WASTEWATER TREATMENT AND RECYCLING

TECHNOLOGIES AND APPLICATIONS

PRESENTATED BY

CLEAR-ION EXPERTS

OCT - 2019

AGENDA

- Introduction of wastewater and types, Some facts about wastewater
- Pollutants, their effects and need to reduction
- Technologies for wastewater treatment
- Technologies comparison
- Instrumentation and Equipments selection in wastewater treatment
- Emerging issues and trends in wastewater treatment
- Wastewater reclamation
- Energy from wastewater, Conclusion – Q&A

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WHAT IS WASTEWATER ?

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WASTEWATER INTRODUCTION

- Any used water from a Domestic, Commercial and Industrial process is wastewater
- Approximately 90% water becomes wastewater in domestic or similar process
- Un-purportedly wasted fresh water and storm water run off is also wastewater
- Wastewater may or mayn't have pollution strength

WASTEWATER TYPES

INDUSTRIAL

Industrial Trade Effluents

-Have different characters

- Mild to tough in polluting strength

- May or mayn't be biodegradable

STORM

Nature Generated

-Storm Water

- No polluting strength

MUNICIPAL

Municipal Wastewater /Sewage

-Typical uniform character

- Easily biodegradable

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POLLUTING STRENGTH OF WASTEWATER

- Physical Constituents

  - Color, both inorganic and organic nature
  - Odor, from dissolved gases and aromatic compounds
  - Particulates, like rags, leaves, fruits and vegetables, used objects etc.
  - Temperature, this is process and environment dependent

- Chemical Constituents

  - Organic, like aromatic, aliphatic, carbohydrates and fatty compounds
  - Inorganic, like nitrogen, phosphorus and metal compounds
  - Gases, dissolved like ammonia and emanating like hydrogen sulphide
  - Excess acidity or basicity

- Biological Constituents

  - Bacteria of various types
  - Virus of various types
  - Protozoa and cysts
  - Living or dead macro creatures
  - Small plants like algae

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DOMESTIC WASTEWATER CHARECTERIZATION-1

Parameter	Unit	Weak	Medium	Storm
Total Solids (TS)	Mg/Liter	350	720	1250
Dissolved Solids (TDS)	Mg/Liter	250	500	800
Fixed	Mg/Liter	145	300	525
Volatile	Mg/Liter	105	200	325
Suspended Solids (TSS)	Mg/Liter	100	220	350
Fixed	Mg/Liter	20	55	75
Volatile	Mg/Liter	80	165	275
Settleable Solids	Mg/Liter	5	10	20
BOD5, at 200C	Mg/Liter	110	220	400

TSS & BOD are key parameters

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DOMESTIC WASTEWATER CHARECTERIZATION-2

Parameter	Unit	Weak	Medium	Storm
Total Organic Carbon (TOC)	Mg/Liter	80	160	290
Chemical Oxygen Demand (COD)	Mg/Liter	250	500	1000
Total Nitrogen (TKN)		20	40	85
Organic	Mg/Liter	8	2	35
Free Ammonia	Mg/Liter	12	25	50
Nitrites	Mg/Liter	Nil	Nil	Nil
Nitrates	Mg/Liter	Nil	Nil	Nil
Total Phosphorus (TP)	Mg/Liter	4	8	15
Organic	Mg/Liter	1	3	5
Inorganic	Mg/Liter	3	5	10

COD & TKN are key parameters

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DOMESTIC WASTEWATER CHARECTERIZATION-3

Parameter	Unit	Weak	Medium	Storm
Chloride #, as Cl	Mg/Liter	250	500	1000
Sulphate #, as SO_4	Mg/Liter	20	40	85
Alkalinity, as $CaCO_3$	Mg/Liter	8	5	35
Oil and Grease (O&G)	Mg/Liter	12	25	50
Total Coliform	MPN/100 Ml	10^6-10^7	10^7-10^8	10^8-10^9
Volatile Organic Compounds (VOCs)	Mg/Liter	Nil	Nil	Nil

#Water source dependent

O&G is key parameters

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POLLUTANTS CONSEQUENCES

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HOW HARMFUL ARE POLLUTANTS

- **Organic and Inorganic Matter**
  - Increases turbidity, BOD & TOC
  - Directly or indirectly depletes free oxygen levels in water bodies
  - Creates odiferous compounds directly or indirectly
- **Particulates**
  - Restricts free movement of water and reduces general acceptance
  - Makes water unsuitable for various uses
  - Emanates pollution over a long period till degrades completely
- **Temperature**
  - Directly troubles aquatic life if too high or low
- **Oil, Grease and Floating Material**
  - Directly depletes oxygen level
  - Reduces natural oxygen dissolution
  - Increases BOD & COD, troubles aquatic life
- **Nutrients- Nitrogen & Phosphorus**
  - Directly and indirectly depletes oxygen level
  - Supports Eutrophication and troubles aquatic life

Untreated wastewater affects complete environmental chain

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HOW HARMFUL ARE POLLUTANTS

- **Dissolved Gases**
  - Some gases are toxic to life like Ammonia
  - Some gases are toxic as well as odiferous like Hydrogen Sulphide
  - Gases also affects water chemistry, CO_2 and Ammonia affects pH balance
- **Excess acidity or basicity**
  - Makes water unsuitable for various uses and natural biodegradation
  - Negatively impacts water chemistry and troubles aquatic life
- **Biological Constituents**
  - Causes mild to severe water borne diseases like cholera, hepatitis, typhoid etc
  - Adds to organic load
- **Dissolved Solids**
  - Makes water unsuitable for irrigation and other uses
  - Increases BOD & COD levels
- **Suspended and Settleable Solids**
  - Increases turbidity, hampers appearance and reduces general acceptance
  - Increases BOD & COD levels
  - Restricts free movement of water

