Online Capacity Building of SAARC Professionals on Commercial Scale Biogas Plants
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Biogas plant design concepts and considerations for establishment of commercial scale facilities

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Introduction

- Biogas plants, their types, components and resource requirements.
- Small scale v/s commercial biogas plants
- Size analysis, commissioning and construction of biogas plants
- Design and selection factors for bio-digesters
- O/M and feasibility /scalability assessment of plants
- Quality control of biogas plants

Biogas Plant designs based on....

Fermentation systems

- Closed system
- Semi-continuous
- Fed-batch
- Continuous

Gas storage system

- Floating drum
- Fixed dome
- Rubber balloon
- Others

Biogas Plant designs contd…

Flow of slurry

- Vertical
- Horizontal

Operating temperature

- Thermophilic (45-57 C)
- Mesophilic (10-40 C)
- Psychrophilic (below 10 C)

Biogas Plant designs contd…

Stages in digester

- Biphasic
- Single phasic

Size of digester

- Family
- Institutional
- Commercial / Community

Biogas Plant designs

Solid content

- Dry fermentation (SC>11%)
- Wet fermentation (SC<11%)

Loading rate

- Low loading rate
- High rate biomethanation reactors

Components......

- Gas generation subsystem

1. Foundation, digester and inlet-outlet chambers
2. Gas storage structure and additional storage units

- Feed and slurry handling subsystem

1. Pre-digestion tank
2. Mixing platform and mixer unit
3. Slurry dewatering and pumping system

- Gas distribution and utilization subsystem

1. Gas pipe line and water removers
2. Gas utilization appliances such as burners, generators, engines or compressor/bottling units

Small scale v/s Commercial systems.....

Capacity restricted to smaller units for meeting energy demand of small family/group of persons	Higher capacity capable of meeting the energy demand of larger population /society
Easy to install, operate and maintained by semi-skilled persons	Installation, operation and maintenance requires trained and skilled manpower
Initial investment is less	Higher initial investment
The biogas can be used for cooking, lighting or electricity generation without up gradation	The biogas can be upgraded and converted to CBG for meeting the energy demand in transport sector also
Limited employment opportunities	Large employment opportunities for local peoples
Entrepreneurship opportunities at lower scale	Sustainable entrepreneurship opportunities as a profit making venture
Limited marketing opportunities for sale of products	Scope of carbon credit, vast market for bio-manure, CBG and electricity

RATE OF BIO-METHANATION

- RATE AT WHICH AN ORGANIC MATERIAL UNDERGOES BIODEGRADATION IN A DIGESTER (Under anaerobic condition)

- DIGESTION TAKING PLACE AT A FASTER PACE IS CALLED HIGH RATE BIO-METHANATION

Design and selection factors for bio-digesters

- On the basis of type of waste material available for digestion – it affects the HRT
- The quantity of biogas required – it decides the volume of storage chamber
- Purpose for which biogas is required – it reflects the economics and operating system

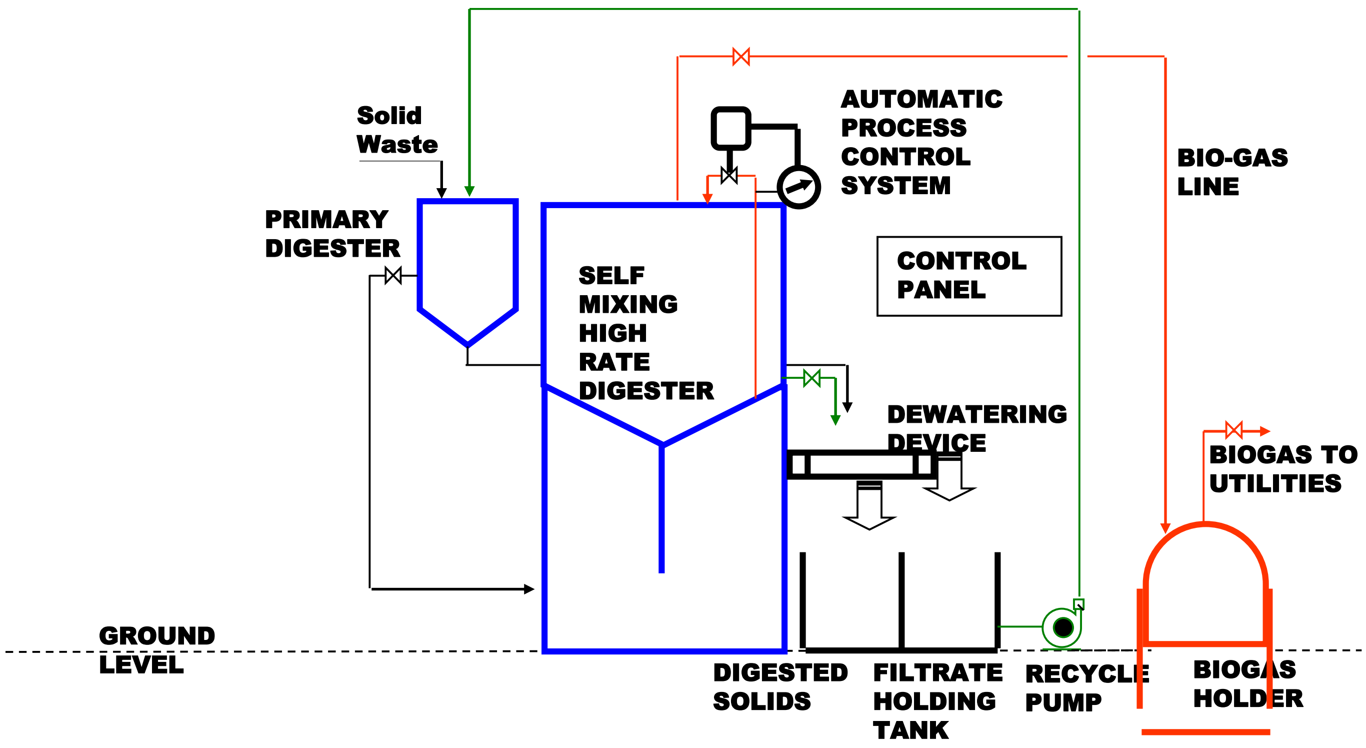
- Site selection
- Size selection
- Appropriate design selection
- Pre-digestion parameters
- Low capital cost of construction and operation
- Achieving pollution control and reduction of pathogens
- Optimal methane production per m3 digester volume

