.d	0.08-0.32	0.24 - 0.48	0.32 - 1.0
Depth, m	1.5-3.0	1.25 - 2.5	1.0 - 2.0
Recirculation ratio	0	0 - 1	1 - 3; 2 - 1
Filter media	Rock, slag etc	Rock, slag etc	Rock, slag, synthetic materials
Power requirements kW/103.m3	2 - 4	2 - 8	6 - 10
Filter flies	Many	Intermediate	Few, larvae are washed away
Sloughing	Intermittent	Intermittent	Continuous
Dosing intervals	Not more than 5 min (generally intermittent)	15 - 60s (continuous)	Not more than 15s (continuous)
Effluent	Usually fully nitrified	Partially nitrified	Nitrified at low loadings

Rotating Biological Contactor (RBC)



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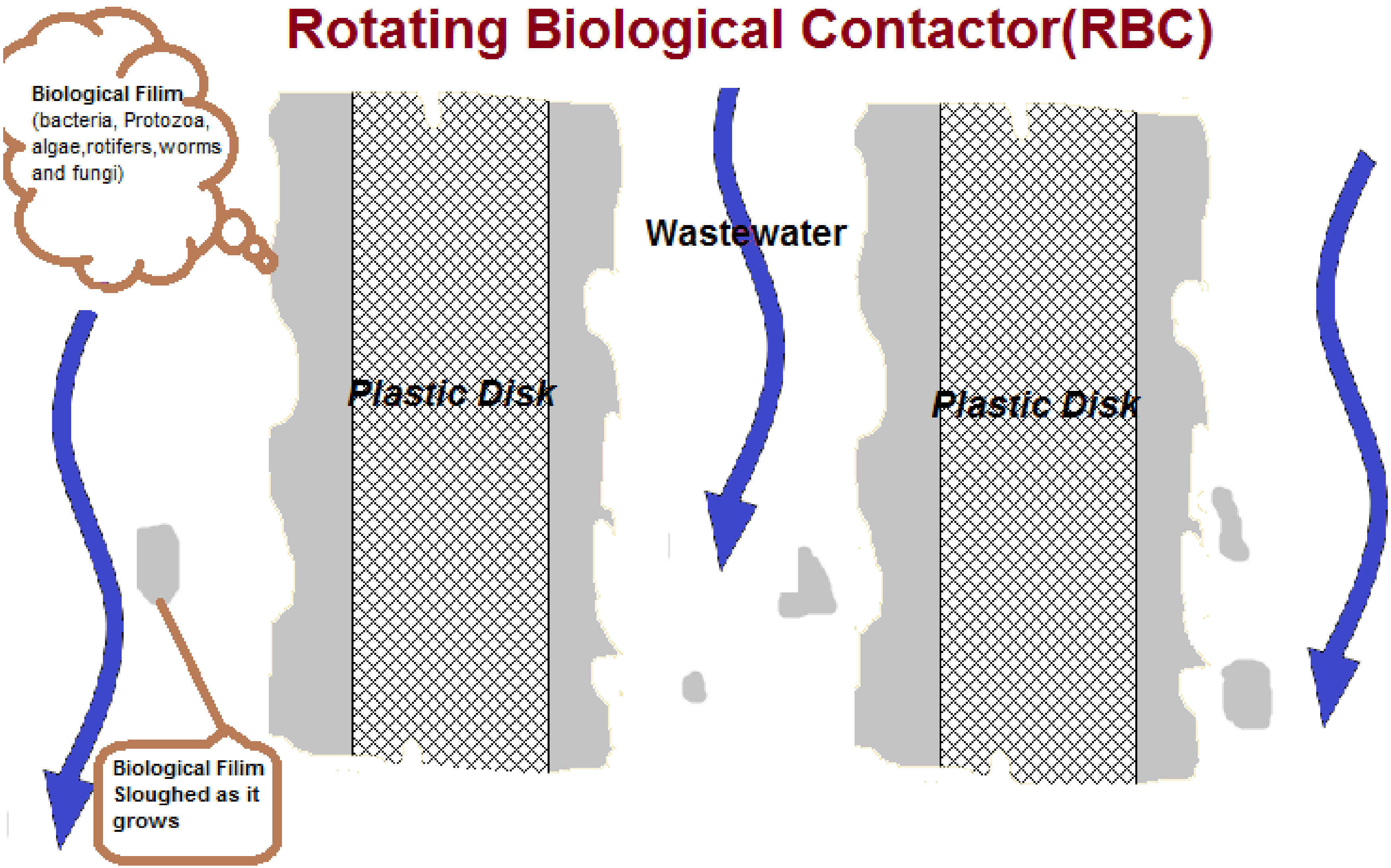

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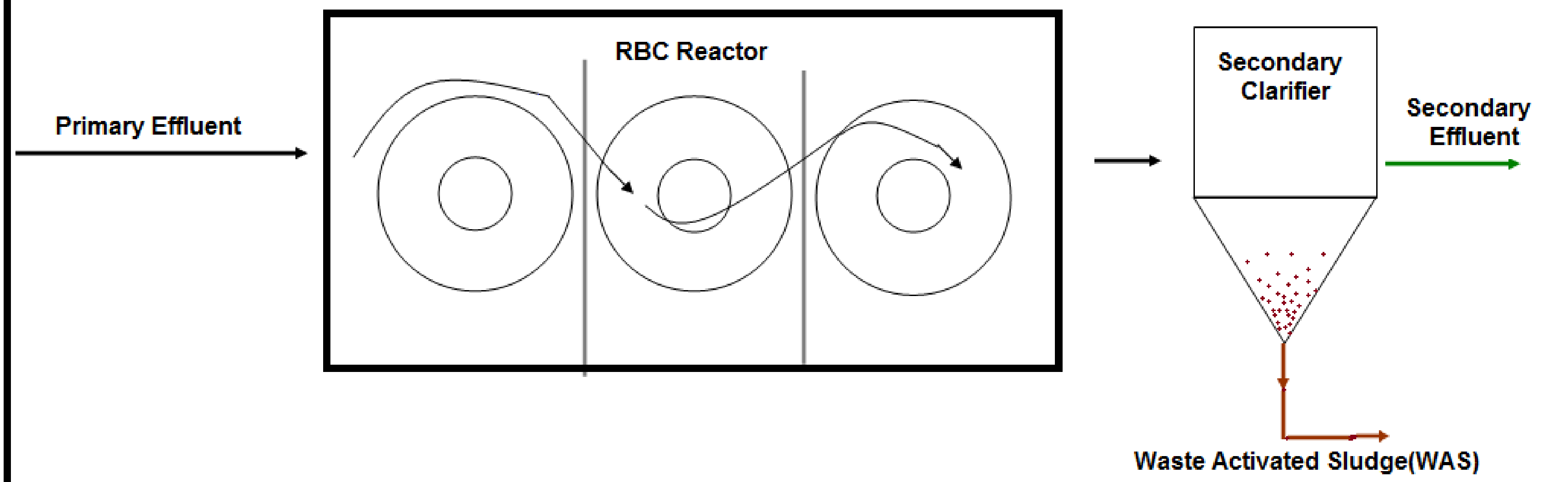
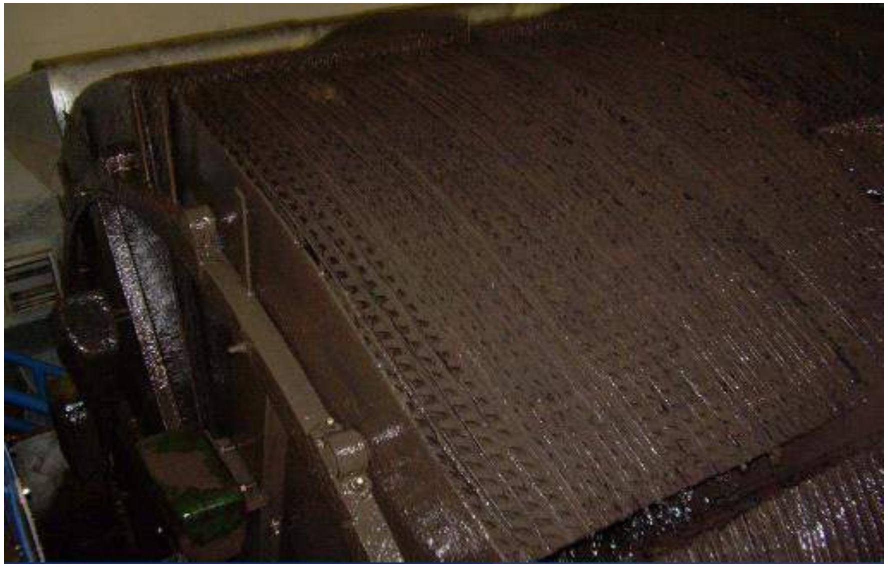
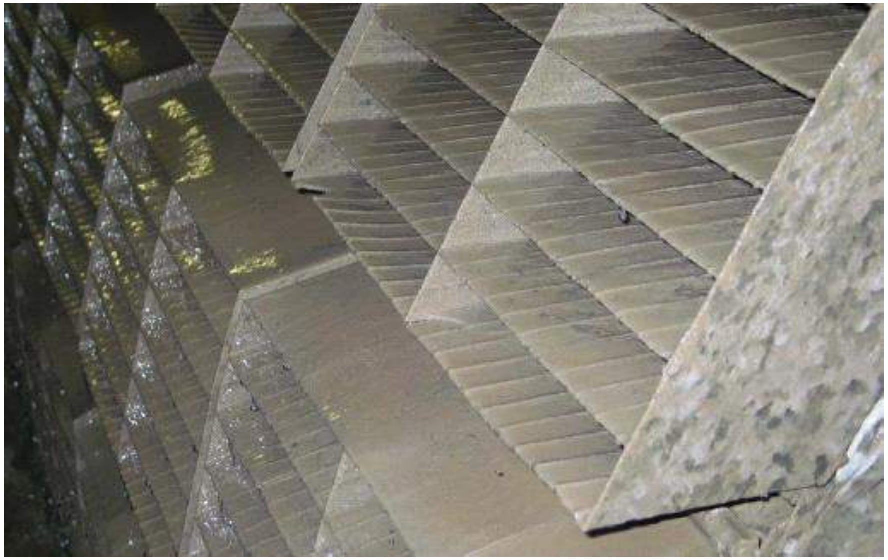


RBCs

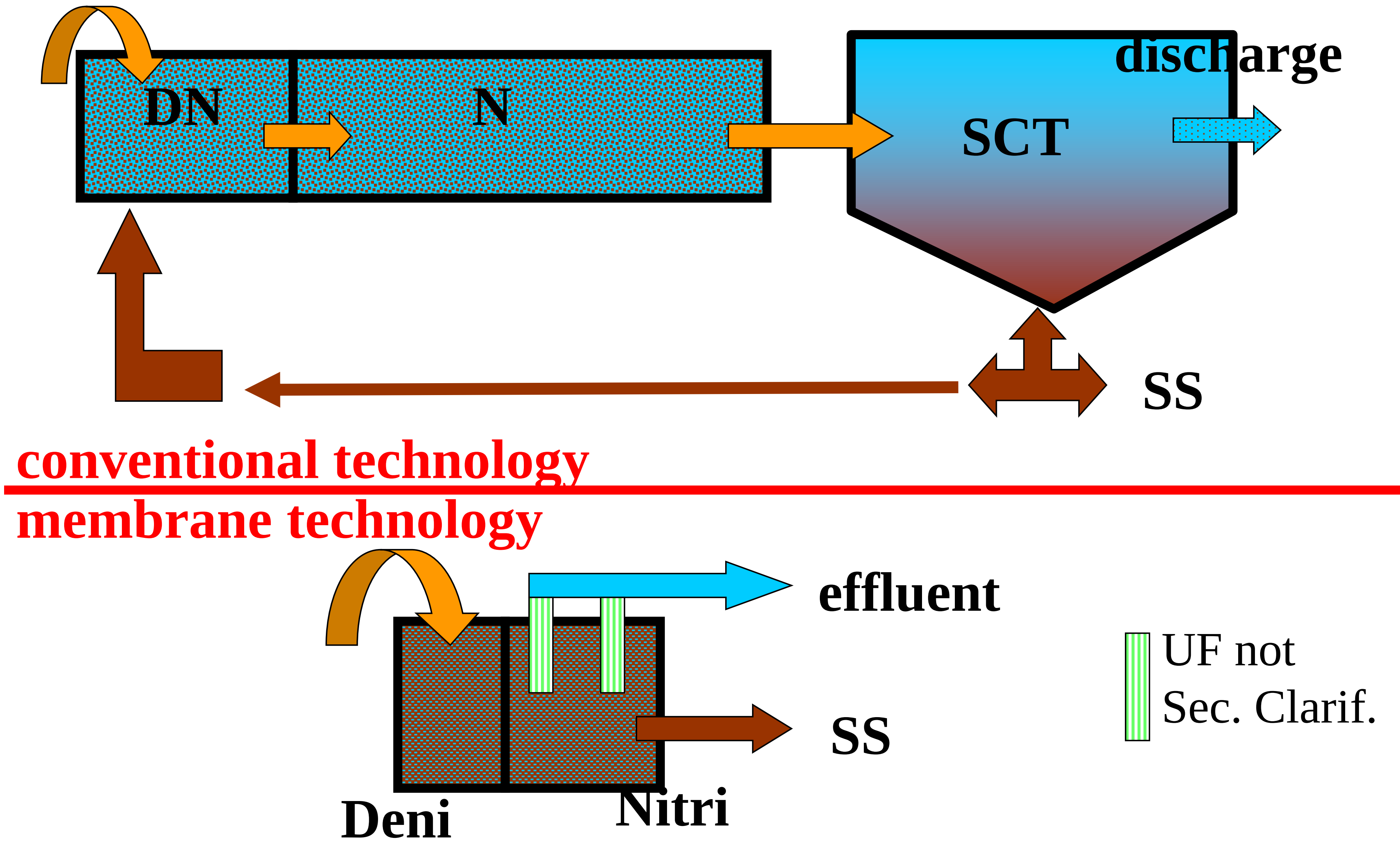




Membrane Bioreactors

- Employ biological reactor and membrane filtration as a unified system for the secondary treatment of wastewater
- Membranes perform the separation of the final effluent from the biomass through filtration
- Filtration takes place by the application of a pressure gradient

