Technology Options for Treatment of Liquid Wastes.

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INTRODUCTION

- Conventional anaerobic digestion process was developed for the generation of biogas from municipal sewage sludge and plants are in operation in Mumbai, Delhi and in some industrial townships.

Anaerobic digestion has been adapted in full-scale installations for several process wastewaters

- Distillery
- Paper
- Dairy
- Pharmaceuticals (Fermentation)
- Leather
- Poultry
- Yeast
- Starch
- Rayon
- Rubber
- Abattoir
- Food processing
- Dairy farm
- Domestic sewage

AD Process Benefits

- Energy recovery
- Stabilized residue
- Low capital and operating costs
- Power savings and high efficiency.
- A mature and proven waste-to-energy option.

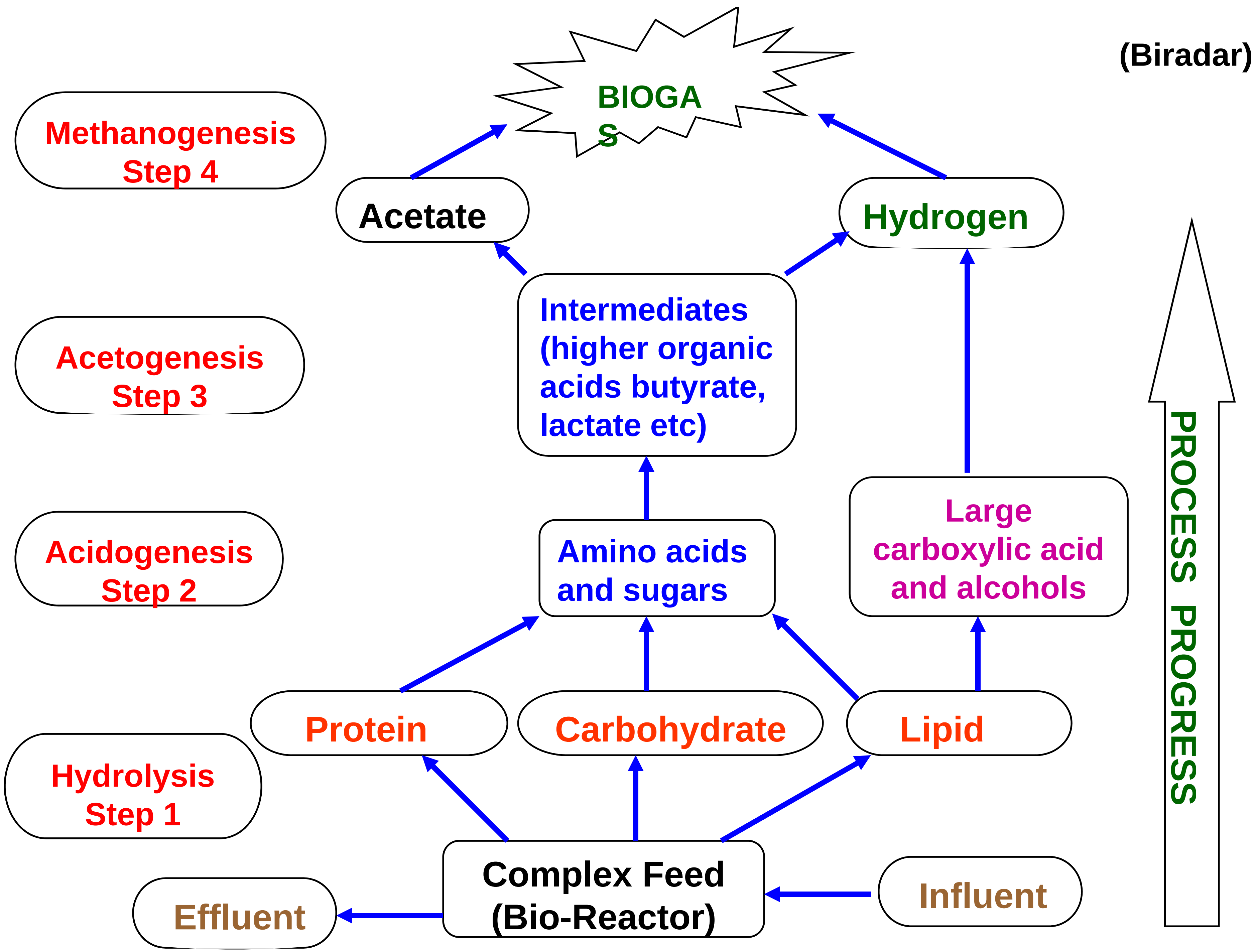
Principles of Biomethanation

- The overall process involves both direct and indirect symbiotic associations between different groups of microorganisms.
- The methanogenic bacteria are crucial for the anaerobic stabilization of a variety of substrates, since they constitute the final step leading to the generation of biogas.

