PRESENTATION
ON
DESIGN OF SEWERAGE SYSTEM

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OVERVIEW

- Sewerage – Basic Principles
- Sewer Design
- Sewer Appurtenances
- Latest Sewerage approaches
- Overview of STP design
- Design Criteria of STP Components
- DEWATS
- Recap

SEWAGE AND SEWERAGE

- **Sewage:**

  It is domestic waste water consists **BLACK AND GREY** water:

➢ Black water:

Consists Faecal matter & Urine.

➢ Grey water:

Consists Waste from Bath room, Wash Rooms and Kitchen.

- **Sewerage:**

  It is the system of collection, conveyance and disposal of sewage.

TYPES OF SEWER SYSTEM

- COMBINED SEWER SYSTEM
- SEPARATE SEWER SYSTEM

- Combined sewer system consists both storm water and Sanitary liquid waste.
- Separate sewer system consists only sanitary liquid waste

MAIN COMPONENTS FOR DESIGN OF SEWERAGE PROJECT

- Command Area or Area to be served
- Contour Survey
- Land usage
- Design Period
- Population Forecasts
- Estimation of waste water Flows

POPULATION FORECAST

- Population may be projected for the design period using standard population forecasting methods.
- Check the projections using graphical & log-log methods also and choose the most appropriate one for the context.
- In case the population figures for the past 30 years are not available, the population densities can be taken from the CPHEEO Manual may be adopted .

Population Densities

Size of town Population	**Density (**population/Ha**)**
Up to 5,000	75-150
5,000-20,000	150-250
20,000-50,000	250-300
50,000-100,000	300-350
above 100,000	350-1000

ESTIMATION OF WASTE WATER FLOWS: PEAK FACTOR

- Generally 80% of the water supply is expected to reach the sewers. However, the sewers should be designed for a minimum sewage flow of 100 lpcd.
- Sewers are not expected to receive storm water.
- The maximum Quantity of Sewage is to be calculated duly multiplying the peak factor as specified the CPHEEO detailed below:

Contributory Population	Peak factor
Up to 20,000	3.50
20,000-50,000	2.50
50,000-7,50,000	2.25
Above - 7,50,000	2.00

DESIGN OF SANITARY SEWER

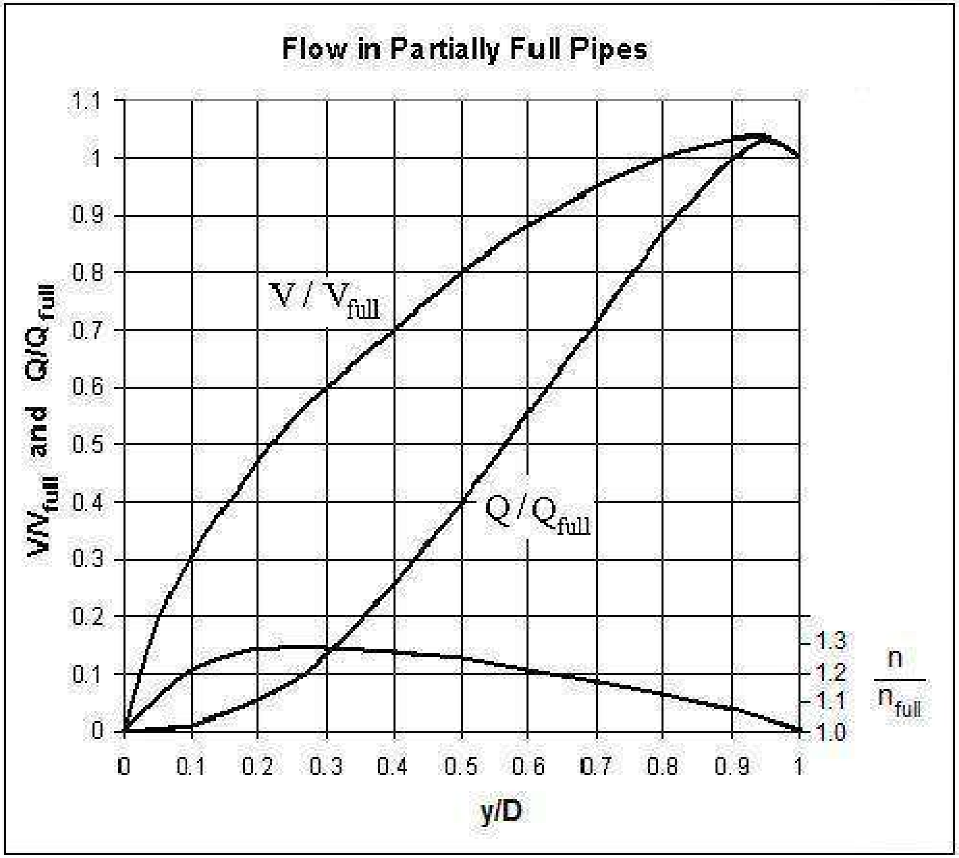
- **Hydraulic Design** of sewers is to achieve:
  - Adequate Capacity
  - Self Cleaning velocity
  - Non scouring velocity
- A sewer should carry the designed peak flow.
- It should transport suspended solids to the STP & minimize deposits

- **Design Period:**
- It is the duration for which the capacity of a sewer is to be adequate.
- **It** is usually taken as 30 years, considering the useful life of materials, wear and tear, projected population & economic justification.

HYDRAULICS FOR DESIGN OF SEWAGE COLLECTION

- When pipe is not flowing full, the discharge, velocity and depth of flow can be calculated readily by the use of partial flow diagram.

- The maximum velocity occurs when the ratio of depth to dia. is about 0.8. The velocity reduces rapidly as the depth of flow decreases below half the diameter.



Partial Flow Diagram

DESIGN OF SEWER NETWORK: CONDITIONS

- Sewers must resist **erosion and corrosion.**
- It's **structural strength** must be sufficient to carry backfill, impact and live loads.
- Where difference in elevation is insufficient to permit gravity flow, **pumping** may be required.
- Ground water **infiltration** varies from 5,000 to 50,000 lit/ha/d. Manual (3.2.7) also gives infiltration values based on length of sewer and per manhole.
- The slope & dia. of sewers shall meet the **following two conditions:**
  - **Self cleansing velocity** is maintained at present peak flow.
  - The **sewer runs at 0.80 full at ultimate peak flow** from considerations of ventilation.

DESIGN VELOCITIES IN SEWERS

- Steady flow conditions are assumed in sewers.
- A velocity of 0.90 m/s is required to transport a sand particle of 0.09mm & specific gravity of 2.65.
- For proper ventilation, the sewers should not be designed to run full.
- Recommended min. velocity in sewers to prevent silting:
  - 0.8 m/s at design peak flow
  - 0.6 m/s for present peak flow
- For present peak flow up to 30 lps, adopt the slopes given in Table 3.7 of Manual for ensuring min. velocity of 0.60 m/s in early years.
- After arriving at slopes for present peak flows, decide the pipe size based on ultimate design peak flow & permissible depth of flow.
- The max. velocity in a sewer is 3.0 m/s to prevent erosion of sewers.

VELOCITY AT MINIMUM FLOW

- Ensure self cleansing velocity in sewers - even in minimum flow conditions
- Upper reaches of laterals pose problem.
- If the flow is partially full even at ultimate design flow, provide flushing arrangements in initial years.
- For sewers running partially full, for given flow & slope, velocity is little influenced by dia.

RECOMMENDED SLOPES FOR MINIMUM VELOCITY

PEAK FLOW IN LPS	SLOPE PER 1,000 MTS.
2	6.0
3	4.0
5	3.1
10	2.0
15	1.3
20	1.2
30	1.0

FLOW-FRICTION FORMULAE

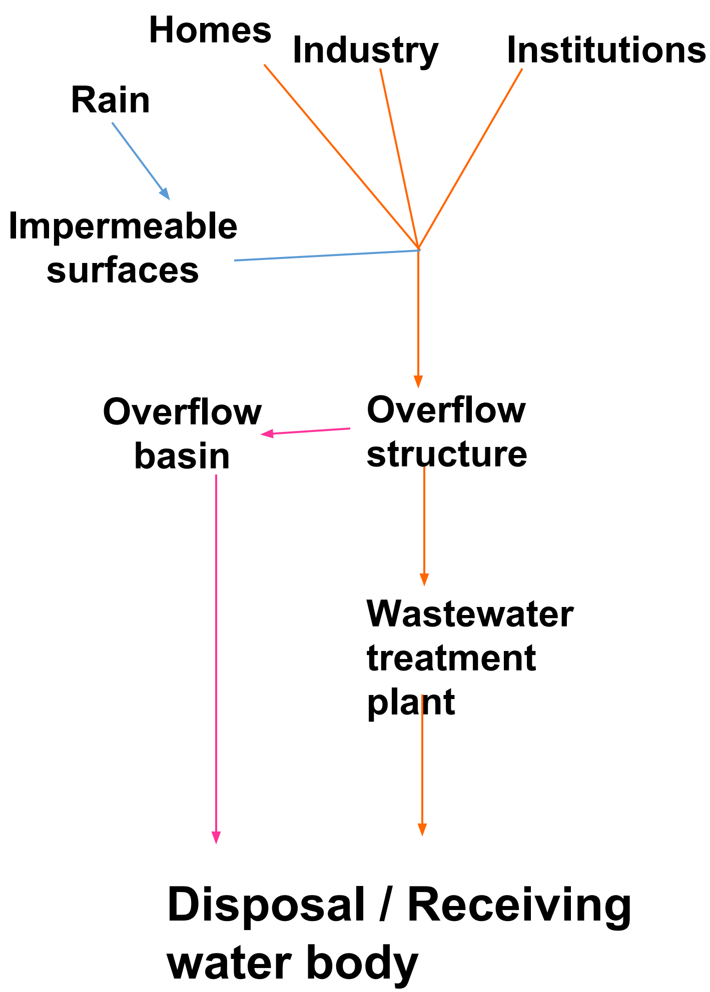
- The available head in waste water lines is utilized in overcoming surface resistance & in small part, in attaining kinetic energy for flow.
- Manning's formula is used for open channel flow
- The coefficient of roughness for SWG pipes is 0.012 (good) to 0.015 (fair), and for RCC spun pipes (S/s joints) 0.011
- Modified Hazen Williams and Darcy-Weisbach formula is used for closed conduit or pressure flow.
- **Design Flows:** The sewer network is to be designed for the anticipated maximum discharge considering the following:
  - Existing and projected population for the design period
  - Commercial establishments like hotels, hostels, schools etc.
  - Industrial discharge.
  - Town master plans etc. which direct future growth.

MUNICIPAL WASTEWATER COMPONENTS

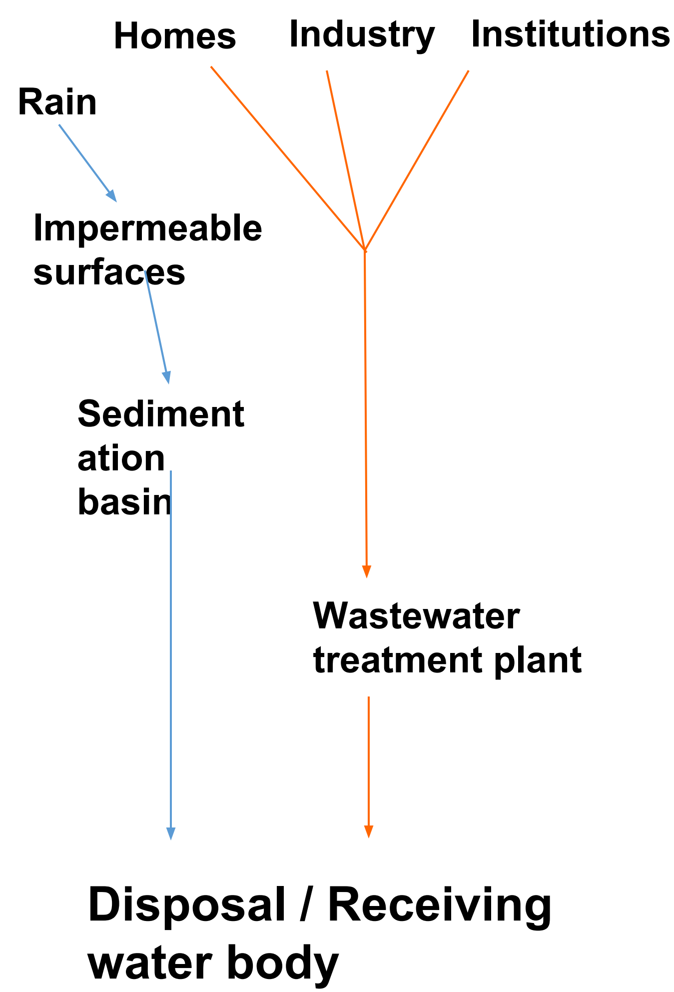
Households institutions and Establishments	Black water (Toilets) Grey water (Kitchen, Bathroom)	Domestic waste water	Municipal waste water
Industries	Pre-Treated / Untreated	Industrial waste water	
Surface run off	Separate sewers / Open drains		Storm water drainage

SEWER SYSTEM DESIGN

Combined sewers



Separate sewers



SEWER NETWORK: DESIGN CRITERIA

- The minimum dia. for a public sewer may be 150 mm.
- The minimum dia. for a public sewer in hilly areas may be 100 mm.
- Where sewers of different characteristics are connected, sewer transitions occur.
- At the sewer transitions, a drop should be provided for taking care of the head loss & also to help in maintenance.
- Vertical drop may be provided where the difference in elevations is >60 cm & must be designed to avoid entrapment of air.
- The crowns of the outgoing sewer should not be higher than that of the incoming sewers, to avoid backing up.
- All drops cause release of gases and maintenance problems and hence should be avoided where possible.
- Special chutes or steeply inclined sewers may be preferred in place of vertical drops.

GENERAL GRADIENTS OF SEWERS
(With respect of discharge)

Dia of Sewer	Discharge in lpm	Grade 1 Over
150	700	150
200	1180	270
250	1850	365
300	2680	460
350	3620	570
400	4670	680

INVERT DROPS IN SEWER TRANSITIONS

- If the difference in elevations is up to 0.60m, the slope in the channel and in the Manhole connecting the two inverts may be adjusted.

- The invert drops for various sewer sizes are:
  - For sewers <400 mm — Half the difference in dia.
  - 400 mm to 900 mm — 2/3 the difference in dia.
  - Above 900 mm — 4/5 the difference in dia.

