Training Course on

Service Delivery/Functionality of FHTCs

Organized by Dr. R. S. Tolia Uttarakhand Academy of Administration, Nainital

Grey Water Management

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जलविज्ञान संस्थान
आपो हि ष्ठा मयोभुवः

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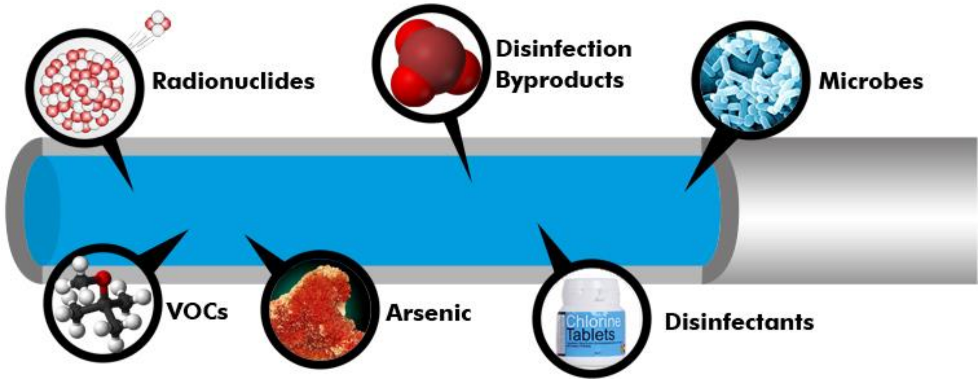
Contaminant & Pollutant



"A contaminant is input of alien and potentially toxic substance into the environment."

"A pollutant is an anthropogenically introduced substance that have harmful effects on the environment."

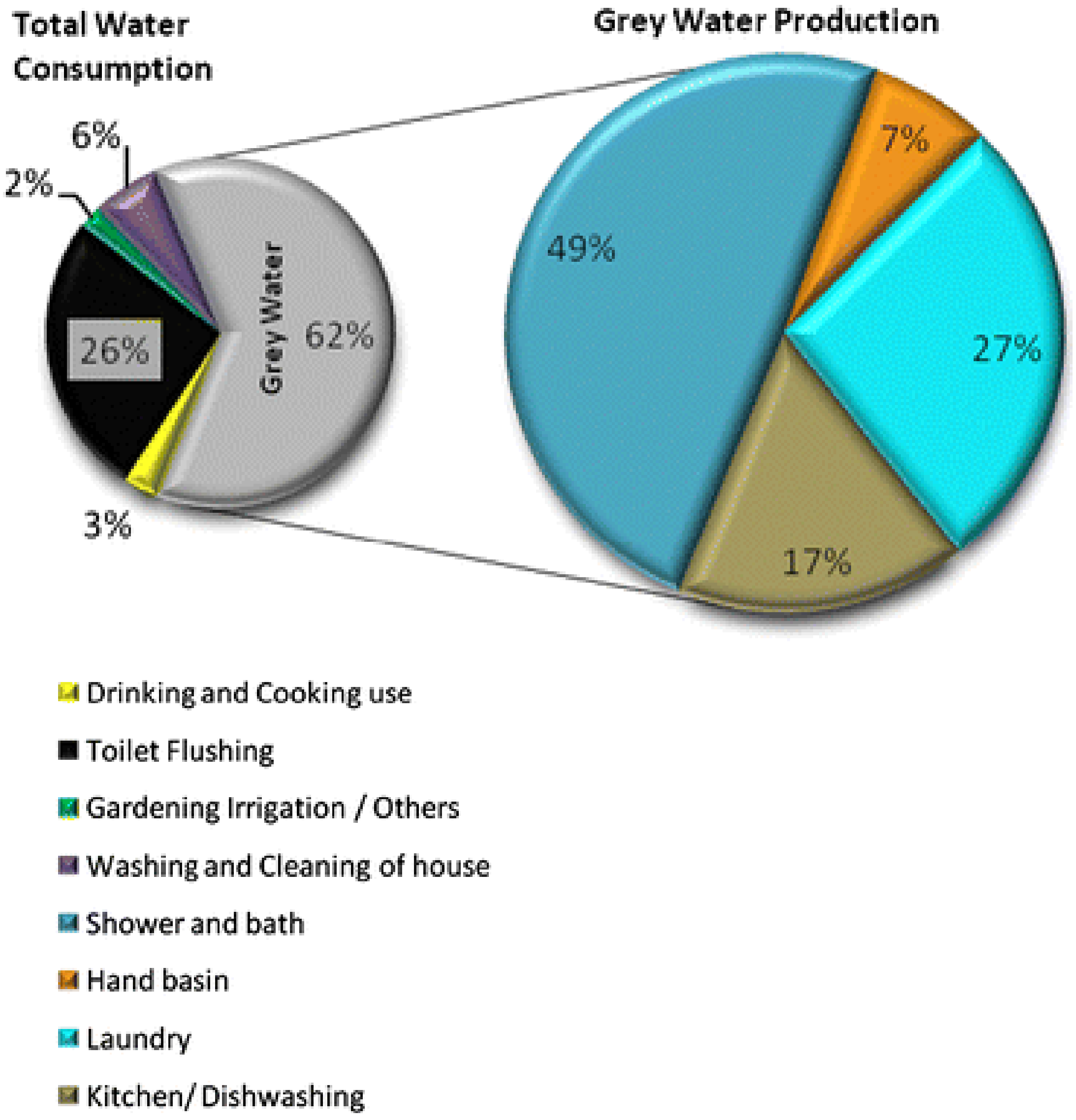
Contaminant ⟷ Pollutant

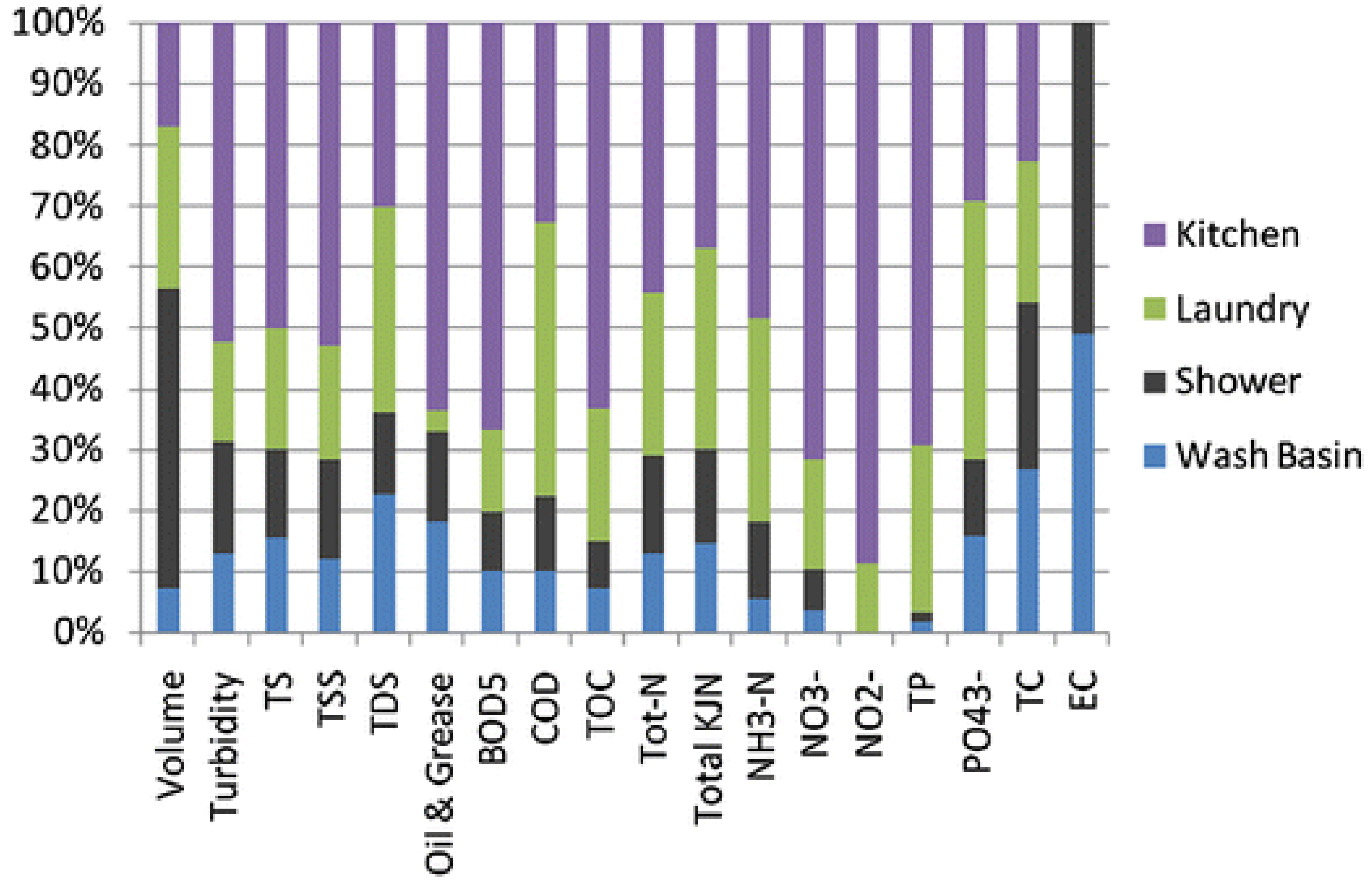
Pollution

"Pollution means the introduction by man, directly or indirectly, of substances or energy into the environment resulting the deleterious effects of such nature as to endanger human health, harm living resources or interfere with amenities or other legitimate use of the environment."

Domestic Wastewater

Domestic Water Consumption & Greywater Production





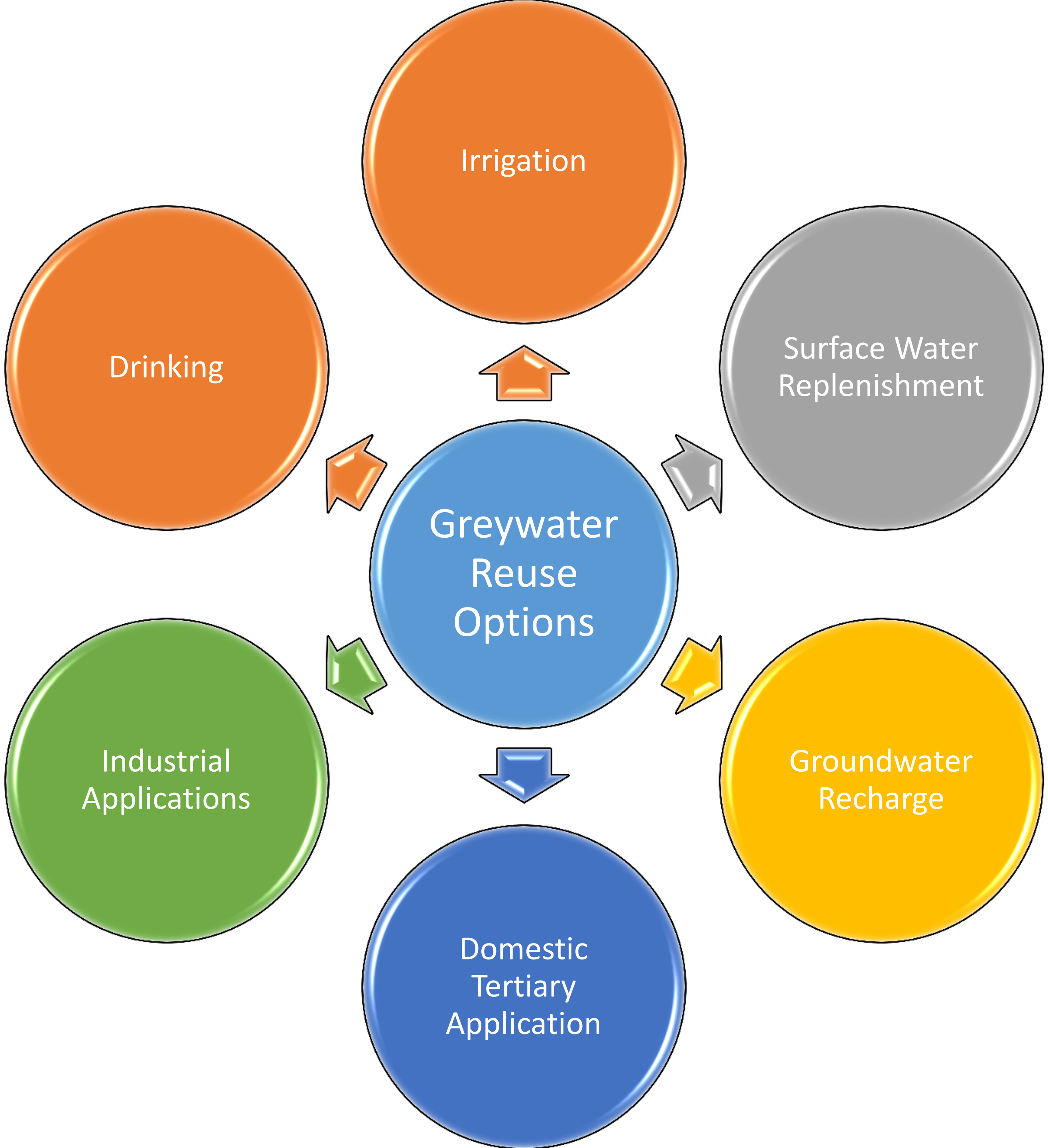
Source: Edwin et al. (2014), Appl Water Sci 4, 39–49

Constituents of Domestic Wastewater

Pollutant	Concentration (mg/l)			
	Raw Sewage			Greywater
	Weak	Average	Strong	Range
Total Solids	350	800	1200	--
Total Suspended Solids	100	240	350	40-340
Alkalinity as $CaCO_3$	50	100	250	100-500
Ammonia Nitrogen	10	20	35	1-26
Total Nitrogen	20	35	80	4-74
Phosphorus	5	10	15	4-14
Oil & Grease	50	100	150	50-150
5-day BOD	120	225	400	45-330
Chemical Oxygen Demand	175	325	575	100-375
Total Organic Carbon	65	125	220	--

Source: Water Quality Control Handbook, McGraw Hill Companies Inc., USA

Impact of Pollutants on Water Resources


Irrigation
Drinking
Surface Water Replenishment
Greywater Reuse Options
Industrial Applications
Groundwater Recharge
Domestic Tertiary Application


NEWater
A PRODUCT OF PUB

Water Scenario Projection in India

- **Total Precipitation including snowfall = 4 000 BCM**

- **Average annual water resource potential of the country = 1869 BCM**
  (after accounting for losses due to evaporation etc.)