Process Basics



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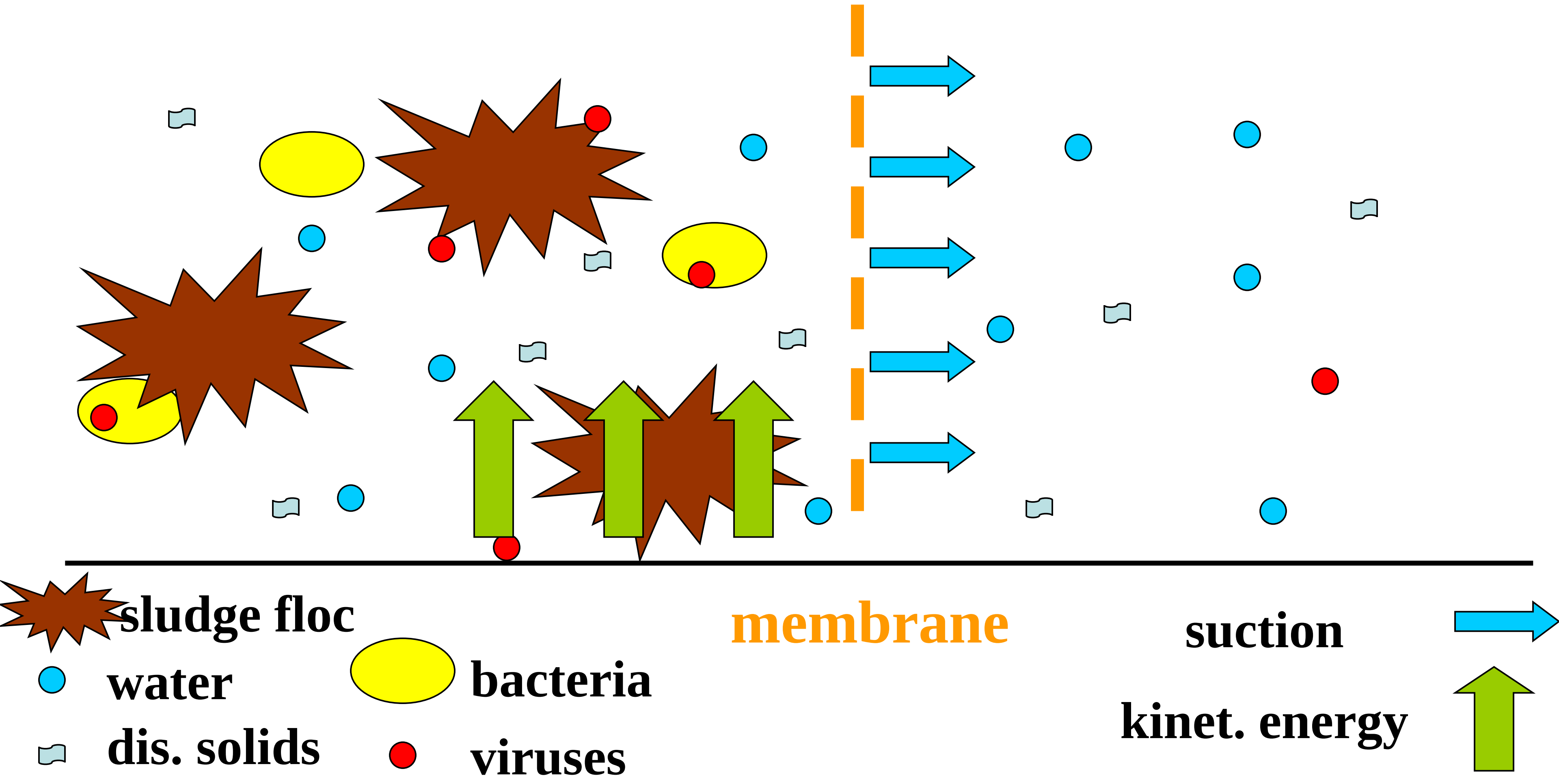
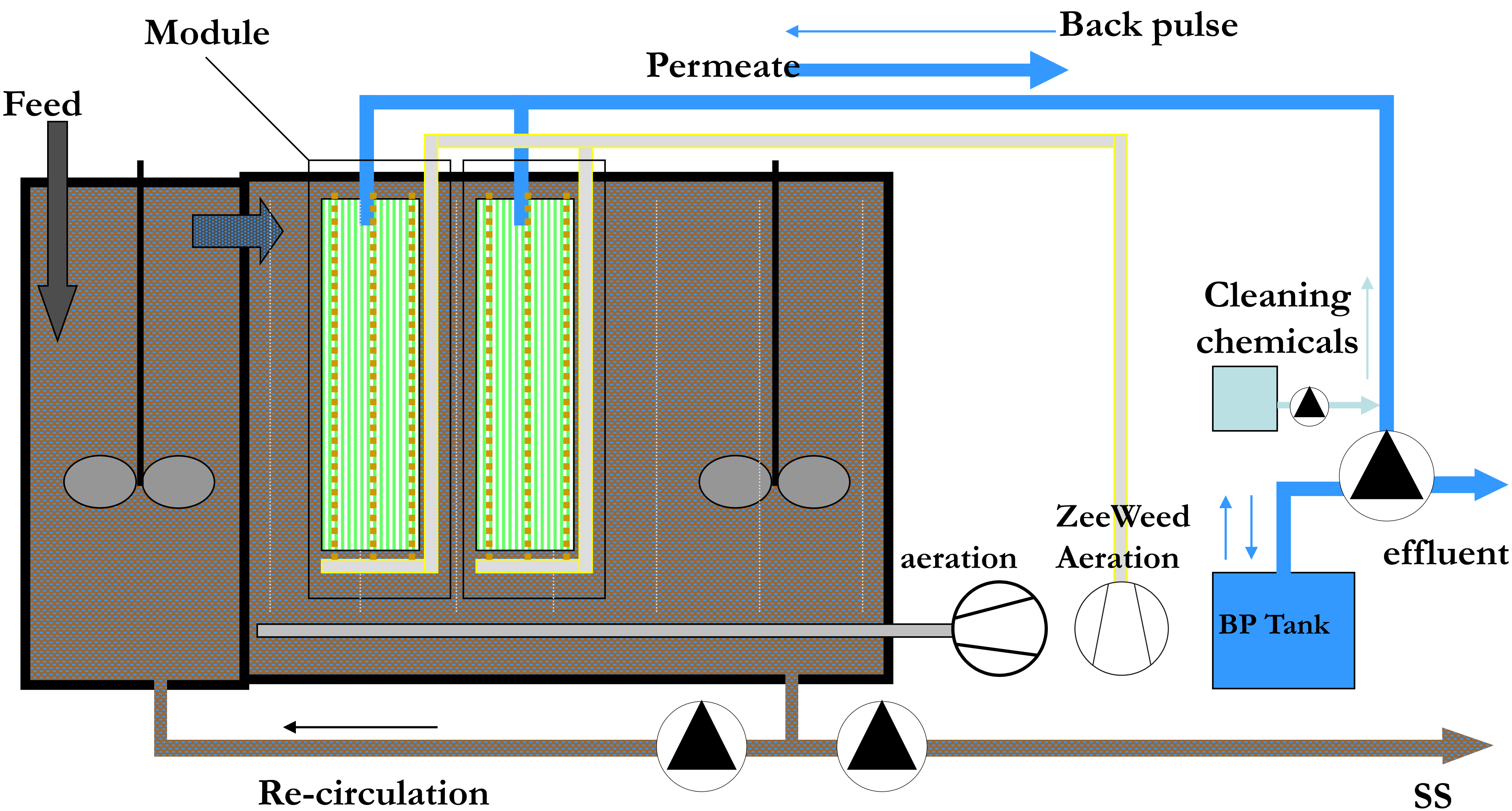
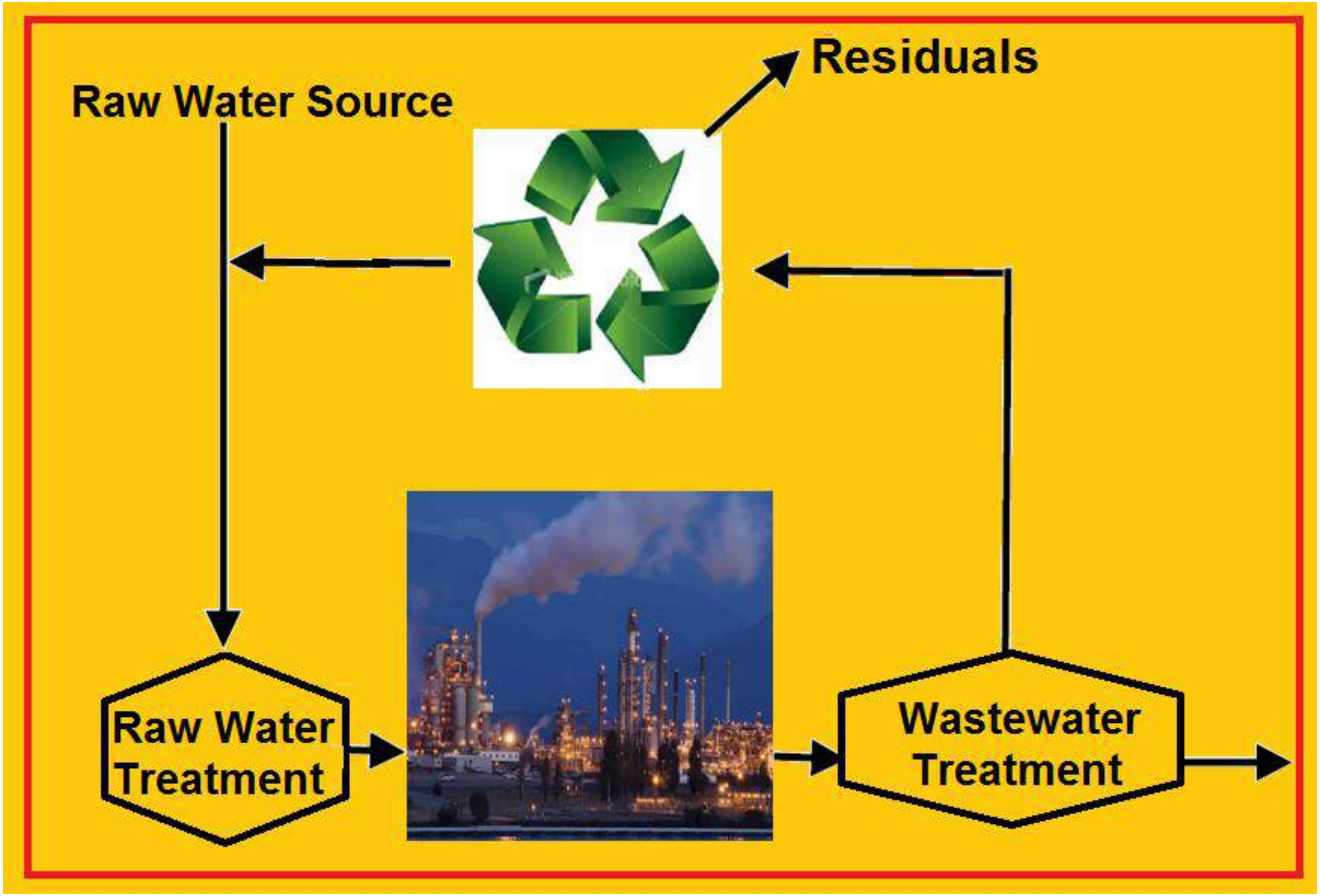


Submerged MBR System



Assessment of MBR Technology

- Advantages
  - High effluent quality
  - No sludge settling problems
  - Reduced volume requirements
- Disadvantages
  - Membrane fouling
  - Increased operational costs


Residuals
Raw Water Source
Raw Water
Treatment
Wastewater
Treatment

Wastewater reuse applications

Wastewater reuse categories	Issues/ constraints
Agricultural irrigation crop irrigation Commercial nurseries	Surface and groundwater contamination Marketability of crops and public acceptance
Landscape irrigation Parks, School yards, Freeway medians, Golf courses, Cemeteries Green belts, Residential	Effect of water quality, particularly salts, on soils and crops Public health concerns related to pathogens Use area control including buffer zone may result in high user costs
Industrial recycling and reuse Cooling water Boiler feed Processes water Heavy construction	Constituents in reclaimed water related to scaling, corrosion, biological growth, and fouling Public health concerns, particularly aerosol transmission of pathogens in cooling water Cross connection of potable and reclaimed water
Groundwater recharge Groundwater replenishment Saltwater intrusion control Subsidence control	Possible Contamination of groundwater aquifer used as a source of potable water Organic chemicals in reclaimed water and their toxicological effects Total dissolved solids, nitrates, and pathogens in reclaimed water

Wastewater reuse applications

Wastewater reuse categories	Issues/ constraints
Recreational/environmental uses Lakes and ponds Marsh enhancement Stream-flow augmentation Fisheries, Snowmaking	Health concerns related to presence of bacteria and viruses Eutrophication due to nitrogen and phosphorus in receiving water Toxicity to aquatic life
Nonpotable urban uses Fire protection Air conditioning Toilet flushing	Public health concerns about pathogens transmitted by aerosols Effect of water quality on scaling, corrosion, biological growth, and fouling Cross connection of potable and reclaimed water lines
Potable reuse Blending in water supply reservoirs Pipe-to-pipe water supply	Constituents in reclaimed water, especially trace organic chemicals and their toxicological effects Aesthetics and public acceptance Health concerns about pathogens transmission, particularly enteric viruses

Selection of Treatment Technologies

Life cycle analysis of wastewater treatment systems

- **The treatment system should be**
- **Economically viable, Environmentally Friendly, and Sustainable.**
- **Many times these factors are not being considered.**

Develop guidelines for life cycle analyses of wastewater treatment systems.

- **Pros and cons of the systems**
- **Eg: Energy consumption, Residual pollution left over, Environmental degradation, contribution to global warming etc..**

Thankyou

HOUSE PLUMBING...

PRESENTED BY :
Asst.Professor
TEJASREE VEMURI

TRAPS:

- Foul gases produced in the sewers , drains , waste-pipes may cause nuisance by entering In houses through house-connecting pipes , if there passage is not checked by some suitable devices.

- The efficiency of the traps depends on the deeper the seal more efficient will be the trap.

- The following are the requirements of a good trap:

1. It should be made of non-absorbent material.
2. It should provided sufficient depth of water seal all times(about 50mm) having large surface area.

3.It should be self-cleaning and should not obstruct the flow of sewage.

4.It should be provided with access door for cleaning.

THE WATER SEAL OF THE TRAP CAN BREAK UNDER THE FOLLOWING CONDITIONS:

1. If there is any crake in the bottom of seal or the joint is faulty.

2. If for a long time the seal or the joint is faulty.

3. If due to blockage or any other reason there is increase in the pressure of the sewer gases , it will pass through the water of seal.

4. If partial vacuum is created in the sewer fittings , it will suck up the seal water . To avoid the breakage due to this reason, the portion between the trap and the soil pipe should be connected to the vent pipe.

TYPE OF TRAPS:

1. P , Q and S-types.
2. Gully – traps.
3. An intercepting traps.
4. Anti- D trap.
5. Anti- siphon trap.

1.P , Q and S-Trap:

these traps are classified according to there shape .
they essentially consist of a u-tube which
retains water acting as a seal between the
foul gas atmosphere.

2. Gully – traps :

this trap is provided at different place in the drain pipes.
Waste water from sinks, bath etc.
enters in through back inlet and unfoul water form
the sweeping of rooms, courtyards etc.
enters from he top , where a coarser screen
grating is fitted to check the matter.

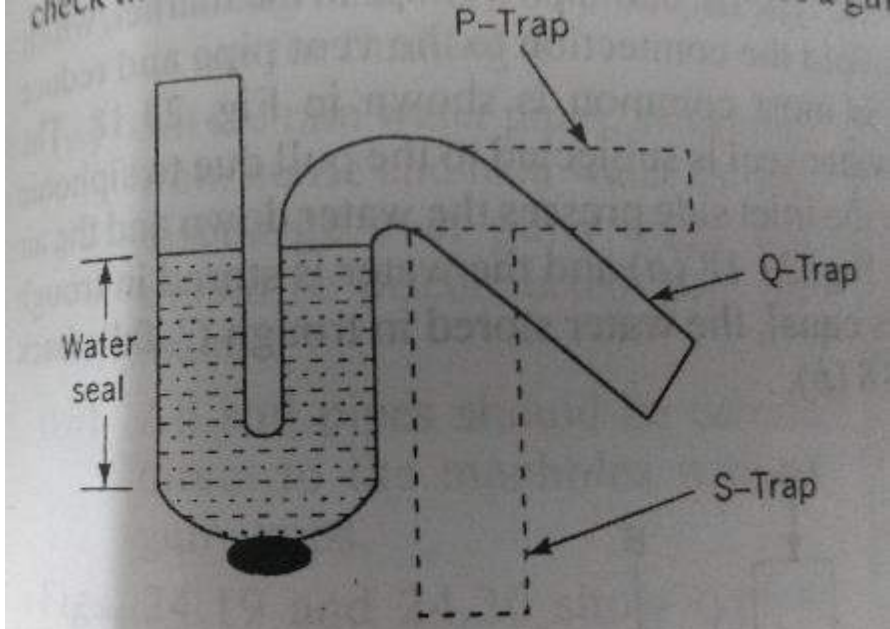


Fig. 24.14, PQ and S-Traps.