CONVENTIONAL DIGESTERS	HIGH RATE COMMERCIAL PLANT DIGESTERS
Requires 45 to 60 days for complete digestion	Requires 15 to 25 days to complete digestion
Efficiency in terms of solids digested is 50%	Efficiency in terms of solids digested is 80-90%
Loading rate is 1-2 kg/m^3	Loading rate is 5-8 kg/m^3
Gas production 0.5 m^3/kg solids	Gas production 0.7 m^3/kg solids
Inconvenient operations	Easy to operate & no manual work
Generates secondary effluents	Zero water consumption & No secondary effluents
Maximum size of a single digester is less than 100 m^3 (BATTERY OF DIGESTERS NEEDED FOR HIGHER SCALE LEADING TO LARGE SPACE REQUIREMENT)	Size of a single digester can vary from 1 to 5000 m^3 (DIGESTER SIZE INCREASE VERTICALLY AND SAVES SPACE REQUIREMENT)

ADVANTAGES OF HIGH RATE COMMERCIAL BIO-METHANATION PLANT

- HIGH LOADING RATE IN DIGESTER
- LESS TIME REQUIRED TO COMPLETE THE DIGESTION
- HIGH TREATMENT EFFICIENCY IN TERMS OF TOTAL SOLIDS DIGESTED
- LESS SOLIDS DISCHARGED POST DIGESTION
- DIGESTED SOLIDS HAVE BETTER PROPERTIES
- INCREASED BIOGAS GENERATION

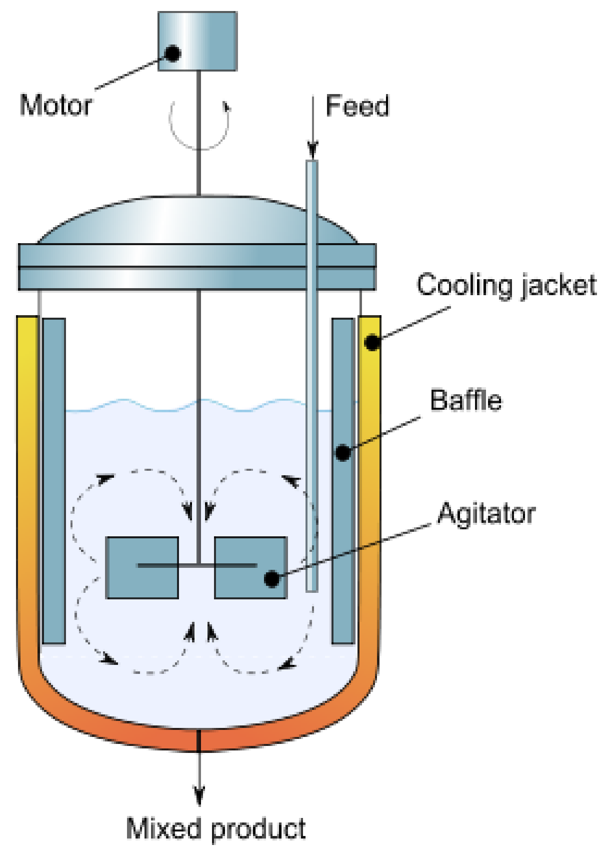
FLOW DIAGRAM OF HIGH RATE COMMERCIAL BIO-METHANATION PLANT



Completely Stirred Tank Reactor (CSTR)

- First developed by Schroepfer and Ziemke (1959).
- CSTR consisting a vessel and a stirrer.
- Keeps bacteria homogeneously suspended.
- Easy to handle and low cost.