- **Utilizable water = 1123 BCM (690 BCM SW + 433 BCM GW)**
  (due to topographical and hydrological constraints)

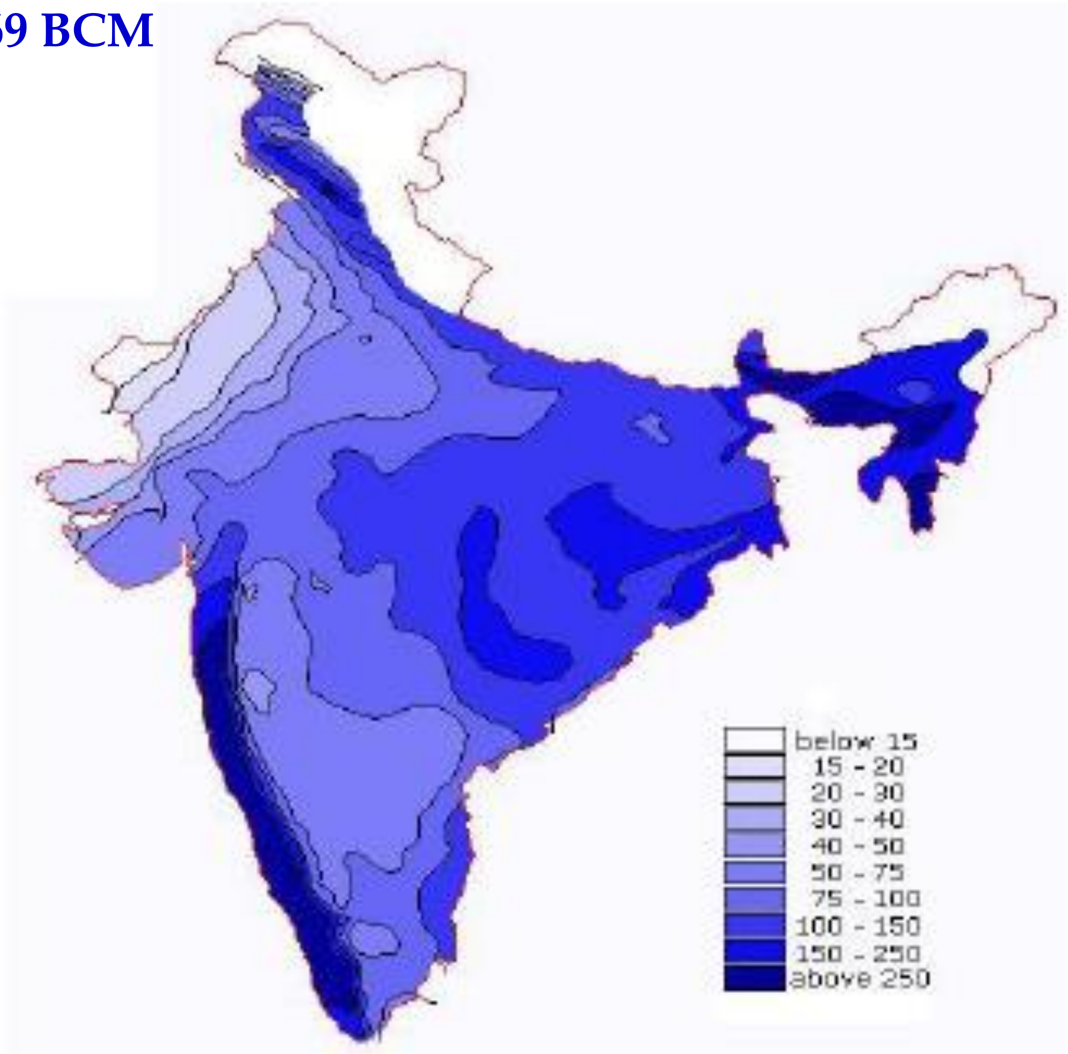
NET SOWN AREA

- **Lower rainfall zone (<750 mm) = 33%**

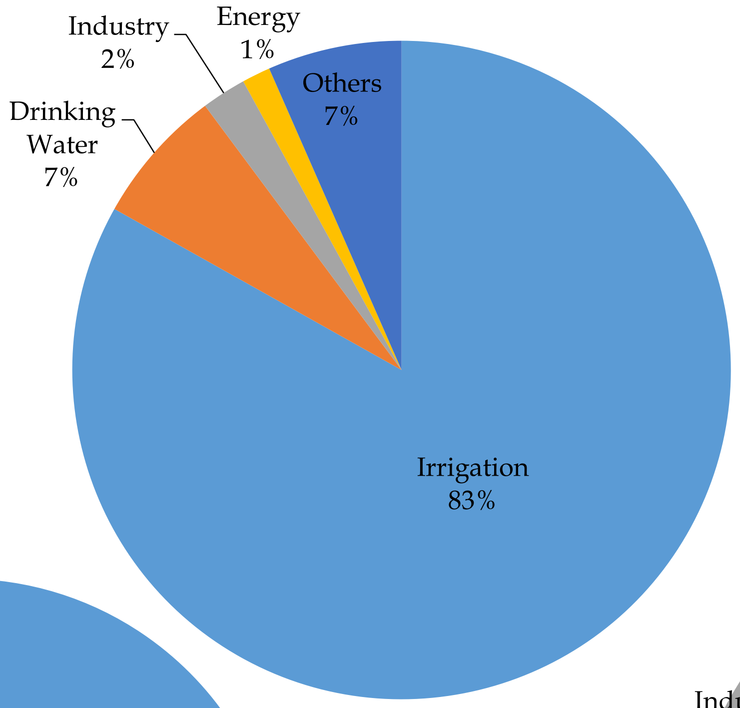
- **Medium rainfall zone (750-1125 mm) = 35%**

- **High rainfall zone (1125-2000 mm) = 25%**

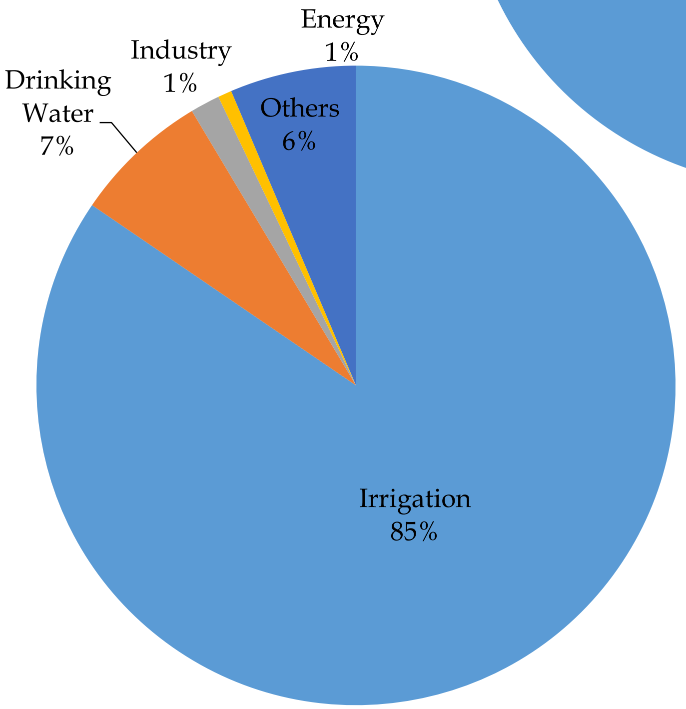
- **Very high rainfall zone (> 2000 mm) = 8%**



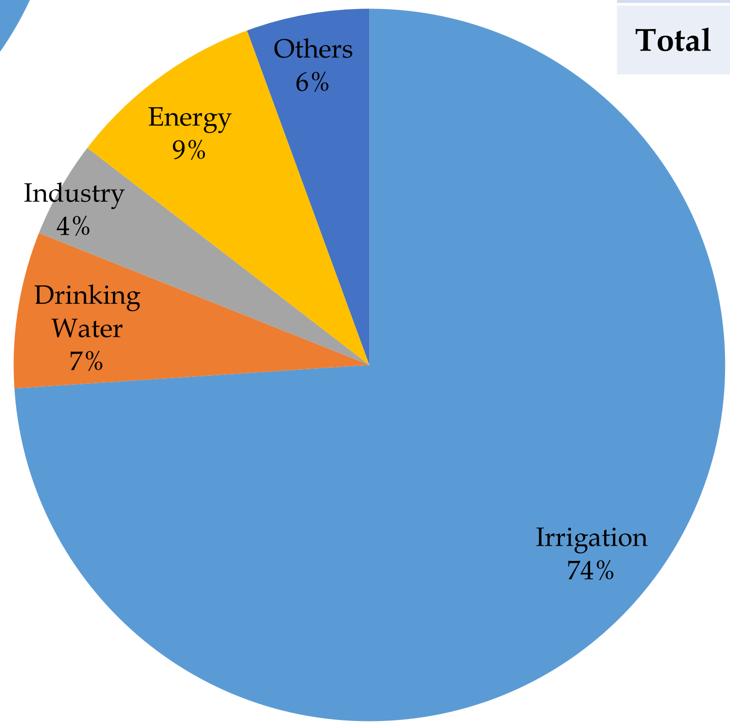
Fresh Water Requirement – Indian Scenario



2025



2010



2050

Sector	2010	2025	2050
Irrigation	688	910	1072
Drinking Water	56	73	102
Industry	12	23	63
Energy	5	15	130
Others	52	72	80
Total	**813**	**1093**	**1447**

Per Capita Water Availability

- India has only 4 % of average annual rainfall but 16 % of world population.
- Water

2011	1210	[illegible]	928
2019	1362	1372	825
2025 (Proj	[illegible]	[illegible]	769

From where this excess demand can be meet out ????????

Wastewater Recycling

- r scarce ement
- Present u storage capacity)
- Extra storage capacity requirement ????

Compulsions of Treating Effluents

- **To satisfy Discharge Norms**
- **Water Shortage – Recycle / Reuse effluents**
- **Zero Discharge**
- **Environmental Awareness**

Technical Options for Greywater Management

Technology

On site

Household

- Soak pit
- Leach pit
- Magic pit
- Kitchen garden

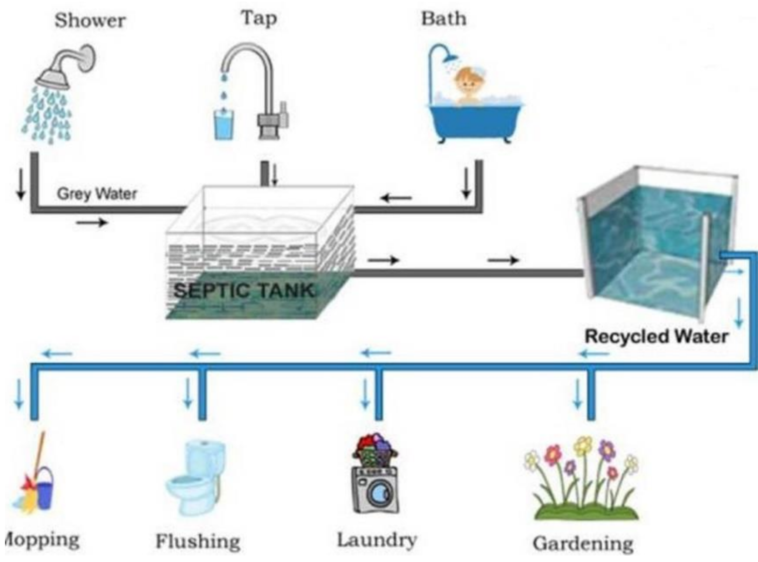
Community

- Community Soak pit
- Community Leach pit
- Community level wet land
- Community Kitchen garden

Off site

Village

- Small Bore System (Conveyance system)
- Waste Stablisation Ponds
- Duck Weed Pond System
- Constructed Wetland
- Soil Bio Technology (SBT)
- Phytorid Technology
- Anaerobic Baffled Reactor (ABR)
- Moving Bed Bio-Film Reactor (MBBR)



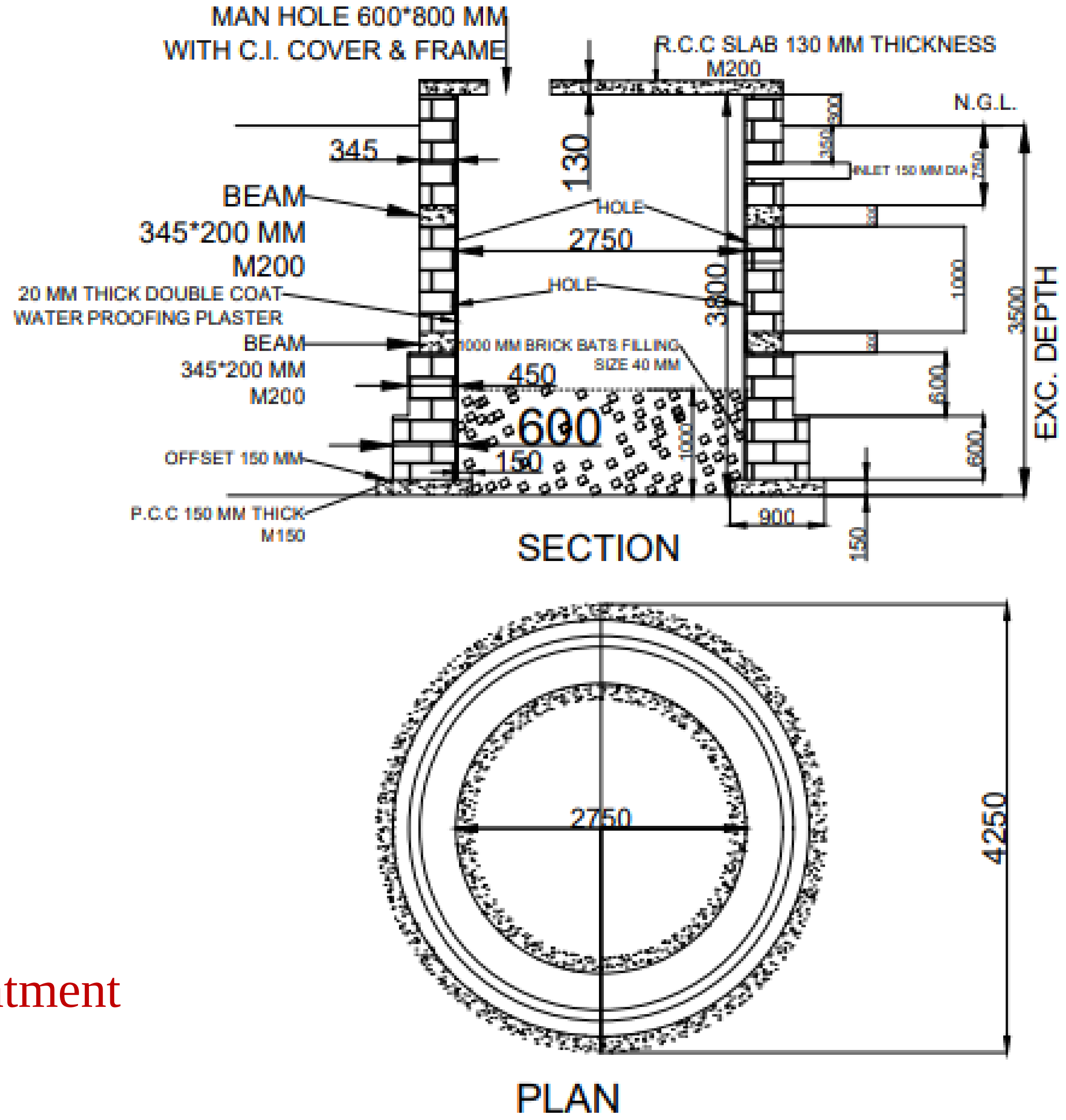
Source: https://sujal-swachhsangraha.gov.in/sites/default/files/Grey_water_Management_Resource_Book_GoI.pdf

Soak Pit

- Depth: 2-4 m
- Diameter: >0.9 m
- Detention time: ≈12 hrs
- Distance from DW Source: >30 m
- Distance from GW table: >2 m