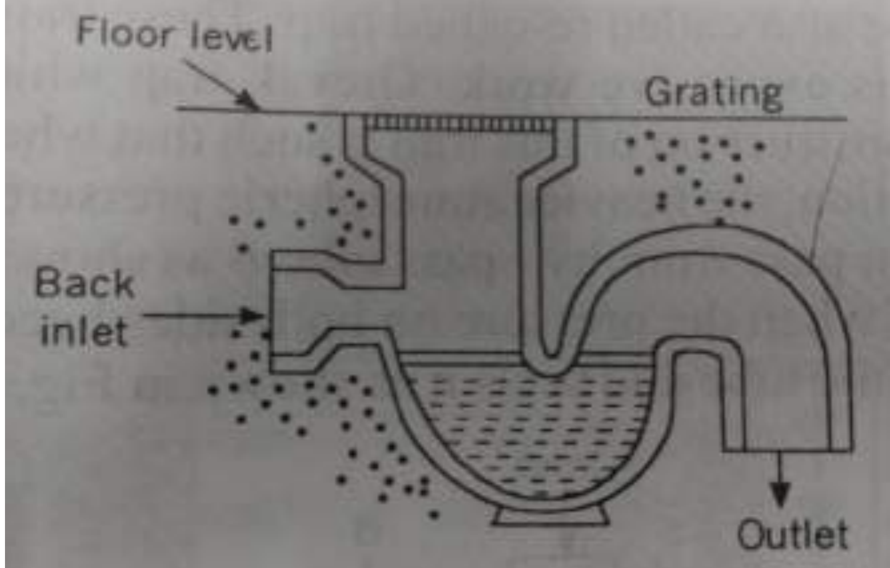


Fig. 24.15. Gully Trap.

3. An intercepting trap:

the sewage from every house goes in street sewers which carry it away from the city . the street sewers contain foul gases in it and if there passage are not checked from street sewer to the house.

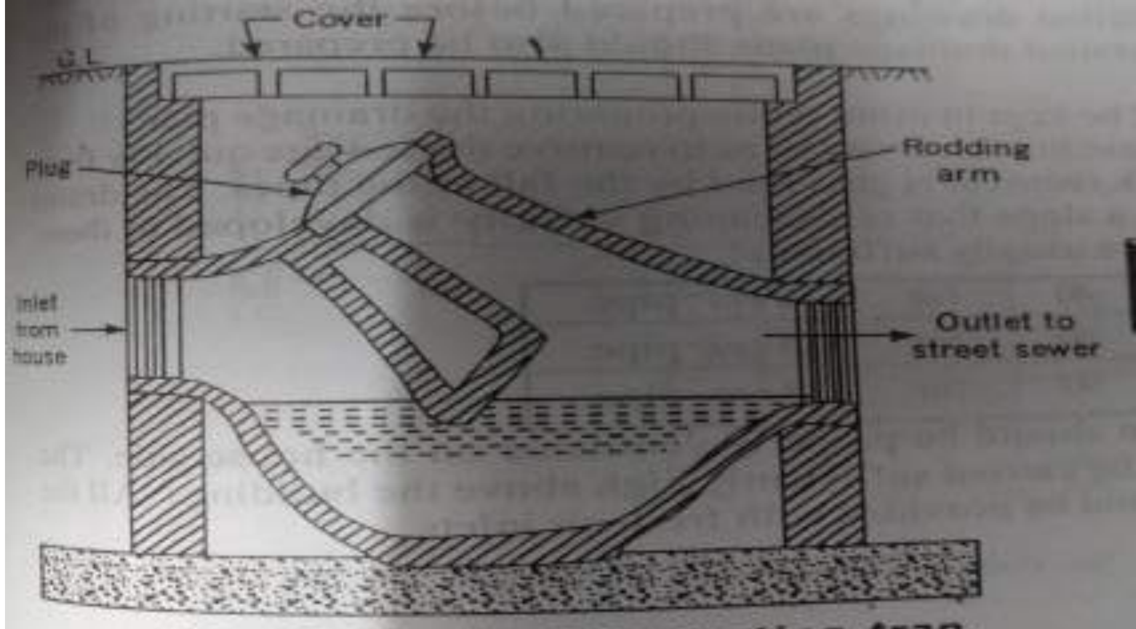


Fig. 24.16. An intercepting trap.

4. Anti-D Trap:

P , Q and S trap are largely used for baths , sinks and lavatories. In such cases, they are made with enlarged mouth so that waste pipe may be thoroughly flushed out. But in this trap full bore of trap is not interfered with by the discharge.

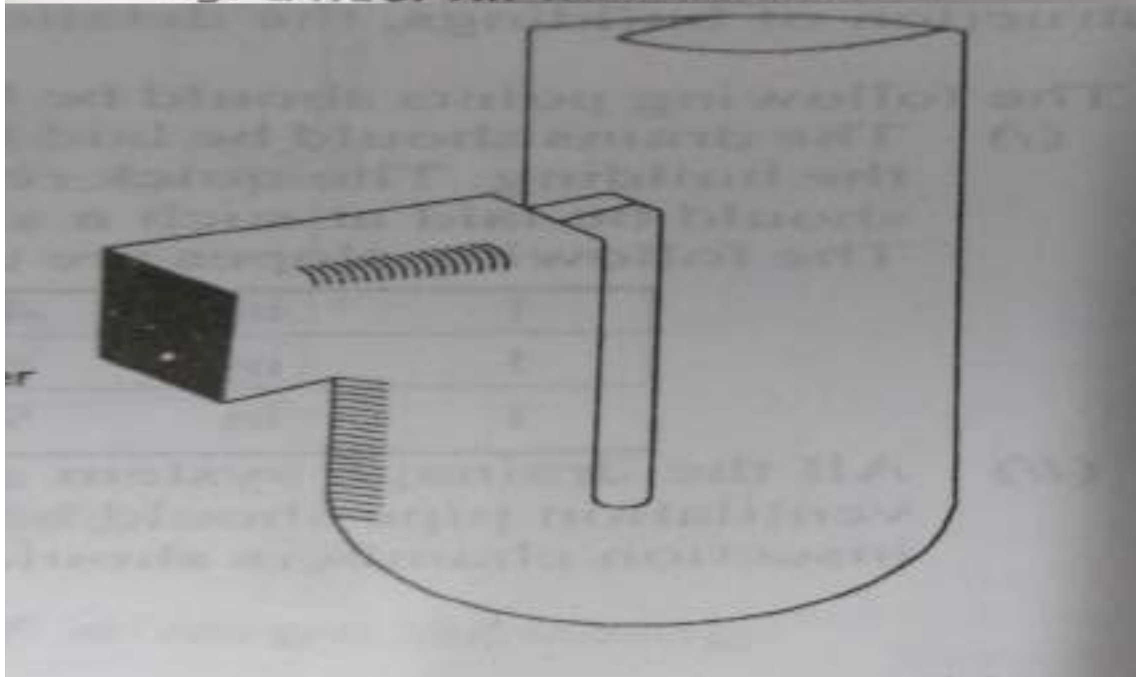


Fig. 24.17. Anti-D trap.

5. Anti- siphon trap:

* there are several types of anti- siphon traps in the market, which we call re-called traps .

* these traps are avoid the connection to the vent pipe and reduce this expensive work.

* Grevak trap which is most common.

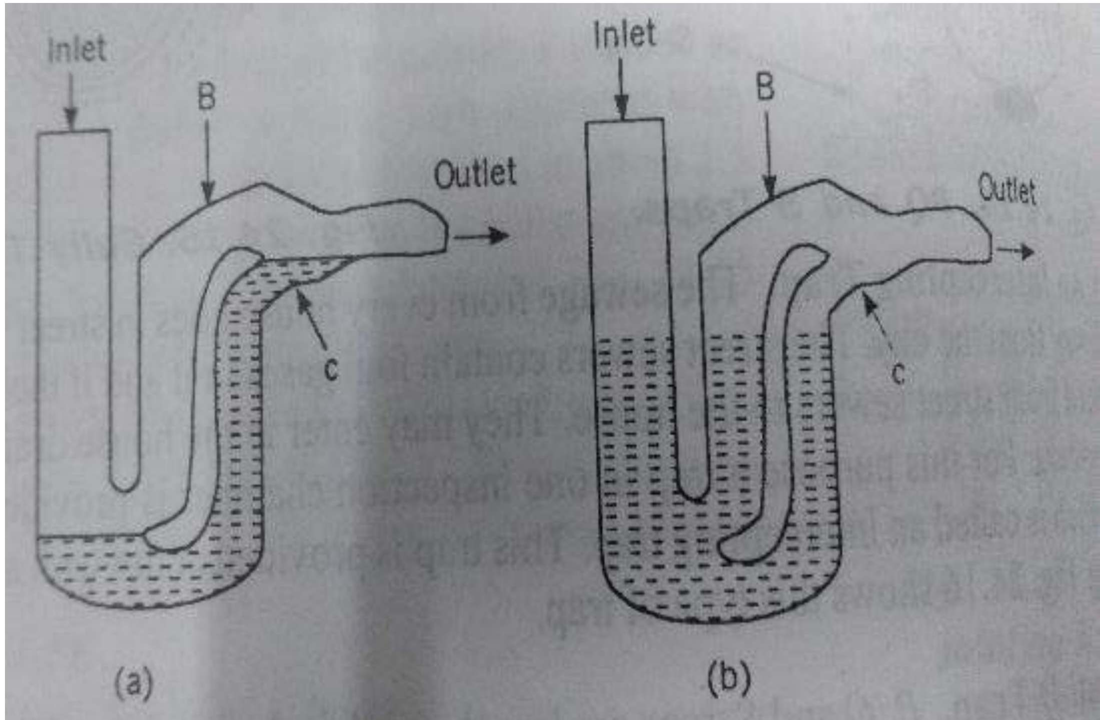


Fig. 24.18. Grevak trap.

SYSTEM OF PLAMBING :

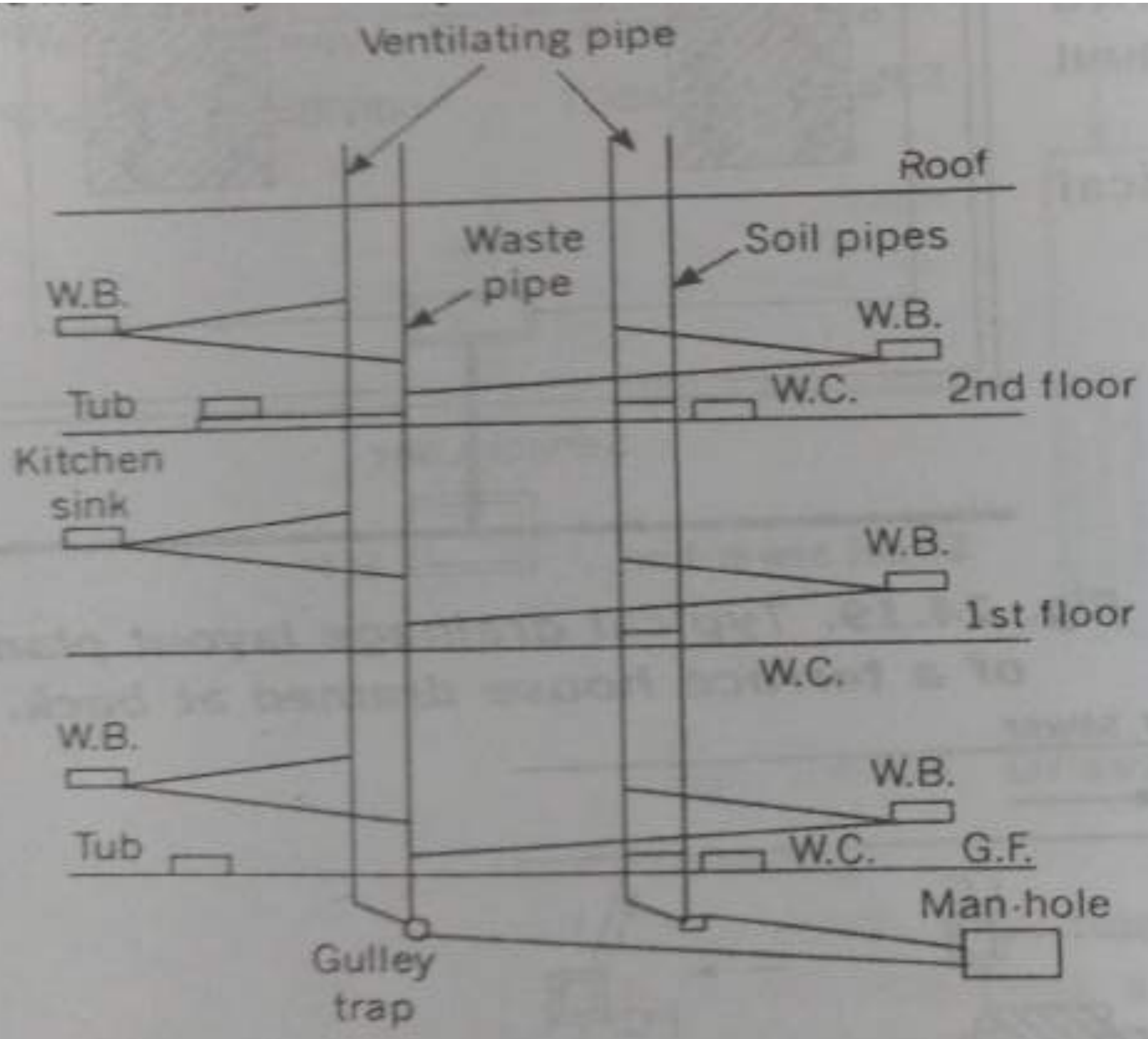


Fig. 24.21. Two-pipe system.