Fresh water sources are rapidly polluting

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TREATMENT TECHNOLOGIES

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TREATMENT METHODS

- Biological aerobic
  - Activated sludge process – Extended aeration, oxidation ditch, SBR, MBBR, MBR, SAFF and FAB etc.
  - Trickling filters
  - Rotating biological contactors
  - Aerobic lagoons
- Biological anaerobic
  - Septic tanks
  - Soak pits
  - Anaerobic lagoons
  - Anaerobic filters
  - Anaerobic reactors- UASB, Fixed film, fluidized film, fluidized bed, conventional Digesters & SMAR etc
- Biological Constituents
  - Bacteria of various types

Biological Treatment is mild to nature

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TREATMENT CONSIDERATIONS

BE THE SOLUTION TO WATER POLLUTION

-Understanding of prevailing regulatory requirements

- Degree of target treatment for disposal or end use

- Design capacity, period and future expansion

- Wastewater flow rates (Peak, Average, Minimum)

- Wastewater characteristics and fluctuations

- Due consideration to wastewater generation process

- Climatic conditions

- Degree of automatic and instrumentation for target treatment

- Available space and height constraint

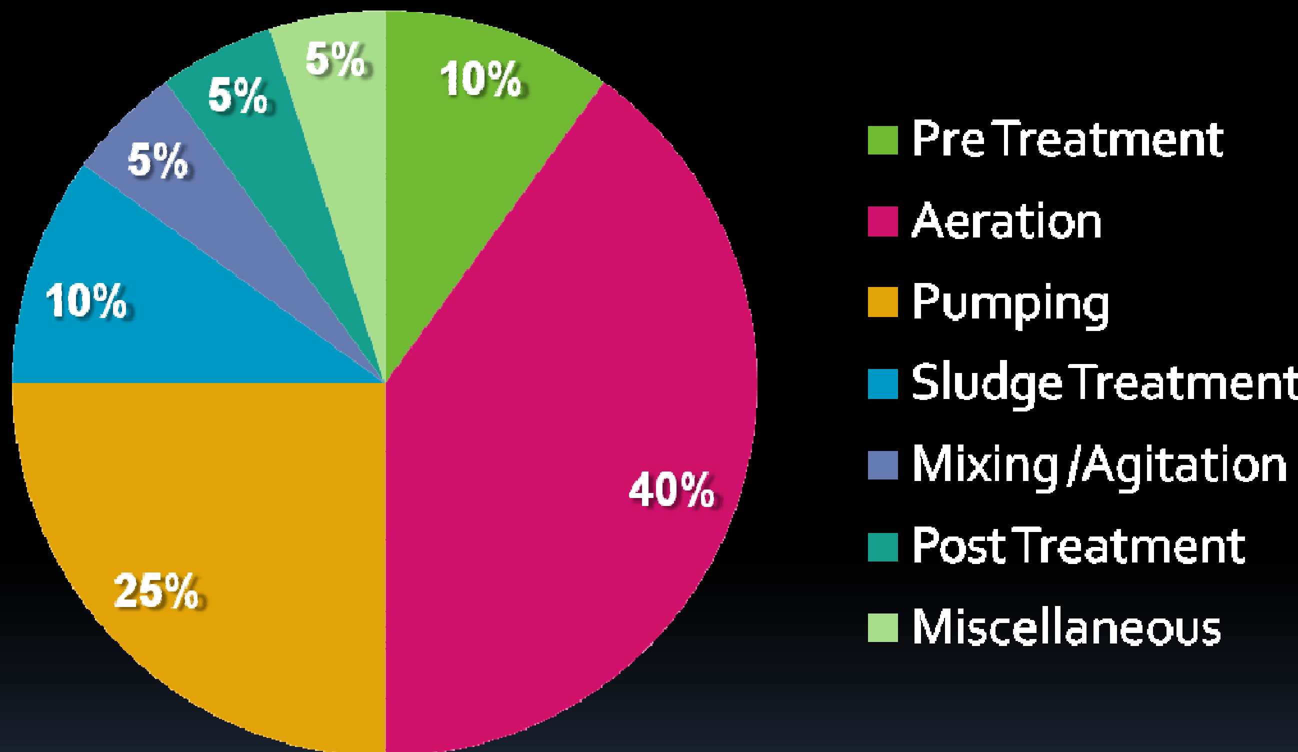
- Aesthetics and possible odour issues, nearby activities and possible conflicts

- Process refusals quantity, treatment and disposal

Right Treatment selection is half the battle won

WHERE ENERGY GOES

Energy is the major consideration in wastewater treatment plants operation cost



Aeration and pumping consumes >50% power

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TECHNOLOGIES COMPARISON

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TECHNOLOGIES COMPARISON-1

Parameter	Lagoons	Extended Aeration	SBR	MBR	MBBR & SAFF	UASB+EA
Foot print	High	High	Medium	Low	Low	Medium
Energy Consumption	Low (KWH 0.5/m^3)	High (KWH 1.8-2.0/m^3)	Medium (KWH 1-1.5/m^3)	Medium (KWH 1-1.5/m^3)	High (KWH 1.5-1.8/m^3)	High (KWH 1.5-1.8/m^3)
Operational issues	Low	High	High	Medium	High	High
Capital cost	Low	Medium	Medium	High	Medium	Medium
Operation cost	Low (Rs. 10-15/m^3)	High (Rs. 20-25/m^3)	Medium (Rs. 15-18/m^3)	Medium (Rs. 15-20/m^3)	Medium (Rs. 15-20/m^3)	Medium (Rs. 15-20/m^3)
Manual attention	Low	High	Medium	Low	High	High
Sludge Generation	Low	High	Medium	Medium	Medium	Medium
Installation time	Medium	High	Low	High	Medium	Medium
Efficiency BOD Removal	60-80%	90-95%	90-95%	95-98%	90-95%	90-95%