- The crowns of sewers are always kept continuous.

INVERTED SIPHONS

- When a sewer line dips below HGL, it is called an inverted siphon provided under a canal etc.
- Two considerations governing the profile of a siphon are:
  - provision for hydraulic losses and
  - ease of cleaning.
- Inverted siphons should not have any sharp bends.
- It is necessary to have a self-cleansing velocity of 1.0 m/s at the min. flow to avoid deposition in the line at inverted siphon.

DESIGN OF MANHOLES

- A manhole facilitates a person to access the sewer for inspection, testing, cleaning and removal of obstructions from the sewer line.
- MHs are built at every change of alignment, gradient or diameter, at the head of all sewers and at every junction of two or more MHs.
- In sewers cleaned manually & which can not be entered for cleaning or inspection, the max. distance between MHs should be 30 m.
- Spacing of MHs may be 90-150 m in straight runs for sewers of dia. 900 to 1500 mm.

MANHOLES- SHAPES

- Rectangular manholes (MHs)
- Arch type MHs
- Circular Man Holes.
- Circular Manholes are stronger than other shapes
- Circular MHs can be provided for all depths.

DIAMETER OF CIRCULAR MHS (Internal)

- Depending upon the depth of MH, the dia of MH changes
- The internal dia. of circular MHs for varying depths as follows:
  - For depths >0.90m and upto 1.65 m, 0.90 m dia.
  - For depths >1.65m and upto 2.30 m, 1.30 m dia.
  - For depths >2.3m and upto 9.00 m, 1.50 m dia.
  - For depths >9.0m and upto 14.00m, 1.80m dia.

DROP MANHOLES

- If the difference in level between peak flow level of main line and invert level of branch line is >0.6 m, a drop connection is provided in a MH
- The vertical drop pipe from the higher sewer to the lower one may be outside the shaft.
- Dia. of the back drop pipe should be at least as large as that of the incoming pipe

MANHOLE COVERS AND FRAMES

- For MHs more than 0.90 m depth, the size of manhole covers should be such that the clear opening is not less than 560 mm
- The MH frames should be firmly embedded to correct alignment and level in PCC
- Then the MH covers should be sealed with thick grease
- In high GWT areas, MHs may be constructed in RCC M20 in circular shape
- The MH covers and frames shall be of FRC/SFRC in M20 of EHD/HD/MD as the case may based on traffic and changes in alignment.

HOUSE SEWER CONNECTIONS

- HSCs should preferably be 150mm or more in dia with a min. slope of 1:60
- For large dia. Sewers, house connections may be given through rider sewers which are connected to MH
- New connections to the main street sewer should normally be made with ‘Y’ braches

CATCH BASINS AND VENTILATORS

- Catch basins are meant for retention of heavy debris in storm water from entering into the sewer system
- Their use is not recommended since they are a source of mosquito breeding and pose maintenance problems
- There is no need to provide ventilation since the intercepting traps in HSCs are omitted now

SEWERAGE DESIGN CRITERIA

- Design Periods: 20 years and less.
- Peak factor used in Brazil & Colombia: 1.8
- Design: 0.8 times the water use in Sao Palo;
- In the absence of reliable water use info,
  - Design min. flow: 1.5 lps; Infiltration: 0.05-1.0 l/s/km of pipeline
- Min. Dia of Sewer: Latin America: 150 mm; Brazil: 100 mm dia. Laterals up to 400 m length of sewer for unpaved streets
- Ensuring Self-cleansing instead of min. velocity criterion
- To maintain a boundary shear stress (tractive tension) of 0.1 kg/m2 at peak flow which is sufficient to re-suspend a 1 mm particle of sand.
  - Eg: A 100 mm *sewer* laid at a gradient of 1 in 200 will serve around 2,800 users with a waste *water* flow of 60 L/person/day.

SEWERAGE DESIGN CRITERIA

- A 60 cm square/circular inspection box is placed between the building & service line. All sewers/drains from building enter this box.
- The box is usually located under the side walk (foot path).
- Pipes smaller than 1050 mm can be made flatter compared to min. velocity approach.
- Pipes larger than 1050 mm need to be made steeper than in conventional design to maintain self cleansing.

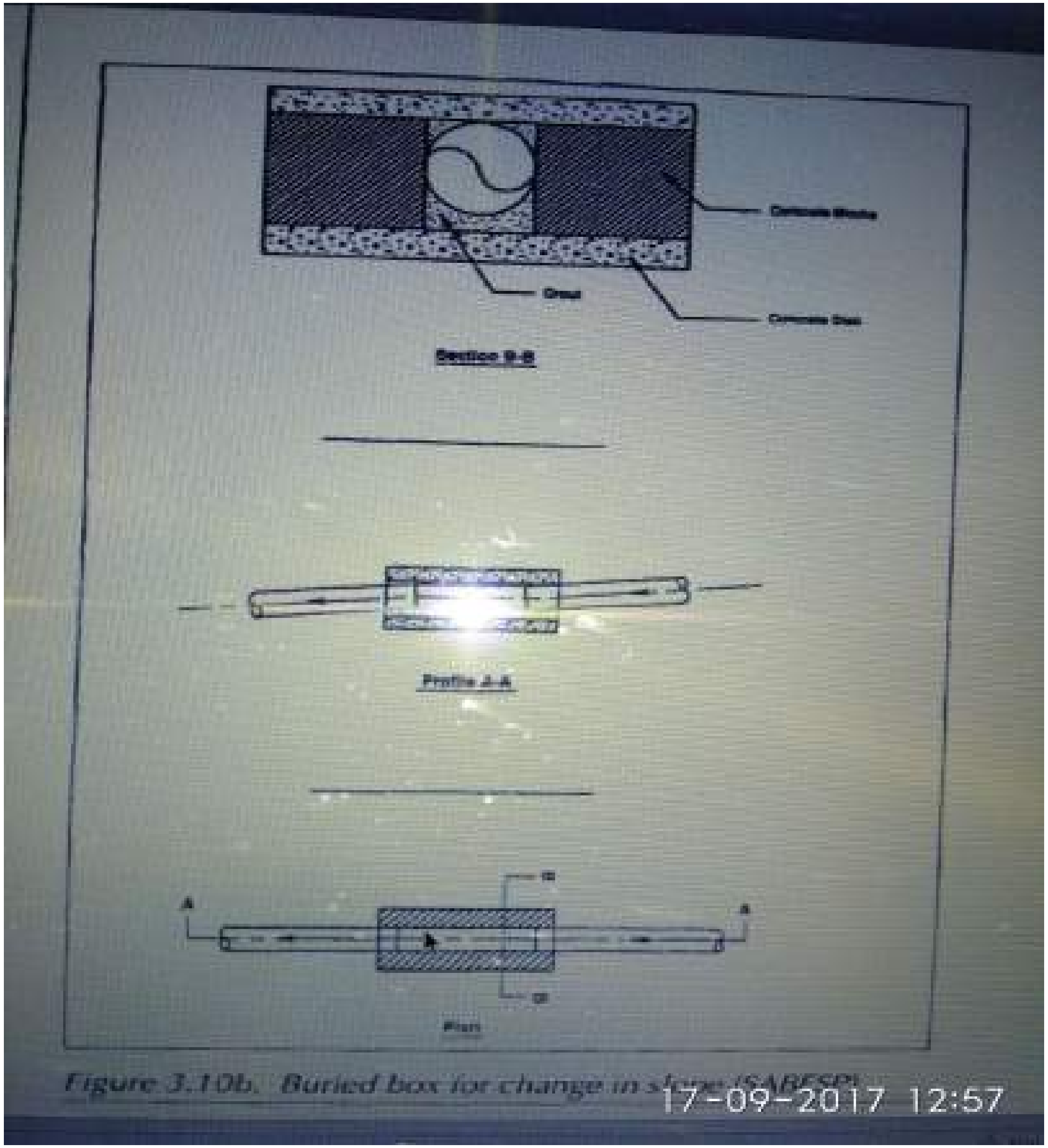
SEWERAGE DESIGN CRITERIA

- Min sewer depths are:
  - 0.65 m below side walks;
  - 0.95-1.50m below residential streets (depending on road width & traffic);
  - 2.50 m below heavy traffic roads.
- Building levels are not considered while setting the invert levels of the sewers. The householder is responsible for enabling connections.
- The cost of manholes is a function of depth, spacing, strength of design and cleaning equipment.
- Manholes only of 0.60 to 0.90 m dia. and used only at major junctions.
- Manholes at change of depth or direction are with underground concrete boxes or chambers.
- Materials used: SWG, AC & UPVC.

SOME SIMPLIFIED ALTERNATIVES TO CONVENTIONAL MANHOLES

Situation	Solution
•Starting point of a sewer	•Inspection & Cleaning terminal
•Long straight sewer	•Intermediate inspection tube
•Horizontal curve of 90 degrees	•Two separate 45 deg. curves
•Service connection	•Y branch & one 45 deg. Curve
•Change of diameter	•Underground concrete box
•Change of slope	•Underground concrete box.

BURIED BOX FOR CHANGE IN SLOPE



SMALL BORE SEWERAGE / SEWERED INTERCEPTOR TANK SYSTEMS (SITS)

- It is also called Solids Free Sewerage system
- Interceptor tanks are designed to provide space for four separate functions:
  - Solids interception;
  - Digestion of settled solids;
  - Storage of digested solids; and
  - Storage of scum.

SEWERED INTERCEPTOR TANK SYSTEMS (SITS) / SMALL BORE SEWERAGE

- **The Interceptor tank** is a buried watertight tank with baffled inlet and outlet. It is designed to detain the liquid flow for 12 to 24 hours and to remove both floating and settleable solids from the liquid stream.
- Typically, a single-chamber septic tank is used as an interceptor tank.
- **The House connection** is made at the inlet to the interceptor tank.
- The sewers are small bore plastic pipe of min. dia.100 mm trenched into the ground at a depth sufficient to collect the settled wastewater from most connections by gravity.
- Not necessarily laid on a uniform gradient with straight alignment.
- It may have an inflective gradient & the alignment may curve to avoid obstacles.
- O**bjective** of design is to utilize to the maximum extent the energy resulting from the difference in elevation between the u/s & d/s.

SMALL BORE SEWERS
ADVANTAGES & CONCLUSIONS

Advantages: Reduced

- water requirement - since solids are separated.
- cost of excavation - due to the flatter gradients.
- material costs - low PF, reduced excavation reduced pipe size, no. & depth of manholes, and simpler pumps.
- treatment requirements - since the interceptor tanks perform partial biological treatment.

Conclusions

- They can be used in areas mostly covered with existing septic tanks, which act as interceptor tanks to arrest solids etc.
- They can be a part of the Septage Management system of sewage treatment and disposal.
- They are less costly, practical and utilize the existing infrastructure to the maximum extent.

SEWAGE TREATMENT PLANT: DESIGN CRITERIA

STP DESIGN OVERVIEW

❖ **STP with Extended Aeration**:

- Bacteria in aeration tank digests organic pollutants in sewage. Hence the influent must remain in aeration tank long enough for digestion.
  - 1st task before designer is to retain sewage long enough in aeration tank.
- The bacterial population needs Oxygen to survive.
  - 2nd task before the designer is to provide adequate Oxygen.
- Activated sludge is recycled & retained in aeration tank. Treated water overflows from clarifier tank, is further filtered, disinfected. A portion of it is reused for non-potable purposes.
  - 3rd task before the designer is to clarify, filter & disinfect waste water
- Bacteria in aeration tank increase the sludge vol. Its pop. is max. when its average age is 25 days. This is achieved by bleeding excess sludge regularly.
  - 4th task before designer is to provide for disposal of excess sludge.

DESIGN PROCESS OF A STP

- Estimate the **amount of sewage** generated, which is the basis for calculating all physical properties of the STP (tank vol., pump capacity etc.)
- Estimates the **amt. of food/nutrition** (carbohydrates, proteins etc.) present in the sewage for the bacteria to digest.
- Find the **amt. of bacteria needed** to digest this amount of food. Based on this figure, the subsystems needed to handle the bacteria are designed (amt. of oxygen needed, amt. of excess sludge to be handled etc.).
- **Influencing factors for STP design:**

Parameter	Typical range	Remarks
F/M ratio	0.05 to 0.30	In Extended Aeration STP, this range is 0.10 to 0.12.
Oxygen requirement	1.0 to 1.8 kg/kg BOD	Providing oxygen consumes energy. Lower is better.
Excess sludge	0.1 to 0.25 kg/ kg BOD	How much sludge is to be disposed off. Lower is better.
Efficiency	70 % to 95 %	The percentage of biodegradable matter broken down in the STP. Higher is better.

DESIGN PROCESS OF A STP….