- Major Disadvantages-
  - No biomass retention
  - Hydraulic short circuiting
  - Disintegration of structure by high force

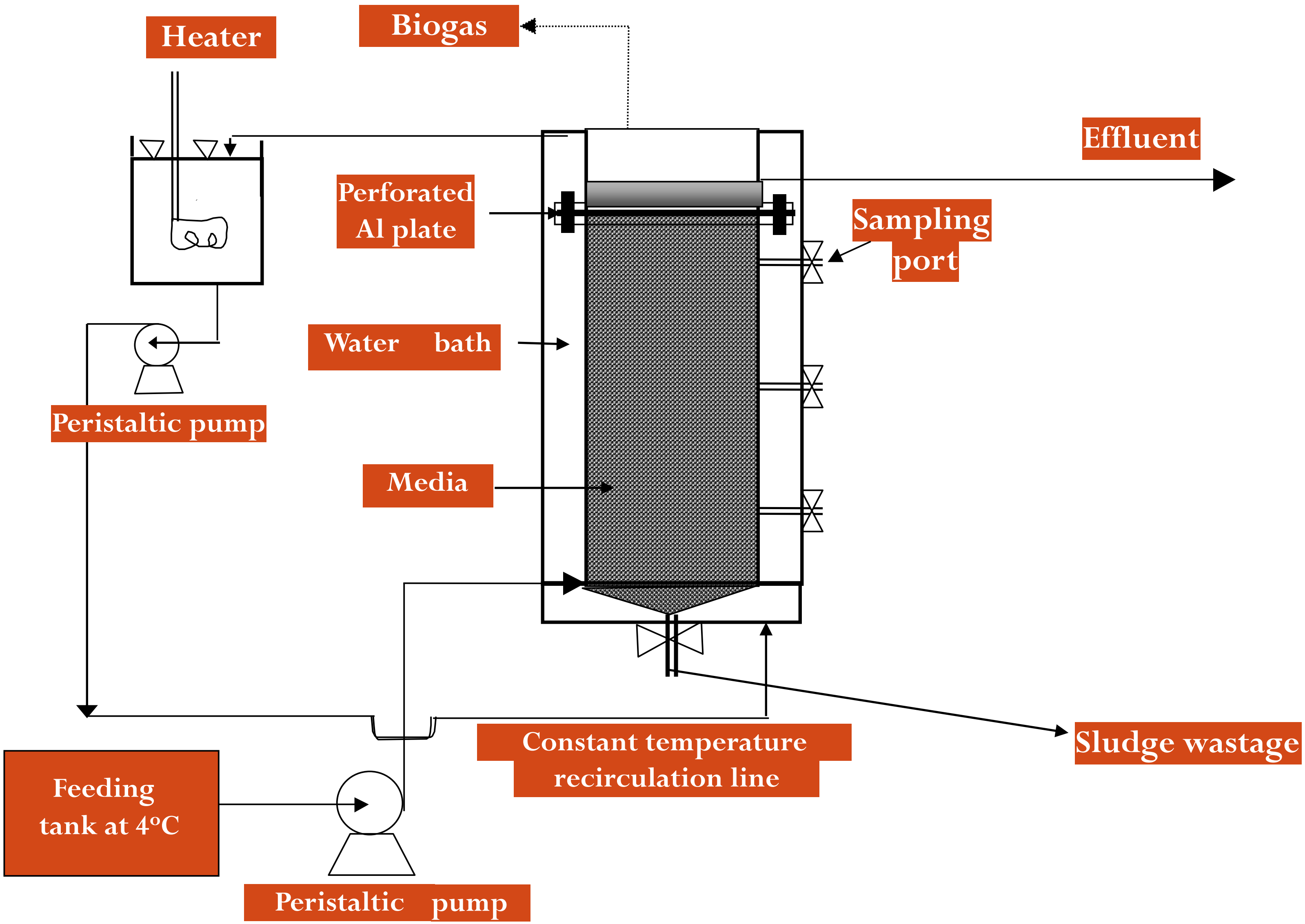


CSTR Mango Waste based Biogas Plant at Faridabad, India

Anaerobic filter

- Developed by Young and Mc Carty in the late 1960s to treat dilute soluble organic wastes.
- The filter was filled with rocks similar to the trickling filter.
- Wastewater distributed across the bottom ad the flow was in the upward direction through a bed of rocks
- Whole filter submerged completely
- Anaerobic microorganisms accumulate within voids of media (rocks or other plastic media).
- The media retain or hold the active biomass within the filter
- The non-attached biomass within the interstices forms bigger flocs of granular shape due to rising gas bubble/liquid.
- Non-attached biomass contributes significantly to waste treatment
- Attached biomass not be a major portion of total biomass
- 64% attached and 36% non-attached.