Disadvantages

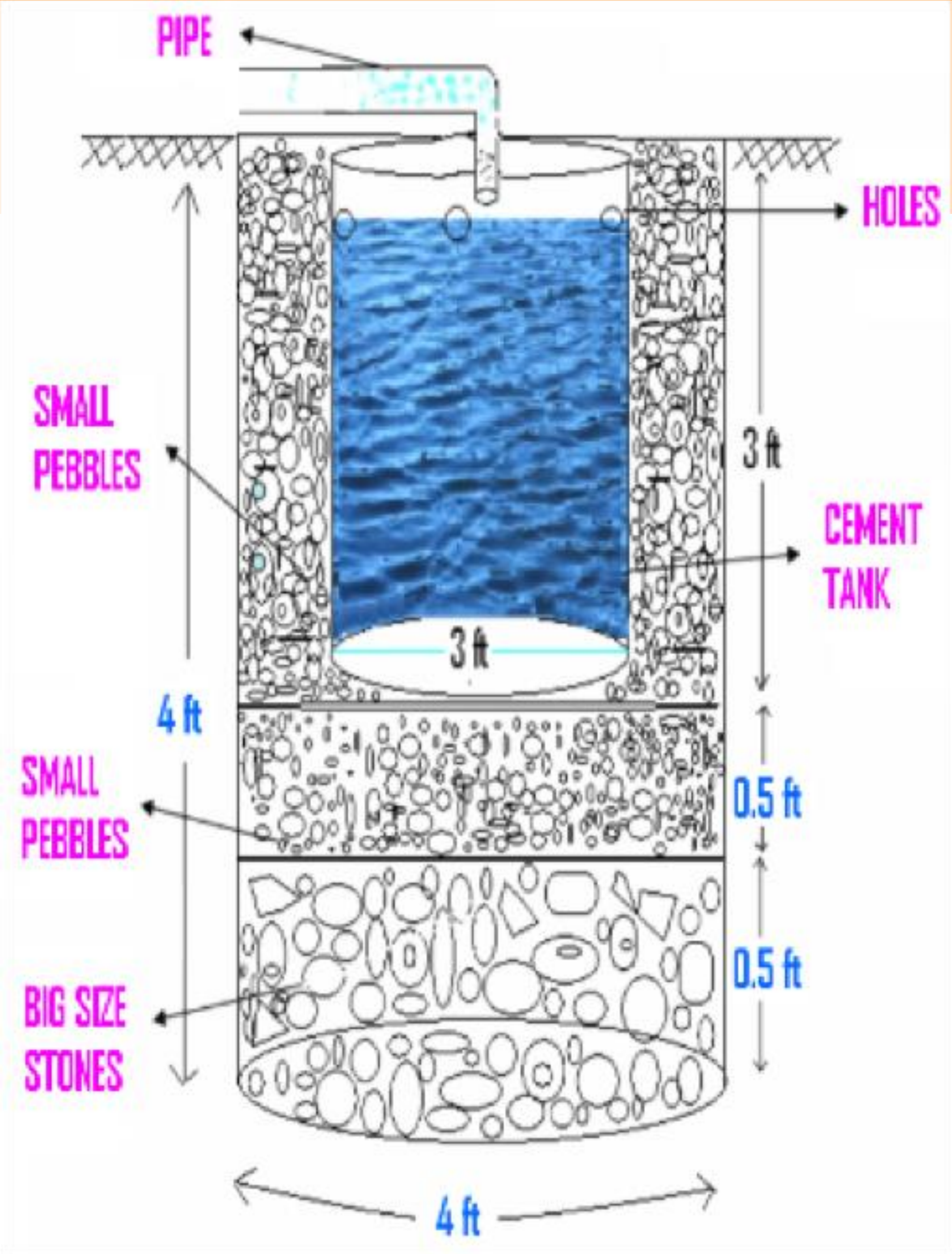
- Not suitable for flood areas / cold regions
- Not suitable for clay soil
- Clogs frequently in absence of primary treatment
- Can affect groundwater



Magic Soak Pit

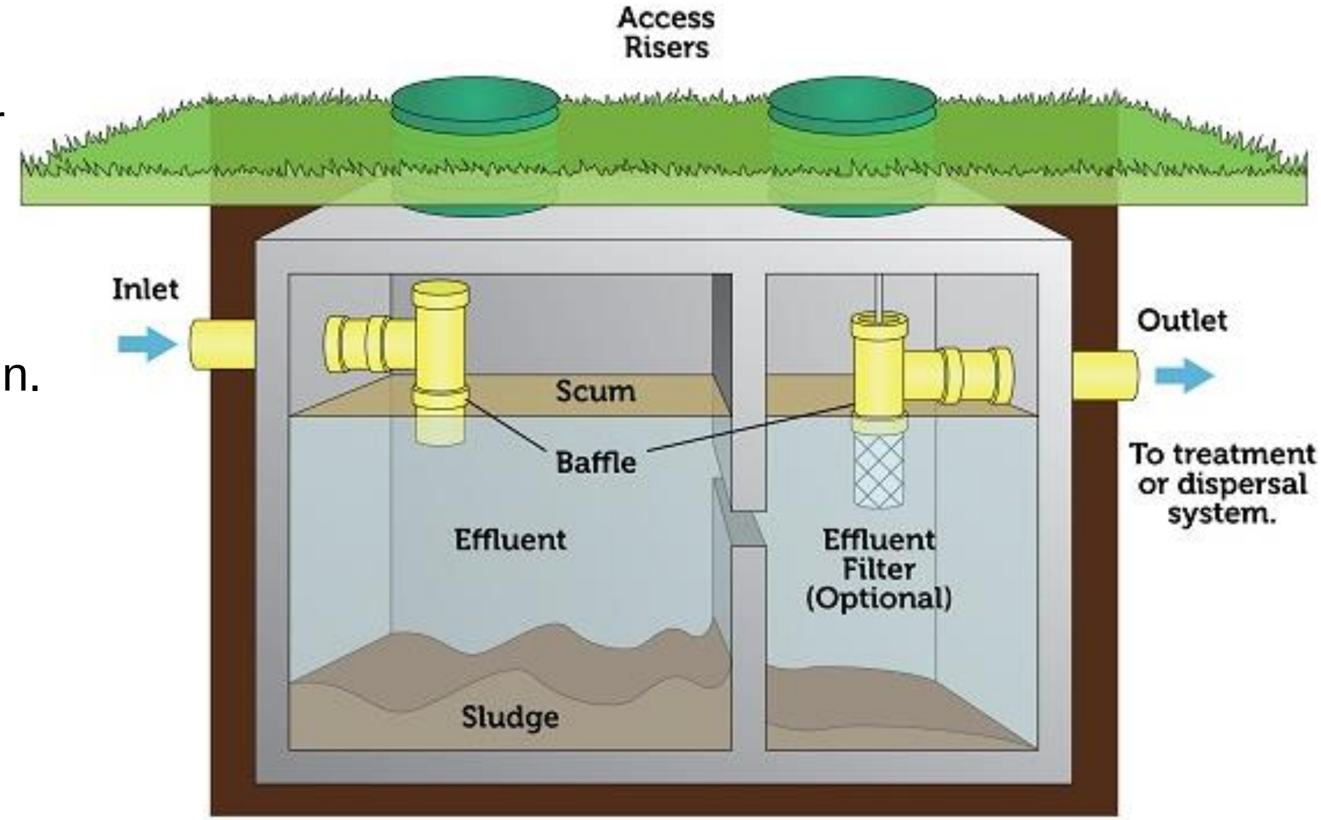
Soak Pit with Concrete Tank in the Centre

- Depth: 1.2-2 m
- Gravels and Pebbles: 0.8-1 m
- Concrete tank: 0.5-1 m depth & 0.3-0.5 m dia



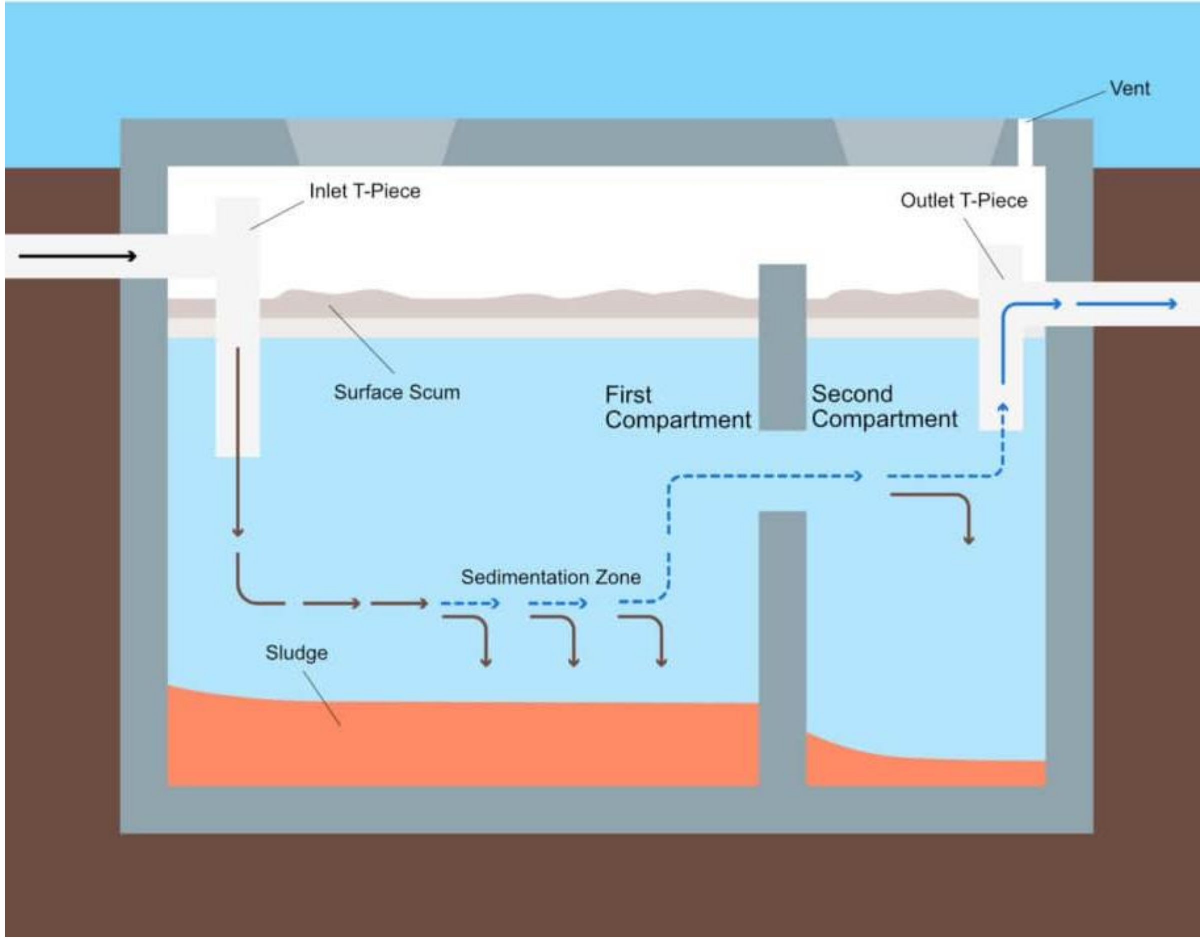
Septic Tank

- A septic tanks is an underground watertight chamber (generally rectangular, sometimes round) made out of brick work, concrete, fiberglass, PVC or plastic.
- They are used as primary wastewater treatment unit for the on-site treatment of greywater or biodegradable industrial wastewater.
- Solids settle to bottom of the tank where the organic fraction of the solids are reduced via anaerobic digestion.
- A baffle retains the settled solids. The only moderate treated liquid (supernatant) flows out of the tank on the opposite site of the inlet and is either infiltrated into the soil (through a soak pit, leach field or mound) or transported via a simplified sewer system to a (semi-) centralized treatment facility.
- One every few years, the accumulated sludge in the bottom of the chamber needs to be disposed correctly.



Working of Septic Tank

- The **solids settle** to the ground while scum (oil and fat) floats to the top and liquid flows through (*Physical Treatment*).
- Anaerobic microorganism living in the bottom sludge start to degrade the organic fraction of the wastes, transforming it into methane (CH_4), carbon dioxide (CO_2), hydrogen (H), nitrogen (N) and hydro sulphide (H_2S) = ***Biogas***. This process is called **anaerobic digestion** (*Biological Treatment*).
- Ventilation is necessary if biogas is not recovered.



- The **settling capacity of the solids depends on the wastewater flow**. A rather slow flow will settle better. But a turbulent flow will increase the contact of the new sludge with the microorganism responsible for degradation.

Design of Septic Tank

- Minimal two compartments**: one settling chamber, and the following to calm the turbulent liquid**.
- A **baffle** between the chambers to prevents scum and solids from escaping the settling chamber.
- A **T-shaped outlet pipe** (30 cm below water level), will further reduce the scum and solids that are discharged (SASSE 1998)
- If only two chambers, the first one should be **2/3 of the total length** (TILLEY et al. 2008)
- Chamber depth of 1.5 to 2.5; sometimes the first chamber is made deeper for higher sludge retention volume.
- Hydraulic Retention Times **(HRT) of about 24 to 48 hours** (MOREL & DIENER 2006; TILLEY et al. 2008) plus solid storage volume equivalent to 1/3-1/2 of HRT.
- Sludge Retention Time **(SRT) of several years**.
- Sludge production depends on number of users and portion of settable solids, average annual temperature, desludging intervals etc.
- **80 to 100 L of volume should be considered per domestic user** (SASSE 1998)

Septic Tank: Health Aspects

- Effluent from septic tanks can **contain pathogens**. (WHO 1992)
- Since there is no way of differentiating between freshly added excreta and excreta in the tank, the septic tank sludge must be considered as **microbiologically contaminated**. (WHO 2006, Vol. III)
- Direct reuse of effluent is not to be considered.
- **Underground infiltration** of effluent is recommended.
- Sludge should be stored minimal four weeks before reuse. (WHO 2006, Vol. III)
- **Aerobic composting of sludge** before use to reduce health risk.
- Care should be taken during operation and maintenance interventions (prevent contact with sludge and effluent).

Septic Tank: Operation & Maintenance

- Start-up: Seeding (inoculation) is required.
- No harsh chemicals should be introduced into the tank as this could kill the microorganisms.
- De-sludging is needed when 1/2 to 2/3 of depth (between the water level and the bottom of the tank) are occupied by sludge and scum (WHO 1992)
- Desludging is required every 1 to 5 years.
- Desludging can be done manual (with a gulper) or mechanized.
- Some sludge must be left in the tank to maintain the microorganism responsible for anaerobic digestion.
- Emptied sludge must be treated by composting, further anaerobic digestion, waste stabilization ponds, constructed wetlands, or drying beds.