CORE BIOCHEMICAL STEPS IN ANAEROBIC DIGESTION

Step	Core reactions	Process	Type of bacteria
1	**Hydrolysis**	**Fermentation of complex organics to soluble organics.**	**Fermentative**
2	**Acidogenesis**	**Soluble organics converted to volatile fatty acids (VFAs) and alcohols.**	**Acidogenic**
3	**Acetogenesis**	**VFAs and alcohols converted to acetic acid, carbon dioxide and hydrogen**	**Acetogenic**
4	**Methanogenesis**	**Acetic acid converted to methane and carbon dioxide** **Carbon dioxide and hydrogen converted to methane and water.**	**Methanogenic**

- The conversion possibilities serve as a convenient basis for emphasizing some important biochemical and environmental requirements of anaerobic treatment of municipal, agricultural and industrial wastes and for development or selection of substrate-linked process configurations.



(Biradar)
BIOGA
S
Methanogenesis
Step 4
Acetate
Hydrogen
Acetogenesis
Step 3
Intermediates
(higher organic
acids butyrate,
lactate etc)
Acidogenesis
Step 2
Amino acids
and sugars
Large
carboxylic acid
and alcohols
PROCESS PROGRESS
Protein
Carbohydrate
Lipid
Hydrolysis
Step 1
Complex Feed
(Bio-Reactor)
Effluent
Influent

Screening & Selection of AD systems :

- **Source and nature of wastewater.**
- **Flow rate.**
- **Organic pollutants (BOD, COD)**
- **Suspended solids**
- **Temperature**
- **Toxicants**
- **Biogas and sludge generation**

Process Parameters

- **The rates of Methanogenesis in anaerobic microbial conversion processes depend primarily upon:**
  - **Substrate availability**
  - **Viable microbial population**
  - **Environmental factors**
    - **pH,**
    - **temperature,**
    - **Ionic strength or salinity,**
    - **Nutrients,**
    - **Toxic or inhibitory substances.**

pH

- Operates best at pH 6.5-7.5 (alkalinity 1,000 to 5,000 mg/l, and VFA below 250 mg/l.)

- Gas production and pH levels are good indicators of performance and pH below 6 indicates an upset and excessive acid accumulation is inhibitory to methanogens

Temperature

- Methanogenesis reactions are strongly temperature-dependent
- Mesophilic ($35^{0}C$) and Thermophilic (55 to $60^{0}C$).
- Sub-optimal temperatures require longer start-up times

Ionic Strength and Salinity

- Sulfate ions exert a significant control on the viability of methanogens vs sulfate-reducing bacteria (SRB).
- Salinity above 0.2 M NaCl is reported to be inhibitory.

Nutrients

- Organic constituents of the waste usually supply the macronutrients (C,N)

- The inability of many anaerobes to synthesize some essential vitamins or amino acids require nutrient supplements like nitrogen and phosphorous for growth and metabolism. (BOD:N:P ratio of 100:0.5:0.1).

Nutrients Contd…

- Trace elements
  - **Iron**
  - **Nickel**
  - **Magnesium**
  - **Calcium**
  - **Sodium**
  - **Barium**
  - **Tungstate**
  - **Molybdate**
  - **Selenium**
  - **And cobalt.**

*** Industrial wastewaters lack a balanced nutrient status (Supplemented by sewage)**

Toxicity

- Inhibition of methanogenic processes caused by intermediary products –
  - **VFA**
  - **Hydrogen sulphide**
  - **Ammonia**
  - **Heavy metals**
  - **And cyanide present in process wastewaters.**

- The range of effluents and wastes that can be treated by anaerobic digestion has increased substantially over the last ten years due to greater understanding of
  - Microbiological processes,
  - Development of new methods of process control,
  - Better reactor designs
  - And development of strategies to overcome problems caused by nutrient imbalance and toxicity.

BOD (COD)

- Anaerobic treatment can give 80-90% BOD removal, leaving a relatively high residual of undergraded organics in treated effluents.
- Aerobic processes appropriate for BOD or biodegradable COD below 2,000 mg/l.
- Anaerobic process applied in low or high rate forms between 1,000 and 30,000 mg/l.