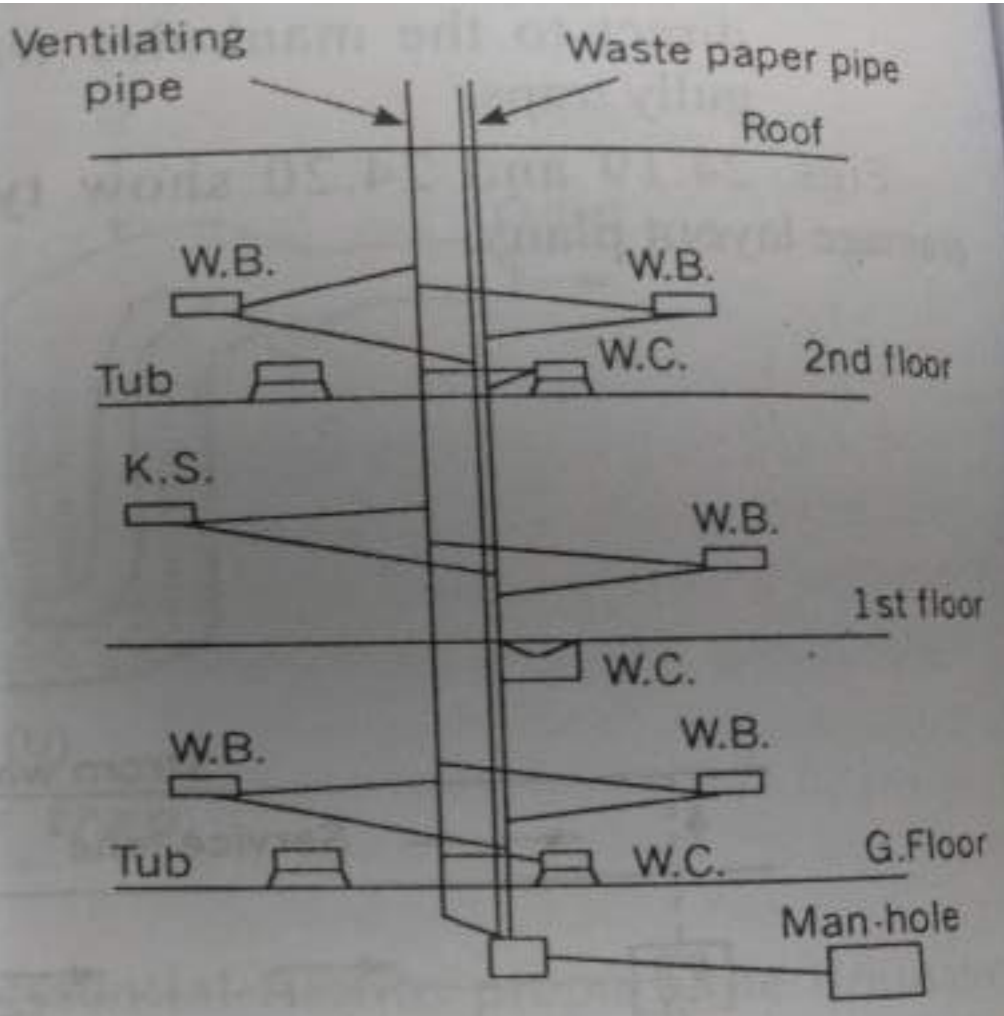
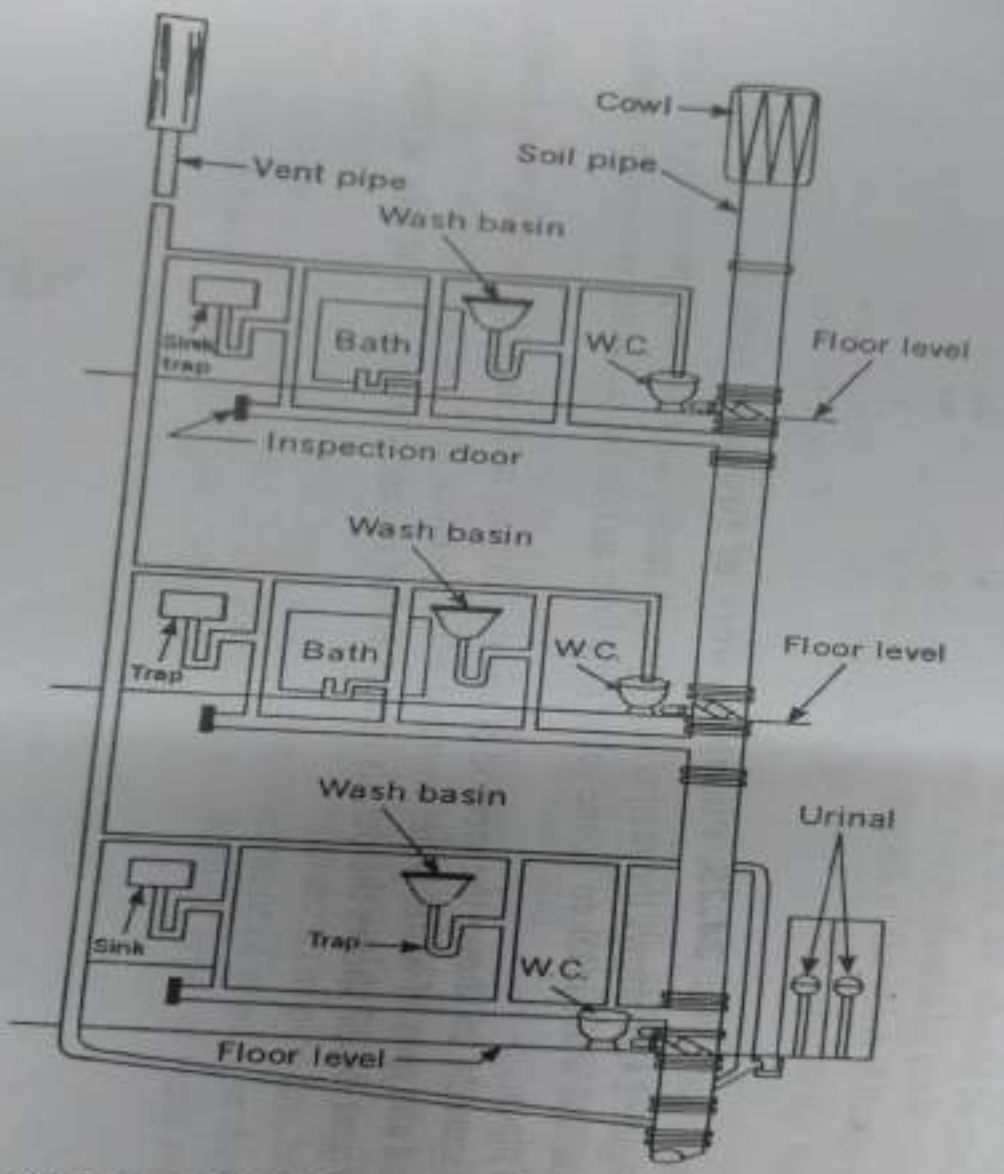
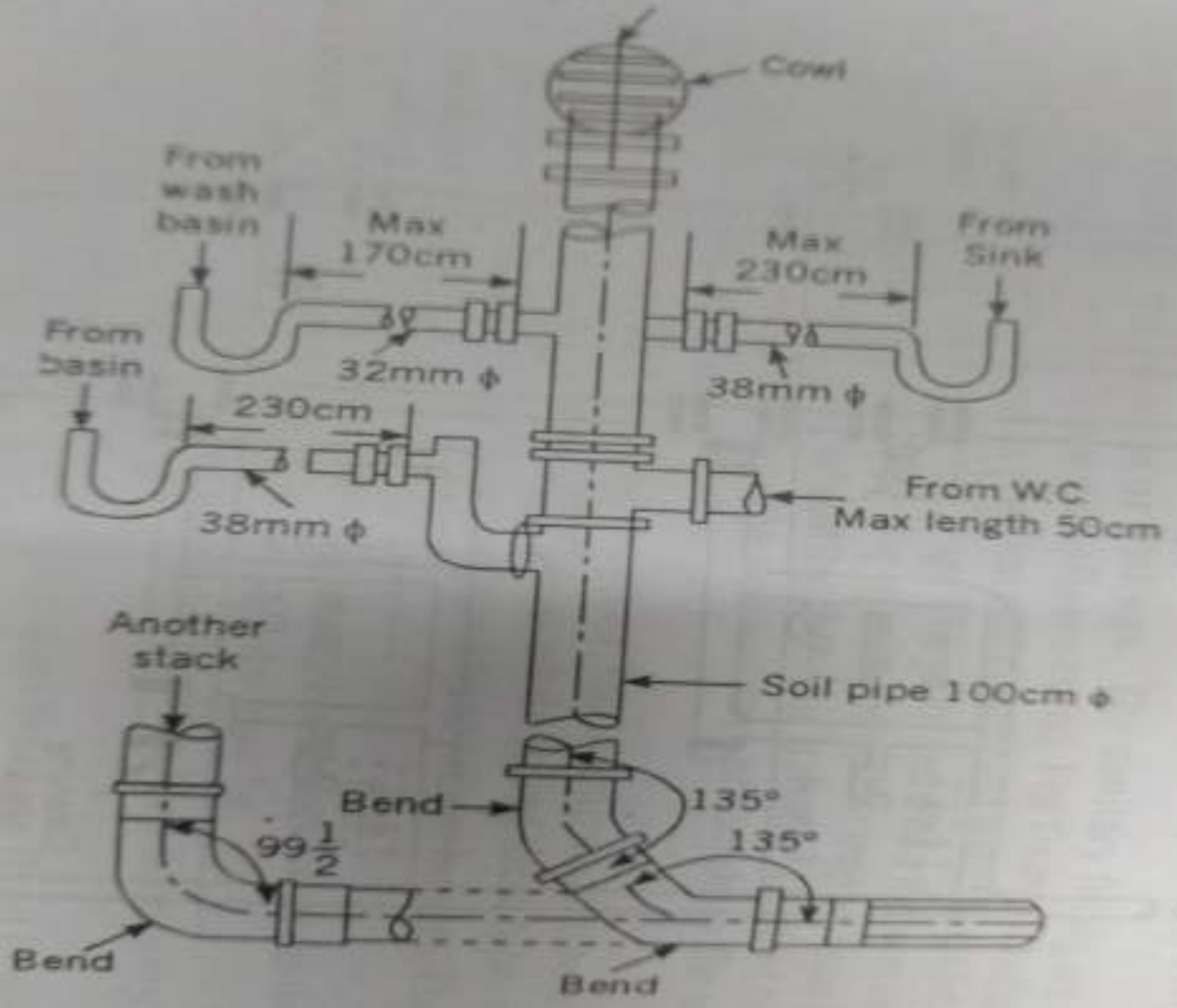


Fig. 24.22. One-pipe system.



24.26. Plumbing work of one-pipe system.



. 24.27. Details of Joints of one-pipe system.

SANITARY FITTINGS…

IN THE BUILDING THEY HAVE VARIOUS TYPE OF SANITARY FITTINGS ARE REQUIRED TO COLLECT THE WASTE WATER.

1. ABLUTION FITTING:

A. Wash basins.

B. Sinks.

C. Bath tubes.

D. Flushing cisterns.

E. Drinking fountations.

2. SOIL FITTING:

A. Water closets.

B. urinals.

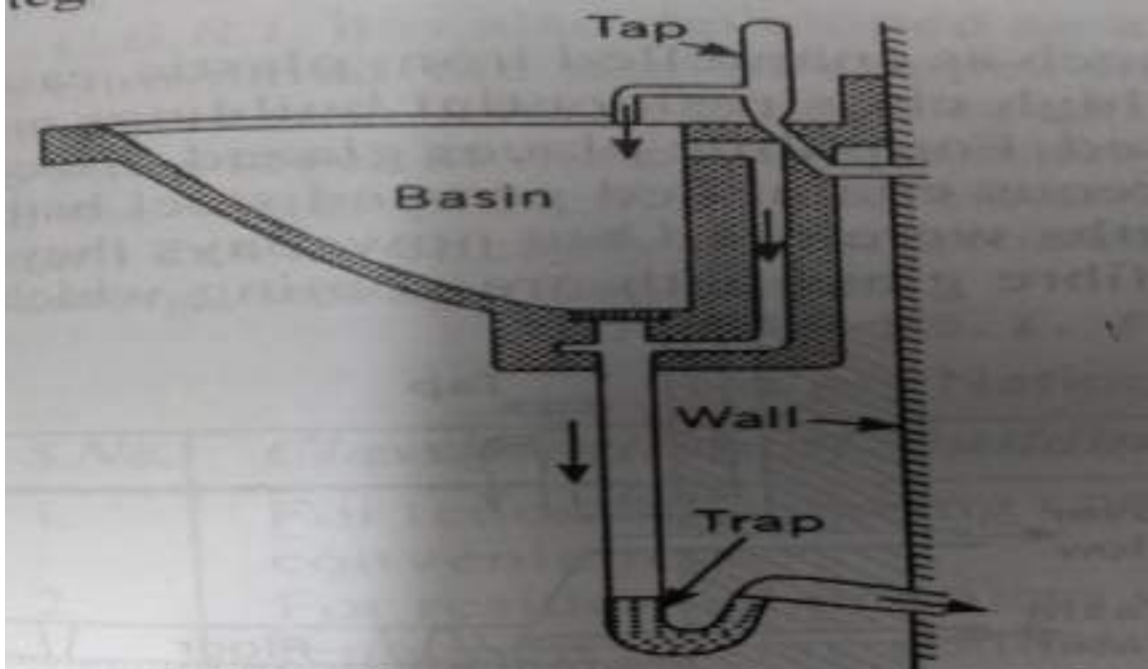
C. Slop sinks.

WASH BASIN :

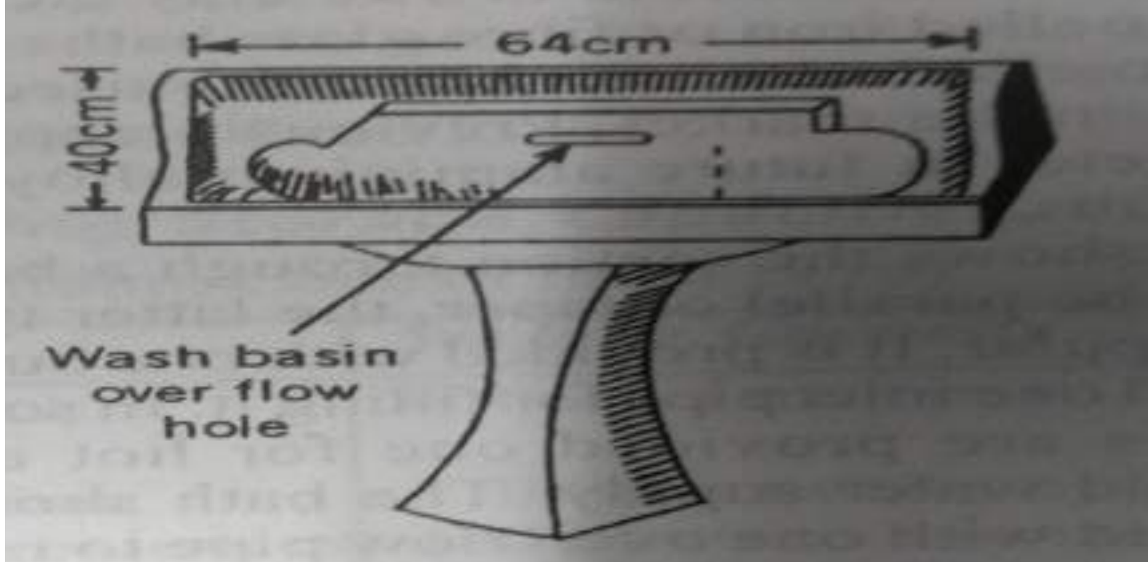
the wash basins are available in various patterns and size in market .
there are mostly two patterns:

1. Flat back for mounting on walls
   size: (630*450) and (550*400)

2. Angle back for fixing at the junction of two walls
   size: (600*480) and (400*400)



(a) Sectional view of wash basin.



(b) Isometric view of wash basin.

SINKS:

- there are rectangular shallow receptacles suitable for kitchen or laboratory.

* Kitchen sink which is mostly used.
  Its of one piece construction, provided with or without rim.

KITCHEN SINK :

(600*450*150)mm
(600*450*250)mm
(750*450*250)mm

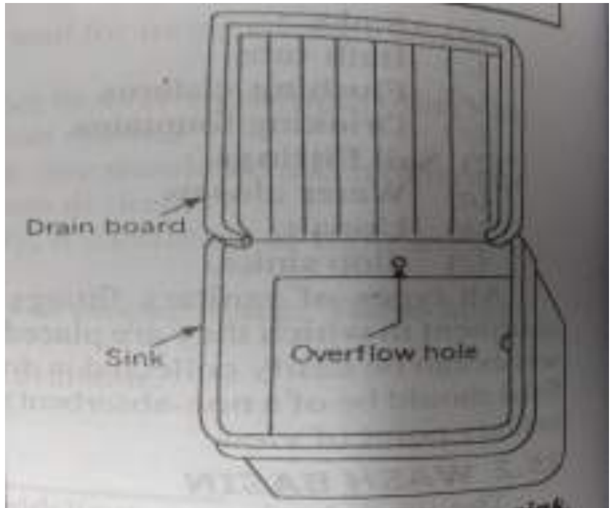


Fig. 25.2. Kitchen sink.