Upflow Anaerobic Filter



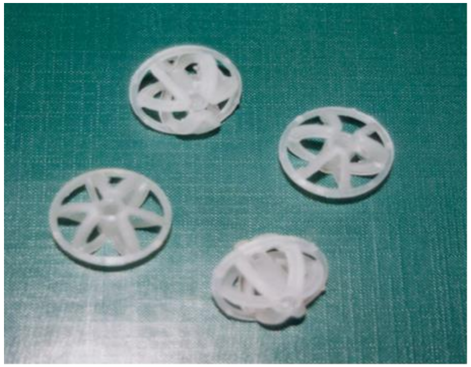
Anaerobic Filter Packing

Originally, rocks were employed as packing medium in anaerobic filter.

Presently, packing media are made up of plastics; ceramic tiles of different configuration have been used in anaerobic filters.

The void volume in these media ranges from 85-95 %.

Moreover, these media provide high specific surface area, typically 100 m^2/m^3, or above, which enhances biofilm growth.

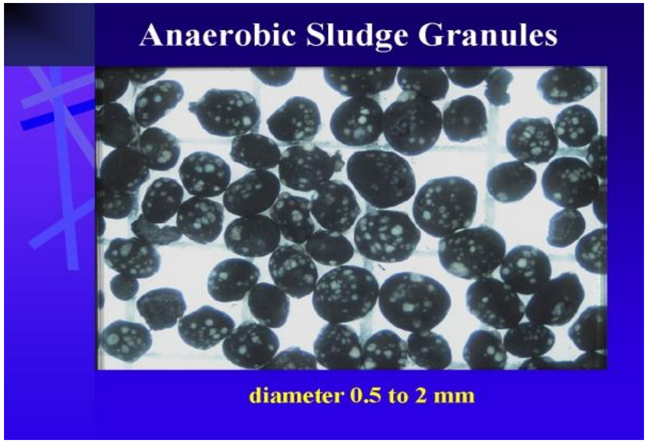


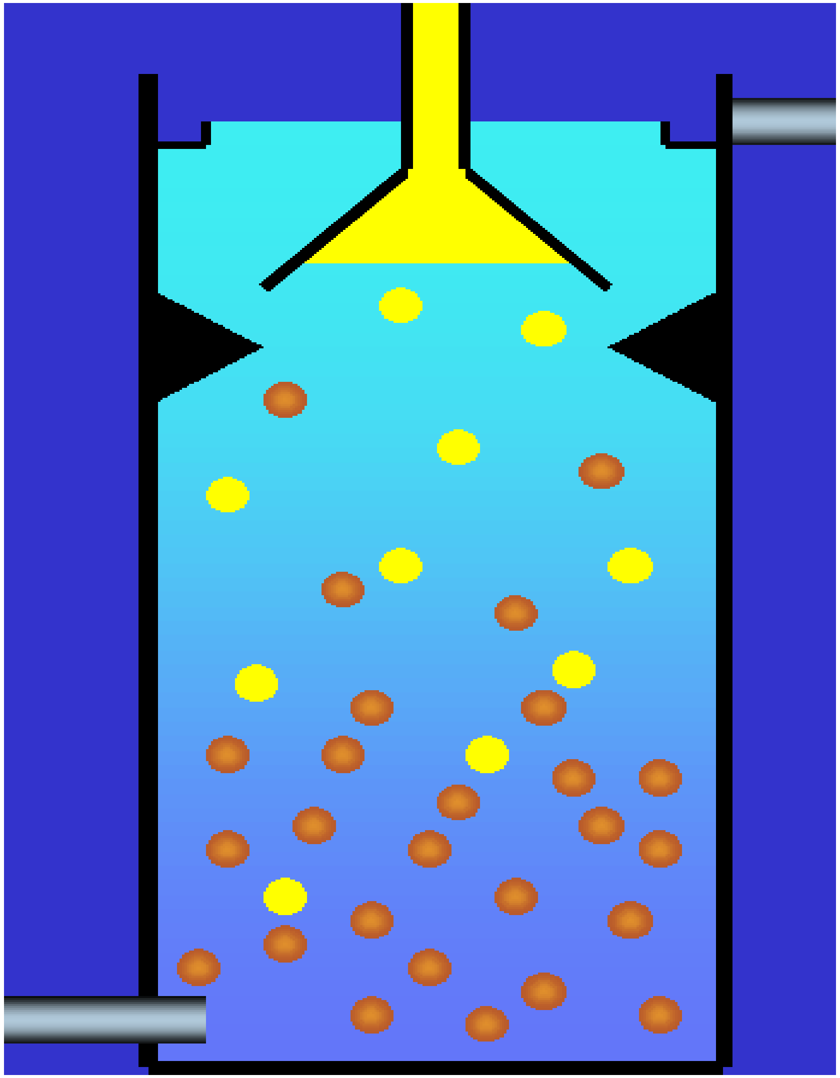
Up-flow Anaerobic Sludge Blanket (UASB)

- Developed in 1970s by Lettinga in the Netherlands.
- It’s a suspended growth system - Hydraulic and organic loading rate is maintained in order to facilitate the dense biomass aggregation known as granulation.
- Size of granules is about 1-3 mm diameter.
- Since granules are bigger in size and heavier, they will settle down and be retained within the reactor.
- The concentration of biomass in the reactor may become as high as 50 g/L.
- A very high SRT can be achieved even at a very low HRT of 4 hours.