It's a trade off between cost & efficiency

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TECHNOLOGIES COMPARISON-2

Parameter	Lagoons	Extended Aeration	SBR	MBR	MBBR & SAFF	UASB+EA
Hydraulic Retention Time	3-7 Days	24-28 Hrs	NA	8-10 Hrs	10-12 Hrs	18-28 Hrs
Sludge Age (SRT in Days)	NA	20-30 Days	30-40 Days	30-40 Days	NA	20-30 Days
BOD Loading Rate (Kg/m³/Day)	0.03-0.05	0.3-0.4	NA	0.6-0.8	0.5-0.6	0.3-0.4
F:M	NA	0.05-0.15	NA	0.05-0.15	NA	0.05-0.15
Oxygen Requirement (ppm)	Natural oxygen	0.2-0.4 ppm	NA	0.2-0.4 ppm	0.2-0.4 ppm	0.2-0.4 ppm
BOD after Polishing (ppm)	<50	<30	<30	<10	<30	<30

All Technologies have their pros and cons

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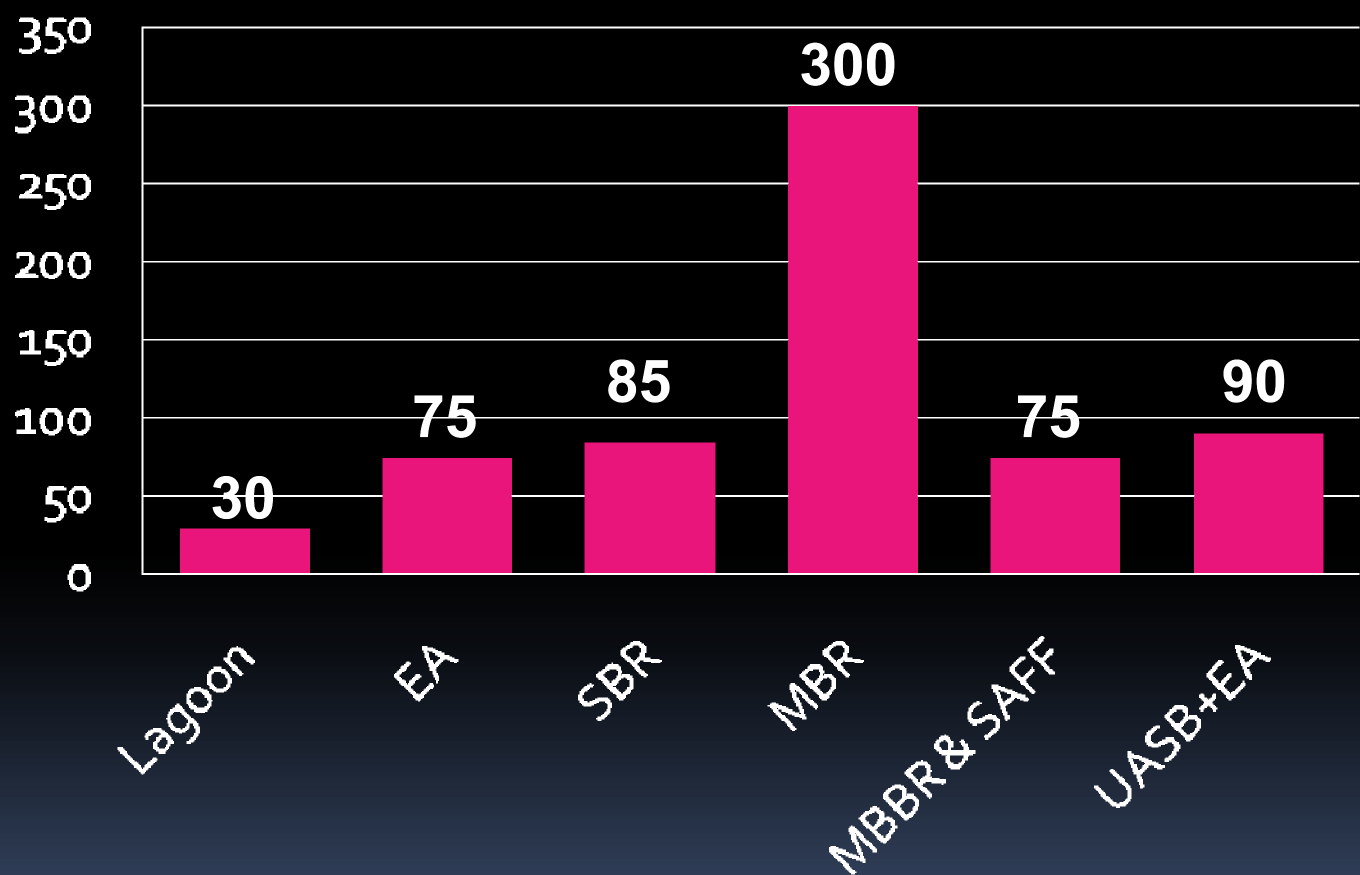
CAPITAL COST REQUIREMENT