- The F/M ratio is the main choice available to the STP designer.
- However, he has to keep in mind that however any ratio chooses will have a major effect on the STP, as detailed below:
- **Effects of F/M ratio**

F/M	Oxygen Requirement	Excess sludge Production	Treatment Efficiency (%)	Aeration Tank volume
LO	HI	LO	HI	HI
MED	MED	MED	MED	MED
HI	LO	HI	LO	LO

Note:
The fonts show whether this is a **good**, **neutral** *or* **bad** *outcome*

DESIGN CRITERIA FOR STP

Item	Design Criteria Used
Bar screen	• Flow velocity thro' screen: Max. 0.3 m/sec • Solids to be captured : 12 mm or more • Placement of a coarse screen before fine screen will be beneficial
Grit Chamber	• The length of trap should be approximately 2 times its depth • Residence time in the trap is optimally 5-20 minutes at peak flow. • Surface area of trap should be 1.5 to 2 times the depth of trap.
Equalization tank	• Minimum detention time. : 4-6 hours (to handle peak flow) • Air for mixing and avoid settling and septicity • Air flow. : 1 m^3/ m^3 of tank volume OR 2 m^3/m^2 of tank floor (whichever is greater)
Raw sewage lift pumps	Capacity calculated based on 20-hour/day working of STP, to leave sufficient margin for change over, maintenance, rest period, etc.
Aeration tank	1. Design BOD : 250 mg/L (equalized sewage) 2. Aeration time. : 16 Hrs minimum (desirable: 18 hrs) 3. F/M ratio : 0.12 (to achieve over 95 % BOD removal) 4. MLSS: 3500 mg/L : 3500 mg/L 5. Air : 50 - 60 m^3/Hr/ kg BOD 6. Diffusers diffuser): Flux rate 8-12 m^3/Rmt./Hr (for 90 OD diffuser)

DESIGN CRITERIA FOR STP

Secondary Clarifier	•Overflow rate: : 12-18 m_3/m_2/Day •Detention time: 2.5-3.5 hours •Solids loading : 2-3 kg/m_2/Hr. •Weir loading : Less than 50 m_3/Running meter/day
Pressure sand filter	Loading rate : Less than 12 m_3/m_2/Hr.
Activated Carbon filter	Loading rate : Less than 10 m_3/m_2/Hr. Carbon charge : For 6-8 months replacement
Softener	Design hardness removal from 300 mg/L down to 100-120 mg/L
Hypo dosing	5 PPM dosing, to leave 0.5-2 PPM residual
Excess Sludge	0.20 – 0.25 kg excess solids per kg BOD removed (dry basis)
Sludge conditioning	0.8-1.2 kg lime per kg dry activated sludge 1 – 2 % polymer to sludge on dry weight basis
Filter press	Sufficient wet cake holding capacity based on excess sludge production, as calculated above (For STP size of 400 m_3/day and above, design for 2 cycles per day)

BAR SCREEN CHAMBER DESIGN CRITERIA

- To prevent solids entry - plastic cups/paper dishes/polythene bags/ condoms & sanitary napkins into STP, clogging, pump damage & stoppage of plant.
- Screening achieved by placing a screen with vertical bars across the sewage flow.
- Larger STPs may have 2 screens: **coarse bar screen** with larger gaps between bars, followed by a **fine bar screen** with smaller gaps between bars.
- In smaller STPs, a single **fine bar screen** may be adequate.
- If unattended for long period, it will generate odor & result in backing of sewage.
- Screen chamber must have sufficient c/s to allow passage of sewage at peak flow
- The screen must extend from the floor of the chamber to a minimum of 0.3 m above the maximum design level of sewage in the chamber under peak flow conditions.

- **Design Criteria**

Bar screen	•Flow velocity thro' screen Max. 0.3 m/sec •Solids to be captured : 12 mm or more •The gaps between the bars may vary between 10 and 25 mm.

GREASE CHAMBER DESIGN CRITERIA

- **T**o arrest solid/fatty matter at source. Output from this unit is taken to the **equalization tank.**
- The solids, fats & other biodegradable waste separated can be used as feed for piggeries.
- Shallow trap (to allow quick rise of oils and fats to the surface)

- **Design Criteria**

Grit Chamber	• The length of trap should be approximately 2 times its depth • Residence time in the trap is optimally 5-20 minutes at peak flow. • Surface area of trap should be 1.5 to 2 times the depth of trap.

EQUALIZATION TANK: DESIGN CRITERIA

- Collects incoming fluctuating rate sewage & passes it on to rest of STP at steady rate.
- Stores the sewage coming at high rate & lets it out during non-peak times.
- Capacity sufficient to hold peak time inflows of 4-6 hrs. of average hourly flow.
- Consider sewage vol. during weekends also & hold max. diff. btw. inflow & outflow.
- Compressed air to be infused into the tank for full floor coverage & uniform mixing.
- C**oarse bubble diffusers** to be used to keep raw sewage aerated & in suspension to avoid septicity & odor.
  - **1.2-1.5 times the volume of the Equalization tank, or**
  - **2.5-3.0 m3/m2 of floor area.** Higher of the two figures is taken as the air vol. reqd./hr.
- No. & location of diffusers to be adequate to dispense calculated amt. of air in tank.
- Capacity of air blower must be adequate to deliver the required quantity of air.
- It must have good ventilation to prevent odor & gas buildup.
- **Design Criteria**

Equalization tank	**•Minimum detention time: 4-6 hours (to handle peak flow)** **•Air for mixing and avoid settling and septicity** **•Air flow: 1 m^3/ m^3 of tank volume OR 2 m^3/m^2 of tank floor (whichever is greater)**

RAW SEWAGE LIFT PUMPS

- If we use gravity to move the sewage through the units of STP, they may have to be placed deeper below the GL. To avoid deep excavations, a pumping stage is introduced to lift sewage to next unit in STP, which is the **aeration tank** in small STPs rated below 5000 m3/day.
- This strategy yields a double benefit:
    - All d/s units may be placed at a convenient level above GL, resulting in cost savings & cheaper maintenance.
    - Pumping rate set at uniform flow, so that d/s units are not affected by fluctuating flows.
- Capacity of raw sewage lift pump to be based on daily ave. rated capacity of STP for 20 hrs/22 hrs./day for small & very large STPs respectively.
- Instead of a single pump, two pumps fixed in parallel, but only one pump is operated at a time, 12 hours each.
- The total lift of the pumps based on level difference btw. sewage-delivery level at aeration tank & floor level of equalization tank.

AERATION TANK
DESIGN CRITERIA

- The Aeration tank (together with the settling tank/ clarifier that follows) is at the heart of the treatment system.
- Bulk of treatment is provided here, employing microbes/bacteria for the process.
- Maintains a mixture of high population level of microbes called MLSS.
- Mixed liquor passed on to clarifier tank, where microbes are made to settle.
- Settled microbes recycled to aeration tank & retained for long period.

AERATION TANK DESIGN CRITERIA…

- Volume of Aeration Tank based on food available for the microbes to eat:
  - Quantity of sewage to be handled per day
  - Pollution potential of sewage in terms of BOD, COD, TSS, Oil & Grease.
- Concentration of microbes to be maintained
  - Treatment efficiency: 90 to 98 % (CPCB/State PCB)
  - F/M ratio (F/M) required: for STPs with extended aeration: 0.10 to 0.12
- Quantity of air to be pumped:
  - to keep the microbes alive and in continuous suspension, mix well with food, and not settle.
  - Air required for microbes: 50-60 m3/hr. of air per kg BOD to be removed (diff. btw Influent BOD & Effluent BOD)

SECONDARY CLARIFIER (SETTLING TANK)
DESIGN CRITERIA

- Allows settling of biomass solids in the Mixed Liquor (biomass slurry).
- Thickens the settled biomass, in order to produce a thick underflow
- Produces clear supernatant water, in the overflow from the clarifier
- Is only a passive device and all the above actions occur due to gravity.
- The thick biomass is recirculated back to the aeration tank.
- The clarifier tanks can be classified as:
  - Mechanized clarifier funnel shape with steep slope
  - Un-mechanized clarifier with gentle slope, with rotating rubber blades to sweep the sludge.

SECONDARY CLARIFIER (SETTLING TANK): DESIGN CRITERIA

- Cross Sectional (CS) area: Depth has no role to play in "clarification". Increasing depth of the clarifier only helps in the "thickening" function.
- CS area: 12 – 18 $m^3/hr/m^2$ of throughput flow of sewage. For small domestic STPs, a figure of 16 may be taken.
- Depth of clarifier between 2.5 to 3.0 m.
- To restrict localized high upflow velocities, clarifiers to be provided with sufficient length of "weir" over which overflow occurs.
- In small clarifiers, the "Weir Overflow Rate" does not assume critical significance.
- In a square tank, a weir on a single side of the tank will be sufficient.
- Circular clarifiers are built with an all-round weir, which is adequate.
- Solids Loading Rate in kg solids/m^2/Hr. In typical domestic STPs, this parameter is not of great significance.

SLUDGE RECIRCULATION
DESIGN CRITERIA

- Combination of aeration tank, settling tank & sludge recirculation constitutes an “activated sludge biological treatment system”.
- The optimum age of microbes is btw. 25 to 30 days & STP needs to maintain a high level of microbes in the aeration tank.
- These objectives are achieved by recirculating the sludge from settling tank, & also bleeding out of excess microbes from the system at regular intervals.
- Design Criteria:
  - If the total biomass inventory in the system is 100 kg, and daily bleed/ wasting rate is 4 kg, then the average age of biomass in the system is 25 days.
  - Sludge recirculation rates are typically between 50-100% of the throughput rate of sewage in the STP.
  - Hence, in a majority of cases, the capacity and specifications of the raw sewage lift pumps are replicated for this duty as well.

CLARIFIED WATER SUMP
DESIGN CRITERIA

- Overflow water from clarifier is collected in an **clarified water sump**, which acts as a buffer between secondary & tertiary treatment.
- Treated water quality at this stage is good enough for reuse on lawns and gardens with sufficient disinfection.
- Design Criteria:
  - Retention time of 2-3 hours of average hourly flow in the STP. During lean inflow periods, backwashing of filters is carried out needing sufficient buffer of water.
  - Any sump that serves pumps should have min. retention period of 30 min., so only due to negligence, the sump may overflow, or the pump may run dry.
  - Due to presence of few live bacteria in this tank, it is advisable to aerate this tank, in order to keep the bacteria alive and keep the water fresh.
  - The compressed air keeps these solids in continuous suspension by constantly agitating the water, preventing the solids from settling.
  - Settled bacteria will eventually starve and die, as this tank does not have enough food for them. That would turn the contents of the tank septic.

FILTER FEED PUMPS (FFP)

- Filter feed pumps are used to take the water from the clarified water sump and pass it through the pressure sand filter and activated carbon filter installed in series.
- Capacity of filter feed pumps may be chosen for 20-22 hours of operation. In this case, the capacity of the intermediate clarified water sump also needs to be enhanced accordingly.
- The discharge head of the filters:
  - May be adopted as 1.5 - 2 kg/cm2
  - To overcome the pressure differential a/c filter, just before backwashing.

PRESSURE SAND FILTER (PSF)

- Pressure sand filter (PSF) is used as a tertiary treatment unit to trap the trace amounts of solids which escape the clarifier
- It can typically handle up to 50 mg/l of solids in an economical manner.
- It is a pressure vessel that is filled with graded sand & gravel media.
- The water filtered with PSF is passed on to the next stage in the STP chain: the Activated Carbon Filter.
- Design Criteria:
  - Average design filtration rate is 12 m3/m2/hr of filter CS area.

ACTIVATED CARBON FILTER (ACF)
DESIGN CRITERIA

- Is a tertiary treatment unit & receives water that is filtered by Pressure Sand Filter
- Improves multiple quality parameters of sewage: BOD, COD, turbidity, color and odor.
- **Design Criteria**
  - Dia. of the ACF be 25% larger than that of the sand filter (SPF) to reduce the frequency of servicing.

DISINFECTION OF TREATED WATER

- The treated water is disinfected to destroy and render harmless disease-causing organisms, such as bacteria, viruses etc.
- The most common methods of disinfection include Chlorination, Ozonization and UV radiation.
- Of these, Chlorine finds widespread application.
- Cl2 damage the cell wall resulting in cell lysis and death. In most STPs, the common form of Chlorine used is Sodium Hypochlorite (Hypo) available commercially at 10-12 % strength, being safe, easy to handle and having a reasonable shelf life.
- **Design Criteria:**
  - Efficiency of disinfection is dependent both on the residual concentration of the chemical used, as well as the contact time, a factor measured as R x T.
  - Generally, a contact time of 20-30 minutes is recommended to achieve over 99 % germicidal efficiencies.

EXCESS SLUDGE HANDLING

- Biological treatment of sewage produces excess bio-solids due to growth of microbes, which needs to be disposed efficiently.
- Process involves sludge removal, storage, dewatering & disposal.
- In Sludge conditioning, sludge solids are treated with chemicals etc. to prepare the sludge for dewatering.
- Sludge is removed from the system from sludge recirculation pipeline.
- Sludge in the form of thick slurry, is taken into sludge-holding tank & aerated to prevent microbes from putrefying until dewatering operations are carried out.
- Before dewatering, polymer/other chemicals be added to condition the sludge, to facilitate dewatering. Sludge is then dewatered.

Design Criteria:

- Quantity of excess sludge produced in STP in m3/day depends on BOD, MLSS, temp.
- F/M loading rate chiefly decides the amount of excess solids produced.
- 0.20 to 0.25 times (on dry mass basis) kg of BOD removed in aeration tank, in extended aeration systems with low F/M.
- Since the excess sludge is available in slurry form from the sludge recirculation line, the slurry consistency may be taken to be between 0.8 to 1.0 %.

ECONOMICS : COST CONSIDERATIONS

- Capital Cost
  - Installation / Construction
  - Land cost
  - Engineering and supervision
  - Interest
- Operation and Maintenance
  - Staff
  - Equipment
  - Power
  - Maintenance and Repairs

DECENTRALIZED WASTEWATER TREATMENT SYSTEMS (DEWATS)

- DEWATS are based on the principle of low-maintenance: low energy inputs & cannot be switched off intentionally.
- Can be constructed & operated anywhere since they rely on natural WWT processes, without special equipment, chemicals, or energy.
- Depending on location, size of town or settlement, context and financial capacity of the town to operate & maintain the system
- DEWATS systems are more dispersed and decentralized to take the advantage of topography, reduced depth of sewers, simplicity of treatment process and low O&M costs.
- Efficient upto 1 MLD

DEWATS SYSTEMS

- Septic tank (Commonly used at domestic level)
- Waste stabilization ponds
  - Facultative lagoon
  - Maturation lagoon
- Land treatment
- Anaerobic Baffled Reactor
- Constructed Wetlands
- Soil Bio-Technology
- Phytorid

DEWATS
TREATMENT PROCESSES

❖ Primary treatment:
  - Screening, Sedimentation, Floatation, Filtration, Sludge accumulation

❖ Secondary anaerobic treatment (in Fixed Bed Reactors/Baffled U/s Reactors/ Anaerobic Filters/SBT/Phytorid
  - Chemical reactions under aerobic, anoxic & anaerobic conditions are illustrated by the decomposition of Glucose.

❖ Tertiary aerobic treatment (Elimination of Pollutants thro' sub-surface flow filters/polishing ponds/Ecology & self-purification in nature - surface water/ground water/soil)
  - N (bacterial action), P (by removal of bacterial mass)
  - Toxic substances (Heavy metals): by settling or other means
  - Pathogens: shallow ponds with long HRT, Constructed wetlands

BIOLOGICAL TREATMENT

The chemical reactions under aerobic, anoxic and anaerobic conditions are illustrated by the decomposition of glucose:

- Decomposition via aerobic respiration:

  $C6H12O6 + 6O2 = CO2 + 6H2O$

- Decomposition via anoxic respiration:

  $C6H12O6 + 4NO3 = 6CO2+6H2O+2N2$

- Decomposition via anaerobic fermentation:

  $C6H12O6 = 3CH4+3CO2$

- Aerobic-Anaerobic

ADVANTAGES OF DEWATS

- Efficient treatment for daily wastewater flows up to 1000m3
- Modular design of all components
- Tolerant towards inflow fluctuations
- Reliable and long-lasting construction design
- Expensive and sophisticated maintenance not required
- Low maintenance costs

SEWAGE TREATMENT TECHNOLOGIES

POLLUTANTS IN SEWAGE

- BOD(Bio Chemical Oxygen demand)
- COD(Chemical Oxygen demand)
- TSS(Total Suspended Solids)
- PH

BOD(Biochemical Oxygen demand)

The BOD is an important measure of water quality .It is measure of the amount of oxygen needed by bacteria and other organisms to oxidize the organic matter present in a water sample over a period of 5 days at 20 degree C.