Suspended Solids

- Most suitable for sewage sludge and manures
- High-rate anaerobic treatment technologies are relevant for soluble organic pollutants

Configuration of Bioreactors

- Three process configurations are suitable for full-scale urban and industrial wastewaters.
  - **Suspended Growth Reactors**
  - **Fixed Film Reactors**
  - **Hybrid Reactors**

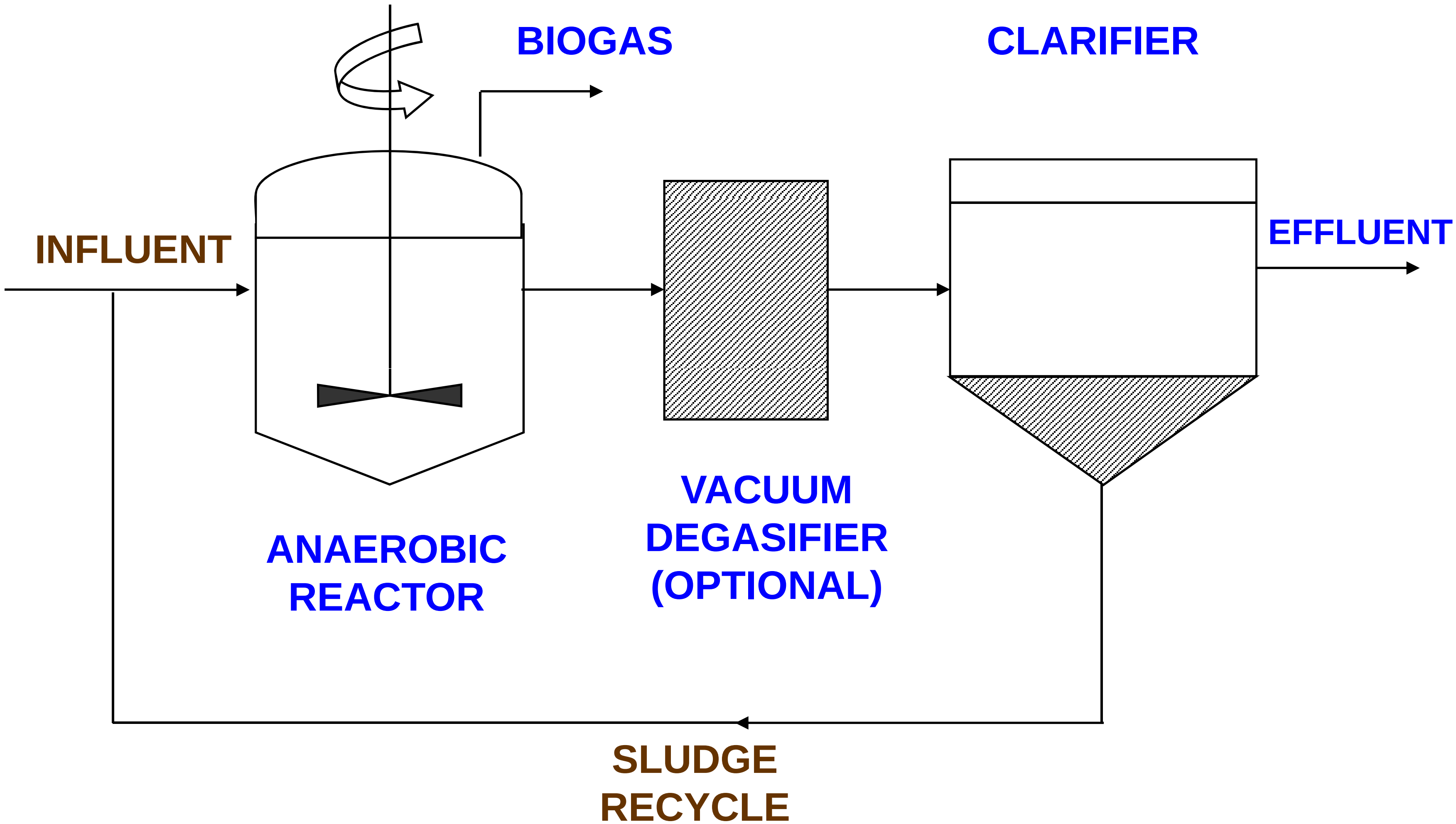
Configuration of Bioreactors Contd…

- **Suspended biomass growth processes are relevant for sludges or high particulate biodegradable material.**