Centralized Greywater Treatment

Factors Deciding Plant Configuration

Factor	Effect
Flow	• Decide equipment sizing
Constituents	• Decide physical, chemical, or biological mode of treatment
Variability of flow and the constituents	• Decides the need for equalization & size of equalization tank
Final point of discharge / final fate of effluent	• Polishing / tertiary treatment of effluent
Capital Cost V/s Operating Cost	• Decides type of equipment
Availability of land	• Decides equipment

Pollutants & Treatment Units

Pollutant	Treatment Unit
Floating Matter	• Screens
Grit	• Grit Chambers
Oil & Grease	• Oil & Grease Traps
Flow & Constituents	• Equalization
Toxic Substances	• Suitable Treatment
Acidity / Alkalinity	• Neutralization
Heavy Metals	• Precipitation
Suspended Solids	• Sedimentation (Clarifiers)
BOD/COD	• Biological Treatment
Dissolved Solids	• Membrane Processes

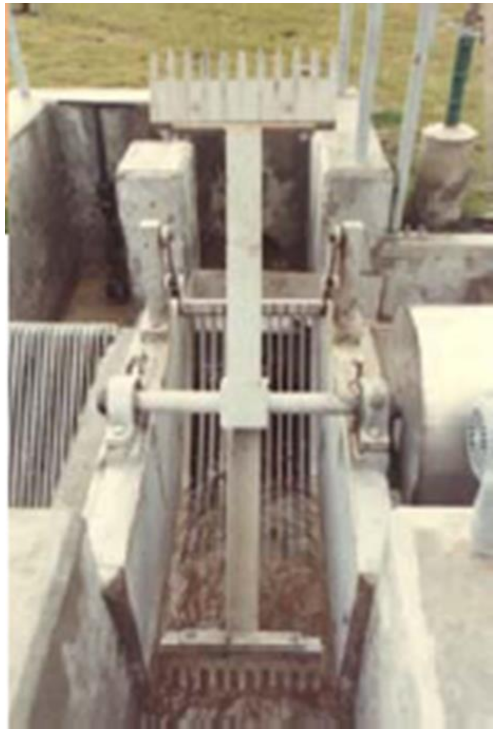
Screens – For Floating & Big size particles

Bar Screen
> 15 mm

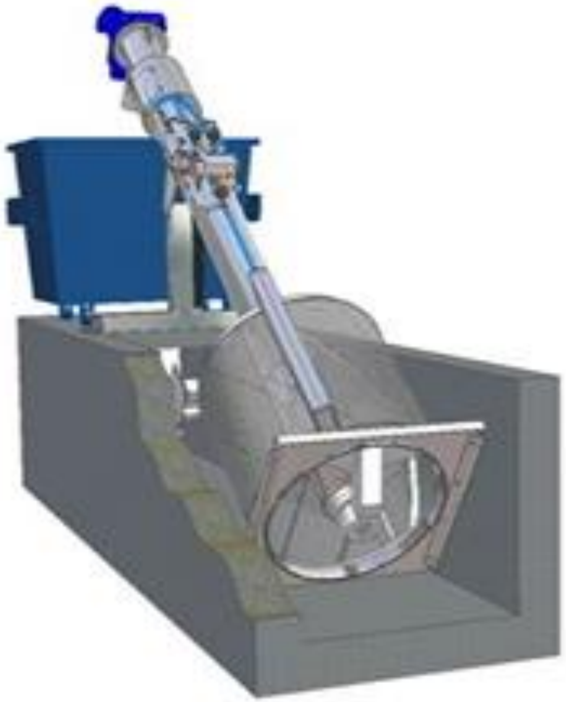
Coarse Screen
< 15 mm

Fine Screen
< 3 mm

Ultra Fine Screen
< 2 mm

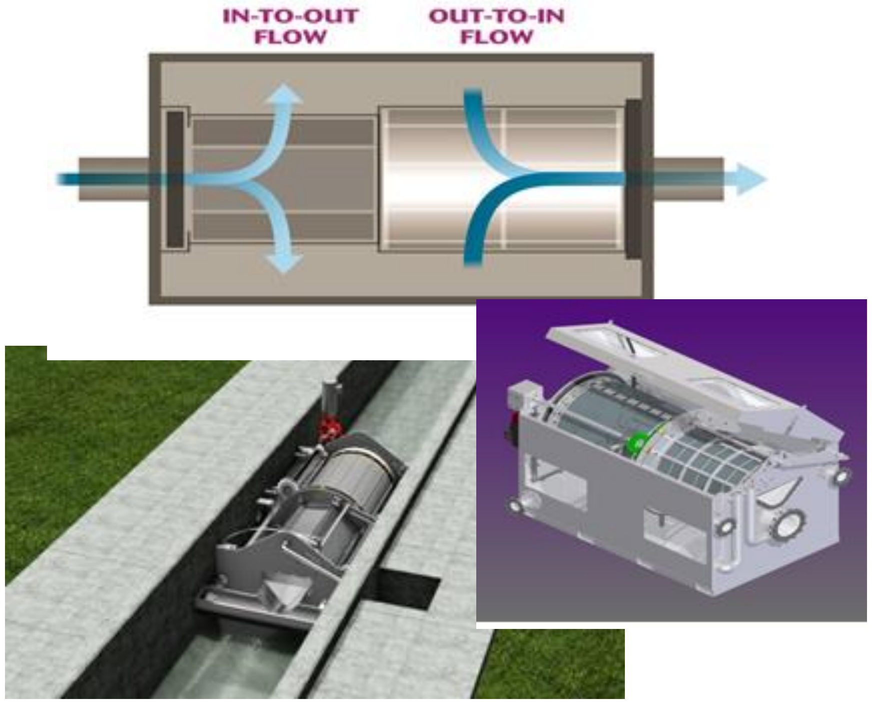


Arc Bar Screen



Rotational drum screens

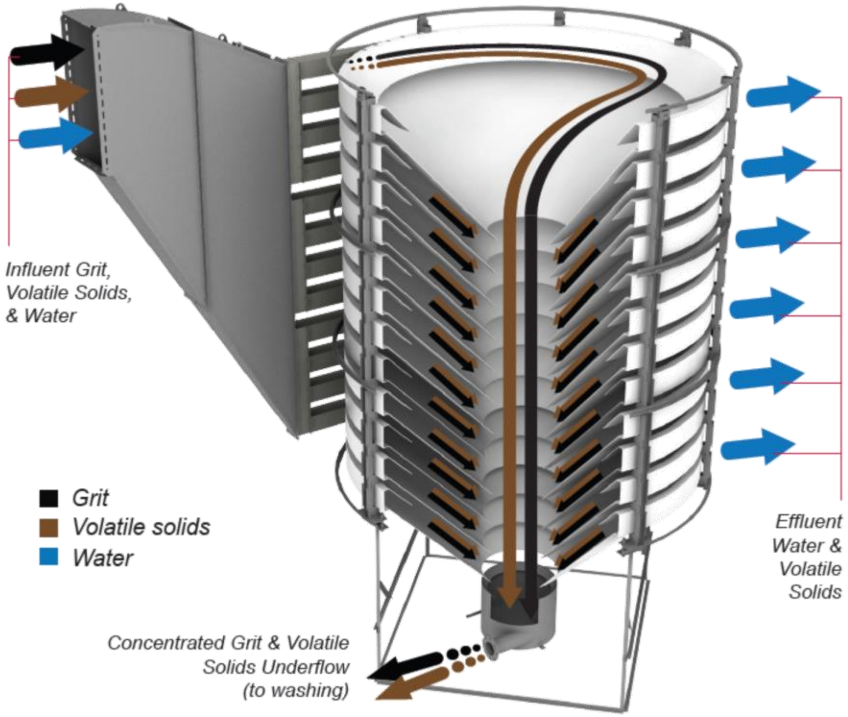
Step (Escalator) Screen



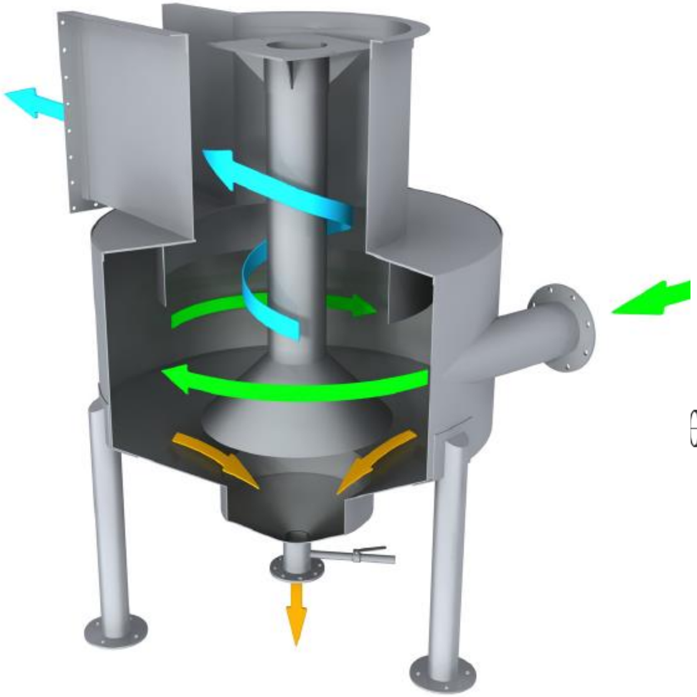
Dual Aperture Screen

Grit Chamber – For Grits (Sp. Gravity 1.3 – 2.7 g/cm^3)

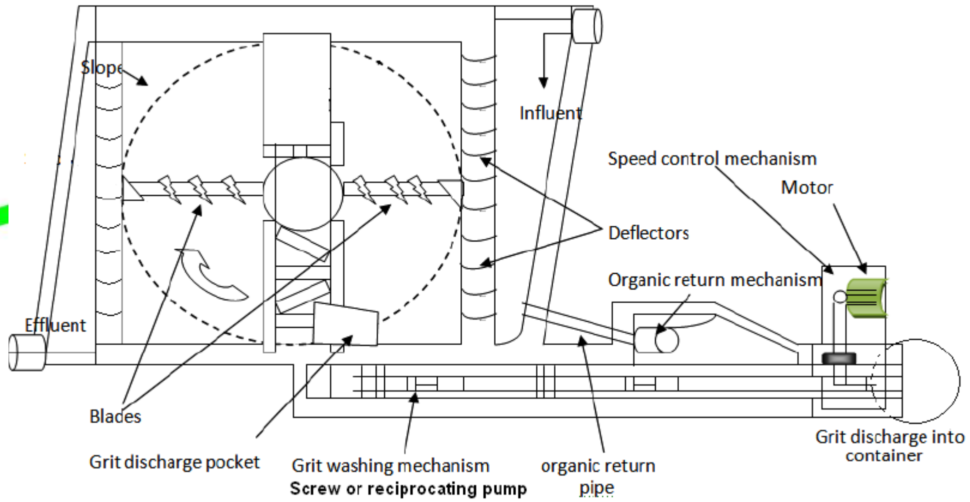
Avoid Clogging → **Abrasion Damage** → **Reduce Efficiency** → **Increased Cleaning & Maintenance**



Head Cell



Grit King



Square Horizontal Flow

Oil & Grease Traps – For Free & Emulsified Oil

Equipments for removal of Free Floating Oil

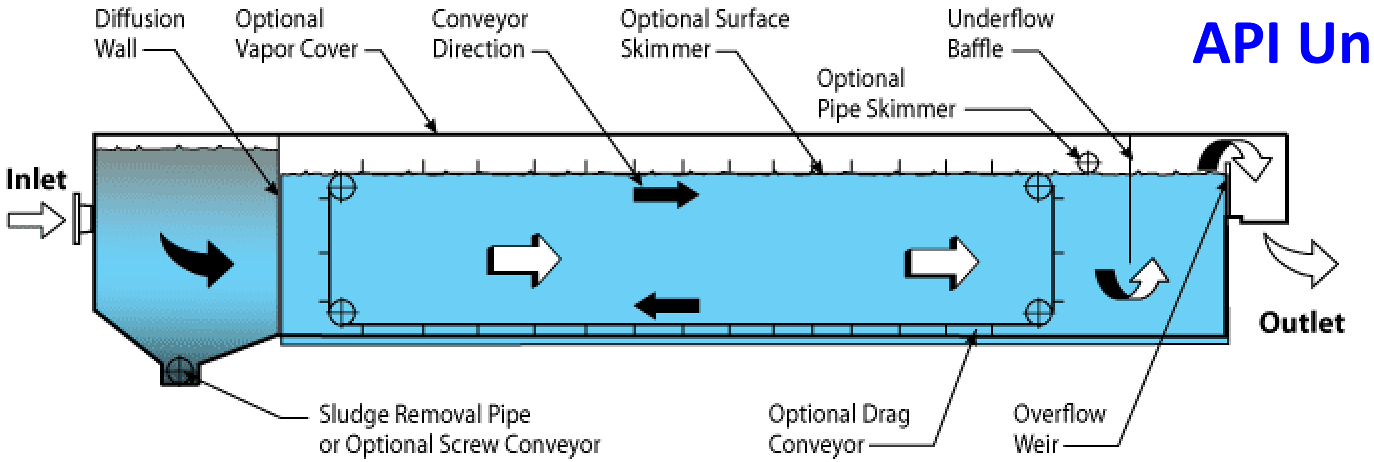
- Oil & grease traps
- API Separator
- Parallel / tilted plate interceptor separator
- Corrugated Plate Separator
- Oleophilic Skimmers (Disc , Drum and Belt)

Equipments/processes for removal of Emulsified or Dispersed Oil

- Acid Splitting
- Chemical Coagulation
- Dissolved Air Floatation
- Coalescer
- Bio - Oxidation
- Membrane Separation (for Stable emulsions only)