COD (Chemical Oxygen Demand)

- COD Measures all organic carbon with the exception of some aeromatics (BENZENE,TOLUENE,PHENOL etc.) which are not completely oxidized in the reaction.
- COD is a chemical oxidation reaction
- Ammonia will not be oxidized.

Total Suspended Solids

- Total suspended solids(TSS) include all particles suspended in water which will pass through a filter.
- As levels of TSS increase, a water body begins to lose its ability to support a diversity of aquatic life.
- Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen(warmer water holds less oxygen than cooler water)

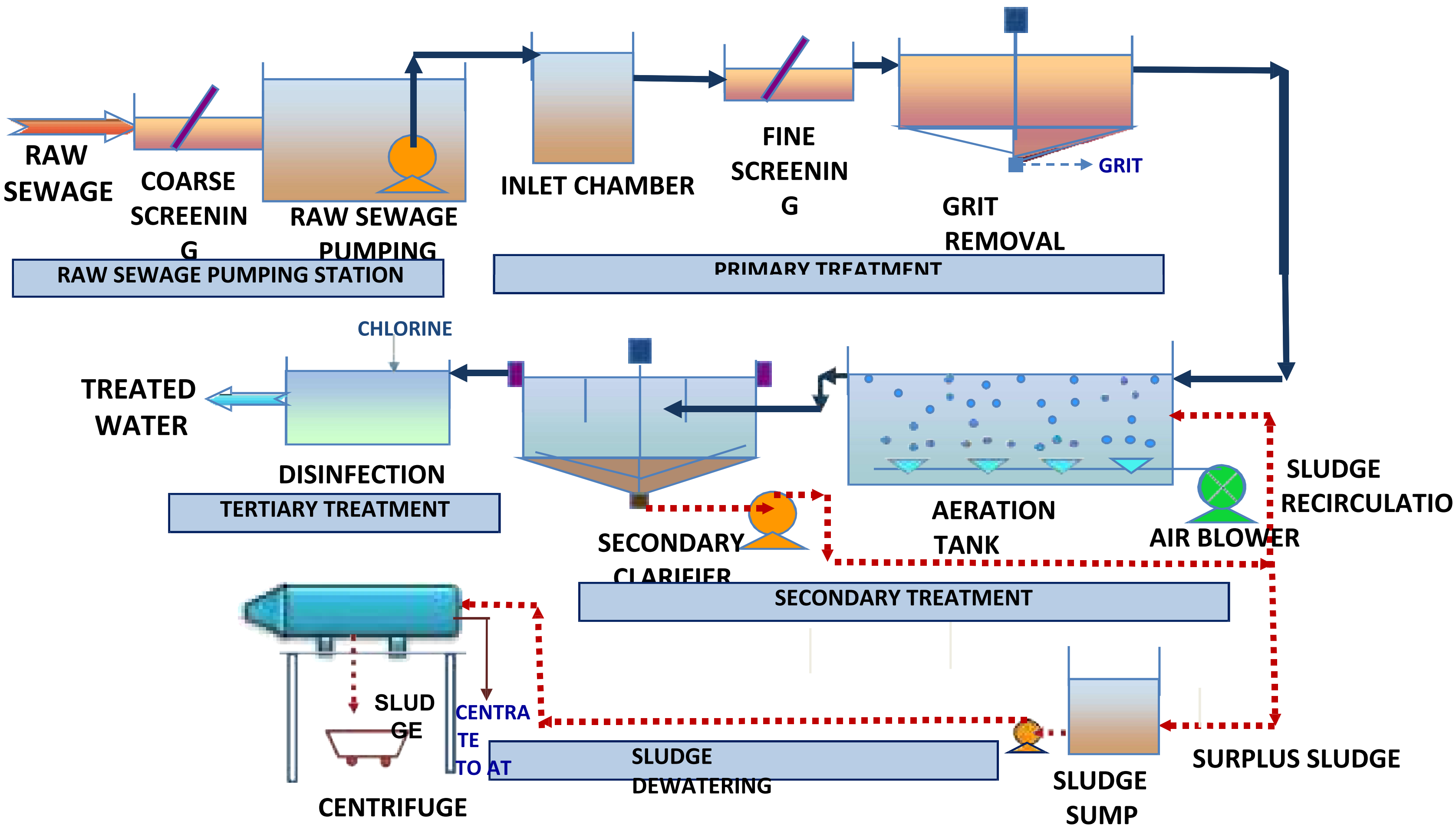
STANDARDS OF RAW / TREATED SEWAGE

Sr. No.	Parameter	Public Sewers	Treated Effluent	
			After secondary treatment	After tertiary treatment
1	pH value	5.5 – 9.0	5.5 – 9.0	5.5-9.0
2	Oil and grease, mg/l max	20	10	2
3	Total residual chlorine, mg/l max	–	1.0	0.5
4	Ammonical nitrogen (as N),mg/l, max	50	50	6
5	Total kjeldahl nitrogen (as N);mg/l, max. mg/l, max	–	100	16
6	Free ammonia (as NH_3), mg/l, max	–	5.0	6
7	Biochemical oxygen demand (3 days at 27°C), mg/l, max	350	30	<5
8	Chemical oxygen demand, mg/l, max	–	250	50
9	Suspended solids mg/l, max	600	100	8.00

COMPONENTS OF SEWAGE TREATMENT PLANTS

- Pumping of Sewage
- Primary Treatment
- Secondary treatment
- Tertiary Treatment

Typical Flow Diagram of Sewage Treatment Plant



Pumping Station

- Receiving Chamber
- Coarse Screening
- Wet Well (Raw Sewage Sump)
- Pump House
- Raw Sewage Pumps

SELECTION OF PUMPS FOR RAW SEWAGE

- FOR MAIN PUMPING STATION (MPS) I:S. 5600-2005 NUMBER OF PUMPS REQUIRED (INCLUDING STANBY)

  2 No. of ½ DWF 2 No. of 1 DWF

  1 No. of 3 DWF
- FOR INTERMEDIATE PUMPING STATION (IPS)

  NUMBER OF PUMPS REQUIRED (INCLUDING STANBY) FOR CAPACITY OF PUMPING STATION UPTO 3 MLD

  1 No. of 1 DWF

  1 No. of 2 DWF

  1No. of 3 DWF

  NUMBER OF PUMPS REQUIRED (INCLUDING STANBY) FOR CAPACITY OF PUMPING STATION ABOVE 3 MLD
  2No. of ½ DWF 2 No. of 1 DWF

  1 No. of 3 DWF

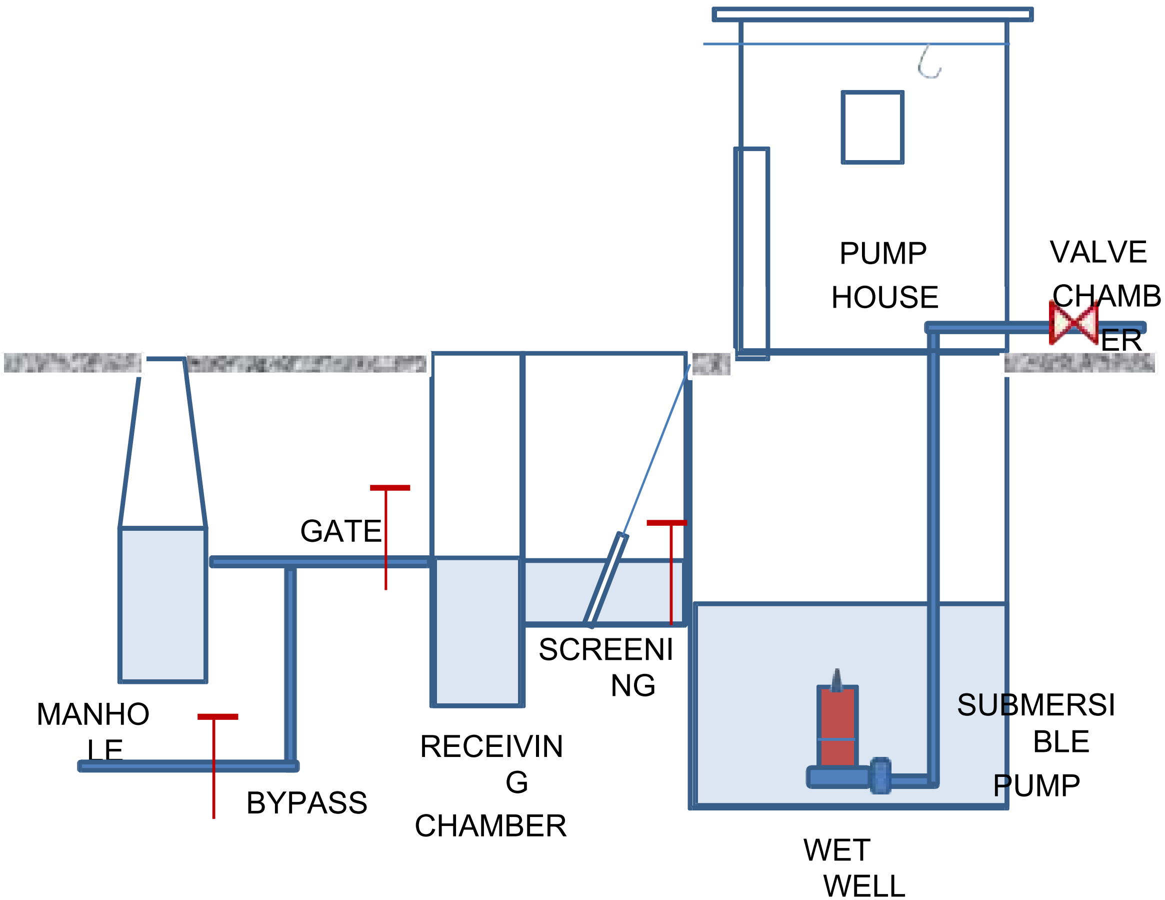
VELOCITY CONSIDERATION IN DESIGN OF PUMPING (RISING) MAIN FOR PUMPING SEWAGE

- The size of Rising main should be designed after taking into consideration that:

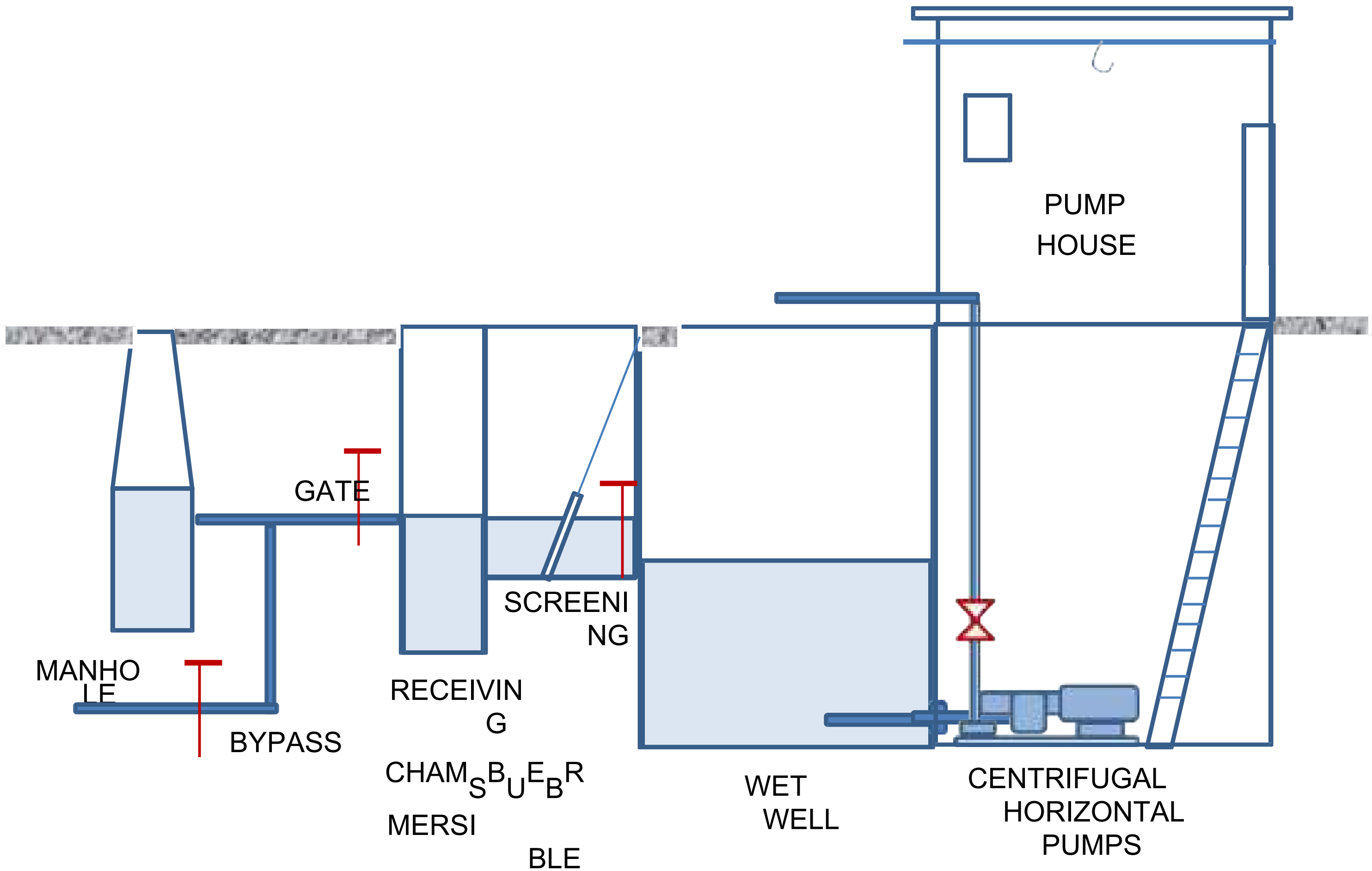
  Maximum velocity at peak flow should not exceed 2.7 m/s.