- **The fixed film processes are well suited to soluble organic substrates.**

- **The hybrid processes falling in the middle, can be applied to wastewaters with intermediate levels of particulates, although performance is usually better with soluble wastewaters.**

Anaerobic Contact Reactor

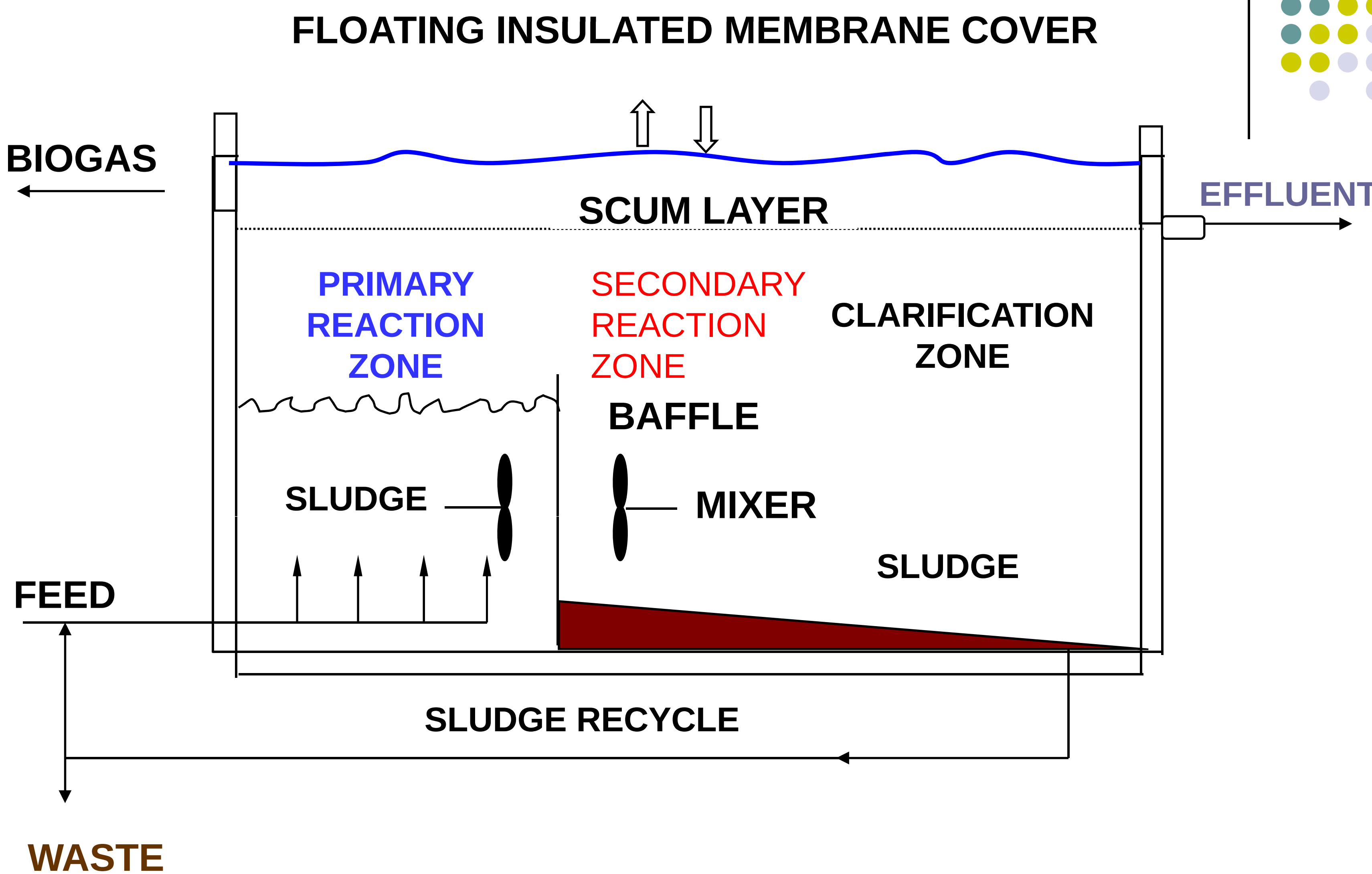


Anaerobic Contact Reactor Contd…

- The clarifier used in the process retains both active biomass to give higher SRT.
- Anaerobic flocs usually entrain biogas. Solids settleability can be improved by gas stripping, vacuum degasification, inclined plate or lamella settlers and the addition of coagulants and flocculants
- 80-90% COD reduction (COD 2,000 – 10,000 mg/)l.