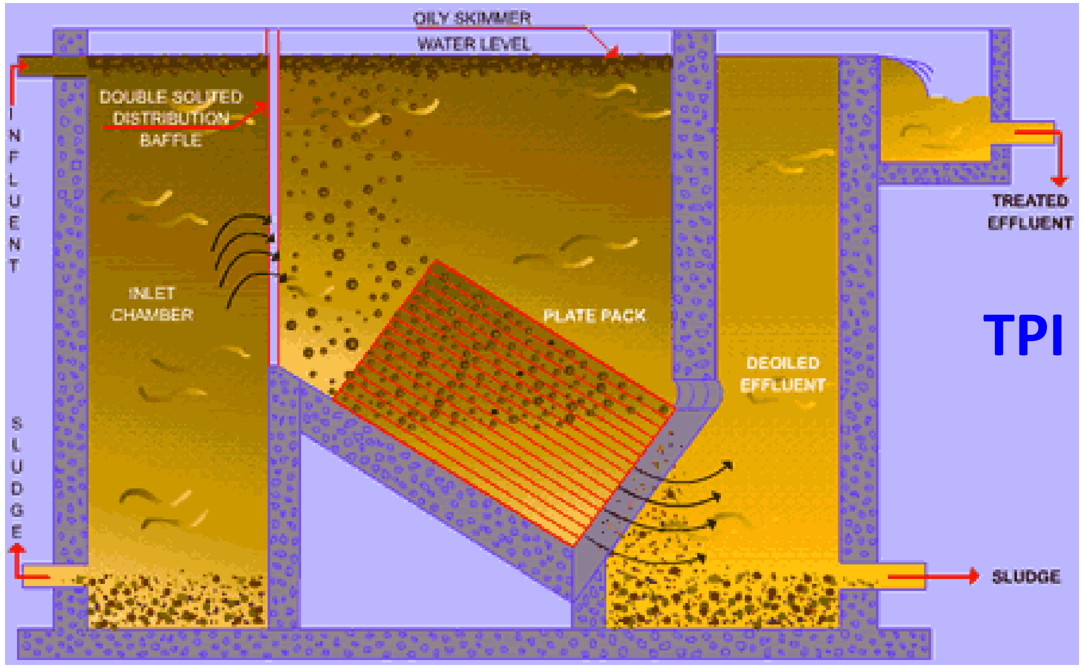
Oil & Grease Traps – Free Oil

API Unit



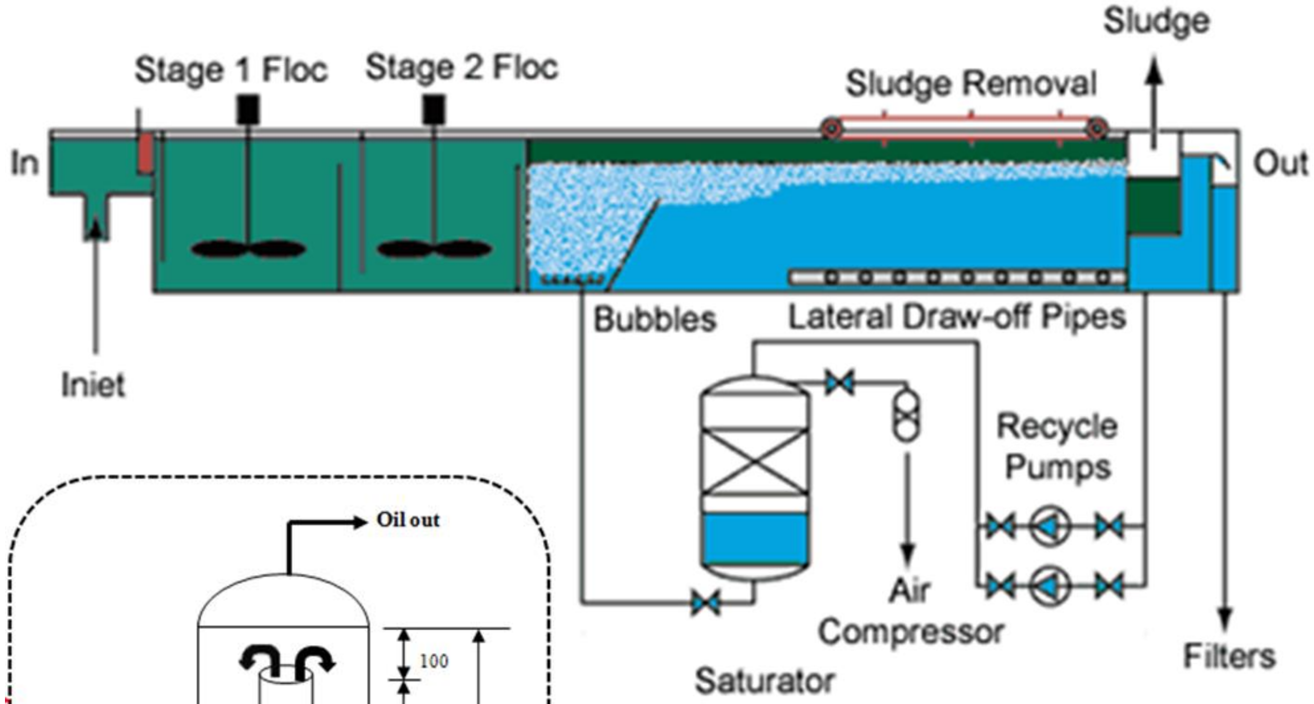
Belt Skimmer

TPI Unit

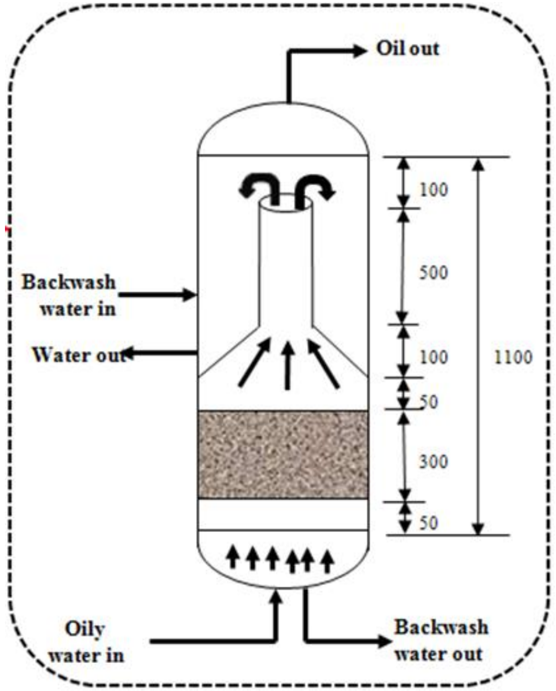


Drum Skimmer

Oil & Grease Traps – Emulsified Oil



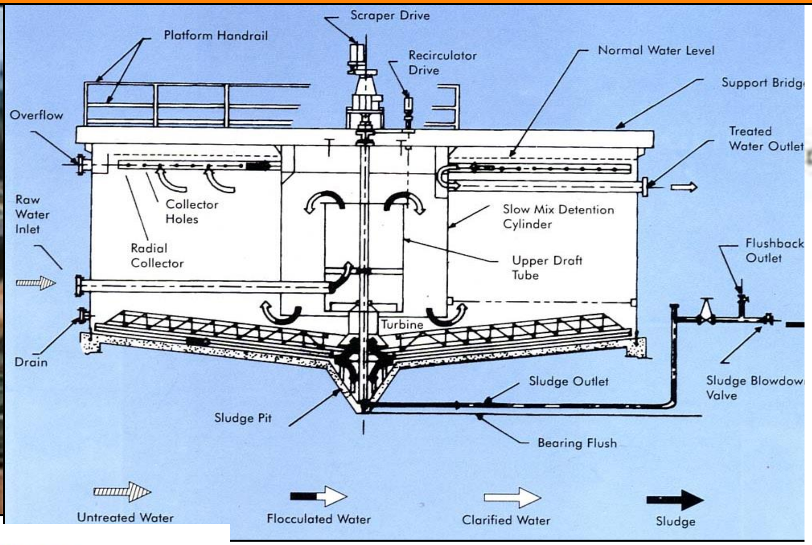
Dissolved Air Floatation Unit

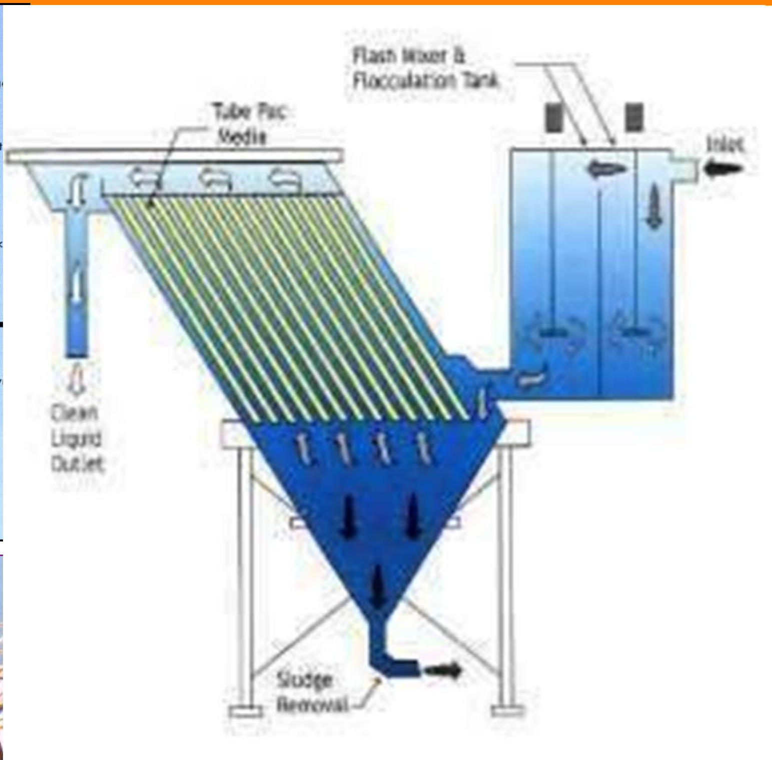


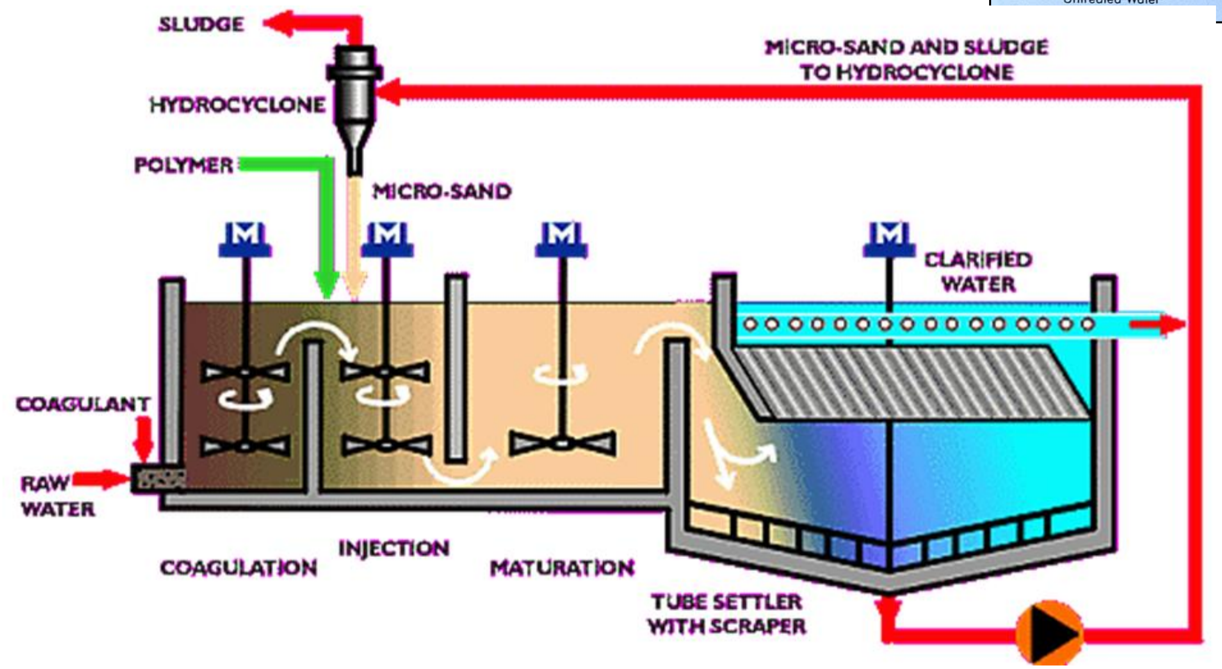
Oil Coalescer

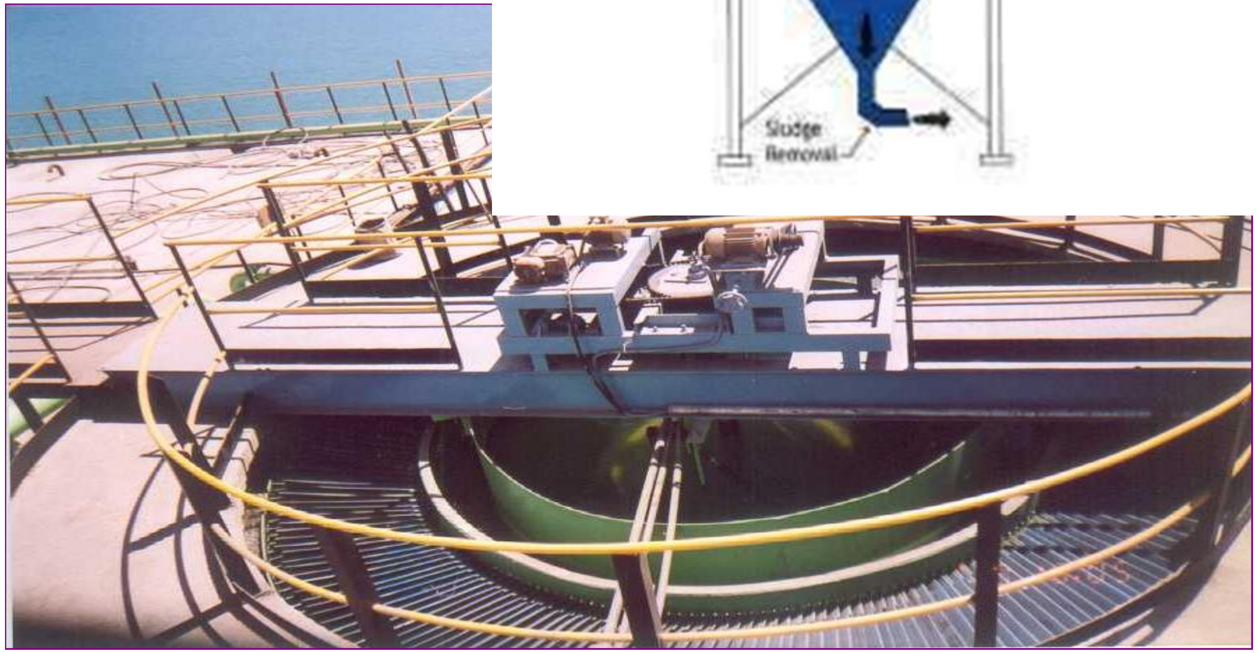
Ceramic Tubular Membranes

Clarifier– Suspended solids & Precipitate removal



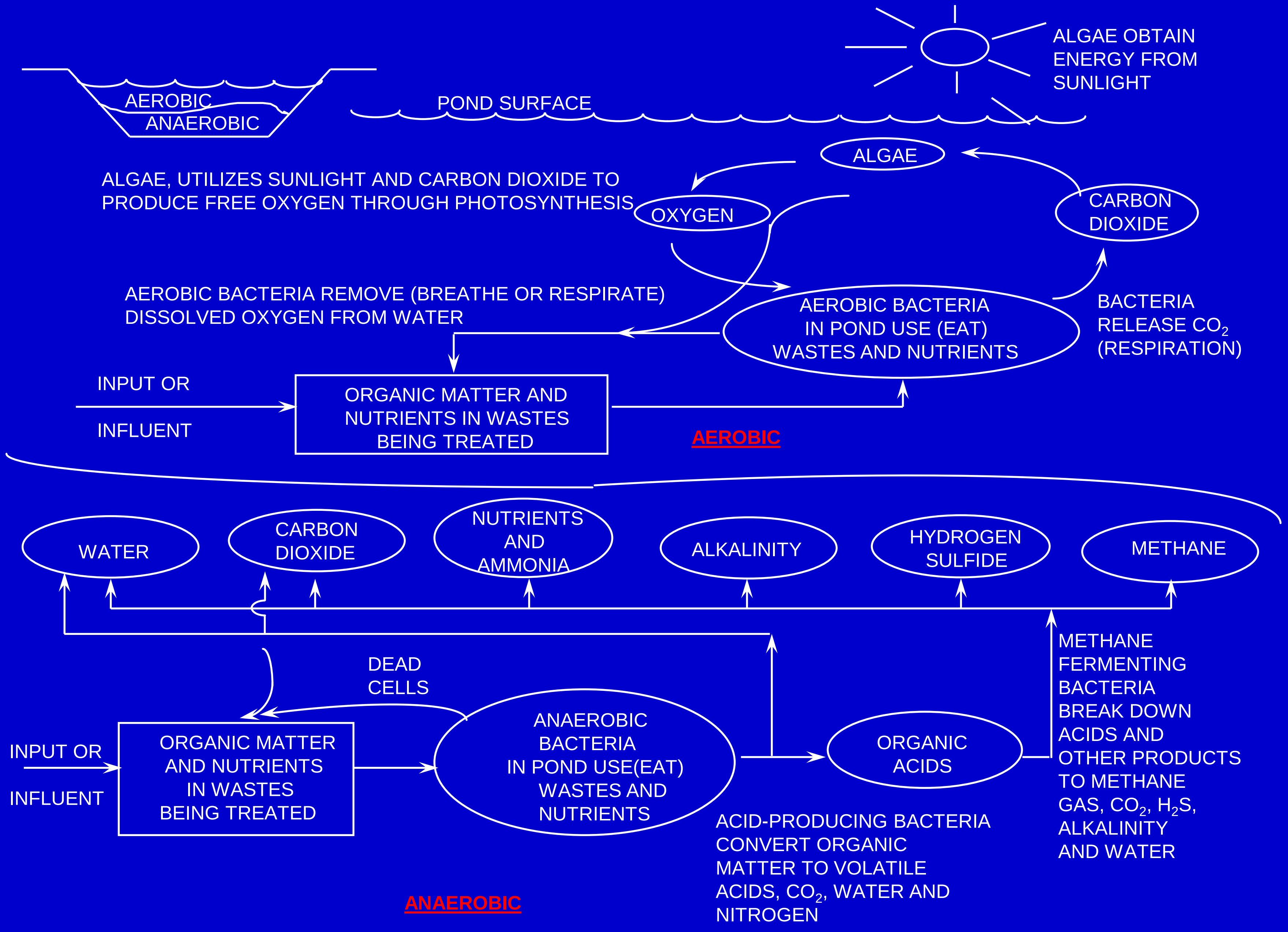






BIOLOGICAL TREATMENT OF WASTEWATER

NATURAL TREATMENT OF POLLUTANTS

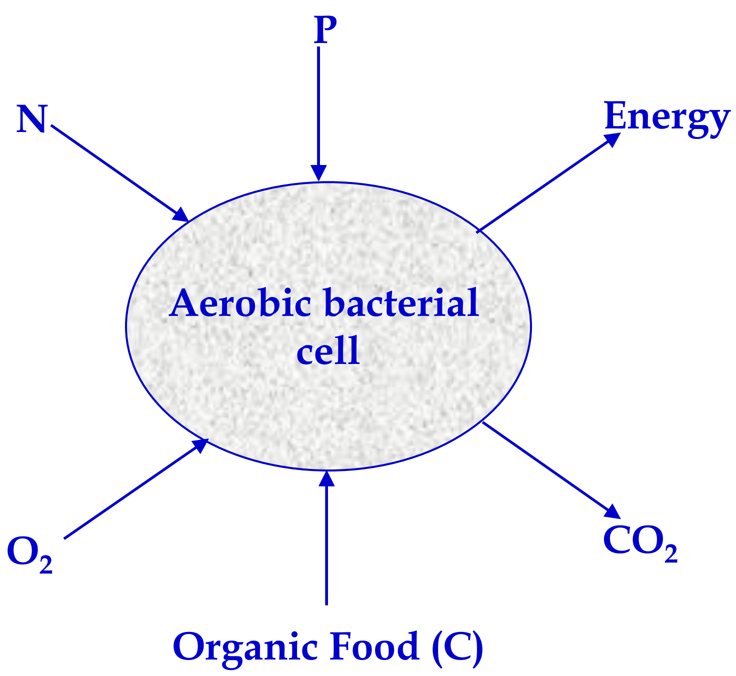


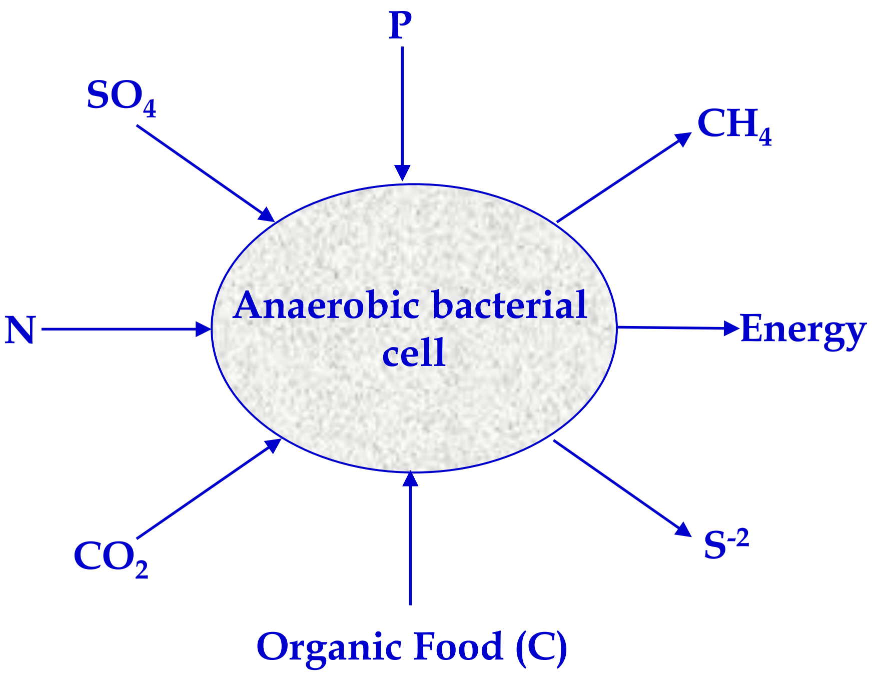
Objective of Biological Treatment