LABORATORY SINK :

(400*250*150)mm
(450*300*150)mm
(500*350*150)mm
(600*400*200)mm

BVATH TUB :

Bath tube may be made of various materials , such as enamelled iron , plastic , cast iron , porcelain enamelled , Marble or fire clay etc…

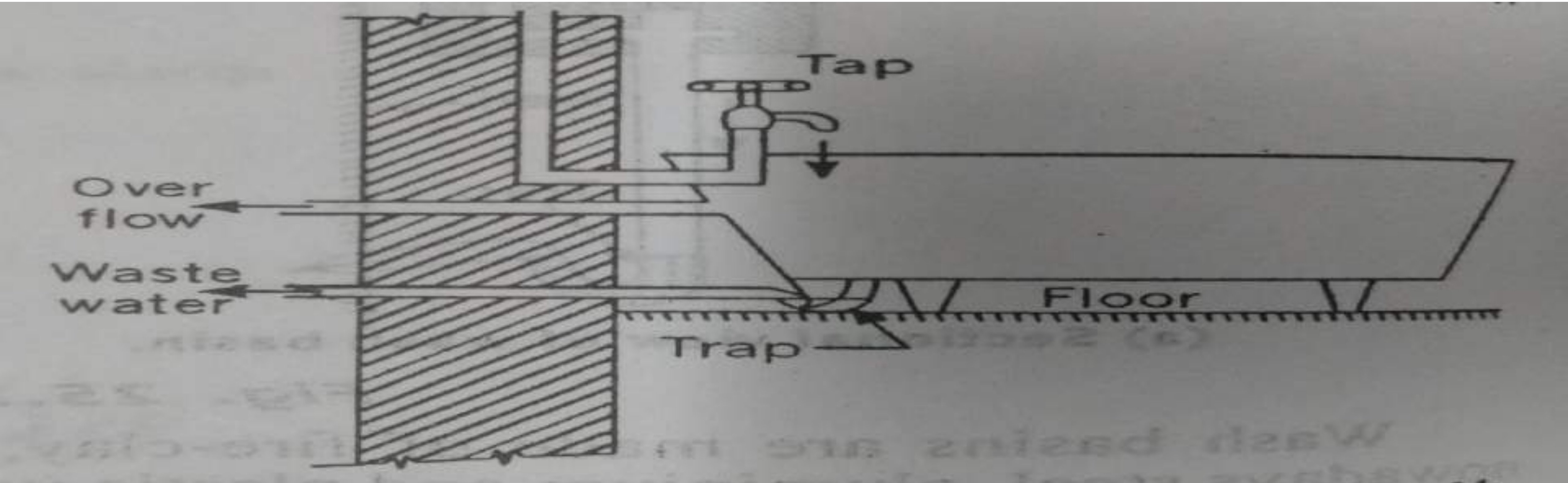


Fig. 25.3. Section through a bath.

FLUSHING CISTERNS :

- These are used for flushing water closets and urinals after use . there are several Varieties of flushing cisterns.
- high-level cisterns are interned to operate with a minimum height of 125 cm between the top of the pan and the underside of the cistern.
- low-level cisterns are intended to operate at a height not more then 30 cm between the top the pan and underside of the cistern.

TWO TYPES OF CISTERNS ARE MOST COMMON NOW A DAYS :

1.Bell type without valve.

2.Flat bottom type fitted with valve.

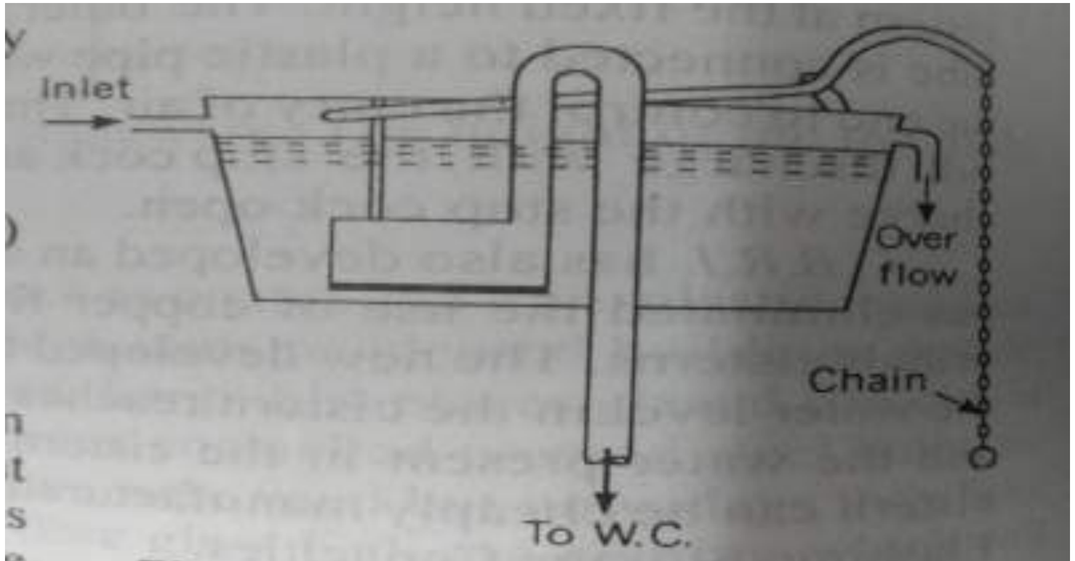


Fig. 25.5. Flat bottom type flushing cistern.

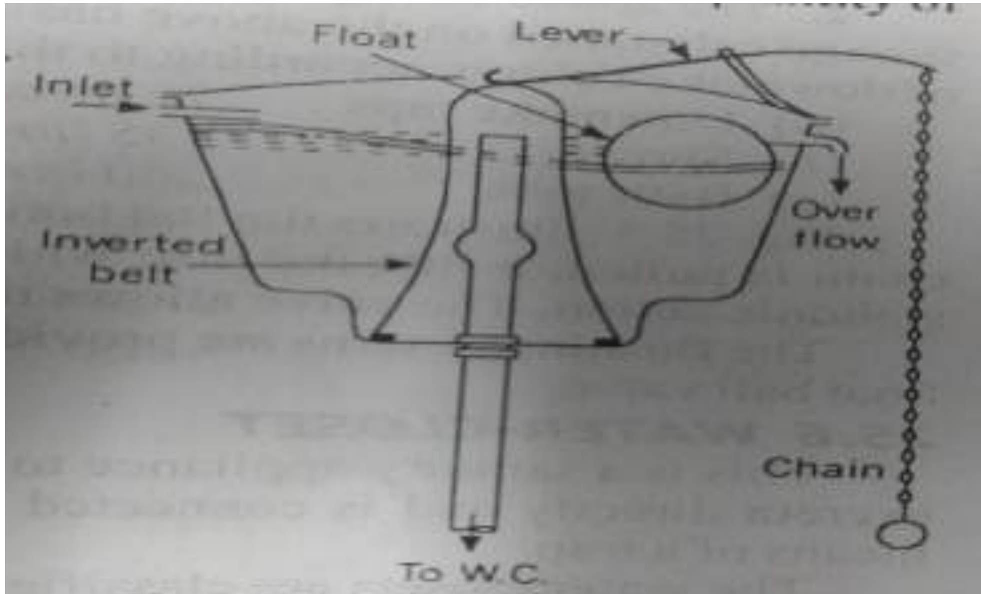


Fig. 25.4. Flushing cisterns (bell type).

URINALS :

S.N.o	PATTERN	SIZE	
1	BOWL SHAPE	(430*260)mm Min.	
2	1. Flat back , 2. Angle back.	(340*430*265)mm , *350 Min.	
3	slab	Slab:(450*1000)mm , (600*1000)	
4	Stall	Single:(1140*460*400)mm	
5	Squatting plate	(600*350)mm and (450*350)mm	

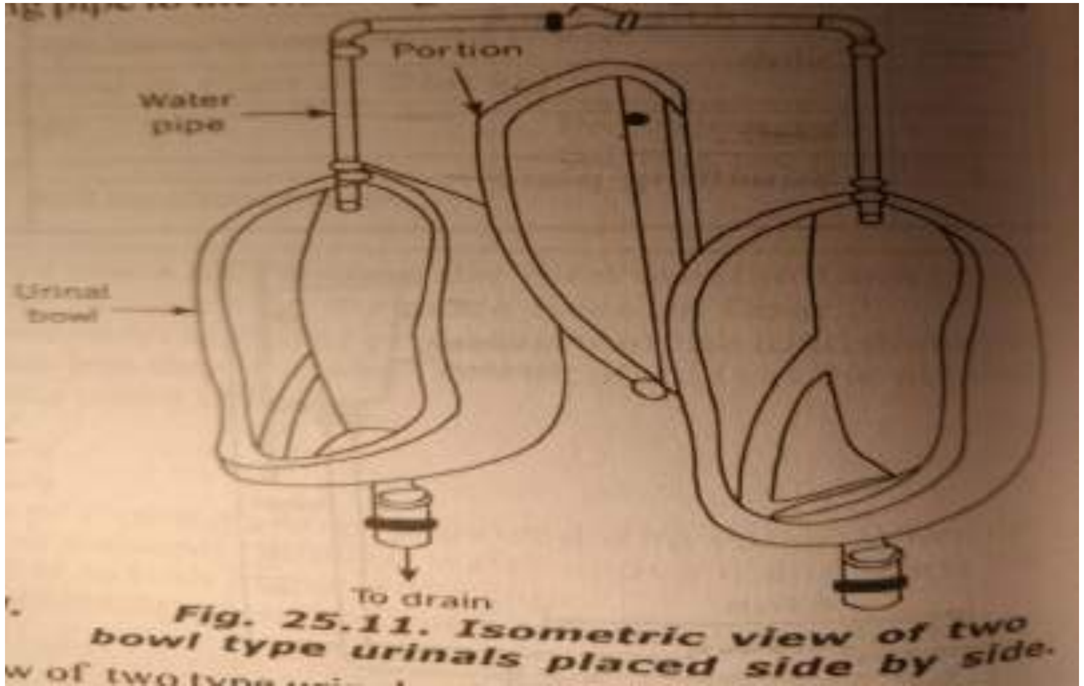


Fig. 25.11. Isometric view of two bowl type urinals placed side by side.

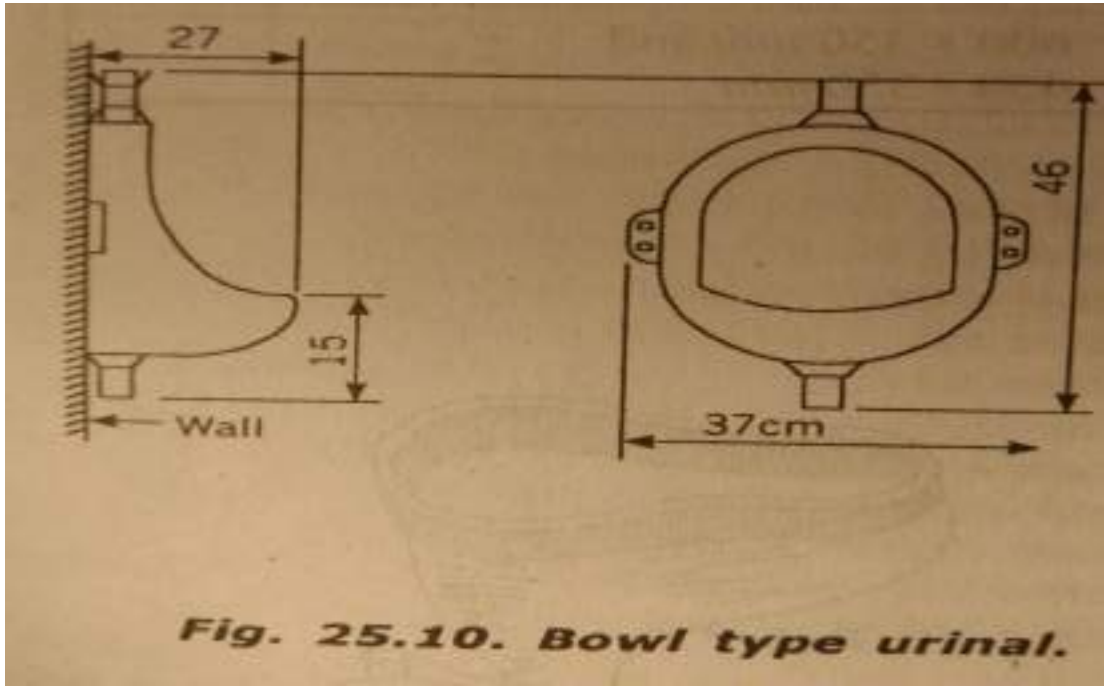


Fig. 25.10. Bowl type urinal.

WATER-CLOSET :

This is a sanitary appliance to receive the human excreta directly and is connect to soil pipe by means of a trap.

THE WATER-CLOSET ARE CLASSIFIED AS FOLLOWING :

1. SQUATTING TYPE OR INDIAN TYPE :

A. long pan pattern

(length 450,580,680 mm)

B. Orissa pattern

(length 580,630,680 mm)

C. Rural pattern (length 420 mm)

2. WASH-DOWN, PEDESTRAL OR EUROPEAN TYPE:

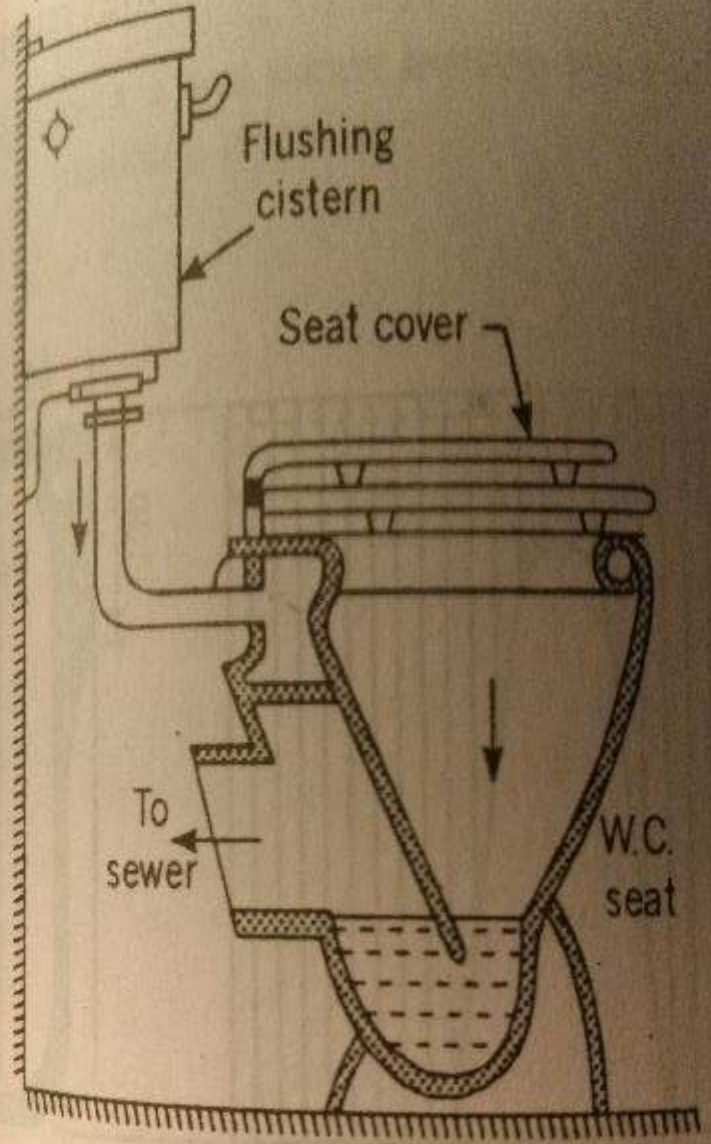


Fig. 25.7. Section through a wash down type water closet.