Up-flow Anaerobic Sludge Blanket (UASB)

- The granules consist of hydrolytic bacteria, acidogen/ acetogens and methanogens.
- Carbohydrate degrading granules show layered structure with a surface layer of hydrolytic / fermentative acidogens.
- A mid-layer comprising of syntrophic colonies and an interior with acetogenic methanogens.





UASB Reactor. Hiriya,Tel Aviv, Israel

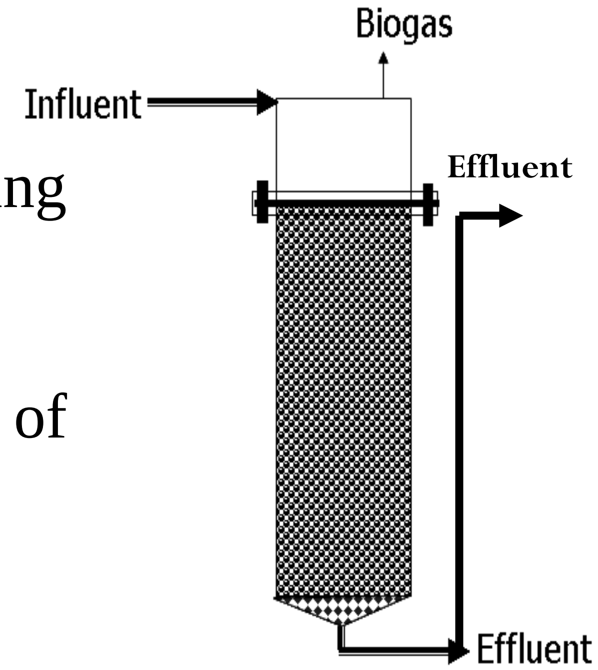
UASB Reactor. Porur, Chennai, India

Static granular bed reactor (SGBR)

• Developed at Iowa State University by Drs. Ellis and Kris Mach

• Just opposite to UASB; flow is from top to bottom and the bed is static

• No need of three-phase separator or flow distributor



• Simple in operation with fewer moving parts

• Major issue: head loss due to build-up of solids

Expanded bed reactor (EBR)

- Expanded bed reactor is an attached growth system with some suspended biomass.

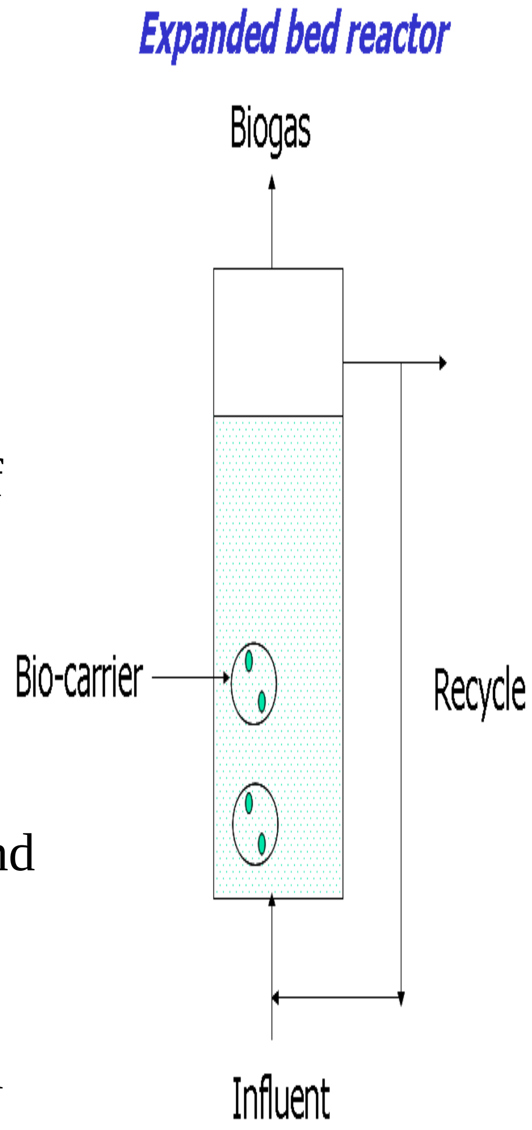
- The biomass gets attached on bio-carriers such as sandman, pulverized polyvinyl chloride, shredded tire beads.

- The bio-carriers are expanded by the up flow velocity of influent wastewater and recalculated effluent.

- In the expanded bed reactor, sufficient upflow velocity is maintained to expand the bed by 15-30%.