- **Main objective is to remove organic matter from wastewater in a natural way without using toxic chemicals**

- **Sometimes the aim is to remove other than organic matter such as ammonia/ heavy metals/ toxic organic chemicals like cyanides, phenols, etc.**

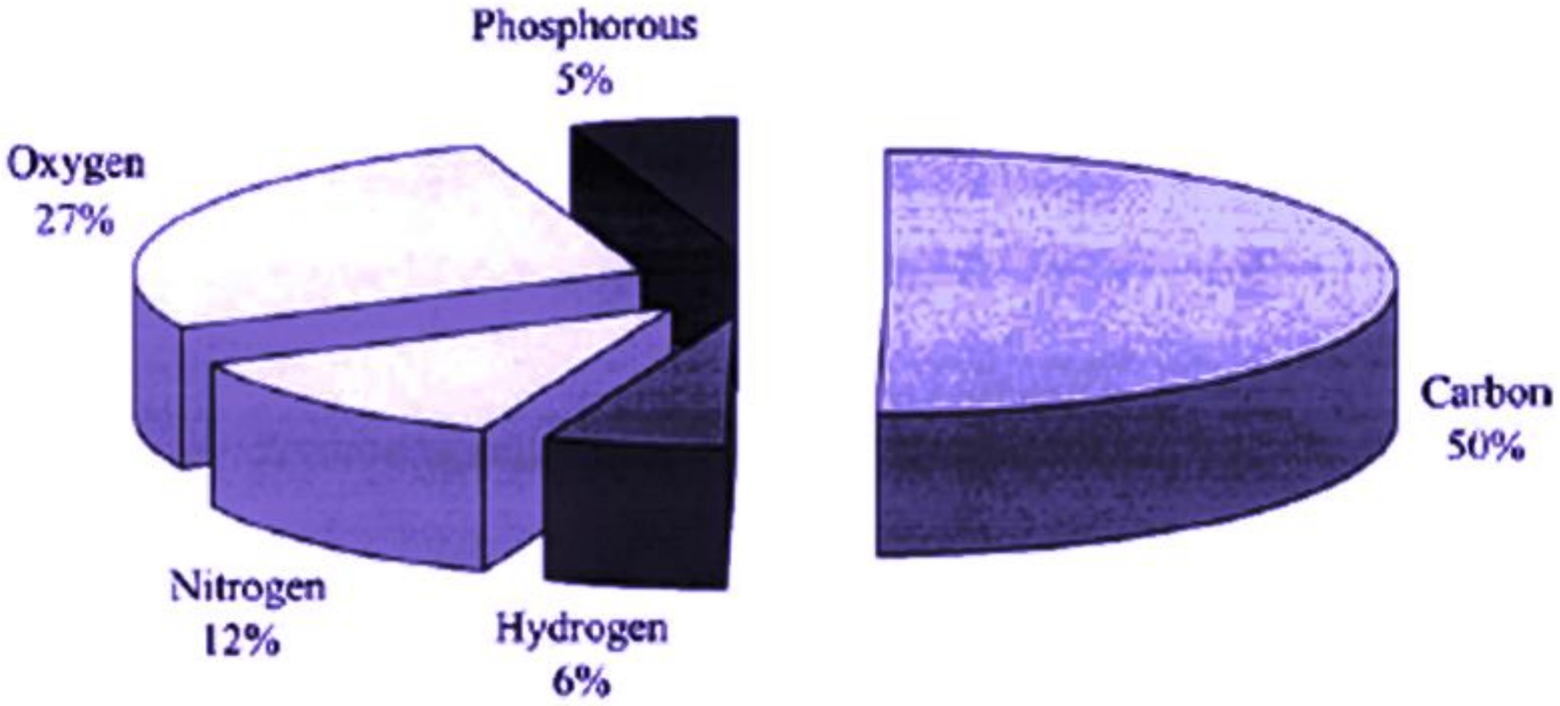
What Happens In Biological Treatment?





- Electron Donor – Organic food
- Electron Acceptor – Combined oxygen

Typical Bacterial Composition



Bacterial Cell – $C_{25}H_{35}N_5O_{10}P$

Available Technologies

AEROBIC	ANAEROBIC
Conventional ASP	Fixed film reactor
Extended ASP	Fluidized bed reactor
Trickling filter	Upflow anaerobic sludge blanket reactor
Rotating bed contactor	Anaerobic baffled Reactor
Fluidized media reactor	Vegetable submerged beds
Fluidized aerobic bed reactor	
Sequencing batch reactor	
Membrane Bio Reactor	