  Minimum velocity at low flows should not be less than 1 m/s.

Pumping Station with submersible pump set



Pumping Station with Centrifugal Pump set



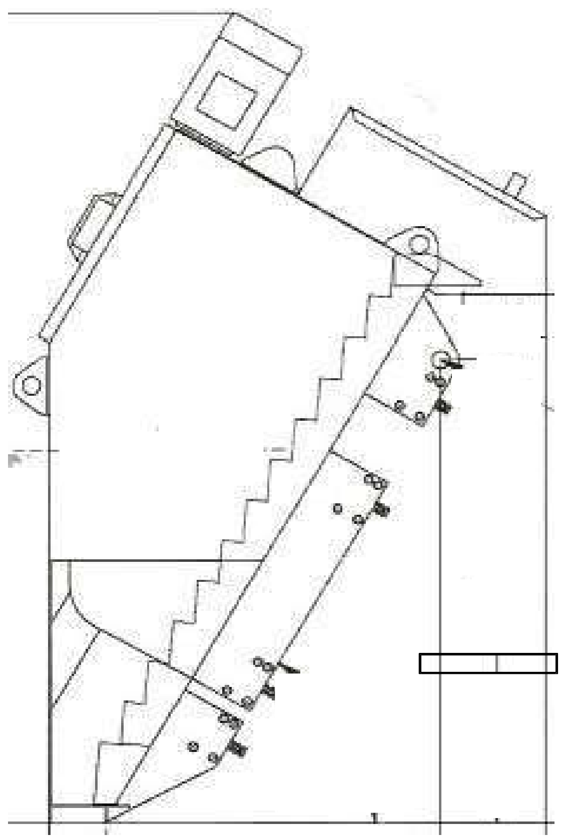
Primary Treatment

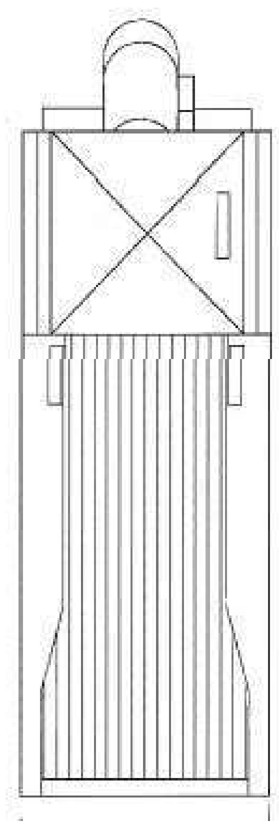
- Fine Screening
- Grit Removal
- Primary Clarification

SCREENING

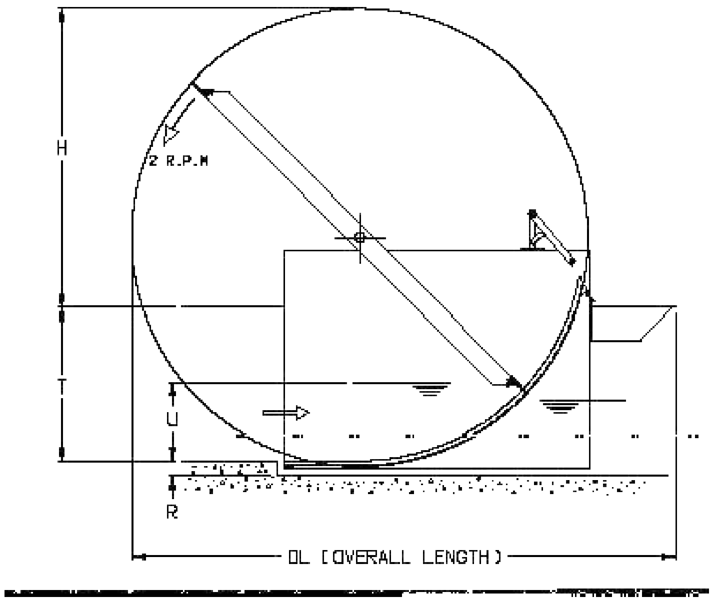
Objective	Removal of coarse solids
Types of screens	Fine / Medium / Coarse
Cleaning of screens	Manual / Mechanical
Benefits	Protection of pumps
Coarse screening	20mm clear spacing in bars
Fine screening	6mm clear spacing in bars

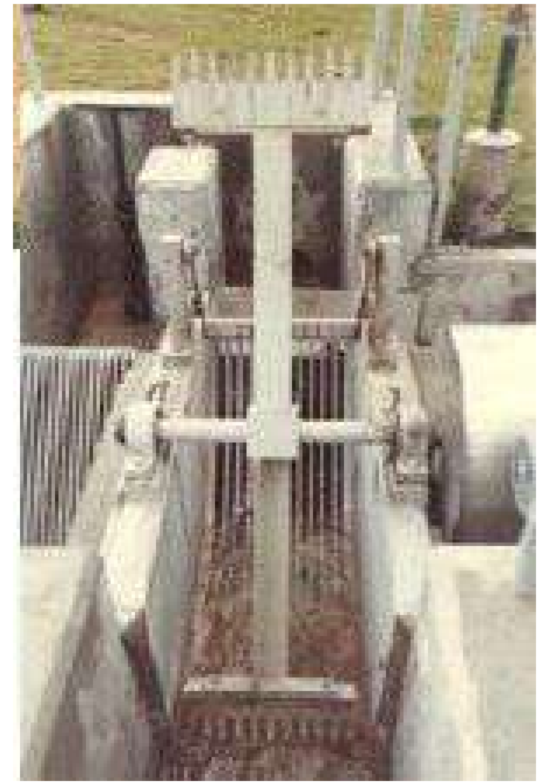
Screening





Screening



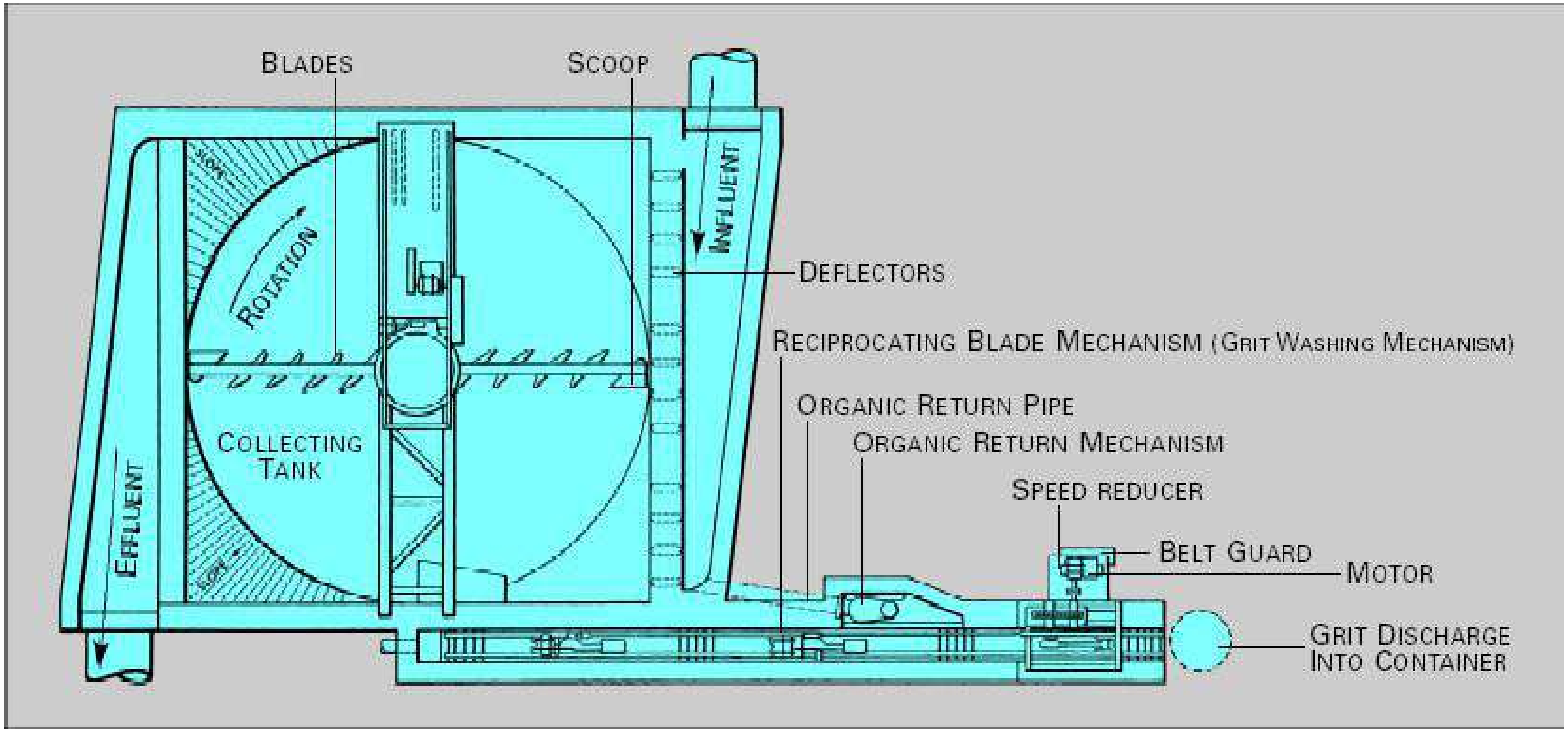


ARC BAR SCREEN

PRIMARY TREATMENT

Grit Removal

- Objective : Removal of inorganic solids eg. ebbles/ sand/ Silt to protect moving mechanical equipment
- Principle : Gravity separation (a) effective size 0.15 mm (b) specific gravity – 2.65
- Types : Manual grit removal - Rectangular channel
  Mechanical grit removal - Circular tank
- Grit removal Mechanism : Screw classifier / reciprocating classifier



MECHANICALLY CLEANED GRIT CHAMBER WITH ORGANIC WASHER

GRIT REMOVAL

GRIT CHAMBER WITH CLASSIFIER & WASHER

SECONDARY TREATMENT

BIOLOGICAL TREATMENT

SEWAGE TREATMENT

Method of Treatment-Aerobic, Anaerobic.

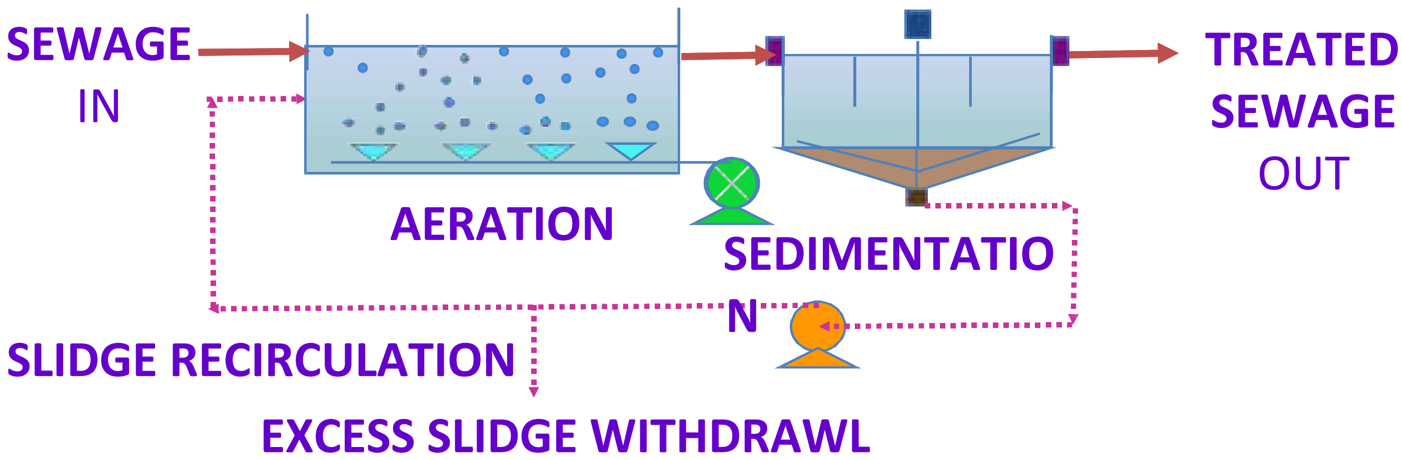
- **Aerobic**-Sewage treatment in the presence of Oxygen-MBBR, SBR-where aerators/blowers are installed-generally no smell during treatment.

- **Anaerobic**-Sewage treatment in the absence of Oxygen-UASB-No aerators/blowers are required-foul smell during treatment.