Covered Anaerobic Lagoon

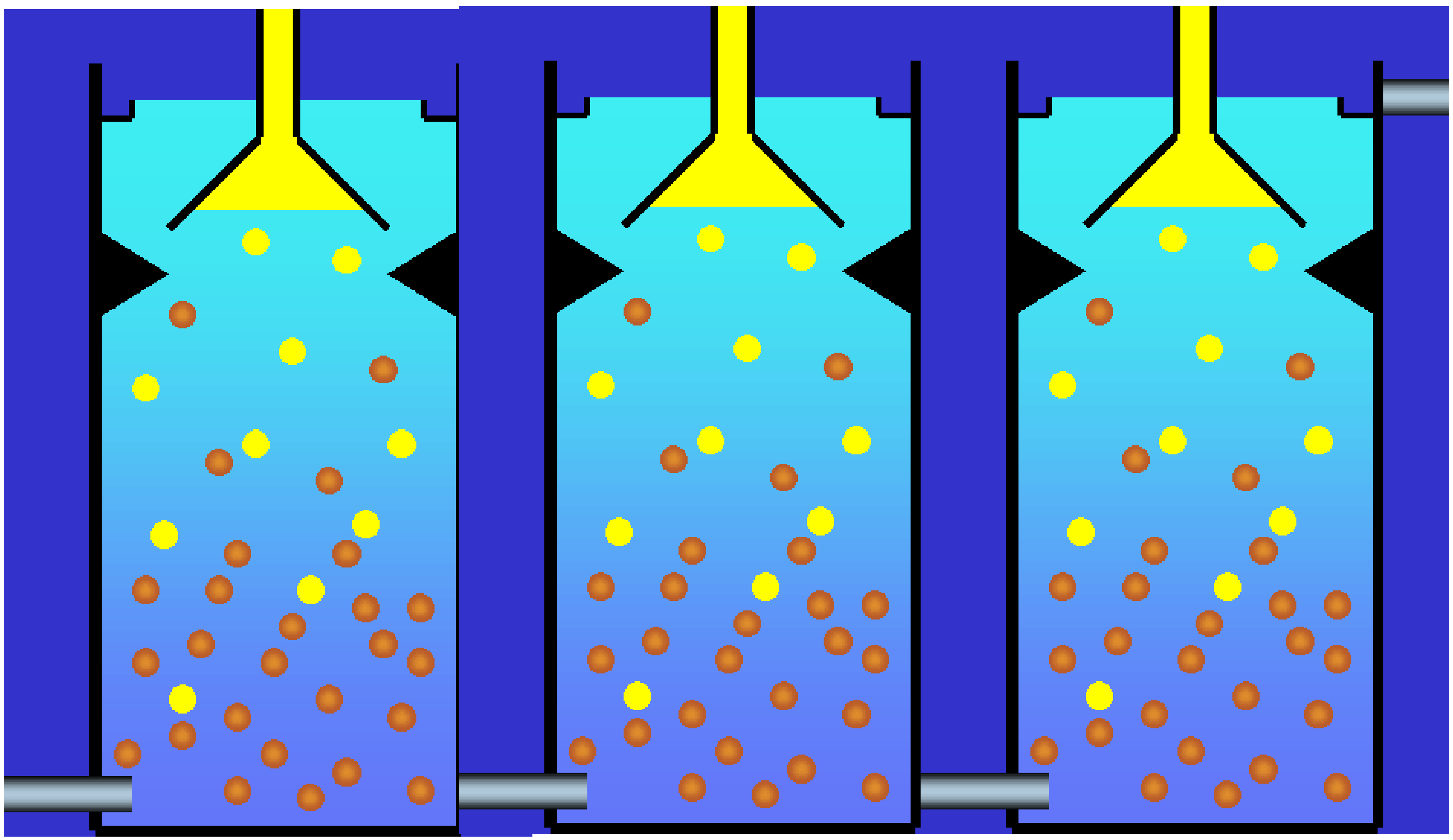
- **A low-rate anaerobic process.**
- **Waste enters through a distribution system to maximize contact with a bed of anaerobic biosludge at the inlet zone.**
- **The biogas causes internal mixing, along the length of the reactor.**
- **Near the outlet, a quiescent clarification zone is maintained to reduce the suspended solids.**
- **The reactor is covered with a floating insulated membrane to conserve process heat and collection of biogas.**