Capital Cost INR Lacs/MLD Tertiary treatment not included



Except MBR other prevailing technologies hovers around same cost

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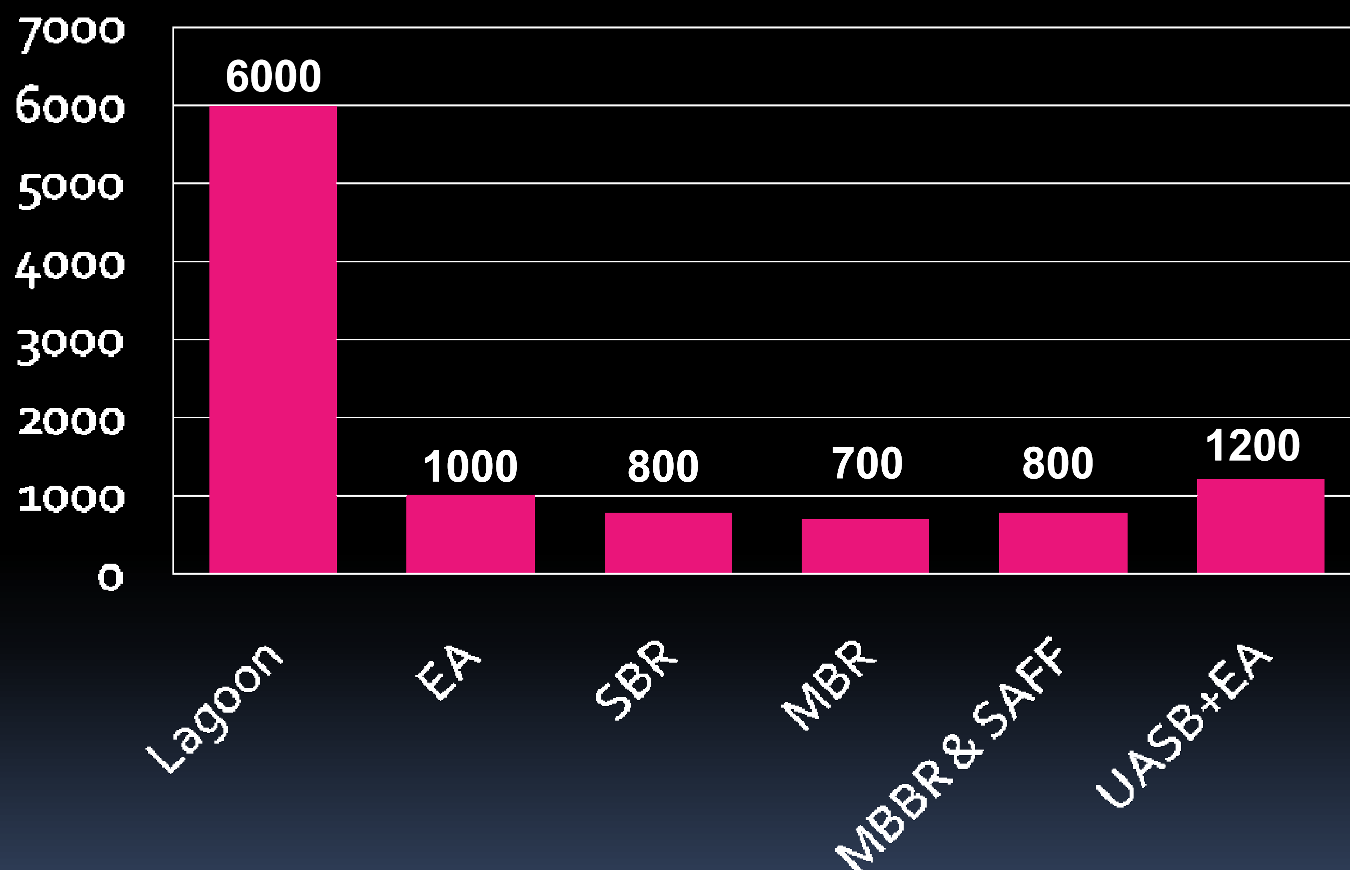
SPACE REQUIREMENT

- Space requirement M²/MLD
- Tertiary treatment not included



MBRs are most efficient on foot print

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WASTEWATER ISSUES AND TRENDS

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EMERGING TRENDS-1

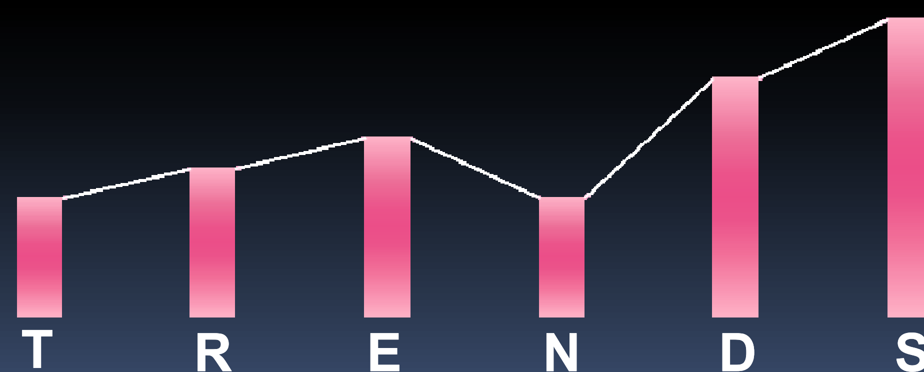
- Point of source treatment
- Biological Vs Chemical
- New technologies

- More reuse acceptance
- Awareness & sensitization
- Long & short term strategies

- Realistic goals
- Law Vs Willingness
- Dual supply network

- More PPP
- Poor water mgt. Vs Scarcity
- Combined approach

- Anaerobic Vs Aerobic
- Energy recovery
- MOCs and automation



Trends have been phenomenal in the last decade

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EMERGING TRENDS-2

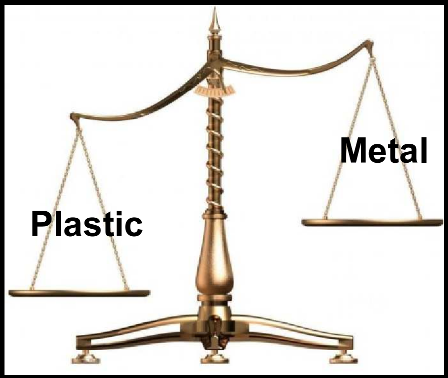
- Zero liquid discharge
- Reuse as a policy
- Stricter regulations