Basics of Aerobic Biological Process

ORGANIC MATTER + BACTERIA + OXYGEN → NEW BACTERIA + CO_2 + H_2O

<u>OXIDATION & SYNTHESIS:</u>

Organic food + O_2 + N + P → CO_2 + H_2O + $C_{25}H_{35}N_5O_{10}P$ + NBDR

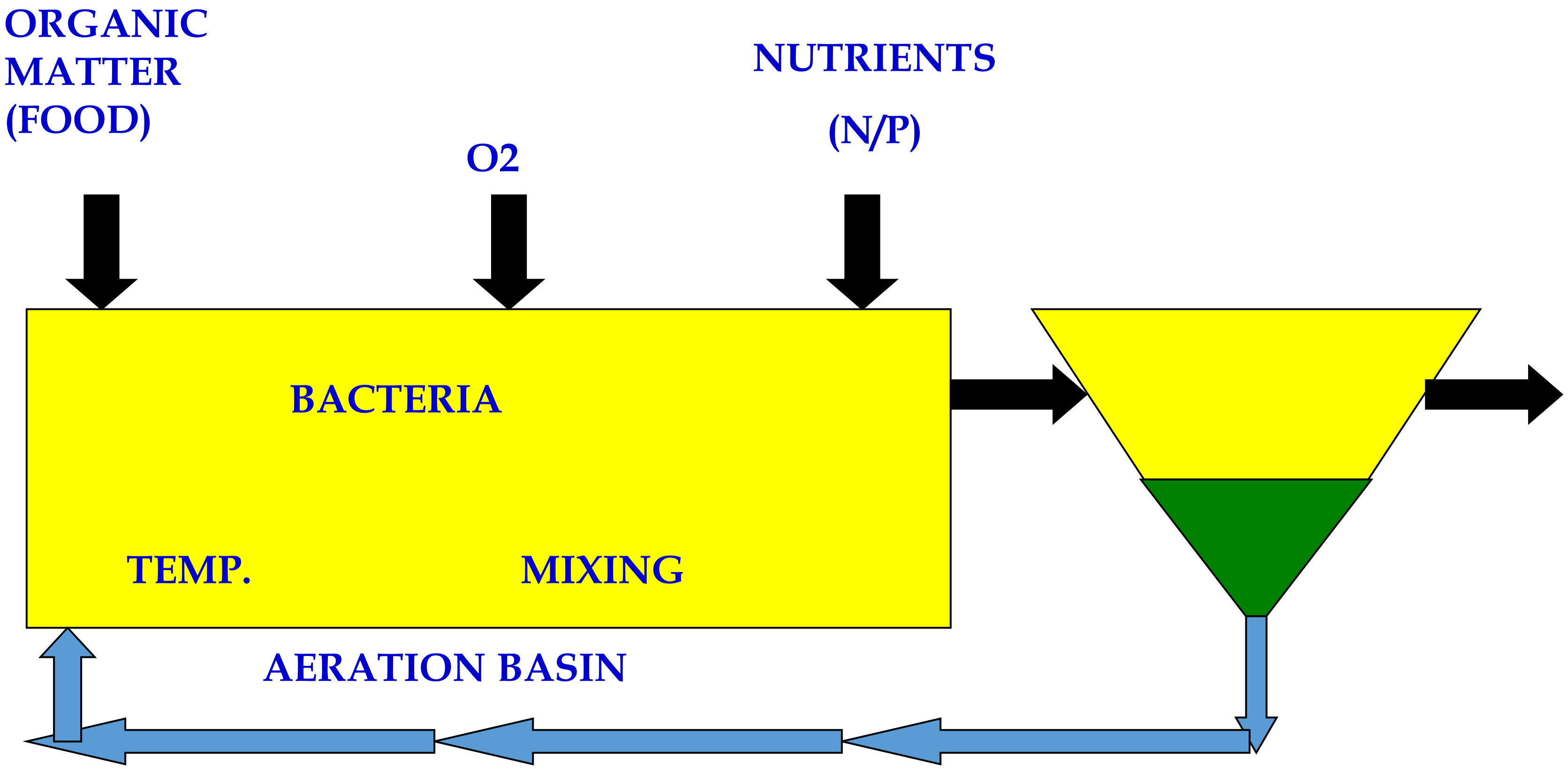
BACTERIA NEW BACTERIAL CELLS

<u>ENDOGENOUS RESPIRATION:</u>

$C_{25}H_{35}N_5O_{10}P$ + O_2 → CO_2 + H_2O + N + P + NBDR

CELLS BACTERIA

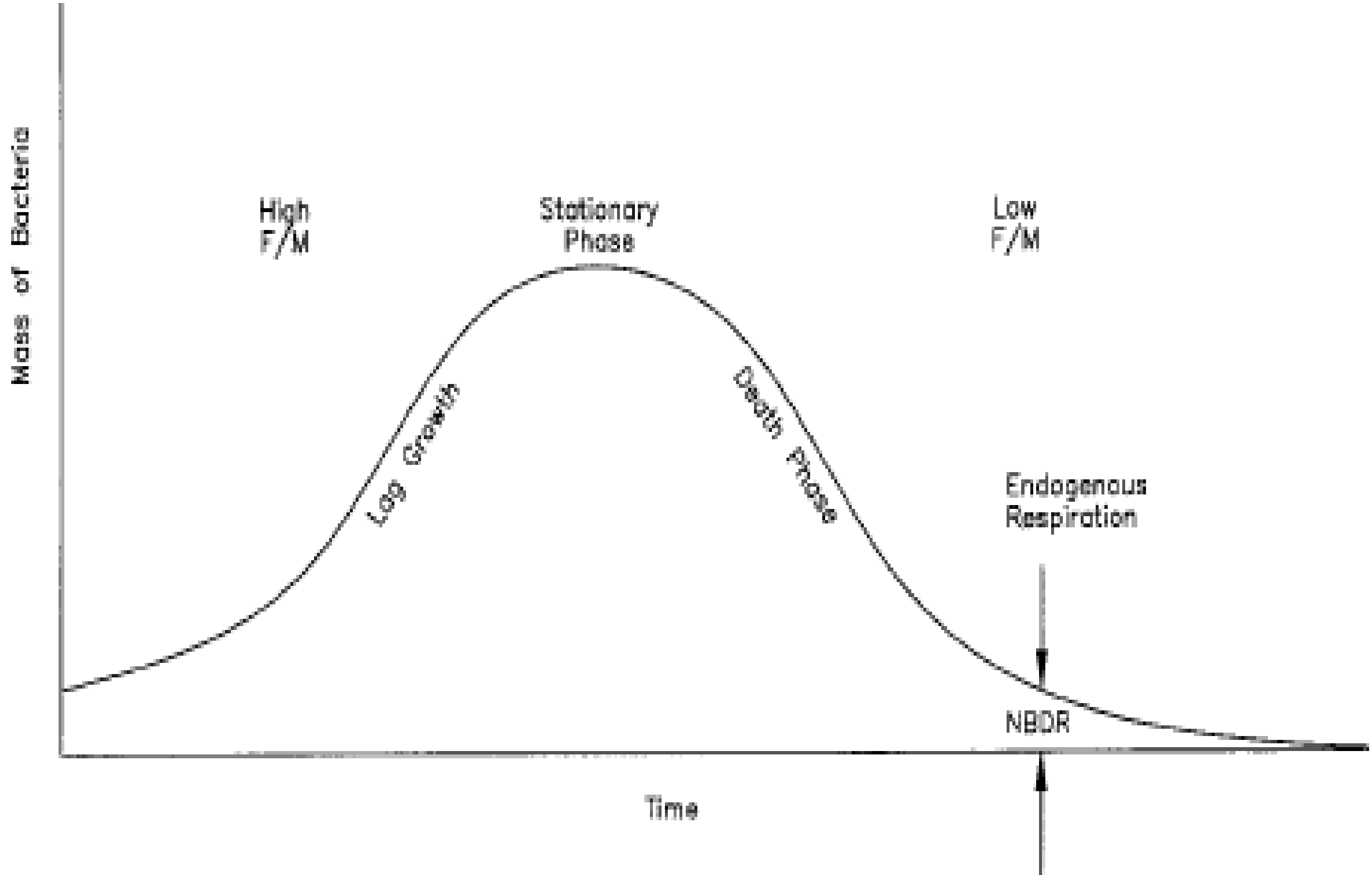
Equipment For Aerobic Biological Process



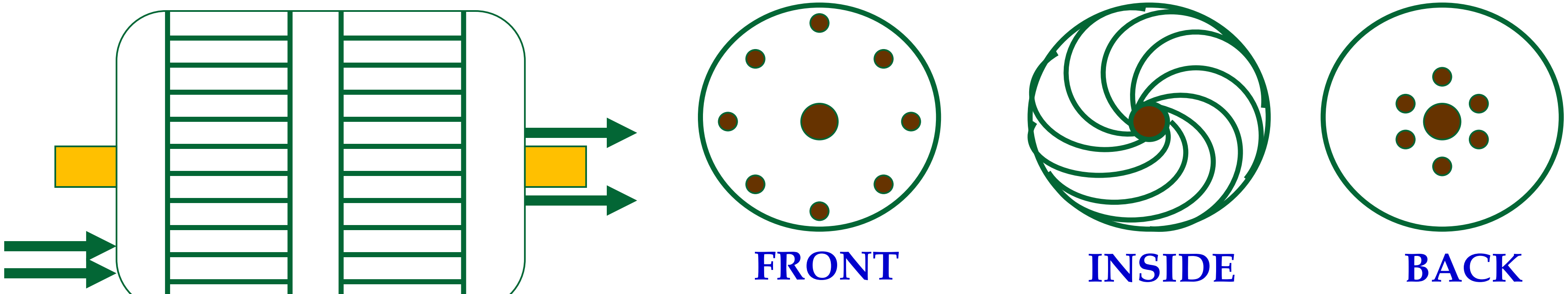
Here organic content, oxygen, and bacteria act as reactant and Aeration tank acts as a reactor. Now as per law of mass action, CO_2, H_2O, & bio mass is produced. This biomass is again organic in nature and needs to be removed.

Efficiency of Aerobic Biological System

- Depends on efficient separation of biomass from aeration tank liquor
  - Effective growth of floc forming bacteria
  - Elimination of growth of filamentous bacteria
  - Maintaining DO levels at around 2 ppm and satisfying nutrient requirements
  - Maintaining proper F/M ratio



Rotating Biological Contactor



Rotating Biological Contactor

Influent

- BOD - 300 ppm
- SS - 300 ppm

→ **RBC** →

Effluent

- BOD - 30 ppm
- SS - 30 ppm

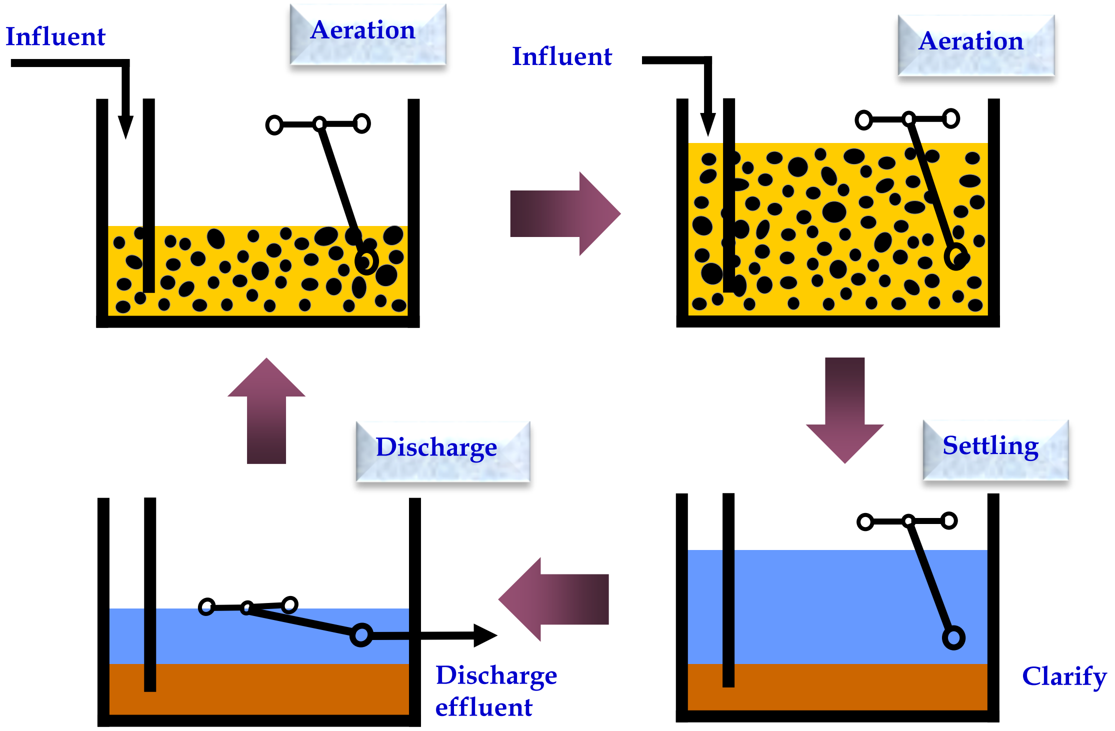
Moving Bed Bio-reactor (FMR / FAB)

- **MBBR / FBBR /FMR /FAB technology is based on a proprietary media and a unique air distribution system.**
- **The media provides a large protected surface area for biological attached-growth, resulting in MLSS concentration of 7000 – 10000 mg/L in aeration tank.**
- **The high density of attached living biomass makes the process much more resistant to toxic shock, sludge bulking, and other problems that can plague pure suspended growth systems.**
- **This technology allows for biological treatment in much less time and space required than for conventional bio-treatment systems currently utilized.**

Membrane Bio Reactor (MBR)

- **Membrane acts as a physical barrier to suspended solids, bacteria and majority of viruses. Hence produces consistent quality of treated water.**
- **MBR can handle MLSS up to 15000 mg/L and hence require 4-5 times smaller space than conventional systems.**
- **In this system, we can go for f/m up to 0.8 , and hence sludge volume also reduces.**

Sequencing Batch Reactor (SBR)



- Anoxic tank - aeration tank - secondary clarifier are all combined into one tank and operated in batch mode of fill-aerate-settle.

- Minimum two tanks are needed, so that when one tank is in filling and aeration mode another tank goes into settling and filling mode for next batch.

Treatment Technologies Performance

SR. No.	POINTS	EASP	RBC	MBBR/FMR	SBR	MBR
1	Process	Suspended growth	Rotating biological contactor	Suspended + Attached growth	Suspended growth	Suspended growth
2	Process performance	BOD = < 30 TSS = < 30	BOD = < 30 TSS = < 30	BOD = < 30 TSS = < 30	BOD = < 15 TSS = < 10	BOD = < 10 TSS = < 5
3	Space requirement	Maximum	Lower than SBR	Lower than RBC	Lower than EASP	Minimum
4	Operating cost	More than RBC	Minimum	Equal to EASP	More than EASP	Maximum
5	Capital Cost	------	------	------	------	------
6	Automation	Can be fully automated	Not required	Can be fully automated	Automation is must	Automation is must
7	Nutrient removal	N&P removal possible	Only P removal	N&P removal possible	Advantage is when N&P removal required	N&P removal possible

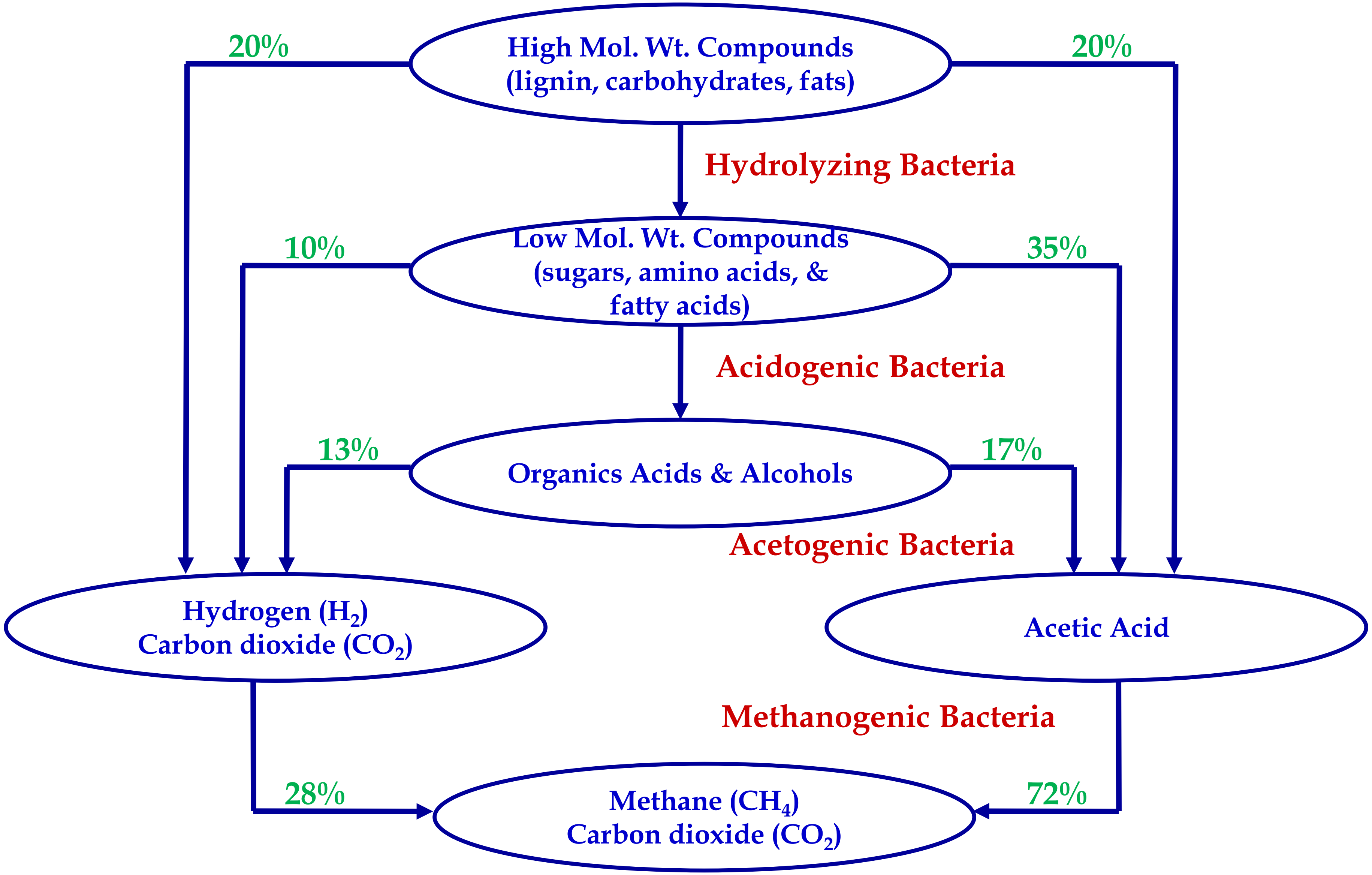
Anaerobic Biological Treatment Processes

Anaerobic wastewater treatment is a biological treatment process that utilizes microorganisms to biologically degrade organic constituents in wastewater in absence of molecular oxygen.

Some Interesting Facts

- **1895 – Gas from septic tank was used for street lighting in Exeter, England.**
- **1939 – Agricultural Research Institute, New Delhi started experiments to generate fuel from cow dung.**
- **1961 – Gobar Gas Research Station was started in 1961 and by 1971 published various designs for gas plants.**
- **1989 – World's first full scale demonstration plant for municipal sewage was constructed in Kanpur under Indo-Dutch project and has been in successful operation since then.**

Mechanism of Anaerobic Treatment Processes



Anaerobic Filter

- **The configuration is attached growth biological treatment process.**
- **Wastewater can flow either in upward or downward direction.**
- **Major disadvantage is the difficulty associated with the removal of bio sludge from the filter media.**

Anaerobic Fluidized Bed Process

- **The configuration is attached growth treatment process in which wastewater flow upwards with velocity sufficient enough to fluidize the media.**
- **The media can be either carbon or of plastic.**
- **The system is having advantage over UASB as we does not need to cultivate the granular sludge.**

Upflow Anaerobic Sludge Blanket Reactor

- **This can also be termed as attached growth treatment process due to presence of granular sludge.**
- **If continued formation of dense granules is achievable, this process is having advantage over other processes in terms of high loading rates, high biomass concentration, and high SRT.**

Anaerobic Baffled Reactor

- The anaerobic baffled reactor (ABR) is similar in design and application to the up-flow anaerobic sludge blanket (UASB) but requires no special granule formation for its operation.
- The sludge in each compartment will differ depending on the specific environmental conditions prevailing and the compounds or intermediates to be degraded.