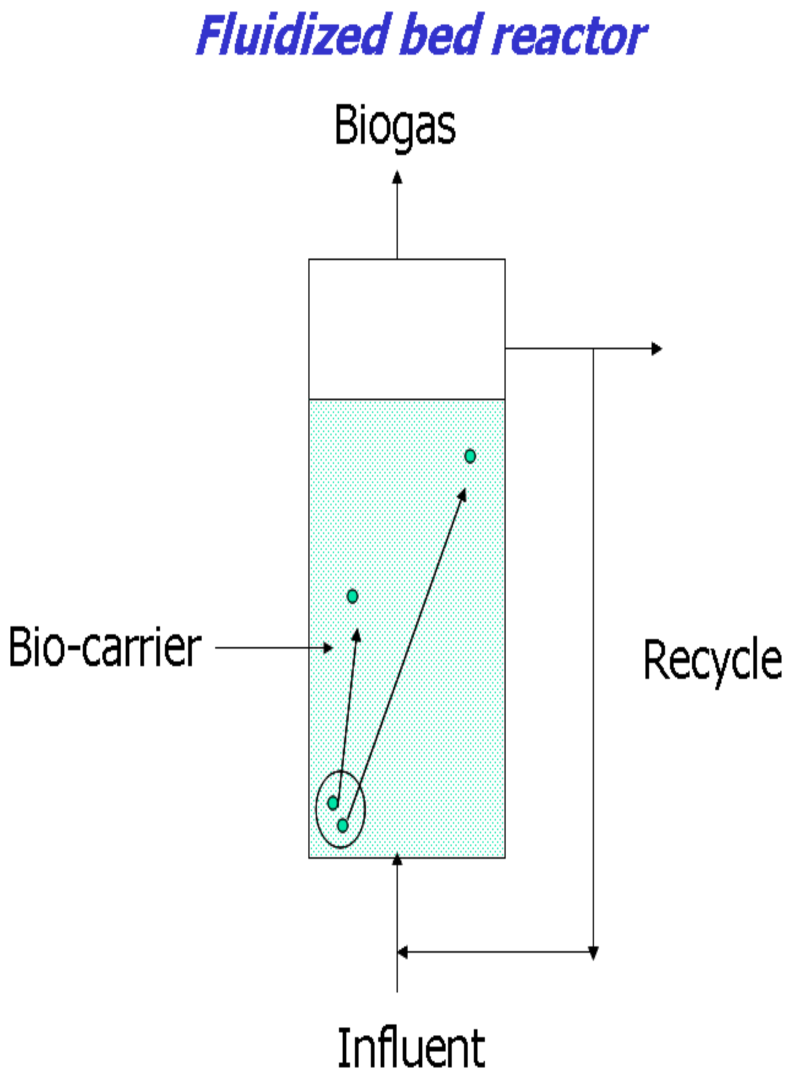
- The expanded bed reactor has less clogging problems and better substrate diffusion within the bio-film.

- The bio-carriers are partly supported by fluid flow and partly by contact with adjacent bio-carriers, which retain the same relative position within the bed.



Fluidized Bed Reactor (FBR)

- FBR is similar to EBR in terms of configuration.
- FBR is truly fixed film reactor as suspended biomass is washed–out due to high up-flow velocity.
- The bed expansion is 25-300% of the settled bed volume, which requires much higher up-flow velocity (10-25 m/hr).
- The bio-carriers are supported entirely by the upflow liquid velocity and therefore able to move freely in the bed.
- The fluidized bed reactor is free from clogging problem, short-circuiting and better substrate diffusion within the biofilm.



Expanded Granular Sludge Bed Reactor for situations where space constraints exist