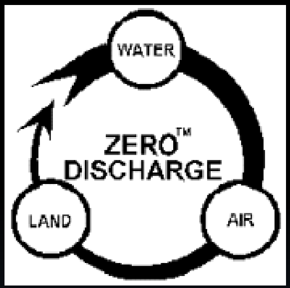
- Alternative water sources
- Energy efficiency
- Lesser foot print

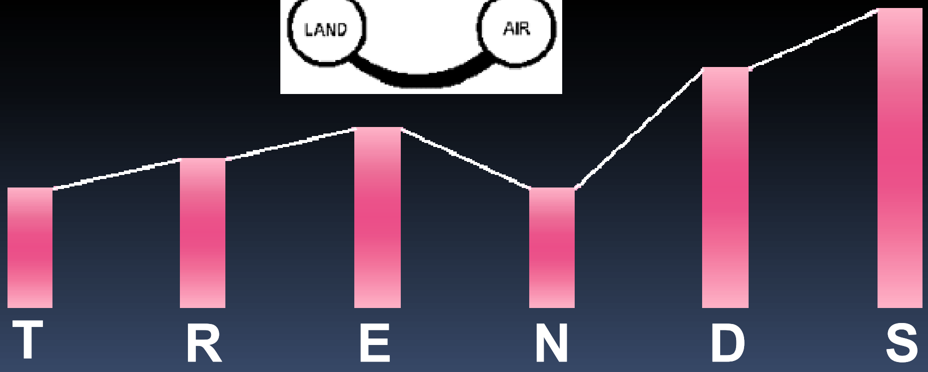
- Cleaner, low sludge technologies
- Membranes are replacing conventional treatments

- Plastics replacing metals
- UV & Ozone replacing chlorine
- Higher automation

- Government for reuse
- Organized sector is in
- Mass sensitization







Focus is shifting from compulsion to willingness

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NUTRIENT REMOVAL - NITROGEN

- Total nitrogen is present in sewage in the rage of 50-75 ppm
- It is present in the form of Ammonia NH_3 ,Ammonia NH_4, Nitrite NO_2 and Nitrate NO_3
- Nitrate limit is 50 ppm in discharge water
- Nitrogen (as nitrate) and Phosphorus (as phosphate) to main in the treated water provided food for aquatic plants (phytoplankton) like algae & -----------
- This growth of excess phytoplankton is called 'Eutrophication'
- Excess phytoplankton depletes oxygen level in the water stream, known as 'Hypoxia'
- Oxygen depleting troubles zooplanktons like fishes

N & P are macro nutrients for plants

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EUTRIFIED WATER BODY

N & P are macro nutrients for plants

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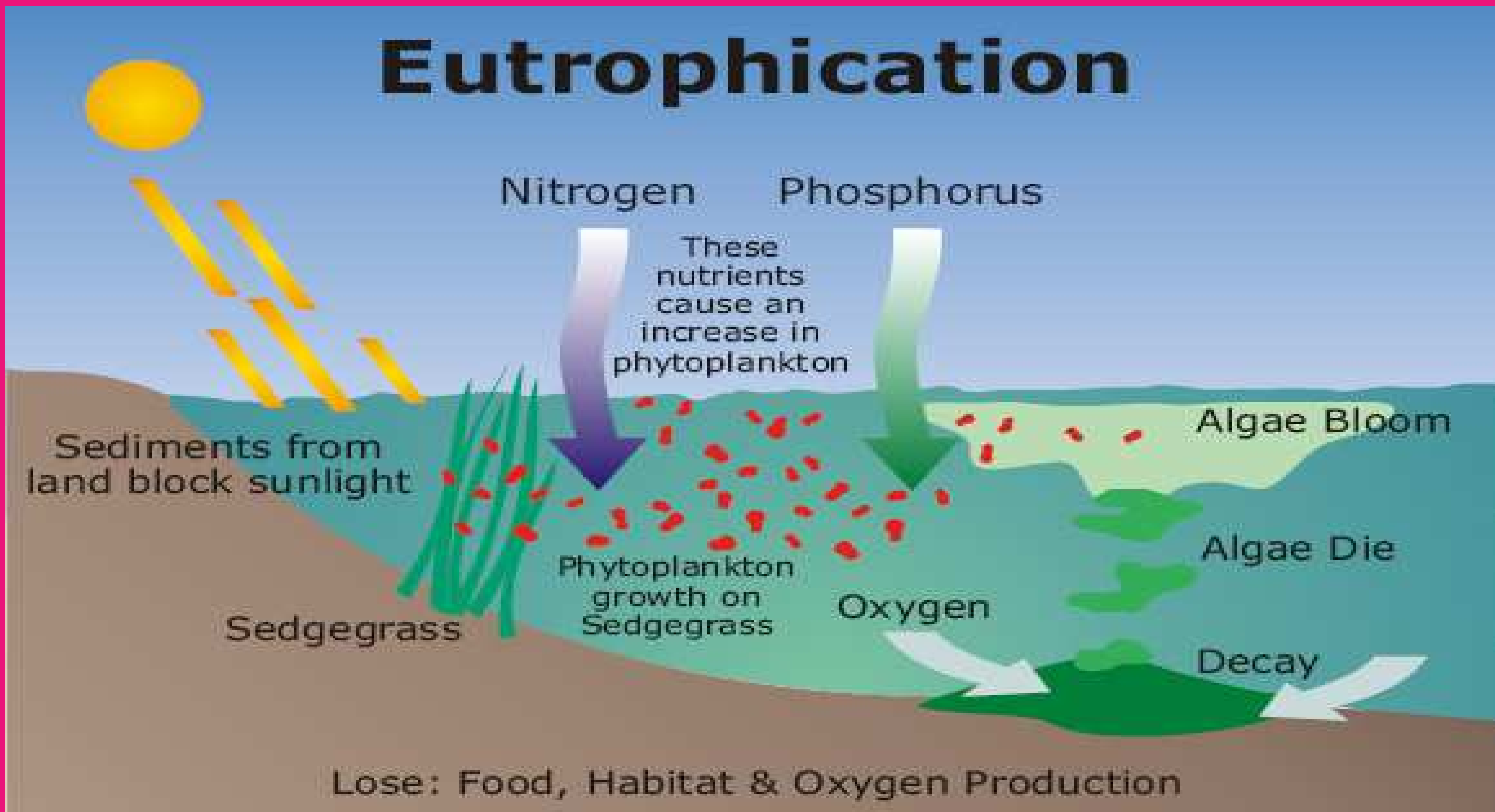
EUTROPHICATION