FLOATING INSULATED MEMBRANE COVER
BIOGAS
SCUM LAYER
EFFLUENT
PRIMARY REACTION ZONE
SECONDARY REACTION ZONE
CLARIFICATION ZONE
BAFFLE
SLUDGE
MIXER
SLUDGE
FEED
SLUDGE RECYCLE
WASTE

Up-flow Anaerobic Sludge Blanket (UASB) Reactor

- UASB reactor incorporates multiple functions of pre-sedimentation, anaerobic treatment, final sedimentation and stabilization in a single unit making it the most attractive high rate wastewater treatment option..
- The basic principle is to develop insitu granular sludge that settle under gravity. Anaerobic bacteria developed in the reactor is retained in the sludge blanket zone to give high SRT

Modular UASB System



(UASB) Contd…

- An integral three phase Gas-Liquid-Solids Separator (GLSS) is provided to dislodge sludge particles from entrapped biogas bubbles.

- Wastewater enters the UASB reactor from the bottom and travels through the reactor in the upward direction.

UASB Contd…

- Some of the advantages :
  - **Low energy requirement**
  - **High rate process with high volumetric loading.**
  - **Anaerobic sludge can be preserved, unfed for many months without any serious quality deterioration and Low land requirement.**
  - **Cost effective in removing bulk of the pollution.**

Fixed Film Systems

- Biofilm reactors utilize a Biofilm for the development of high concentrations of required biomass for efficient anaerobic treatment.
- An inert medium is placed in the vessel and the process is operated to favor the growth of microorganisms on the medium surface