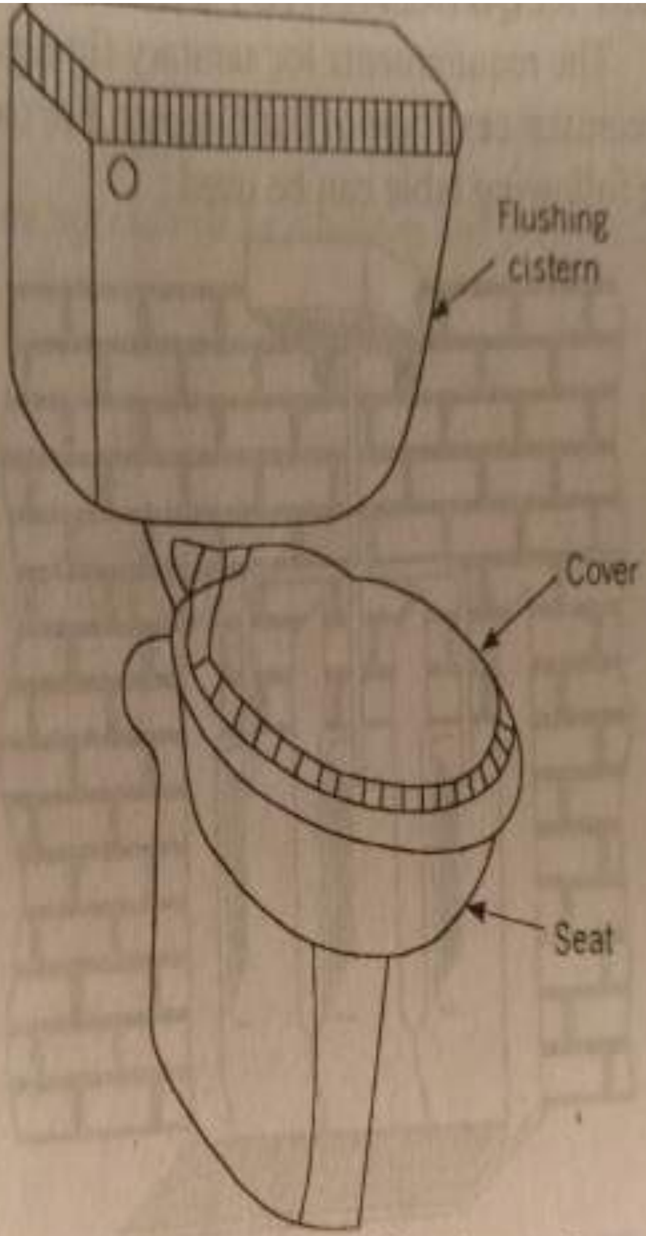


Fig. 25.9. Isometric view of an European type water closet.

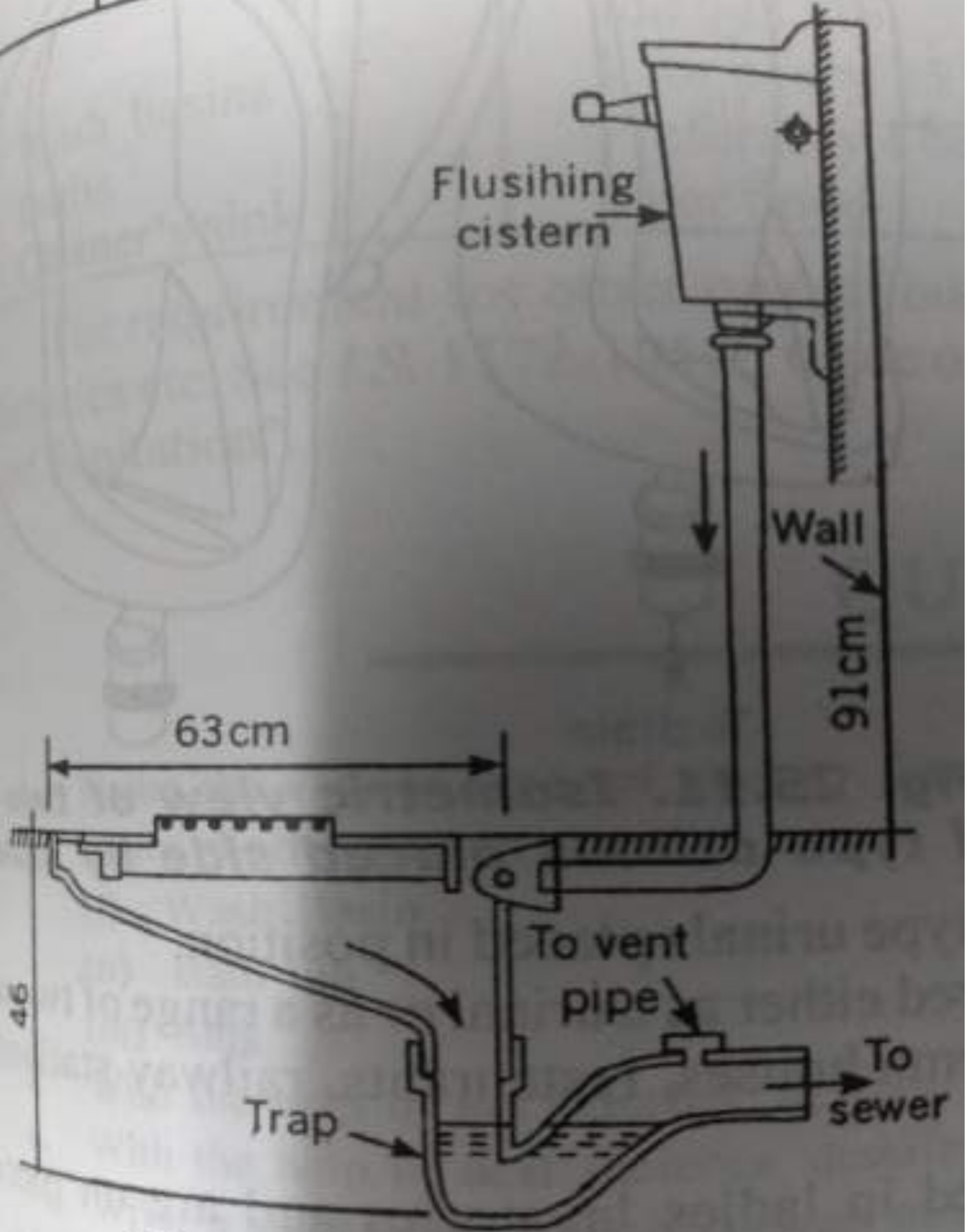


Fig. 25.6. Indian Type Water Closet.


Thank you...

Module II

Hydraulic Design of Sewer

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Course content…

Hydraulic formulae, maximum and minimum velocities in sewer, hydraulic characteristics of circular sewer in running full and partial full conditions, laying and testing of sewer, sewer appurtenances and network , Cleaning and Ventilation of Sewers.

Design of Sewers

- The hydraulic design of sewers and drains, means finding out their sections and gradients, is generally carried out on the same lines as that of the water supply pipes.

- However, there are two major differences between characteristics of flows in sewers and water supply pipes.

- The sewage contain particles in suspension, the heavier of which may settle down at the bottom of the sewers, as and when the flow velocity reduces, resulting in the clogging of sewers.
- To avoid silting of sewers, it is necessary that the sewer pipes be laid at such a gradient, as to generate self cleansing velocities at different possible discharges. The sewer pipes carry sewage as gravity conduits, and are therefore laid at a continuous gradient in the downward direction up to the outfall point, from where it will be lifted up, treated and disposed of.

Hydraulic formulae

1. Chezy's formula

$$v = C\sqrt{Ri},$$

where
V= is the mean velocity [m/s],
C= is the Chézy coefficient [$m^{½}$/s],
R= is the hydraulic radius (~ water depth) [m],
i= is the bottom slope[m/m].

- Constant (C) is very complex. Depends on size, shape and smoother roughness of the channel, the mean depth etc.
- C can be calculated by using Bazin's formula.

2. Bazin's formula

$$C = \frac{157.6}{[1.81 + (K/R^{1/2})]}$$

Where,

K= Bazin's constant

R= hydraulic radius

Sr. No.	Inside nature of the sewer	K values
1.	Very smooth	0.109
2.	Smooth: bricks & concrete	0.290
3.	Smooth: rubble masonry	0.833
4.	Good, earthen material	1.540
5.	Rough: bricks & concrete	0.500
6.	Rough earthen material	3.170

3. Manning's formula

$$V = \frac{k}{n} R_h^{2/3} \cdot S^{1/2}$$

V = velocity of flow (m/s)

k =conversion factor of 1.486 $(\text{ft/m})^{1/3}$

n =Manning coefficient

R_h = hydraulic radius (m)

S = slope of the water surface

* The value of "n" is calculated by kutter's formula

4. Kutter's formula

$$C = \frac{k_1 + \frac{k_2}{S} + \frac{k_3}{n}}{1 + \frac{n}{\sqrt{R}} \cdot \left(k_1 + \frac{k_2}{S}\right)}$$

Where

- C = Chézy's roughness coefficient
- S = Friction slope
- R = Hydraulic radius (m,)
- n = Kutter's roughness (unit less)
- k_1 =Constant (23.0 SI,)
- k_2=Constant (0.00155 SI,)
- k_3= Constant (1.0 SI,)

5. Hazen – William's formula

$$V = k\,C\,R^{0.63}\,S^{0.54}$$

where:

- V is velocity
- k is a conversion factor for the unit system k = 0.849 for SI units)
- C is a roughness coefficient
- R is the hydraulic radius
- S is the slope of the energy line (head loss per length of pipe)

6. Crimp and Burge's formula

$$V = 83.47\, R^{2/3} S^{1/2}$$

Where,

V = velocity of flow (m/s)

R = hydraulic radius (m)

S = slope of the water surface

Minimum Velocity

- The flow velocity in the sewers should be such that the suspended materials in sewage do not get silted up; i.e. the velocity should be such as to cause automatic self-cleansing effect.
- The generation of such a minimum *self cleansing velocity* in the sewer, at least once a day, is important, because if certain deposition takes place and is not removed, it will obstruct free flow, causing further deposition and finally leading to the complete blocking of the sewer.

Self clearing velocity

- To calculate minimum velocity of flow following formula is used.

$$V = \sqrt{(8k/f)\ (es - e)/e\ g.ds}$$

where,

V= minimum velocity of flow in m/s.

k= size of solids in sewage varying between 0.06mm

f= Darcy's coefficient of friction (normally 0.03)

es= specific gravity of solid material flowing in sewage, varies between 1.2 to 2.65

e= specific gravity of liquid in sewage (generally 1)

g= gravitational acceleration cont.

ds= dia of solid particles in mm

Maximum Velocity

- The smooth interior surface of a sewer pipe gets scoured due to continuous abrasion caused by the suspended solids present in sewage.

- It is, therefore, necessary to limit the maximum velocity in the sewer pipe. This limiting or non-scouring velocity will mainly depend upon the material of the sewer.

Effects of Flow Variation on Velocity in a Sewer

- Due to variation in discharge, the depth of flow varies, and hence the hydraulic mean depth (r) varies.
- Due to the change in the hydraulic mean depth, the flow velocity gets affected from time to time.
- It is necessary to check the sewer for maintaining a minimum velocity of about 0.45 m/s at the time of minimum flow (assumed to be 1/3rd of average flow).

- The designer should also ensure that a velocity of 0.9 m/s is developed at least at the time of maximum flow and preferably during the average flow periods also.

- Moreover, care should be taken to see that at the time of maximum flow, the velocity generated does not exceed the scouring value.

(3) Bazin's formula : $C = \dfrac{157.6}{1.81 + \dfrac{K}{\sqrt{R}}}$ 8.3

K = Basin's constant

(4) Manning's formula : $V = \dfrac{1}{N} R^{2/3} S^{1/2}$ 8.4

(5) Crimp and Burge's formula : $V = 83.47\, R^{2/3} S^{1/2}$ 8.5

(6) Hazen - William formula : $V = 0.85\, C\, R^{0.63}\, S^{0.54}$ 8.6

Hydraulic Elements of Circular Sewers :

(1) **Circular section running full :**

Here Area of C / S, $A = \frac{\pi}{4}(D^2)$, D = dia of sewer

Wetted Perimeter $P = \pi D$

$$\therefore R = \frac{A}{P} = \frac{\frac{\pi}{4}(D^2)}{\pi D} = \frac{D}{4}$$

(2) **Circular section running partially full (Refer fig. 8.6),**

Let a = area of cross - section

b = wetted perimeter

r = H.M.D. (Hydraulic Mean Depth)

v = velocity of flow

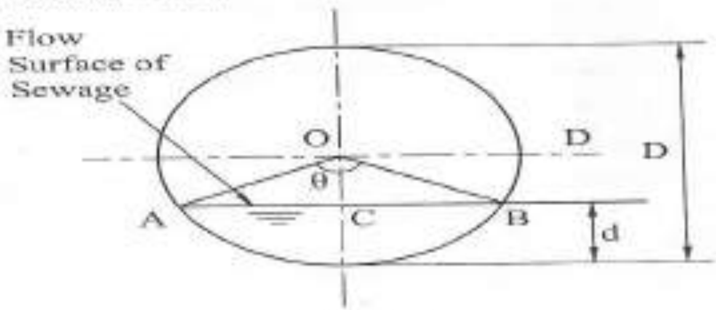


Fig. 8.6

Central angle is given by $\cos \frac{1}{2}\theta = 1 - \frac{2d}{D}$

(1) Depth $d = \frac{D}{2} - \frac{D}{2}\cos\frac{\theta}{2} = \frac{D}{2}(1 - \cos\theta/2)$ 8.7

Proportional depth $\frac{d}{D} = \frac{1}{2}(1 - \cos\theta/2)$ 8.8

(2) **Area** $a = \frac{\pi}{4} D^2 \times \frac{\theta}{360^\circ} - \frac{D}{2}\cos\frac{\theta}{2} \cdot \frac{D}{2}\sin\frac{\theta}{2}$ 8.9

$a = \frac{\pi}{4} D^2 \left[\frac{\theta}{360^\circ} - \frac{\sin\theta}{2\pi}\right]$ ...8.10

$\therefore$ Proportional Area $= \frac{a}{A}\left[\frac{\theta}{360^\circ} - \frac{\sin\theta}{2\pi}\right]$ ...8.11

(3) **Wetted perimeter :**

$P = \pi D \cdot \frac{\theta}{360^\circ}$ 8.12

$\therefore$ Proportional wetted perimeter :

$\frac{p}{P} = \frac{\theta}{360^\circ}$ 8.13

(4) **H.M.D. :**

$$r = \frac{a}{p} = \frac{\frac{\pi D^2}{4}\left[\frac{\theta}{360^\circ} - \frac{\sin\theta}{2\pi}\right]}{\pi D \frac{\theta}{360^\circ}}$$

$\therefore \quad r = \frac{D}{4}\left[1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right]$ ...8.14

$$\text{Proportionate HMD} = \frac{r}{R} = \frac{\frac{D}{4}\left[1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right]}{\frac{D}{4}}$$

$= \left[1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right]$ 8.15

(5) **Velocity of flow :**

$v = \frac{1}{n} r^{2/3} S^{1/2}$ (Manning's) 8.16

where = Manning's rougosity coefficient applicable for partial flow condition

$\therefore$ Proportional velocity, $\frac{v}{V} = \frac{N}{n}\left(\frac{r}{R}\right)^{2/3}$ ...8.17

If $\frac{N}{n} = 1$, $\frac{v}{V} = \left(\frac{r}{R}\right)^{2/3} = \left[1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right]$ 8.18

Table 8.1								
Hydraulic Elements of circular sewer Running Partially full								
d/D	a/A	p/p	r/R	For N/n = 1.0		N/n	For Variation N/n	
				v/V	q/Q		v/V	q/Q
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	1	1	1	1	1	1	1	1
0.9	0.949	0.795	1.192	1.124	1.61	0.94	1.057	1.002
0.8	0.858	0.705	1.217	1.14	0.988	0.88	1.003	0.869
0.7	0.748	0.631	1.185	1.12	0.838	0.85	0.952	0.712
0.6	0.626	0.564	1.11	1.072	0.671	0.83	0.89	0.557
0.5	0.5	0.5	1	1	0.5	0.81	0.81	0.405
0.4	0.373	0.436	0.857	0.902	0.337	0.79	0.713	0.266
0.3	0.252	0.369	0.684	0.776	0.196	0.78	0.605	0.153
0.2	0.143	0.295	0.482	0.625	0.088	0.79	0.486	0.07
0.1	0.052	0.205	0.254	0.401	0.021	0.82	0.329	0.017
0	0				0			

(6) Discharge :

$q = a \times v$ Taking $\frac{N}{n} = 1.0$, we get

$$\text{Proportional discharge} = \frac{q}{Q} = \frac{a.v}{AV} = \frac{a}{A} \times \left(\frac{r}{R}\right)^{2/3} \quad ...8.19$$

$$\therefore \frac{q}{Q} = \left[\frac{\theta}{360^\circ} - \frac{\sin\theta}{2\pi}\right]\left[1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right]$$

$$= \frac{\theta}{360^\circ}\left[1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right]^{5/3} \quad ...8.20$$

For variable value of $\frac{N}{n}$, we get

$$\frac{q}{Q} = \frac{N}{n}\left(\frac{a}{A}\right)\left(\frac{r}{R}\right)^{2/3}$$

Practice problems

Problem – 8.1 : Calulate the velocity of flow and corresponding discharge in a sewer of circular section having diameter = 1.2 m, laid at a gradient 1 in 400. The sewer runs at 0.7 depth. Use Manning's formula taking $N = 0.018$

Problem – 8.2 : Determine the size of a circular sewer for a discharge of 450 lit/s running half full Assume $s = 1/4500$ and $N = 0.016$.