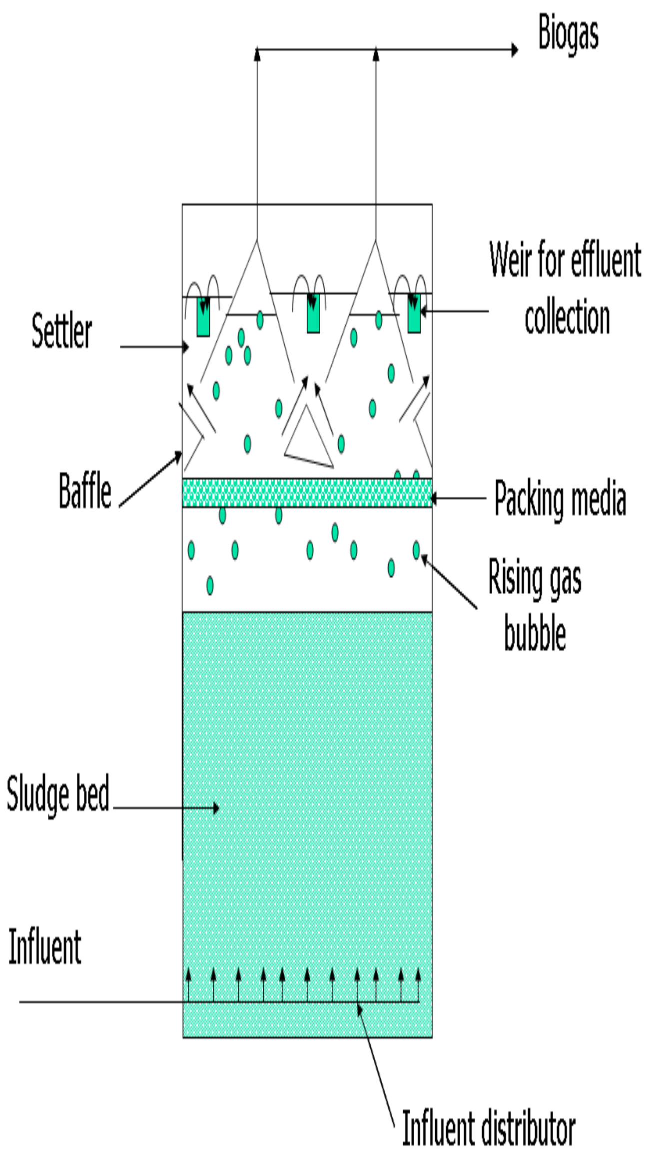
Hybrid System : UASB/AF Reactor

Hybrid system: UASB/AF

Hybrid system incorporates both granular sludge blanket (bottom) and anaerobic filter (top). Such approach prevents wash-out of biomass from the reactor. Further additional treatment at the top bed due to the retention of sludge granules that escaped from the bottom sludge bed.

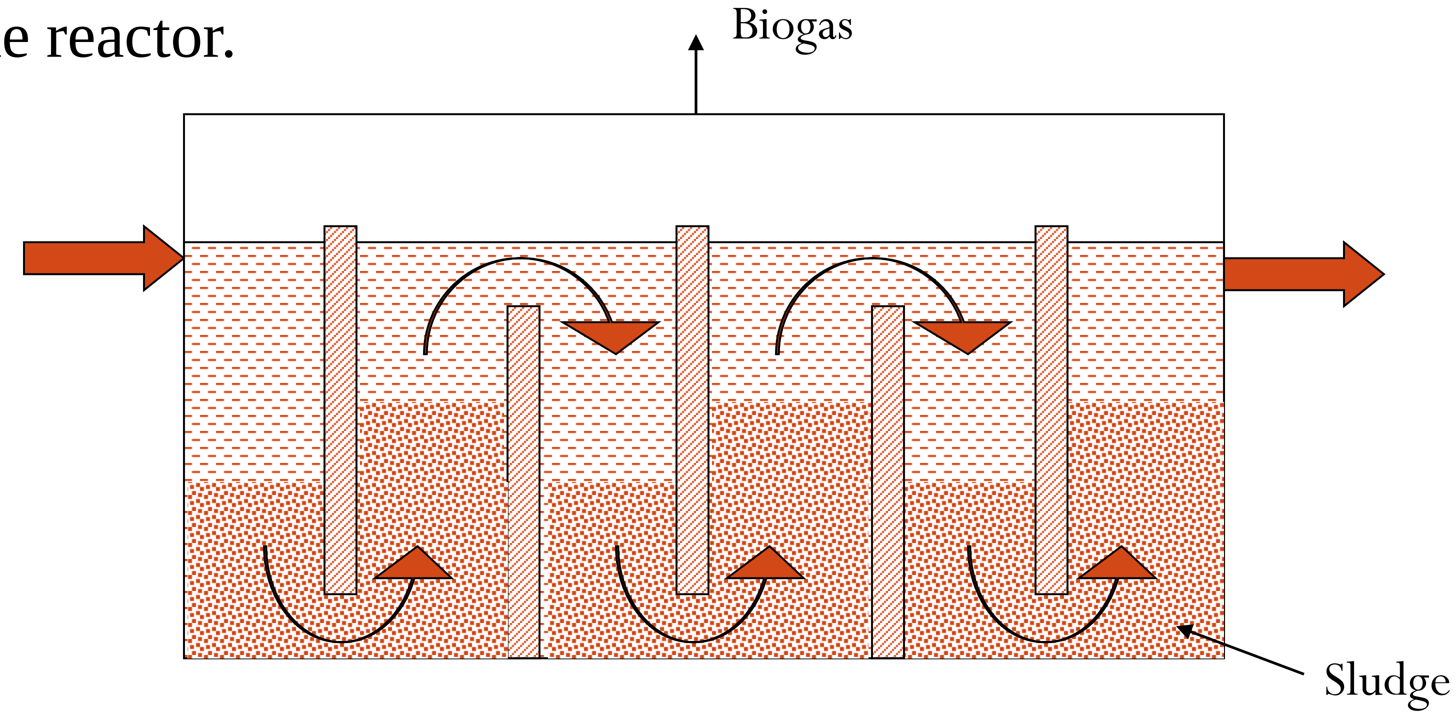
UASB reactor facing a chronic sludge wash-out problem can be retrofitted using this approach.

Hybrid system may be any combination of two types of reactor



Anaerobic baffled reactor

- In anaerobic baffled reactor, the wastewater passes over and under the baffles.
- The biomass accumulates in between the baffles which may in fact form granules with time.
- The baffles present the horizontal movement of biomass in the reactor.
- Hence a high concentration of biomass can be maintained within the reactor.