Comparing Aerobic & Anaerobic Systems

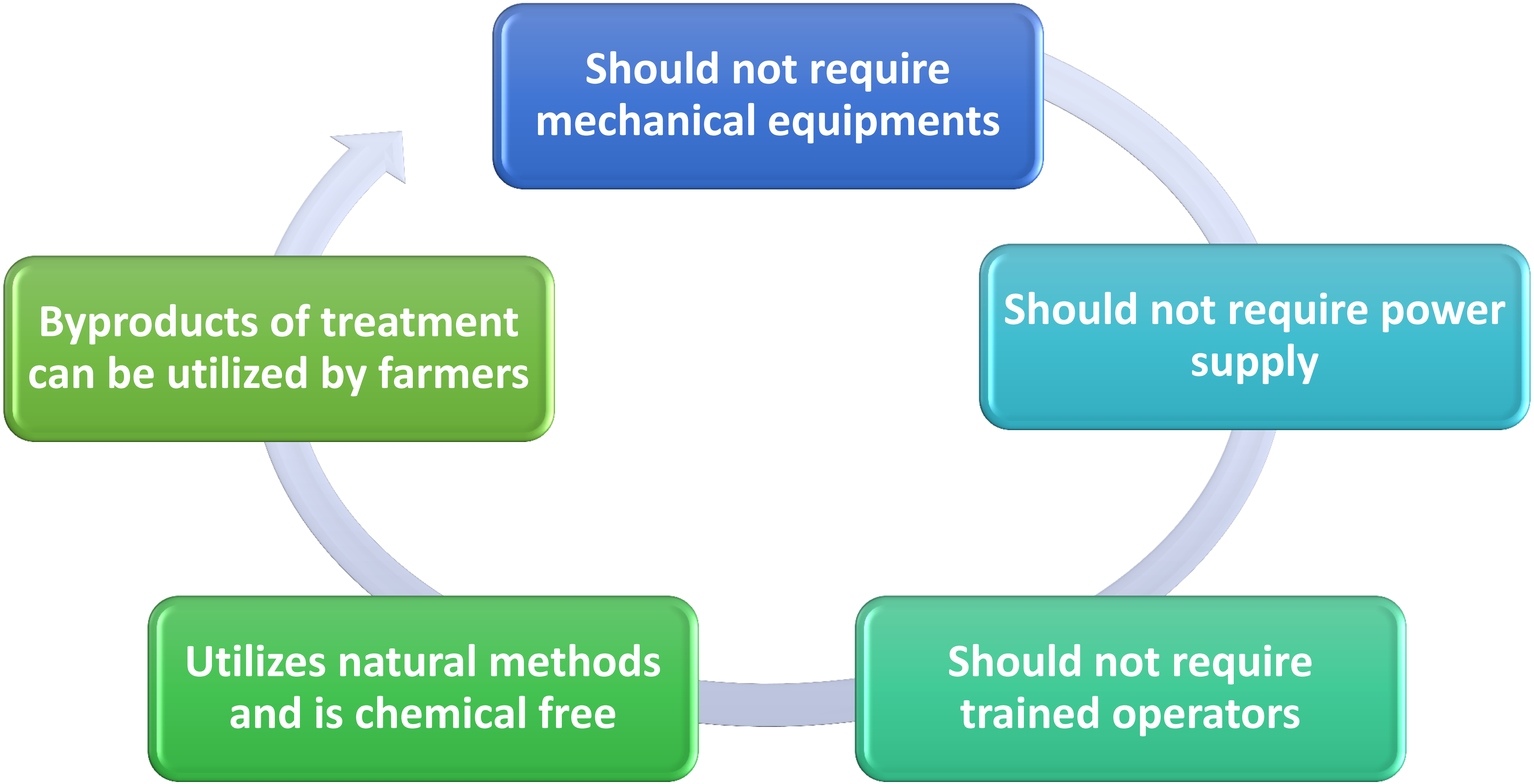
ANAEROBIC TREATMENT	AEROBIC TREATMENT
Methane is useful end product; it is energy productive process	Requires an energy input
Less sludge production	More sludge production
Process can handle high organic load	Due to low O_2 transfer rate, limited BOD/COD can be treated.
Low nutrient required	Comparatively more nutrient is required

Disadvantages of Anaerobic Systems

- **Not suitable for treating with COD values below 100 mg/L.**
- **The main disadvantage is the SLOW GROWTH of the methane forming bacteria. Slow growth rates require a relatively long detention time.**
- **Anaerobic bacteria are highly susceptible to inhibition by a large number of compounds and the process itself is vulnerable to external influences such as *temperature, pH, mixing*.**
- **Aerobic post treatment is required before discharging effluent.**
- **The gas produced consist of H_2S which imparts a rotten odor.**

Are these technologies suitable throughout our country, especially rural India & sustainable?

Treatment Technology Suited for Rural India



Root Zone WWT

- Surface Flow Constructed Wetlands
- Subsurface Flow Constructed Wetlands
- Floating bed Constructed Wetlands

Contaminant Removal

Constituents	Mechanism
Suspended Solids	Filtrations, sedimentation
Organics	Biodegradation by microbes, adsorption
Nitrogen	Nitrification/denitrification, plant uptake, volatilization
Phosphorus	Filtration, sedimentation, plant uptake
Trace metals	Sedimentation, adsorption
Pathogens	Natural decay, physical entrapment, predation, antibiotics from plant roots

Source: Phytoremediation, Springer (pp. 305-319)

Rejuvenation of Pond in Ibrahimpur Masahi Village of Haridwar District

Study Area

Shipla-Halzora sub watershed (Solani River Catchment)	29^{0} 56' to 30^{0} 05' N & 77^{0}48' to 77^{0} 55' E
Population	6,664 (Census 2011)
Village Area	1,426 ha
Households	1,148
No. of Ponds	05 Pond No. 1: CW-NTS Pond No. 4: Reference
Schools	7 (Govt.)+ 2 (Pvt.)

Salient Features of Ponds under Study

Features	CW-NTS Pond	Reference Pond
Village	Ibrahimpur Masahi	Masahi Kala
Latitude	$29^0$58’24.4”	$29^0$59’22.7”
Longitude	$77^0$53’22.3”	$77^0$53’11.11”
Altitude (m)	250.59	241.64
Population	2170	1528
Area (m^2)	2252 (0.6 Acre)	2954 (0.74 Acre)
Perimeter (m)	210.0	251.0
Pond Depth (m)	2.31 (3.4 after de-silting)	1.5
Capacity (m^3)	5202 (7657 after de-silting)	4431

CW based NTS Pond

Reference Pond

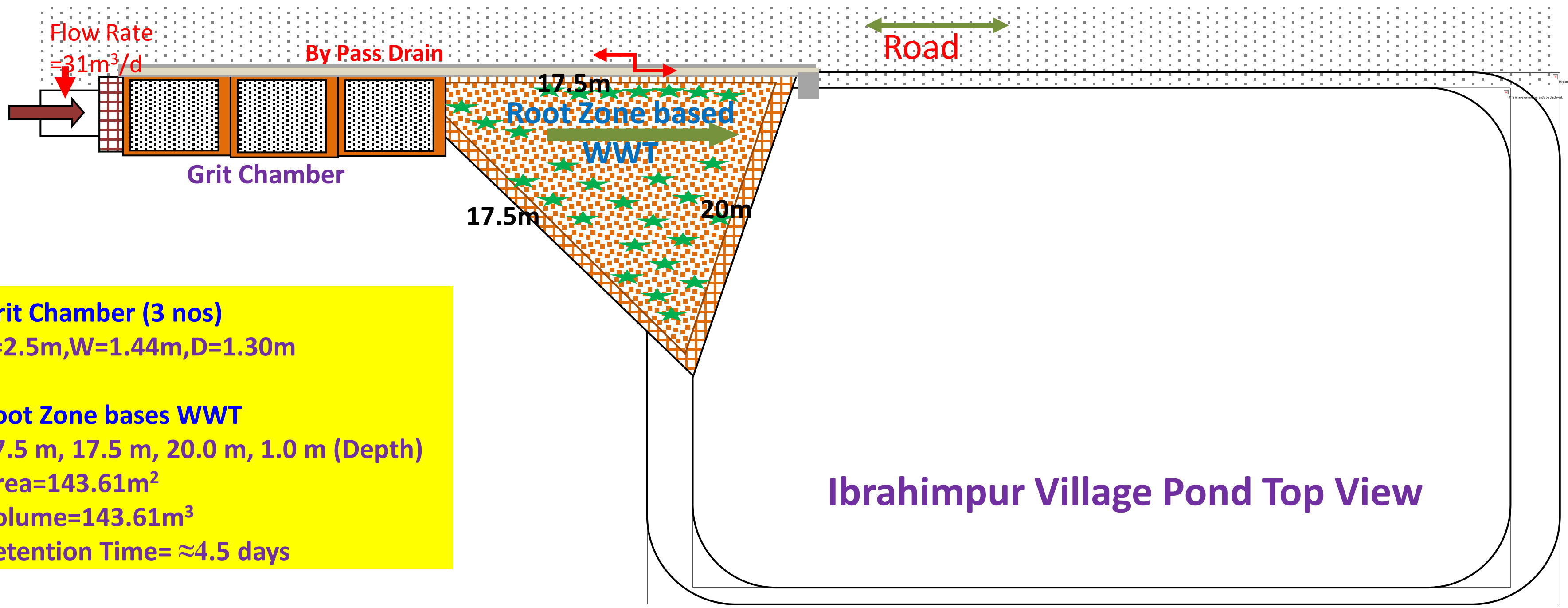
Activities Carried Out

Rejuvenation of Pond

- De-weeding
- Desilting
- Qualitative & quantitative estimation of influent & pond water
- Establishment of root zone based WWT
- Performance evaluation of treatment system and its impact
- Livelihood options and capacity building

Schematic of Installed Unit

Side View



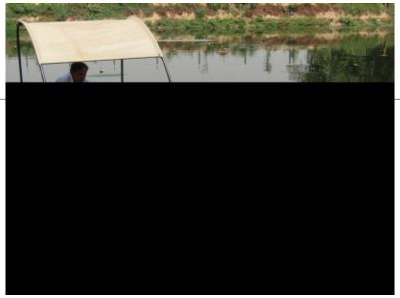
Top View

Grit Chamber (3 nos)
L=2.5m,W=1.44m,D=1.30m

Root Zone bases WWT
17.5 m, 17.5 m, 20.0 m, 1.0 m (Depth)
Area=143.61m^2
Volume=143.61m^3
Retention Time= ≈4.5 days

USEPA Guidelines
BOD load – 6 g/m^2.d
TSS load - 6 g/m^2.d

OVERALL IMPROVEMENT IN POND WATER QUALITY IN COMPARISON TO CONTROL POND (Area: 0.6 Acre; 200 KLD; Cost: ≈Rs. 15 Lakh)



Treatment of Domestic Wastewater in Jalvihar (NIH) Colony

Wastewater Treatment – Jalvihar (NIH) Colony Earlier Status

SSFCW Treatment System

Inlet

Outle
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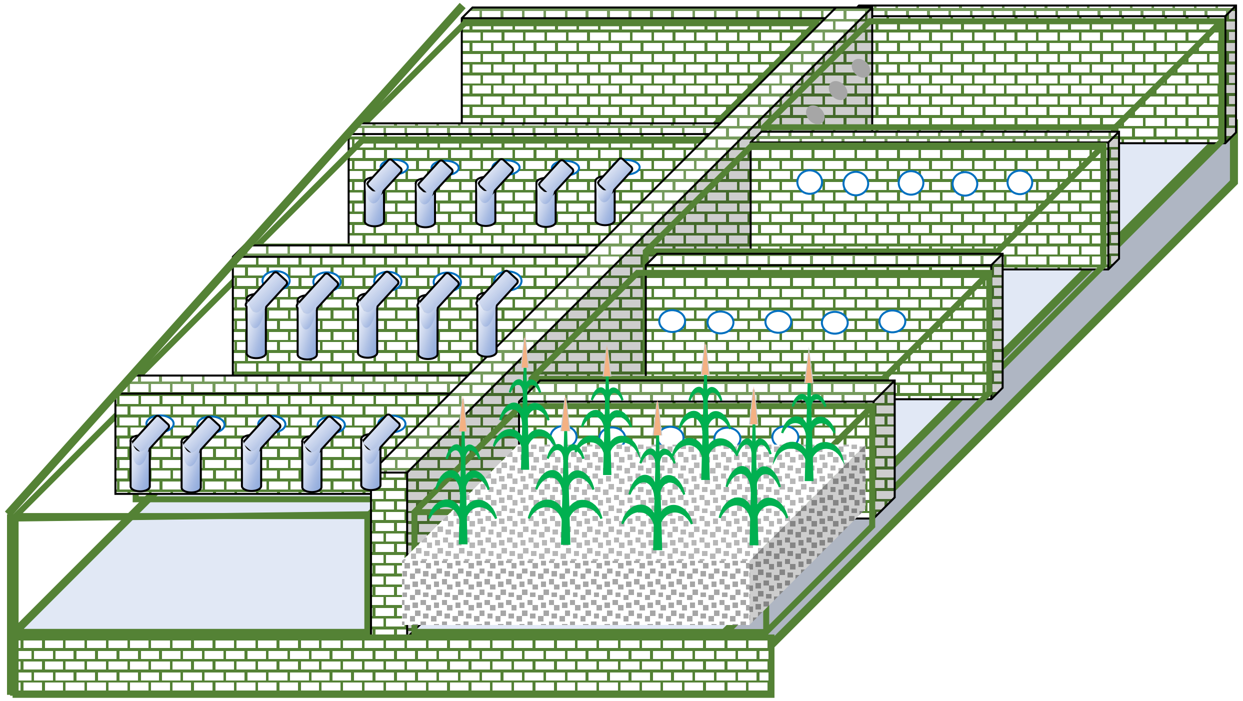
Designing the SSFCW Treatment System



Pollutant Concentration: 80 mg/l (100-120 mg/l)

Population: 272

Sewage generation: 120 lpcd (80% of water supply)

Sewage Inflow: 32.64 m³/d (Population X lpcd)

$$\text{Area Required} = \frac{Flow\ x\ log(\frac{BOD_i}{BOD_f})}{K_t dn}$$

Size of SSFCW: 10 m²/m³ (70-130 mg/l BOD)

	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8
Location	NIH Jalvihar Colony							
Wetland Type	Horizontal flow sub-surface constructed wetland							
Type of wastewater	Sewage							
Surface Area (m²)	35	35	35	35	35	35	35	35
Wetland depth (m)	1.5	1.4	1.3	1.2	1.1	1.0	0.9	0.8
FB (m)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Take Home Message

There are several treatment technologies available for the wastewater treatment, and the appropriateness depends on the site conditions

Thank You

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*"We have change so much the environment,
Now we have to change ourselves for living in it."*