Laying of Sewer

- The basics of laying a residential sewer is lateral in the ground.
- You will need a starting elevation and an ending elevation.
- After the trench is excavated, when entering an open trench, the pipe layer prepares the trench bottom by removing loose dirt and grading the trench bottom to allow for proper flow of sewage within the pipe.

- You need to ensure that the material beneath the pipe is solid so that the pipe does not "sag" after it is backfilled.

- Typically if the "original" ground beneath the new pipe is not disturbed and graded properly, the pipe will be adequately supported.

- If the original ground is over excavated, however, you will need to install compacted sand or gravel bedding beneath the pipe in order to support it.

- Once the ground is prepared, you lay the pipe on the prepared soil.

- In most cases, you should start on the low end of the run and work your way up to the connecting point.

- If you use "hub" pipe, that is, pipe with an integral pipe built into the pipe, you should lay your first pipe beginning on the low end of the run with the hub on the uphill side of the pipe.

- If you are using PVC pipe, both ends of the pipe should be primed with purple primer prior to laying it.
- To connect the two ends of the pipe, you apply glue to the male and to the female ends of the pipe, being careful to not allow dirt to stick to the glued ends of the pipe.
- Insert the male end into the female end and spin the pipe.
- Hold the two pipes in place for ten seconds to ensure that they do not come apart.

- Once the pipes are connected, you are ready to "bed" the pipe.
- This means that you should place sand or gravel around and over the pipe - enough to just cover the top of the pipe.
- Once this is complete, you compact the granular material around the pipe.
- It is important to pay attention to this compaction process so that the pipe does not lift while you are compacting.

- Once the bedding process is complete, you are ready to move on the next pipe.
- It is important to note that as you install more pipe, you should be backfilling the trench behind you up to a safe level.

Testing of sewer

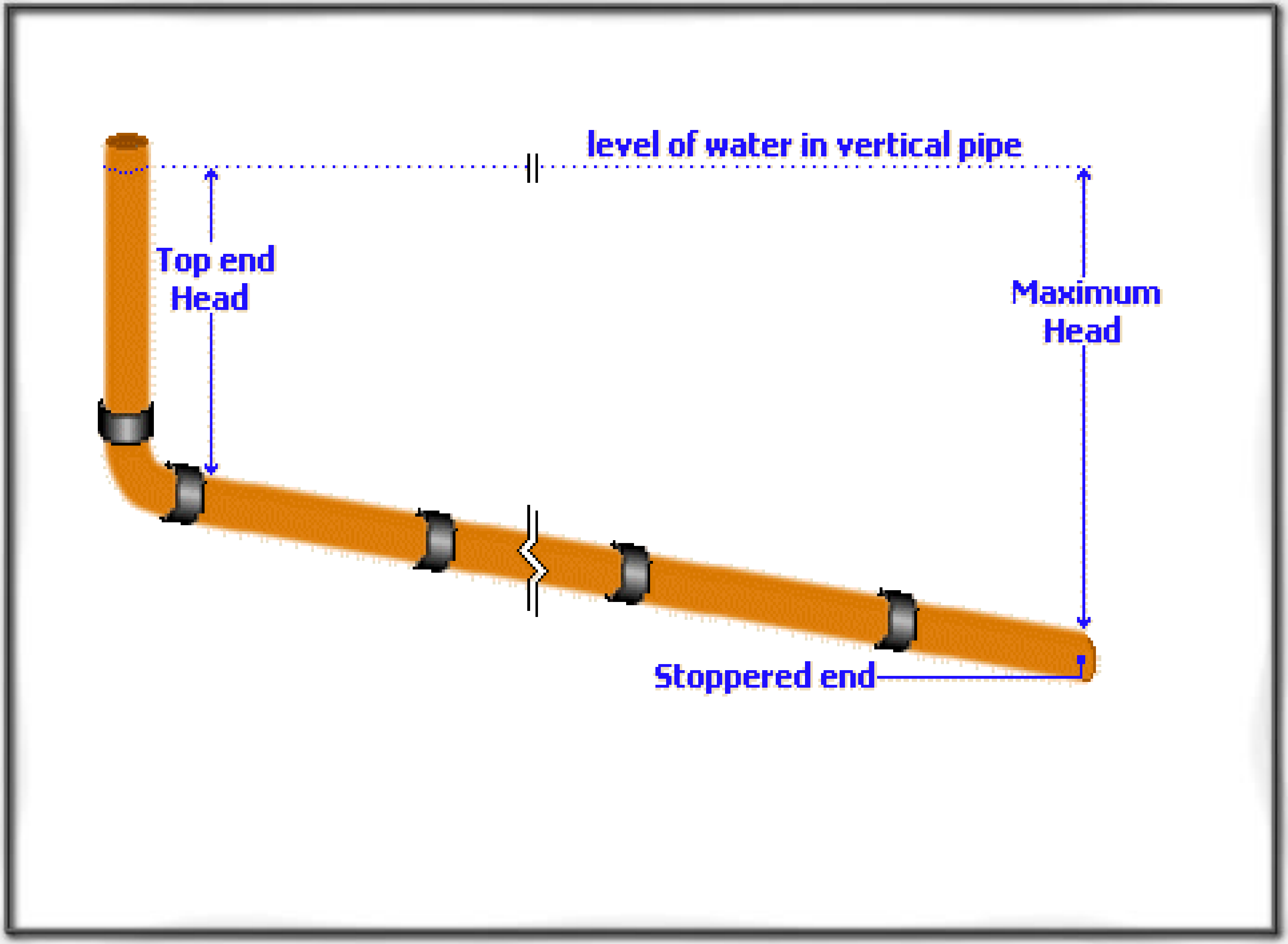
- The testing of sewers is necessary as any leakage, improper joints, straightness or obstruction of sewers may occur during laying of sewers.
- These defects may be removed or repaired after detection.
- So there are various tests by which these defects may be detected. These tests are :-

- Water Test.
- Air Test.
- Smoke Test.
- Test For Obstruction.

Water Test

- This test is carried out for sewer lines between two manholes.
- Plugging is done by rubber plug at its lower end.
- Rubber plug is connected with air blown.
- The upper end of sewer is plugged with a connection to the funnel.
- The sewer is filled with water and to maintain the required head, water level in the funnel is kept 2 m above the upper end.

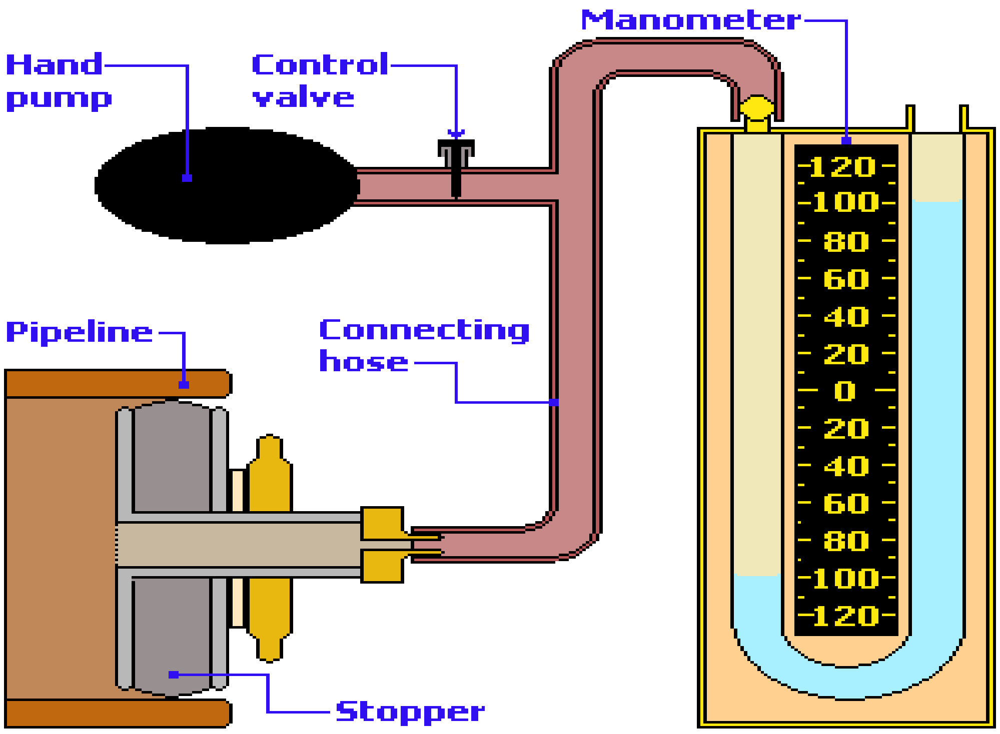
- This head varies with the material of sewer.
- In case of cast iron sewer, the head should be at 9m.
- The acceptable loss or head loss should not exceed 2 litres/cm of length of the sewer.
- To perform this test sufficient amount of water should be available.


level of water in vertical pipe
Top end Head
Maximum Head
Stoppered end

Acceptable water loss	
Pipe Dia [mm]	Max loss per metre in 30 mins [litres]
100	0.05
150	0.08
225	0.11
300	0.15
400	0.20
450	0.23
500	0.25
600	0.30
750	0.38
>750	seek advice

Air Test

❖ When sufficient amount of water is not available, then air test is to be carried out.



- Air is pumped into the pipeline, usually via a hand-pump with a control valve, until the reading on the manometer is around 125-150mm.
- The set-up is then left for 5-10 minutes to allow for temperature stabilisation within the pipe before the pressure is reduced to exactly 100mm on the manometer scale.
- The manometer is then monitored for a period of 5 minutes; the level of water in the manometer should not fall below the 75mm mark during this period.

- This is deemed to be a 'pass' and the pipeline is declared satisfactory and can be backfilled.
- However, if the level in the manometer does fall below the 75mm mark, then the equipment should be checked and cleaned and the pipeline examined for leaks or defects.
- If any problems are identified, they should be rectified before re-testing.

Smoke Test

- The purpose of smoke testing is to find potential points of inflow and infiltration in the sanitary sewer system that could lead to high flows during a storm.

- Smoke testing forces smoke-filled air through a sanitary sewer line.

- The smoke under pressure will fill the main line plus any connections and then follow the path of any leak to the ground surface, quickly revealing the source of the problem.
- Only enough force to overcome atmospheric pressure is required.

Test For Obstruction

- For straightness or obstruction of pipe, this test can be used. There are many methods for obstruction or straightness :

  1. To check the obstruction of sewer pipe, a ball of suitable diameter is rolled down from upstream side. The diameter of ball should be less then the diameter sewer. If there is no obstruction, the ball can be taken out at downstream side.

2. The straightness can also be checked by placing a lamp at one end and a mirror at the other end.

If the full circle of light is visible at other end, then the sewer is straight and there is no obstruction.

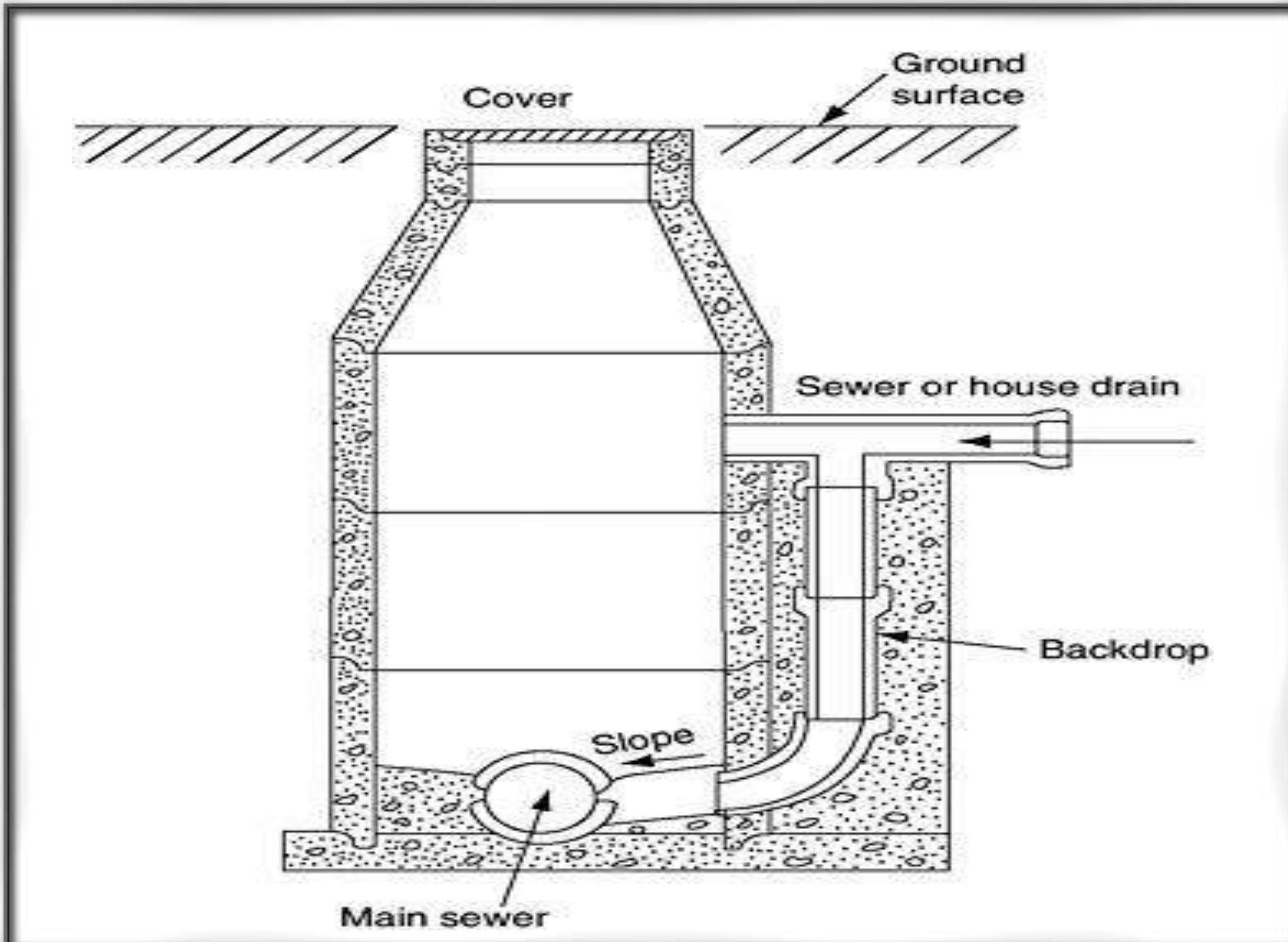
If there is any obstruction within the sewer line, it can also be traced out.