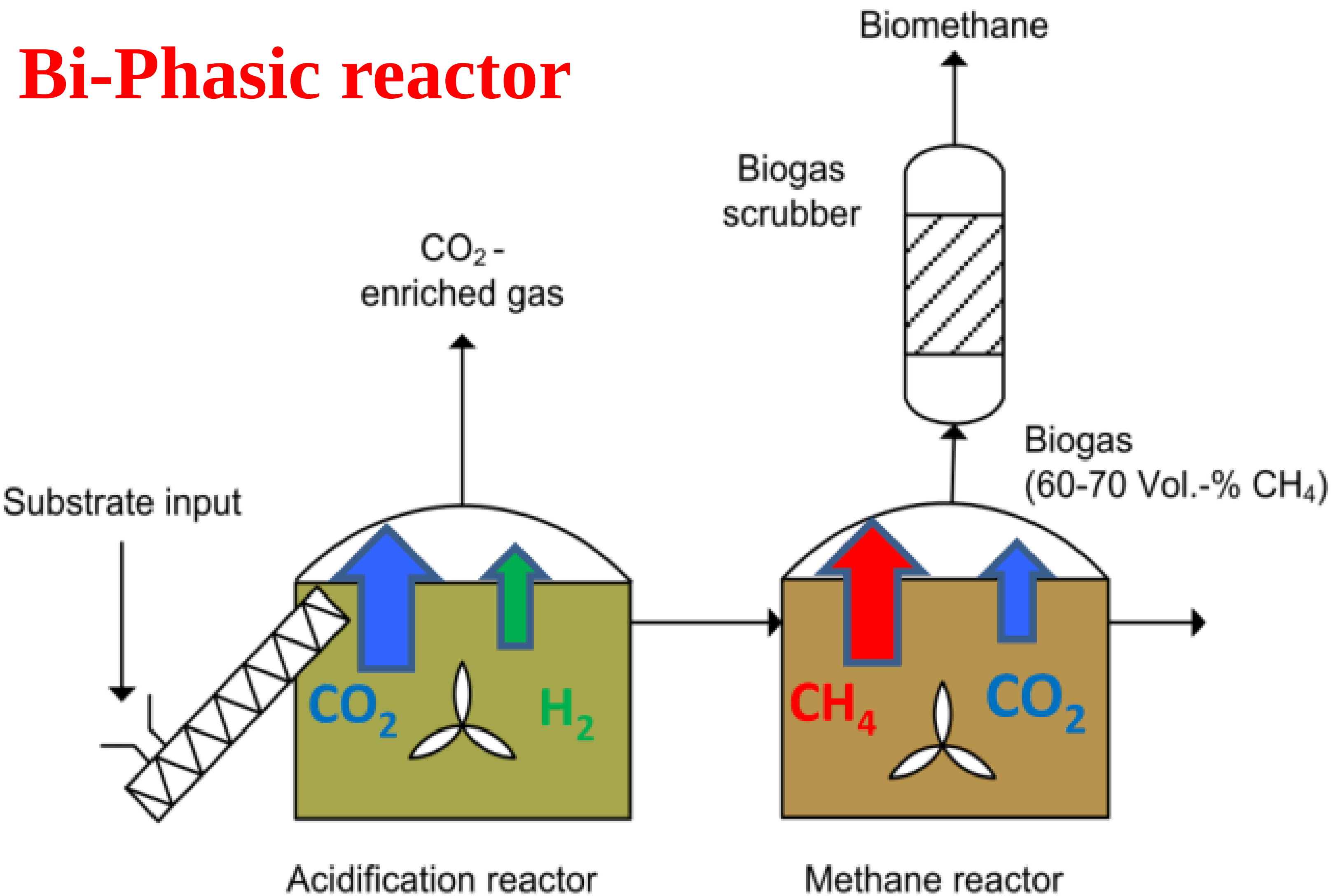


Anaerobic Blanket Sludge Reactor
Global Water Pathogen Project

Bi-phasic reactors

- A biphasic system consists of an open batch acid reactor and an anaerobic filter reactor.
- The acid reactor is fabricated with mild steel plate while methane reactor is constructed of prefabricated reinforced concrete pipe.
- A wire mesh is provided at the bottom to support solid bed of agricultural wastes. The bottom of the reactor is a hopper and an outlet is provided to drain out acid rich liquid.
- A dispersion plate is provided above the bottom of the reactor To support the packing medias and to distribute the flow of influent.
- Brickbats are used as packing media to support the growth of methanogenic bacteria.

Bi-Phasic reactor



This technology is suitable for the utilization of vegetable and fruit waste available in agricultural products markets.

O/M and feasibility / scalability assessment of plants…..

- Estimating time to reach stable steady state
- Assessing the organic loading rate at the beginning
- Control of some chemical parameters during start up
- Handling of digested bio-manure with high moisture content
- Feedstock and effluent characterization
- Analysis for composition of biogas produced
- Stimulating additives and culture agents for higher methane
- Sustainability concept, including green house gas accounting

Suggested Readings

- Biogas Systems: Principles And Applications by Dr. K M Mital , New Age International (P) Ltd.
- www.irena.org/statistics
- Biogas From Waste And Renewable Resources: An Introduction: Second, Revised & Expanded Edition by Deublein D, John Wiley

Thank you