VARIOUS SEWAGE TREATMENT TECHNOLOGIES

- Activated Sludge Process (ASP)
- Upflow Anaerobic Sludge Blanket Reactor (UASB)
- Moving Bed Biofilm Reactor (MBBR)
- Sequential Batch Reactor (SBR)

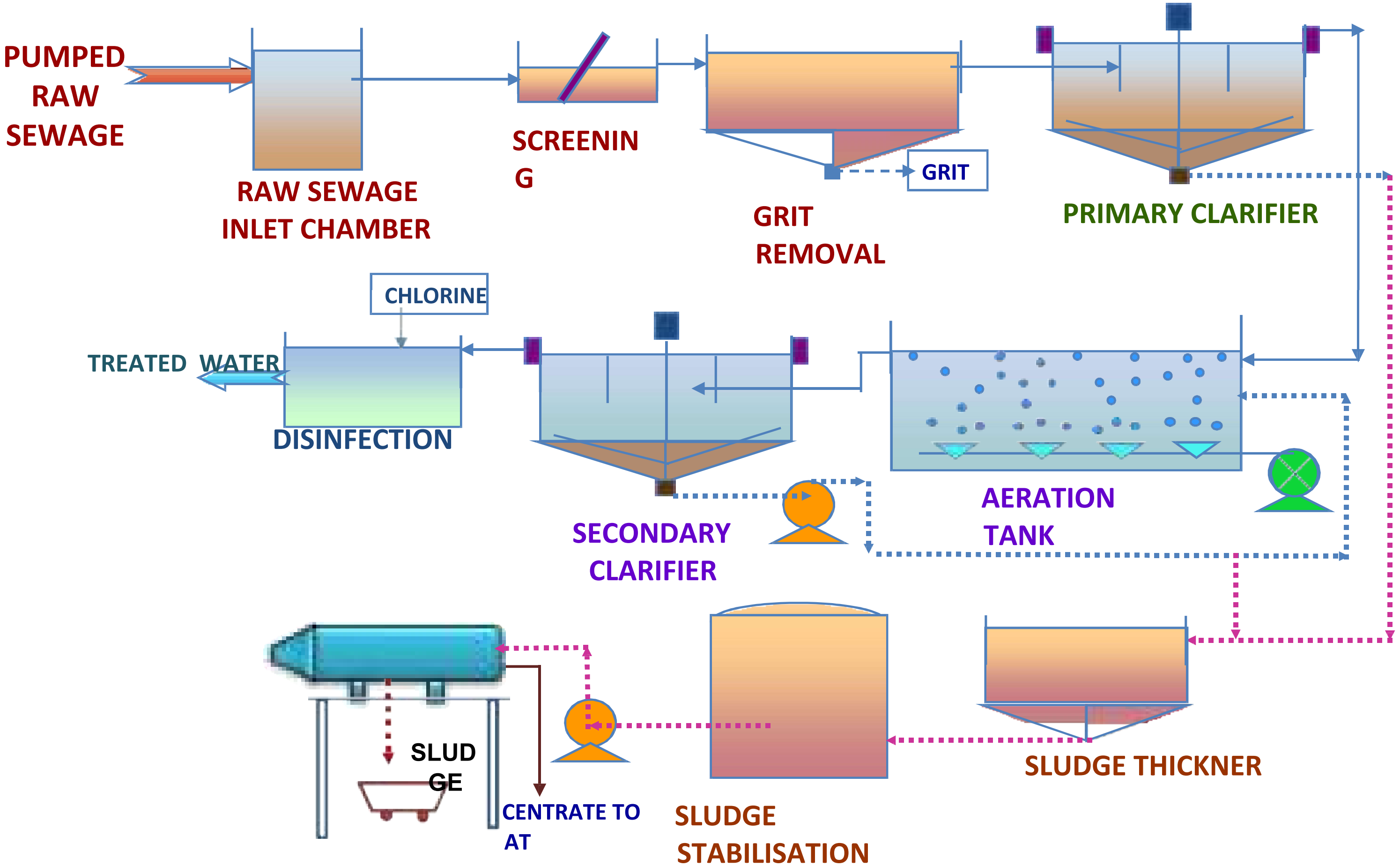
ACTIVATED SLUDGE PROCESS - ASP



- Raw Effluent In
- Aeration
- Sedimentation
- Treated water out
- Sludge Recirculation
- Sludge withdrawl

ASP - FLOW DIAGRAM

PC-AT-SC-CHL



ACTIVATED SLUDGE PROCESS (ASP) TECHNOLOGY

- An activated sludge plant essentially consists of the following:

1) Aeration tank containing micro organisms in suspension in which reaction takes place.
2) Activated sludge recirculation system.
3) Excess sludge wasting and disposal facilities.
4) Aeration systems to transfer oxygen
5) Secondary sedimentation tank to separate and thicken activated sludge.

ASP

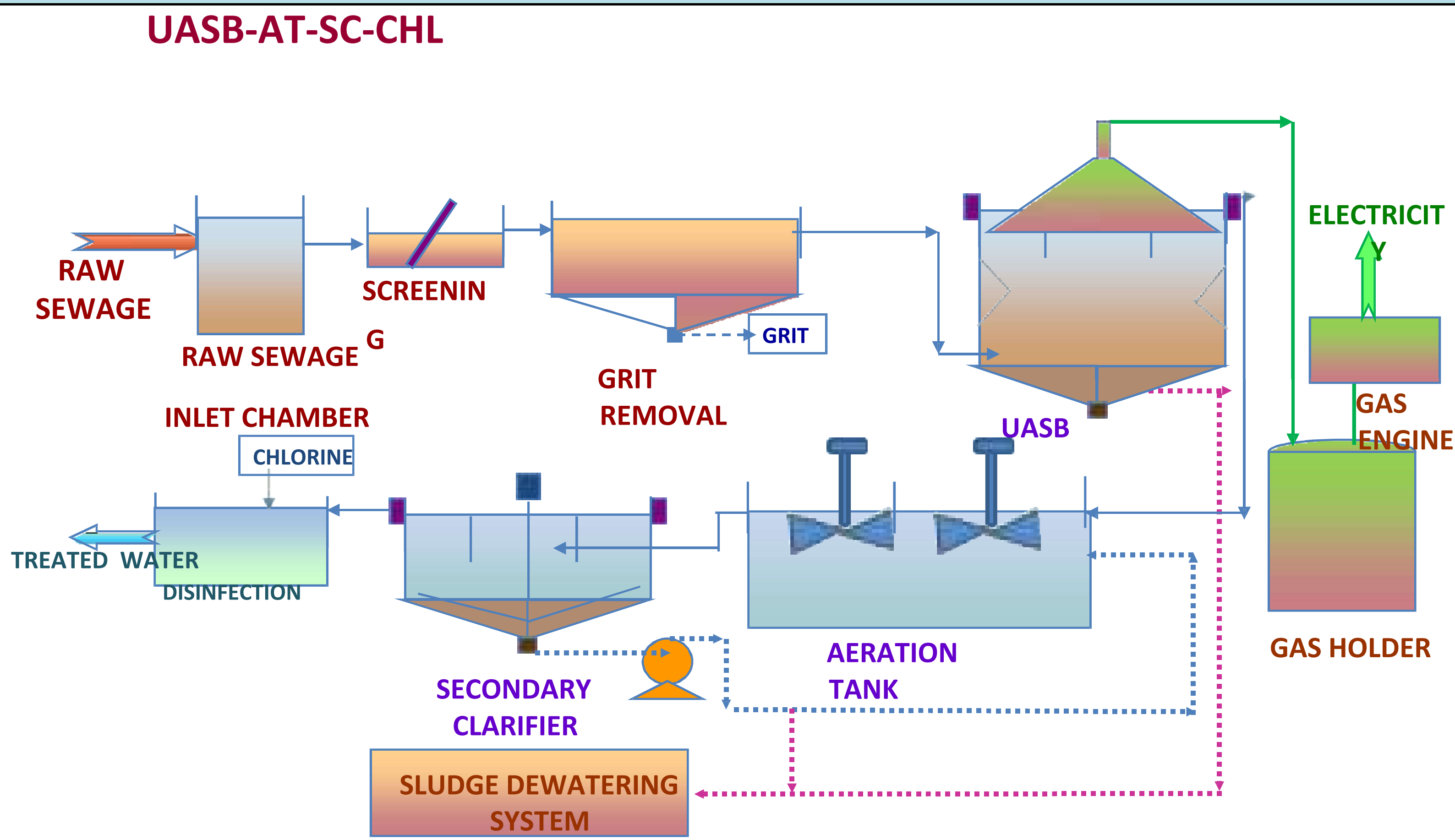
- **Advantages**
  - Can sustain seasonal variation
  - Less land requirement than UASB
- **Disadvantages**
  - High energy consumption
  - Foaming, particularly in winter season, may adversely affect the oxygen transfer, and hence performance
  - Requires elaborate sludge digestion /drying/disposal arrangement
  - More land requirement than SBR & MBBR
  - Nitrogen and Phosphorous removal requires additional anoxic tank and > 3 times internal recirculation

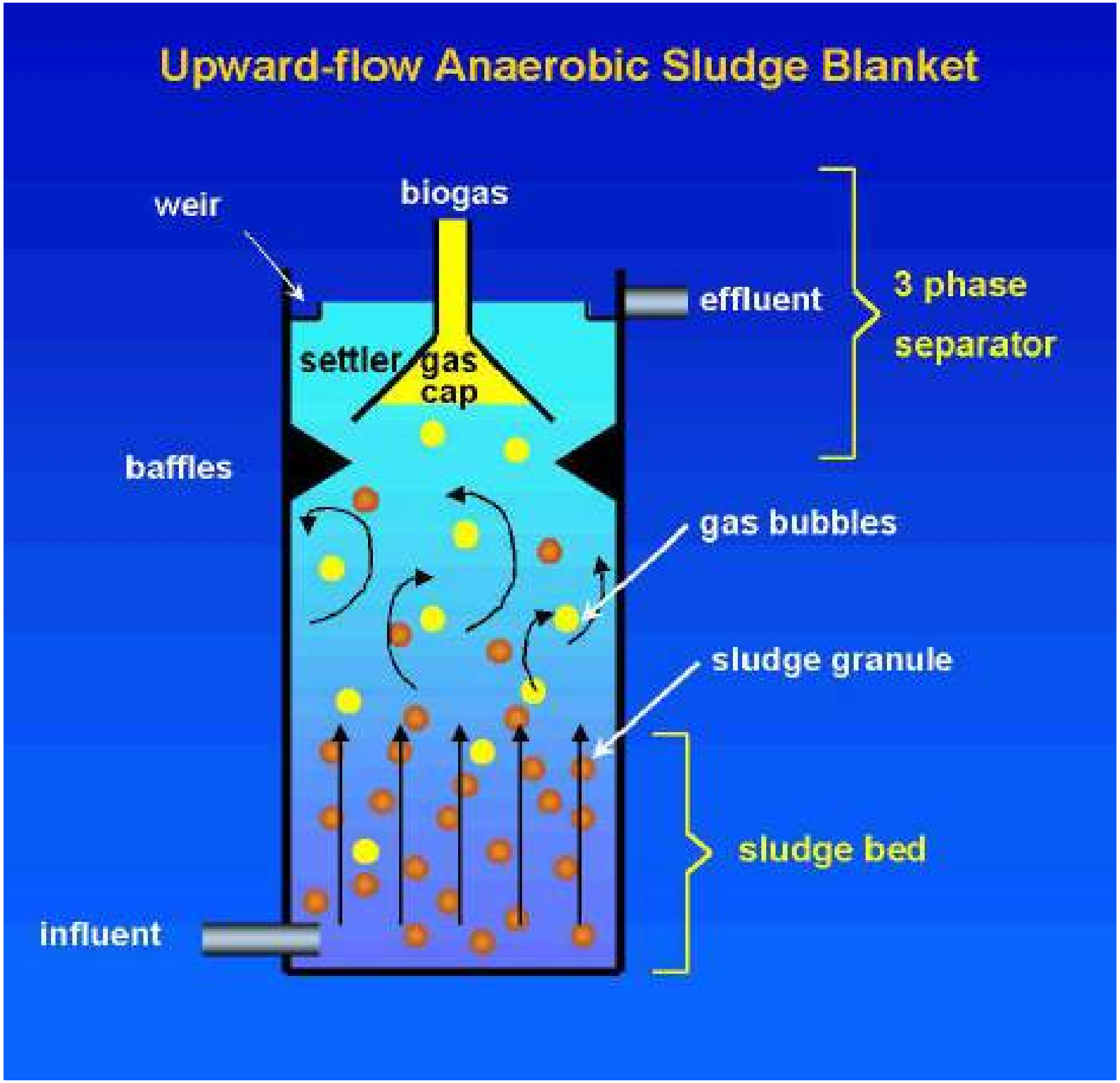
ASP

UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR (UASB)

- The Up flow Anaerobic Sludge Blanket reactor (UASB) maintains a high concentration of biomass through formation of highly settleable microbial aggregates. The sewage flows upwards through a layer of sludge.
- The sludge in the UASB is tested for pH, volatile fatty acids (VFA), alkalinity, COD and SS. If the pH reduces while VFA increases, the sewage should not be allowed into the UASB until the pH and VFA stabilise.
- The reactor may need to be emptied completely once in five years, while any floating material (scum) accumulated inside the gas collector channels may have to be removed every two years to ensure free flow of gas.
- All V-notches must be cleaned in order to maintain the uniform withdrawal of UASB effluent coming out of each V-notch. The irregular flow from each V-notch results in the escape of more solids washout. Similarly, blocking of the V-notches of the effluent gutters will lead to uneven distribution of sewage in the reactor.

Up – Flow Anaerobic Sludge Blanket Rector (UASB) Flow Diagram





Upward-flow Anaerobic Sludge Blanket
biogas
weir
effluent
3 phase separator
settler
gas cap
baffles
gas bubbles
sludge granule
sludge bed
influent

UASB

Advantages

- Requires less power than aerobic processes
- Biogas generated can be used as fuel or electricity.