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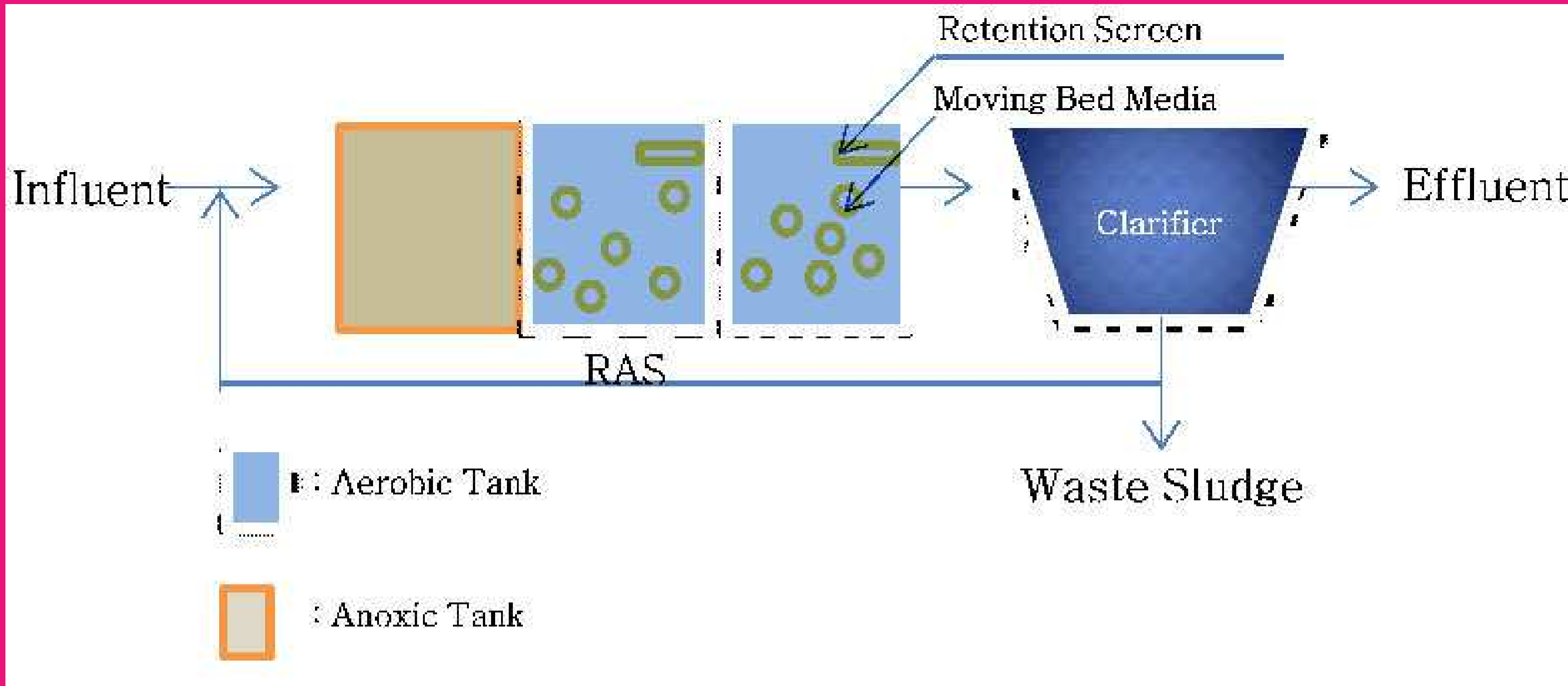
HOW TO GET RID OF NITROGEN?



- Consider suitable provisions in the biological treatment. Some N&P is also required for aerobic synthesis (100BOD:5N:1P)
- There are many variations to achieve nitrogen reduction, all needs nitrification followed by de-nitrification

Nitrogen can be removed in biological process

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NUTRIENT REMOVAL -PHOSPHORUS

- Municipal wastewater may contain from 5 to 20 mg/l of total phosphorous
- 1-5 mg/l is organic and the rest in inorganic
- Normally secondary treatment can only remove 1-2 mg/l
- Excess of phosphorous is discharged in the final effluent, causing eutrophication
- New rules asks P discharges limit into water bodies as 2 mg/l

If inadequate, N&P are added to biological treatment

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PHOSPHORUS REMOVAL

- Biological phosphorus reduction
  - Anoxic step converts organic phosphorus to orthophosphate
  - During aerobic growth, orthophosphate is taken up by organisms during growth and additional phosphate is converted to polyphoshate which accumulates in the biomass
- Chemical phosphorus removal
  - Lime, alum & ferric are widely used in precipitating phosphates
  - Basic reactions are

$$10\,Ca^{2+} + 6\,PO_4^{3-} + 2\,OH^- \longleftrightarrow Ca_{10}(PO_4)_6(OH)_2 \downarrow$$
$$Al^{3+} + H_nPO_4^{3-n} \longleftrightarrow AlPO_4 + nH^+$$
$$Fe^{3+} + H_nPO_4^{3-n} \longleftrightarrow FePO_4 + nH^+$$