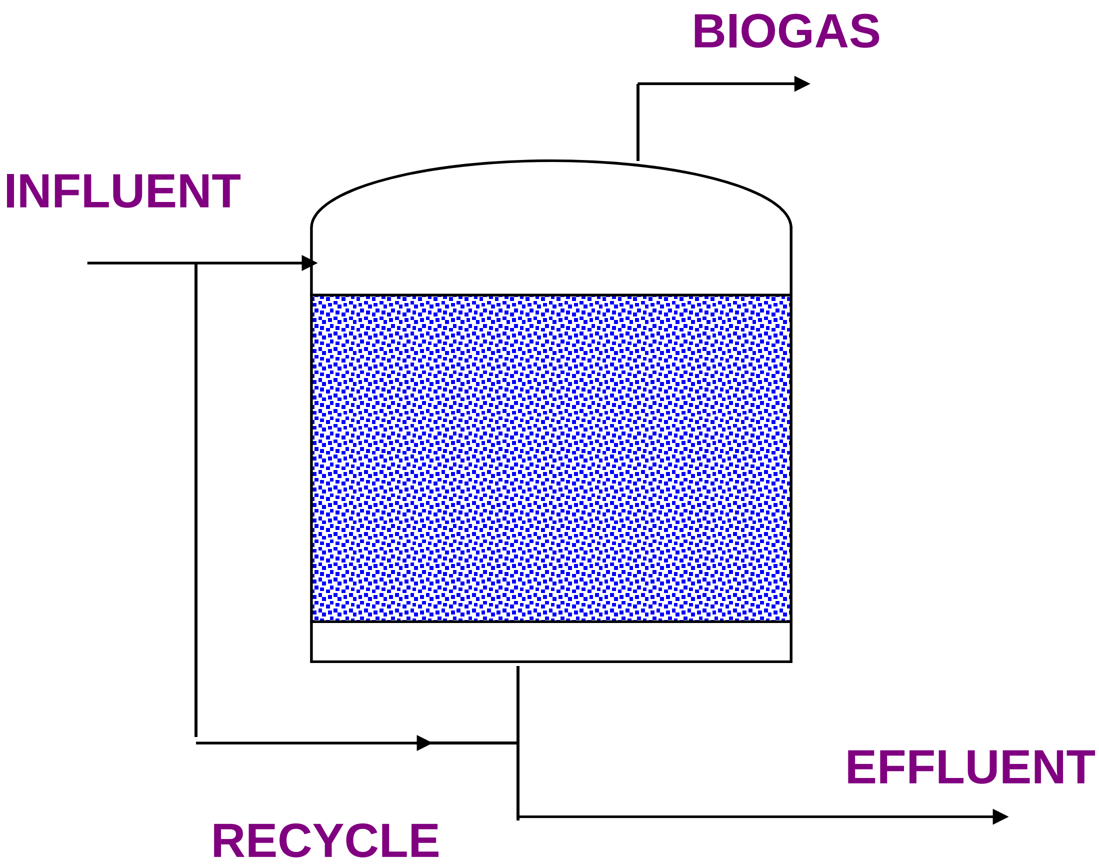
Upflow / Downflow Filters

- **Anaerobic Up-flow Filter, the is passed upward through a bed of medium. The growth of biofilm on the surface of the media contributes to the short hydraulic retention time and high organic loading rates. The packings provide 100 – 150 m2m-3 inter-facial area for biofilm development.**

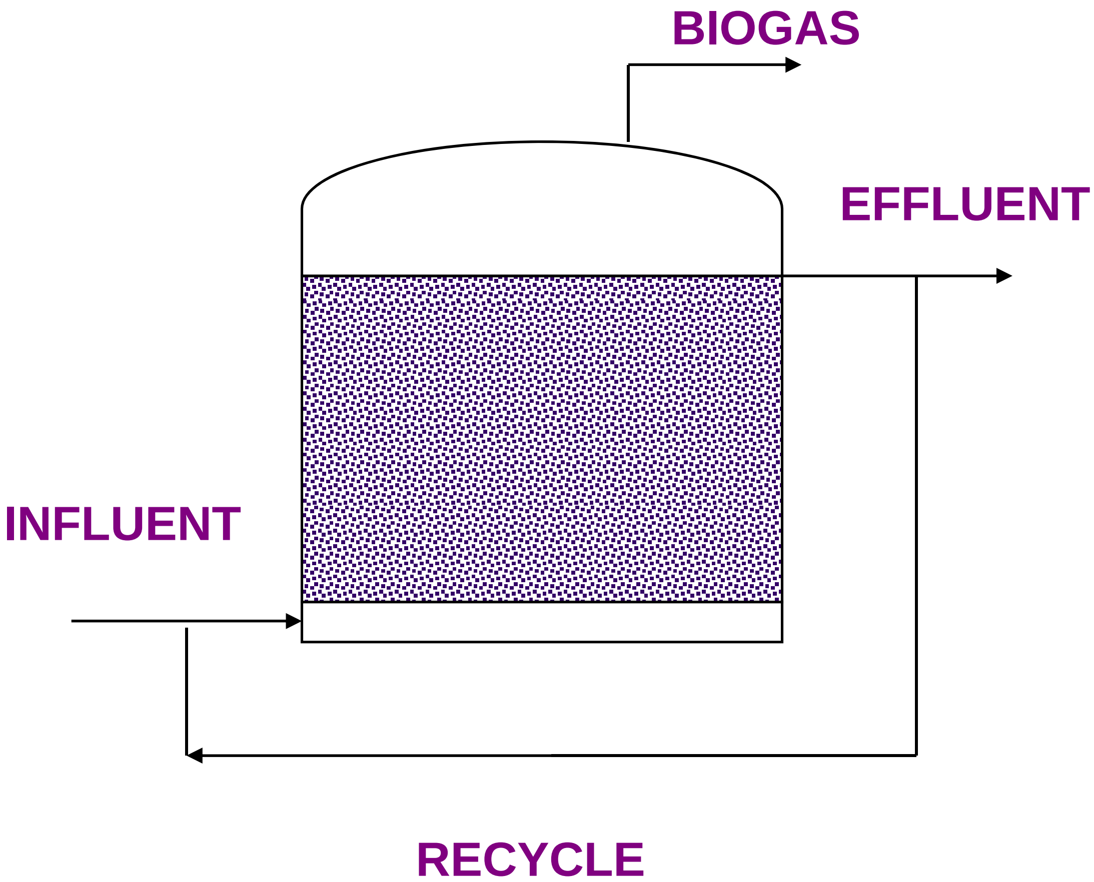
- **The down-flow reactor utilizes ordered modular packing which provides relatively straight vertical flow channels of approximately 40 mm in diameter. By operating the reactor in a down-flow mode, influent suspended solids and sloughed biofilm solids are carried down with the liquid flow and out of the reactor.**

- **Fixed bed anaerobic treatment processes are applicable to wastewaters with COD upto 100,000 mg/L. For higher strength wastewaters, effluent recycle is used to maintain the reactor inlet COD concentration between 8,000 and 12,000 mg/L.**