Disadvantages

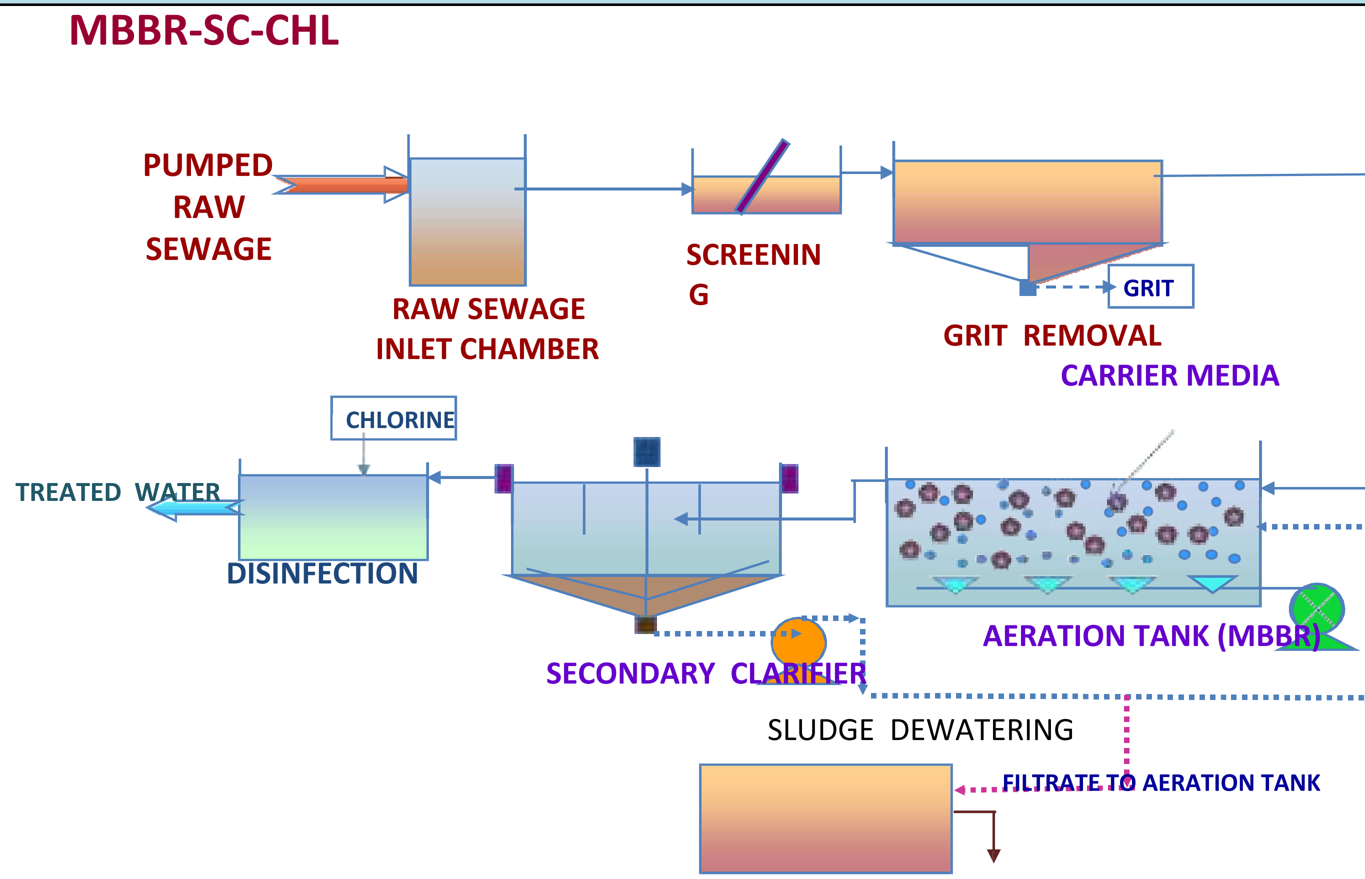
- UASB alone does not treat the sewage to desirable limits, therefore downstream aerobic treatment is compulsory
- Requires very large space due to post treatment
- Recovery of biogas is not sufficient to produce substantial electricity in case of municipal

UASB + AL+FL

MOVING BED BIO REACTOR (MBBR) PROCESS

- Moving Bed Bio Reactor (MBBR) process is based on the bio-film of organisims developed on carrier elements.
- This media is floating in the Aeration tank and kept floating by air from diffusers which are placed at the bottom of tank.
- The process is intended to enhance the activated sludge process by providing greater biomass in aeration tank and thus by reducing volume of the tank
- After aeration tank sedimentation tank is provided for settlement of sloughed biomass
- Clear water clarifier overflows from weir and is further subjected to disinfection.

Moving Bed Bio Rector (MBBR) - Flow Diagram



MBBR

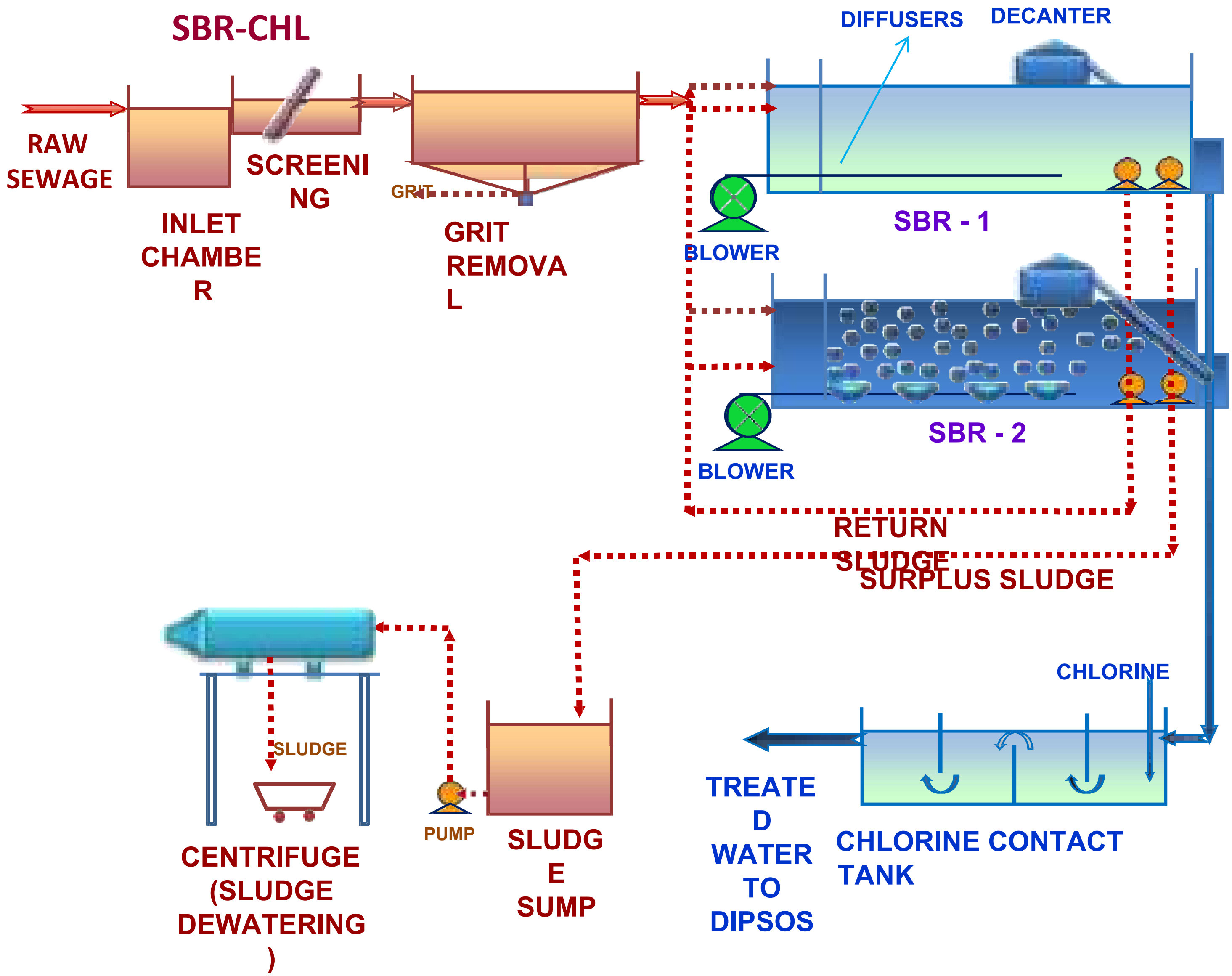
QUANTITY OF BIO MEDIA

- Check Design approved by SE to see quantity of BIO media 1m^3 per 7.5 Kg BOD considering surface area of media 250 m^2/m^3
- The specifications are given in agreement. Specific gravity 0.96.
- Make by Kaldnes biofilm carrier

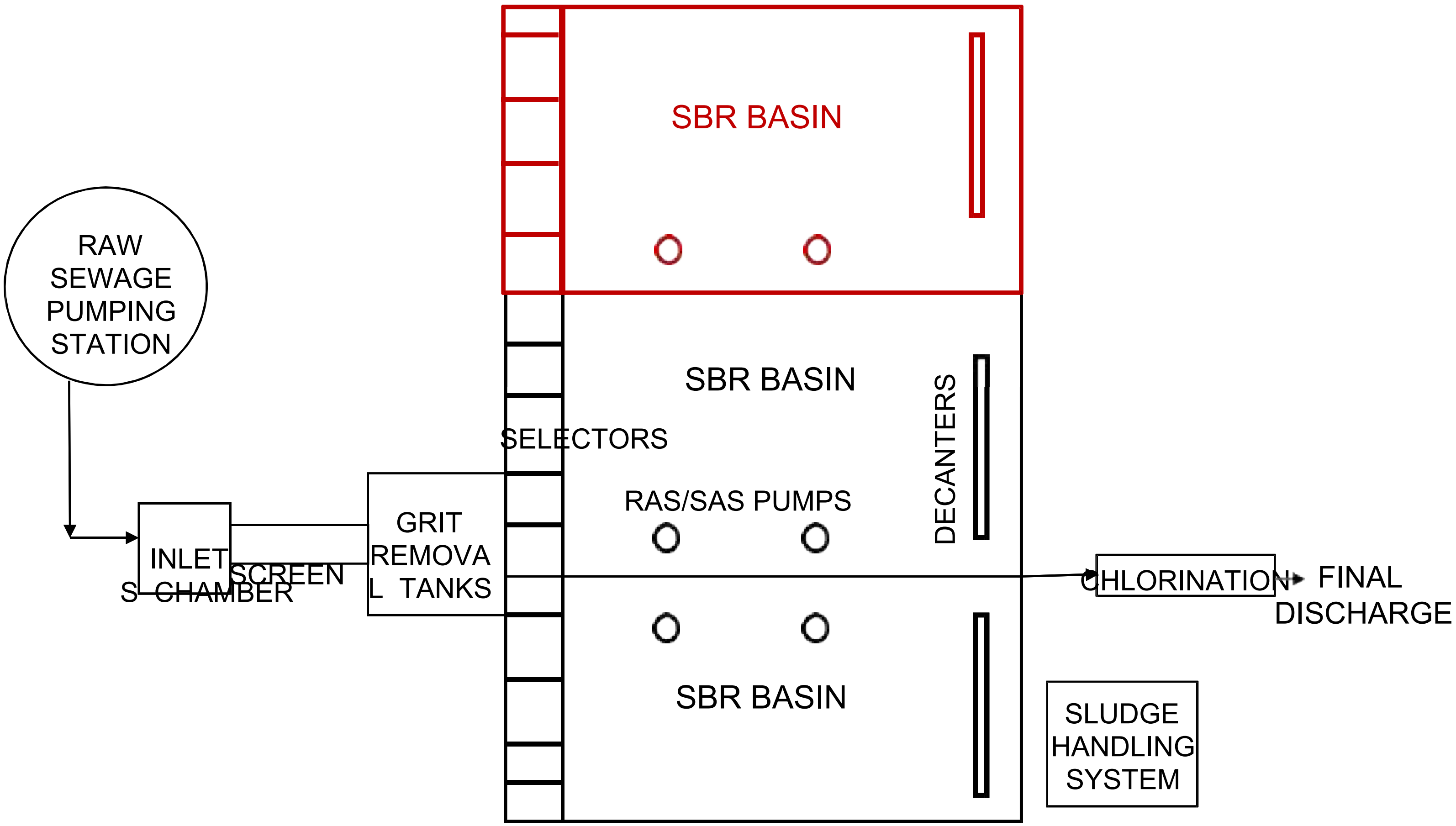
SEQUENTIAL BATCH REACTOR (SBR) PROCESS

- Sequential Batch Reactor is true batch process where fill, aeration, settle and decant steps are carried out in sequence of batches in a single basin.
- Screened, de-gritted sewage is fed into the SBR Basins for biological treatment to remove BOD, COD, Suspended Solids, Biological Nitrogen and Phosphorous.
- SBR process shall work on batch mode in single step.
- It performs biological organic removal, nitrification, de-nitrification and biological phosphorous removal.

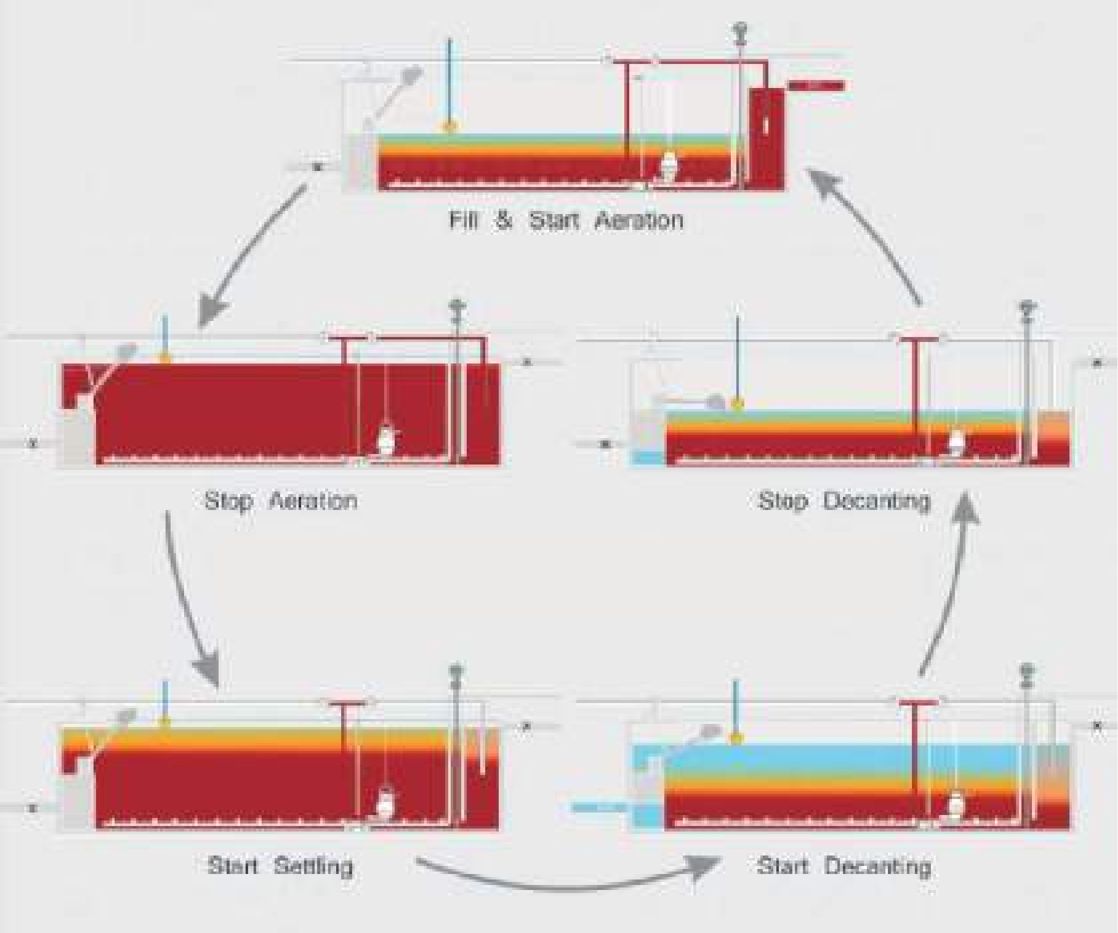
Sequential Batch Rector (SBR) - Flow Diagram



Modular Design



SBR Process



Fill & Start Aeration
Stop Aeration
Stop Decanting
Start Settling
Start Decanting

SBR / CYCLIC ACTIVATED SLUDGE PROCESS

- Better Quality Effluent: 98 % BOD removal efficiency. Sewage can be treated to reuse/recycle quality of TSS < 10 mg/l, COD < 100 ppm, BOD < 10 ppm, TN < 10 ppm, TP < 2 ppm in a single stage of treatment using Batch process.
- Bio-nutrient removal (BNR) : N & P removal
- Secondary clarifier not required, less foot print area
- Flexibility for efficient removal of BOD, TSS, N& P under all loading conditions.
- Automatically controlled by PLC . Based on process requirement, the aeration facility is optimized based on DO levels and by varying operating frequency of the blowers. Less power consumption.