Chemical process is essential for P removal

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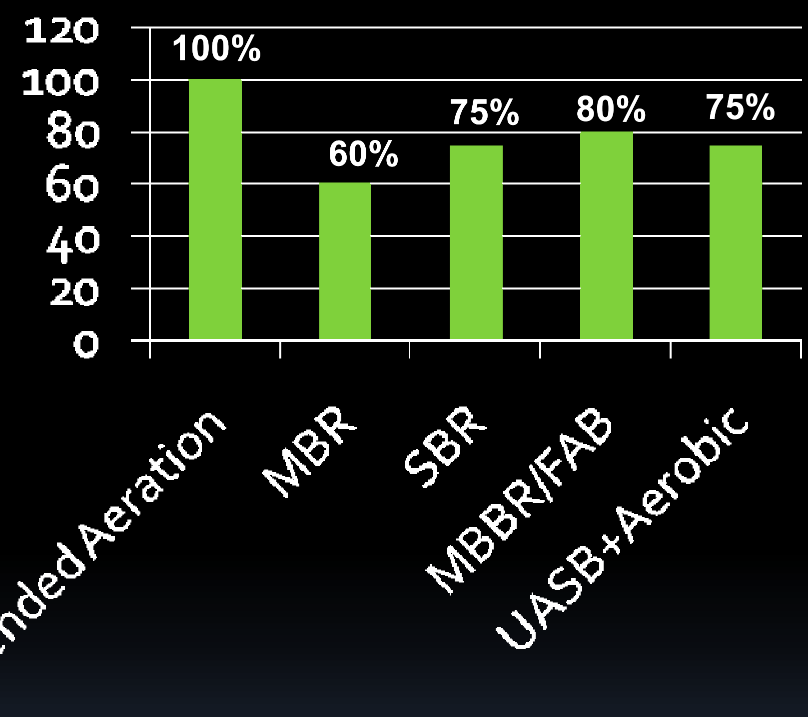
SPACE CONSTRAINT

- Land is at premium in metro cities
- Fortunately the most efficient technologies are also space saving
- Here is the space comparison with respect to extended aeration



Space and height is becoming major consideration

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WASTEWATER RECLAMATION

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CONSIDERATIONS

- First thing first ..know the country's regulations on reclamation. In India MOEF & CPCB are regulatory authorities
- So far direct potable uses or direct human application is not permitted in India.
- Fortunately, above areas need little water, approx 5-10% of total need
- Irrigation is the largest consumer at approx 80%, hence suits most
- Industrial processes are the second choice consuming approx 15-20%
- Third most suitable is recreation activities
- It is important to know the degree of treatment required for the end use
- The selection of tertiary treatment or ERS should be considered

Reclamation is the key to water scarcity

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HOW TO RECLAIM?

Biological Treatment

Polishing/Clarification

Filtration

Ultra-filtration

Reverse Osmosis

Multistage Disinfection

End use decides degree of treatment

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MODEL

World famous NEWater plant, Singapore follows below multi barrier approach

The first barrier is the conventional wastewater treatment process whereby the used water is treated in the water Reclamation Plants.

The second barrier and first stage of the NEWater production process, uses microfiltration/ultrafiltration to filter out suspended solids, colloidal particles, disease causing bacteria, some viruses and protozoan cysts. The filtered water that goes through the membrane contains only dissolved salts and organic molecules.

The third barrier and second stage of the NEWater production process, utilizes reverse osmosis (RO). RO filters out undesirable contaminants such as bacteria, viruses, heavy metals, nitrates, chlorides, sulfates, disinfection by-products, aromatic hydrocarbons, and pesticides. At this stage, the water is already of potable quality.

The fourth barrier and third stage of the NEWater production process, acts as safety precaution. UV disinfection is used to ensure that all organisms are inactivated and the purity of the product water guaranteed. With the addition of some alkaline chemicals to restore the pH balance, the NEWater is ready for use.

Treated wastewater may exceed natural sources quality

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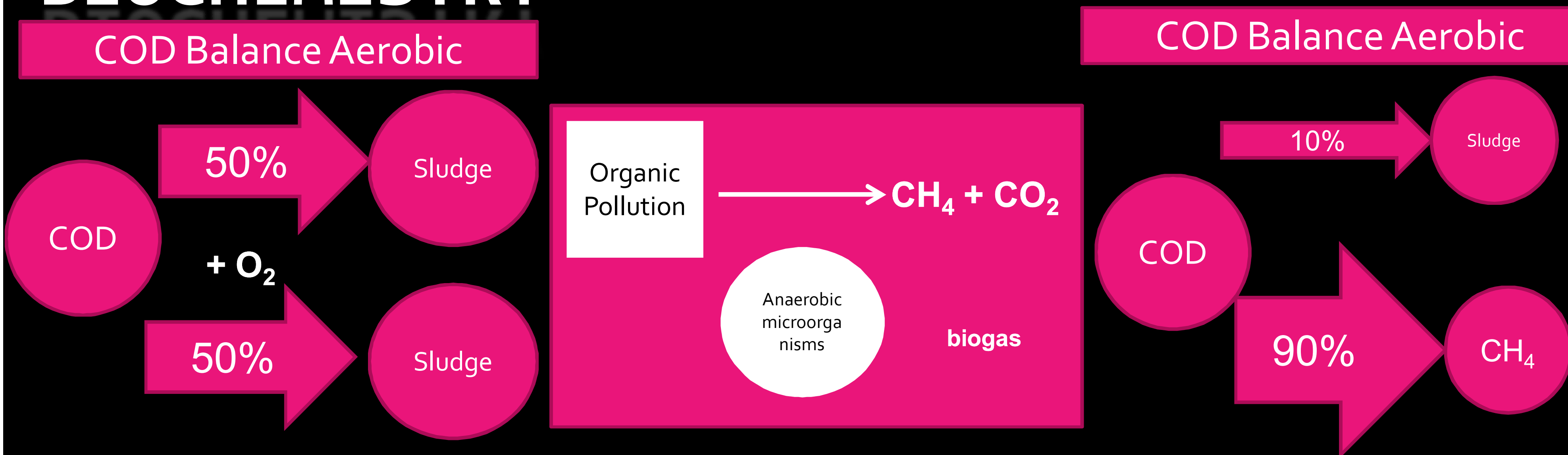
BIOCHEMISTRY