Sewer Appurtenances

- Sewer appurtenances are the various accessories on the sewerage system and are necessary for the efficient operation of the system.

- They include man holes, lamp holes, street inlets, catch basins, inverted siphons, and so on.

- **Man-holes**: Man holes are the openings of either circular or rectangular in shape constructed on the alignment of a sewer line to enable a person to enter the sewer for inspection, cleaning and flushing.
- They serve as ventilators for sewers, by the provisions of perforated man-hole covers.
- Also they facilitate the laying of sewer lines in convenient length.
- Man-holes are provided at all junctions of two or more sewers, whenever diameter of sewer changes, whenever direction of sewer line changes and when sewers of different elevations join together.



Ground surface
Cover
Sewer or house drain
Backdrop
Slope
Main sewer

HELLHOLE

H/L: How many more lives will cost $1.25? Please call 010-62357575 to report manhole cover theft so we can put an end to this.

Challenge: In 2006, 47 people were reported dead and over 10,000 injured across China as a result of stolen manhole covers. Every day, an average of 12 covers go missing from the city streets of Shanghai. 24,000 were reported stolen in Beijing alone in 2004. And for what? A single stolen manhole cover can be sold for no more than 10rmb, or $1.25. Yet that one missing cover creates an unmarked "death trap" for the many people walking or riding on city streets every day.

Solution: 10 manholes around Beijing were marked with handicapped icons and roadblock cones were set up to attract attention. Written in bold Chinese characters was a statistic on the number of people injured every year as a result of missing manhole covers and a hotline number to call for reporting the crime.

Result: According to the Beijing Municipal Administration Commission, the day after the launch they received more than 190 calls from concerned citizens in the morning alone. The reported missing manhole covers were replaced or recovered within 48 hours.

Beijing Municipal Administration Commission

Special Man-holes

- Junction chambers: Man-hole constructed at the intersection of two large sewers.

- Drop man-hole: When the difference in elevation of the invert levels of the incoming and outgoing sewers of the man-hole is more than 60 cm, the interception is made by dropping the incoming sewer vertically outside and then it is jointed to the man-hole chamber.

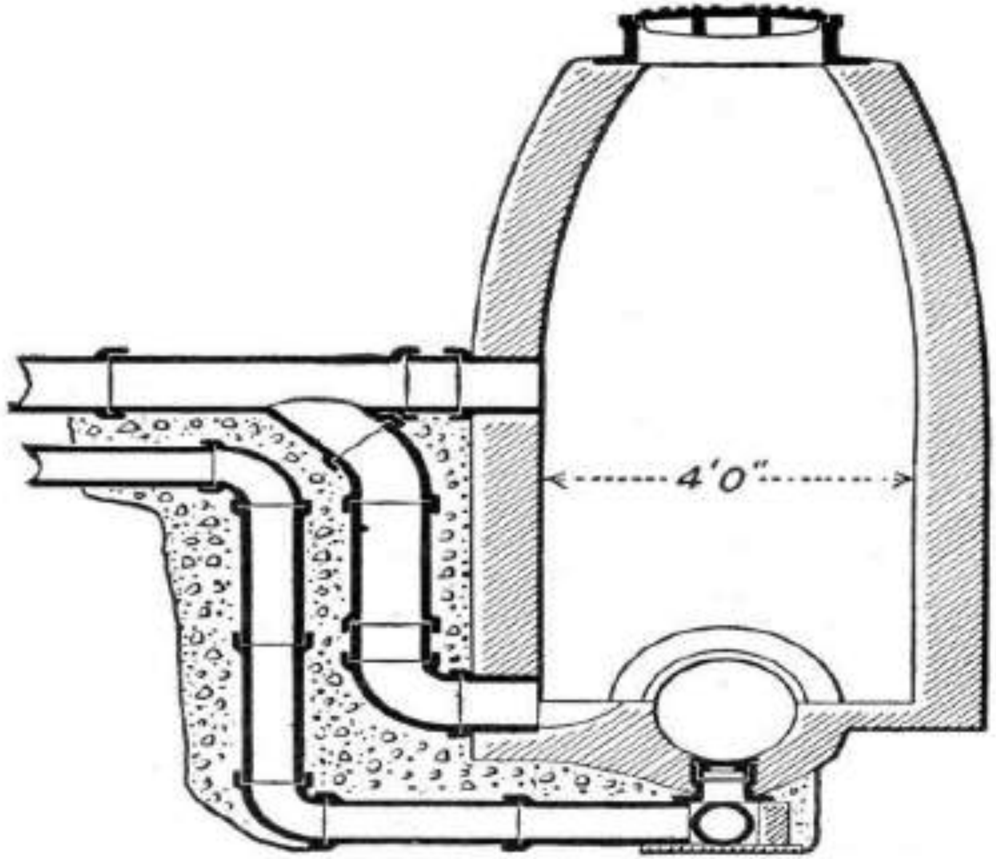
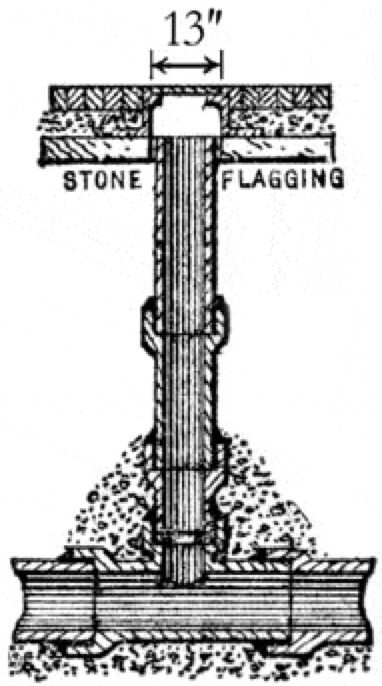


FIG. 219.—Double drop manhole, Medford, Mass.

- **Flushing man-holes**: They are located at the head of a sewer to flush out the deposits in the sewer with water.

- **Lamp-holes**: Lamp holes are the openings constructed on the straight sewer lines between two man-holes which are far apart and permit the insertion of a lamp into the sewer to find out obstructions if any inside the sewers from the next man-hole.

Flushing man-hole



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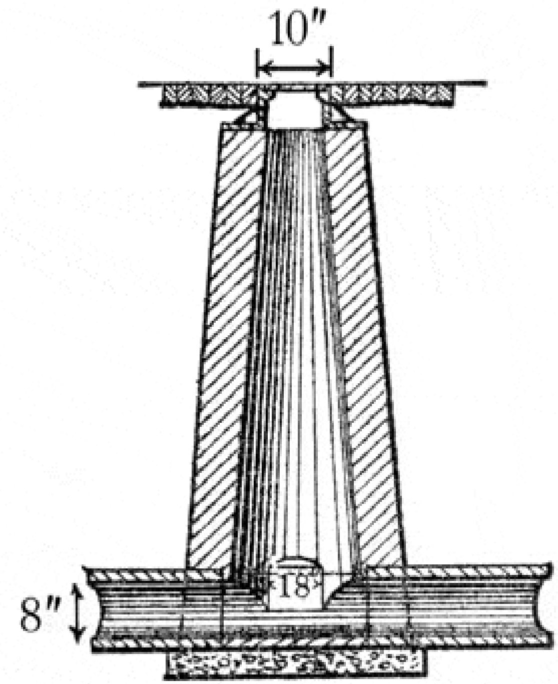
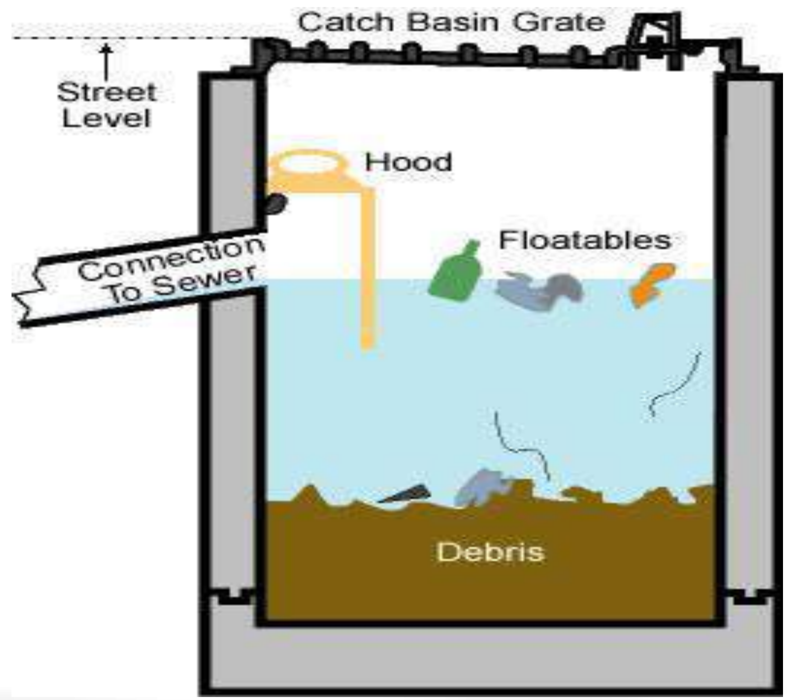


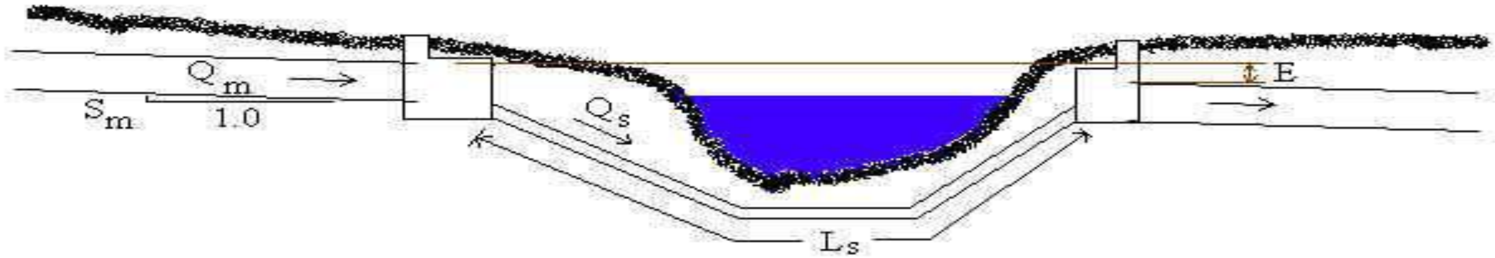
BRICK LAMPHOLE.

- **Street inlets**: Street inlets are the openings through which storm water is admitted and conveyed to the storm sewer or combined sewer. The inlets are located by the sides of pavement with maximum spacing of 30 m.

❖ Catch Basins: Catch basins are small settling chambers of diameter 60 - 90 cm and 60 - 75 cm deep, which are constructed below the street inlets. They interrupt the velocity of storm water entering through the inlets and allow grit, sand, debris and so on to settle in the basin, instead of allowing them to enter into the sewers.



- **Inverted siphons**: These are depressed portions of sewers, which flow full under pressure more than the atmospheric pressure due to flow line being below the hydraulic grade line.
- They are constructed when a sewer crosses a stream or deep cut or road or railway line.
- To clean the siphon pipe sluice valve is opened, thus increasing the head causing flow.
- Due to increased velocity deposits of siphon pipe are washed into the sump, from where they are removed.



Cleaning and ventilation of sewers

- Generally involves their cleaning to keep them free from any clogging and to carry the repairs to the damaged portions.
- It is necessary in order to make the sewerage system function efficiently.
- Frequent inspection, supervision , measuring the rate of flow , cleaning and flushing repairing the leaking joints

Ventilation of sewers

- Use of ventilating columns
- Use of ventilating manhole covers
- Proper design of sewers
- Use of mechanical devices
- Artificial ventilation

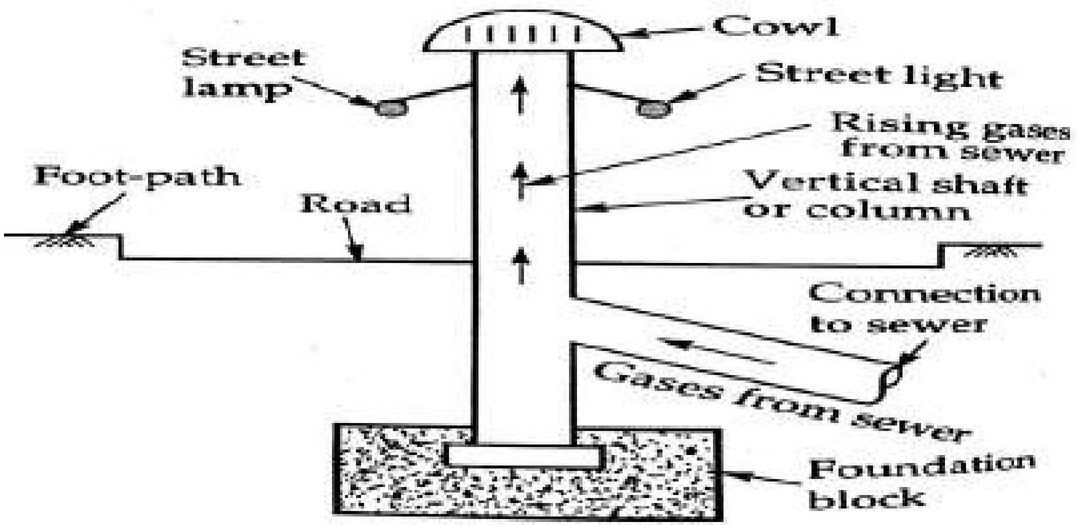


Fig. 5.35. Ventilating column.

Thank u all…


thank you!

Pumping Stations

Unit-II

Introduction

The necessity of lifting wastewater or sewage arises under the following circumstances

- When the **area of a town is so low lying that it cannot be drained by gravity** to discharge into a sub-main or main unless the entire sewerage system in the other parts is installed correspondingly at low level. In such circumstances, it is more economical to pump the sewage from the low lying area into the upper branch mains
- **Pumping is restorted** to, at intervals for a **sewage system in a flat Country, since laying of sewers at the designed grade continuously** all along will mean expensive excavation.

Necessity of lifting wastewater

- **Pumping is resorted** to when outfall sewer is at lower level than the body of water into which it is to be discharged, or when the outfall is lower than the entrance to the treatment plant.
- **When a sewer has to go across a high ridge**, it **will more economical to pump it into sewer laid across the slope of the ridge at reasonable depth**, rather than driving a tunnel.
- **Pumping is required to take out sewage from the cellars or sub-basements of buildings**, when the level of caller is much lower than the invert level of sewer to which drainage connection is to be made.

Introduction

Problems in Sewage Pumping

- The pumping of sewage is not as simple as pumping of water, since the following special problems are to be faced in sewage pumping.
- **(i) Sewage has foul characteristics**
- **(ii) Sewage Contains a lot of suspended and floating materials these may make the running of pumps difficult and may cause frequent clogging of the pumps.**
- **Sewage contains organic and inorganic wastes which may cause corrosion and erosion of parts of the pumps** and reduce the lifts of the pumps.