.

SBR / CYCLIC ACTIVATED SLUDGE PROCESS

Advantages

- Controls growth of filamentous bacteria and avoids bulking of sludge.
- Provides stabilised sludge.
- Process with primary clarifier can generate power
- Allows for easy modular expansion for population growth
- **Disadvantages**
- Compared to the conventional ASP / MBBR /UASB, a higher level of sophistication and maintenance is associated due to automation

SBR GIVES HIGH PERFORMANCE WITH NUTRIENT REMOVAL

BOD < 5 ppm
TSS < 10 ppm
NH4-N< 1 ppm
TP < 1 ppm


Fully Automatic PLC operated

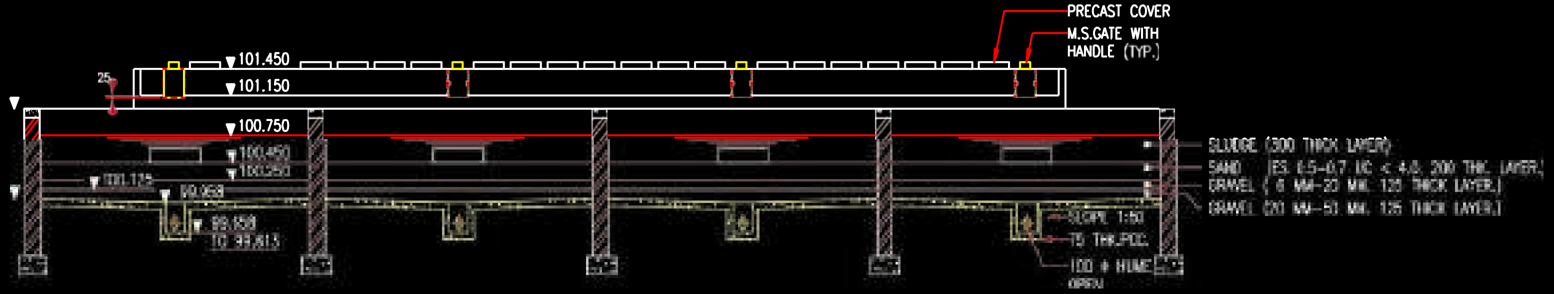
Plant Aesthetics


PUMP HOUSE
WET WELL

SLUDGE HANDLING – SLUDGE DRYING BEDS

- Objective : Dewatering of sludge
- Important Features
  - Conventional method of sludge drying
  - No power requirement
  - Substantial area is required
  - Difficult to operate in monsoon
  - Labour intensive
  - Manual scrapping and loading of dried sludge

SLUDGE DRYING BED



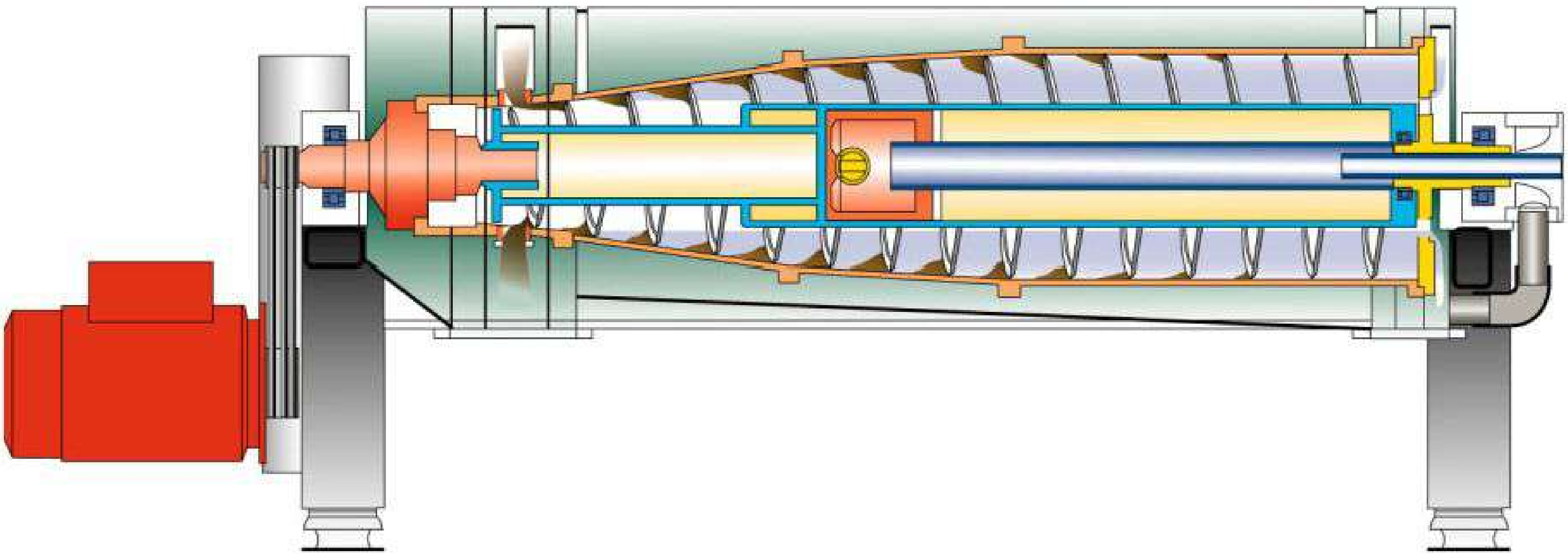
SLUDGE HANDLING – CENTRIFUGE

- Objective : Dewatering of sludge @ 95% of the BOD removed in Kg.
- Important Features
  - Advanced method of solid-liquid separation
  - Less area
  - Power required for pumping the sludge and operation of centrifuge
  - Less time
  - Efficient dewatering
- Design criteria
  - Inlet sludge solid consistency : min 0.8 to1%
  - Outlet sludge solid consistency : 20% expected
  - Polyelectrolyte dosing increases the efficiency

Centrifuge

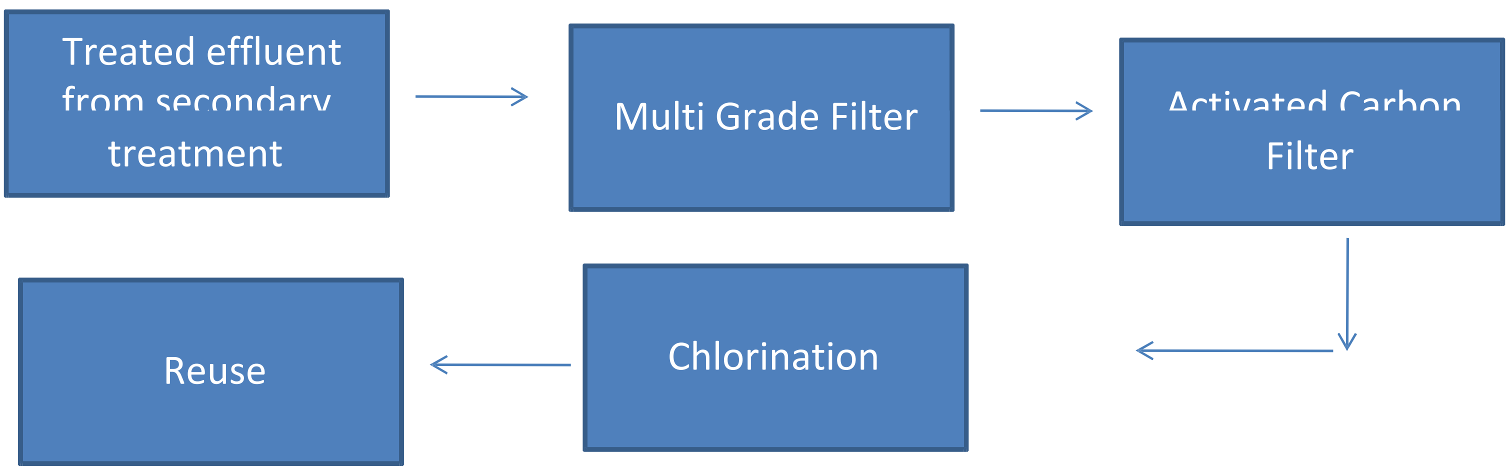
BELT PRESS

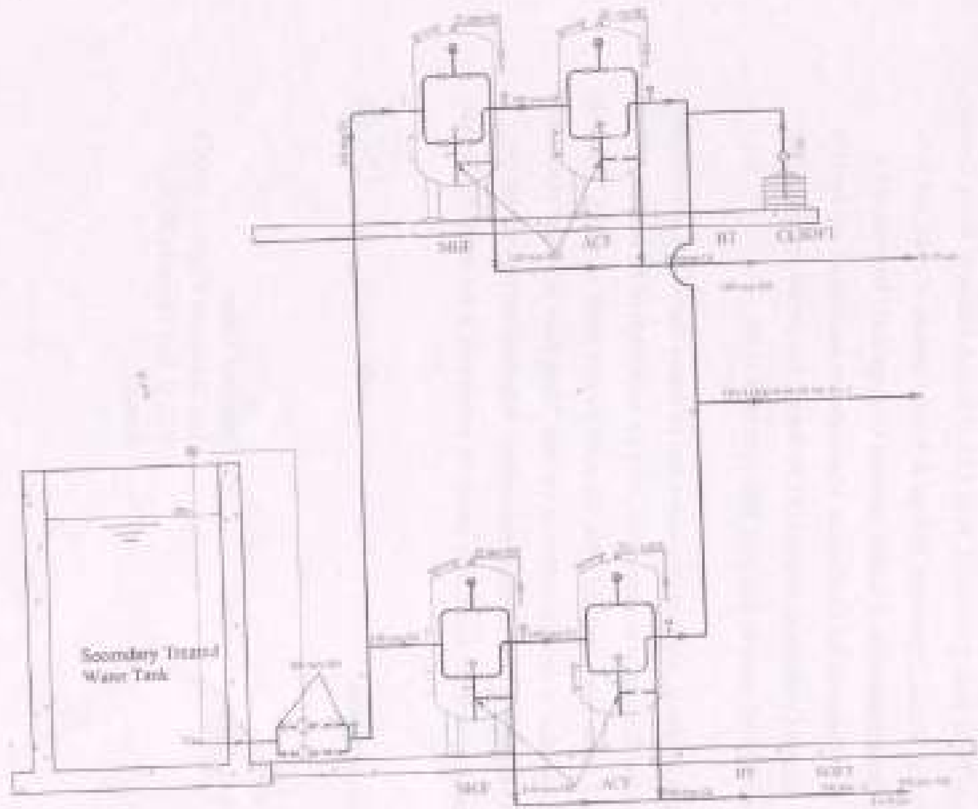
SOLID BOWL CENTRIFUGE



Tertiary Treatment

It is supplementary to primary and secondary treatment for the purpose of removing the residual organic and inorganic substances for reuse of effluent for the purposes of cooling systems, boiler feed, process water etc.





Legend

Mark	Description
	Effluent Line
	Wash Line
	Butterfly Valve
	Non Return Valve
	Pressure Gauge
	Pressure Switch
	Pump
	Air Blower
	Ball valve
	High Level
	Low Level
	Sampling Point

List of Electromechanical Unit

Mark	Description	Motor	Capacity	Quantity
MGF	Multigrade Filter	[illegible]	30000 LPH	2 Nos
ACF	Activated Carbon Filter	[illegible]	30000 LPH	2 Nos
BT	Brine Tank	[illegible]	–	2 Nos
[illegible]	Softener	[illegible]	30000 LPH	2 Nos
	Chlorine Dosing	[illegible]	2x4 LPH	2 Nos

CHLORINATION

- Objective : Disinfection of wastewater to kill pathogens
- Important Features
  - Simple & widely used method of disinfection
  - Used for wastewater treatment
- Design criteria :
  - Types : Dosing chemicals – Sodium hypochlorite
    Vacuum Chlorination – Chlorine gas
  - Contact time : 30 min
  - Dosage after wastewater treatment
    Activated sludge : 3 – 5 mg/l

Chlorine Contact Tank

Chlorine is a Hazardous chemical requiring adequate safety while handling

1. Chlorine leak detector
2. Chlorine absorption system
3. Personal safety eqpt .– mask etc.
4. Safety shower
5. Statutory records

OTHER OPTIONS FOR DISINFECTION

- Chlorine produces carcinogenic disinfection byproducts that are harmful to human and aquatic life.

- It is banned in developed countries.

- Still used in India as it is cheap

- Other options are;
  - Ultra Violet (UV) - like Aquaguard
  - Ozone

ESSENTIALS FOR FULFILLMENT

- DUTY - saturated with LOVE to your fellow beings - Transforms into ***Service***
- LEAD - inspire your associates to make your Goal their Goal
- TEAM work-Together Everyone Achieves More
- TRUST – Learn - Share
- EMPOWER - by Building Human Capacities
- PERSEVERE - Persist - Monitor
- APPRECIATE - Good Performance
- THANK - all stakeholders

RECAP

- Sewerage system comprises sewerage, pumping stations, STPS etc.
- It is important to consider the location, context, existing system and the capacity of the town to operate and maintain the system before selecting the sewerage or sewage treatment technology.
- CPHEEO manual on sewerage and sewage treatment also covers Small Bore Sewerage and Simplified Sewerage system of design.
- Adopting alternative sewerage design results in lower costs & speedy execution.
- Adopting decentralized, low cost low O&M technologies (DEWATS, SBT, Phytorid etc.) make the systems easy to execute & maintain.
- TEAM work alone will help us achieve our Goals & lead to success & fulfillment.
- LOVING is LIVING.

Do you want to make a

Difference

to ***Yourself*** & to your ***People?***

APPO DEEPO BHAVA!

(Be a Light unto thyself – The Buddha)

Thank You

for a

patient listening