- Methanogens are chemoautotrophs
- Methanogens use a number of different ways to produce methane
  Using acetate that may be derived from the decomposition of cellulose:

$$CH_3COO^+ + H^- \longrightarrow CH_4 + CO_2 \quad +36\ kJ\ mol^{-1}$$

  Or using hydrogen and carbon dioxide produced by the decomposers:

$$4H_2\ CO2 \longrightarrow CH_4 + 2H_2O + 130.4\ kJmol^{-1}$$

- Theoretically 1 kg COD destruction yields 0.55 kg Bio Gas
- In Bio Gas, methane is approx 60-80% depending on process efficiency

Enriched biogas is a boon for country like India

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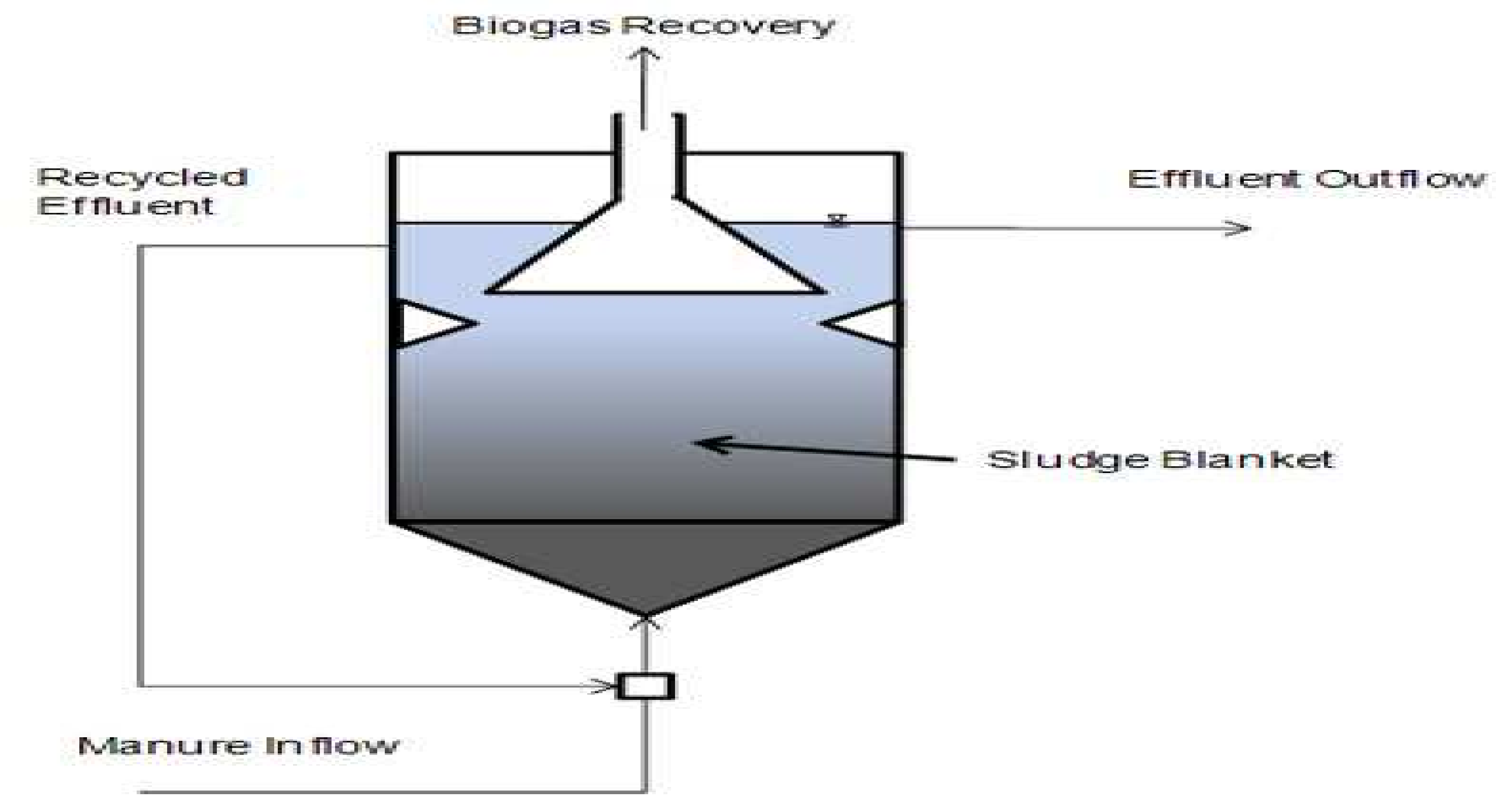
UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR



Dr. Gatze Lettinga developed first UASB in 1979

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GREEN ENERGY

Calorific Value

- BIO Gas 5000-7000 Kcal/m³ and Methane 9100 Kcal/m³
- LPG has a calorific value of 11840 Kcal/kg
- Electricity 860 Kcal/KWH

Equivalency

- 1.3 m³ Methane = 1 Kg LPG
- 0.94 m³ Methane = 10 units Electricity
- 1.1 m³ methane = 1 ltr Petrol

Uses

- Per capita consumption in cooking & lighting 0.3-0.4 m³/day
- Family of six uses approx. 3 m³/day
- Industrial and vehicular fuel

Awakening….. Isn't it

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