Downflow Filter



Upflow Filter



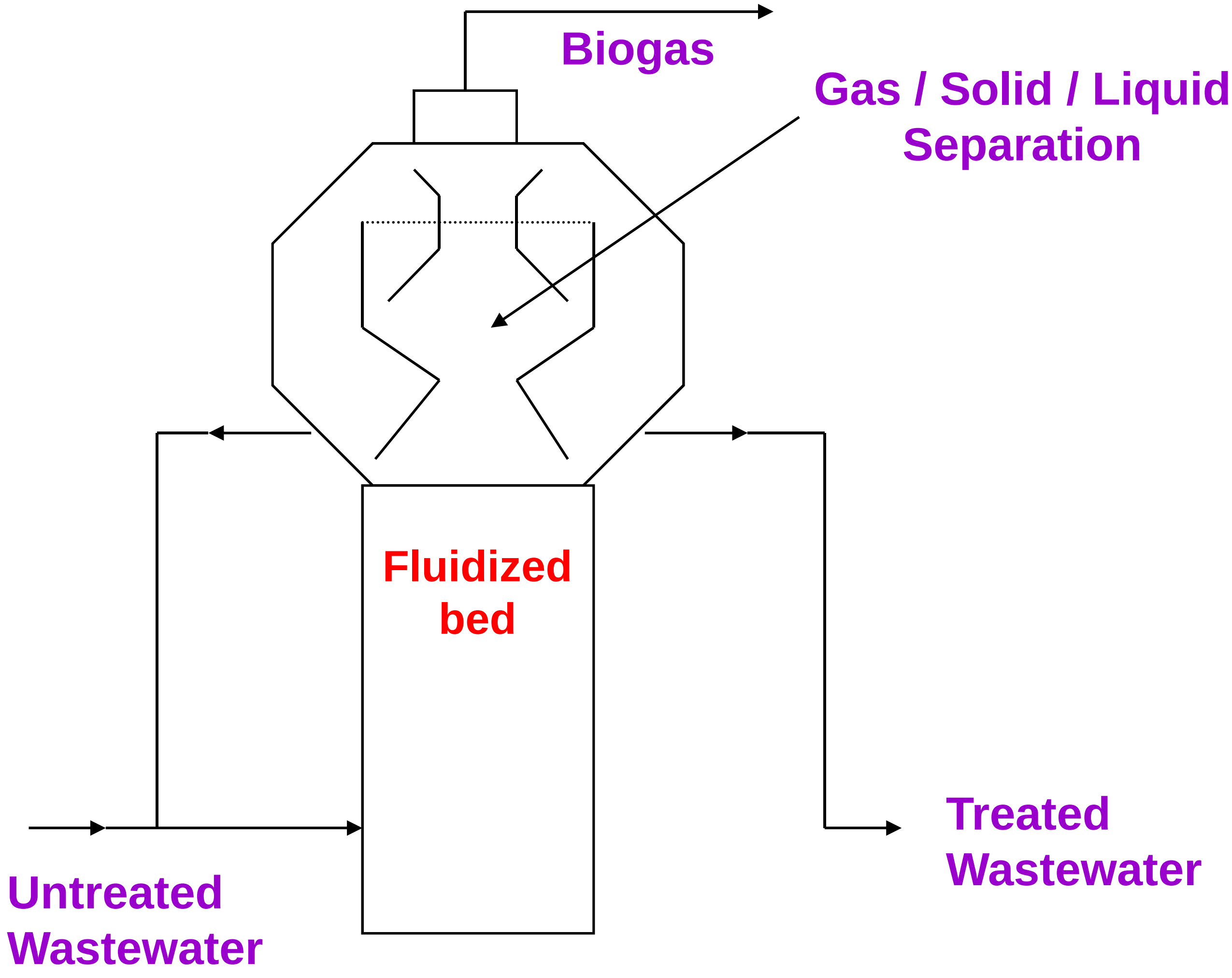
Fluidized Bed Bioreactors

- **Improves mass transfer characteristics in the fluidized bed using small particles (like sand) with very high surface-to-volume ratio.**

- **Energy required for high upflow velocities for 25 to 100% bed expansion.. is a distinct disadvantage.**

- Anaerobic biofilm is developed on the surface of the media. Turbulence at the biofilm/liquid interface promotes good mass transfer . With COD upto 100,000 mg/L and loading rates of 21 kg COD/m^3/d.

Fluidized Bed Bioreactors



Hybrid Systems

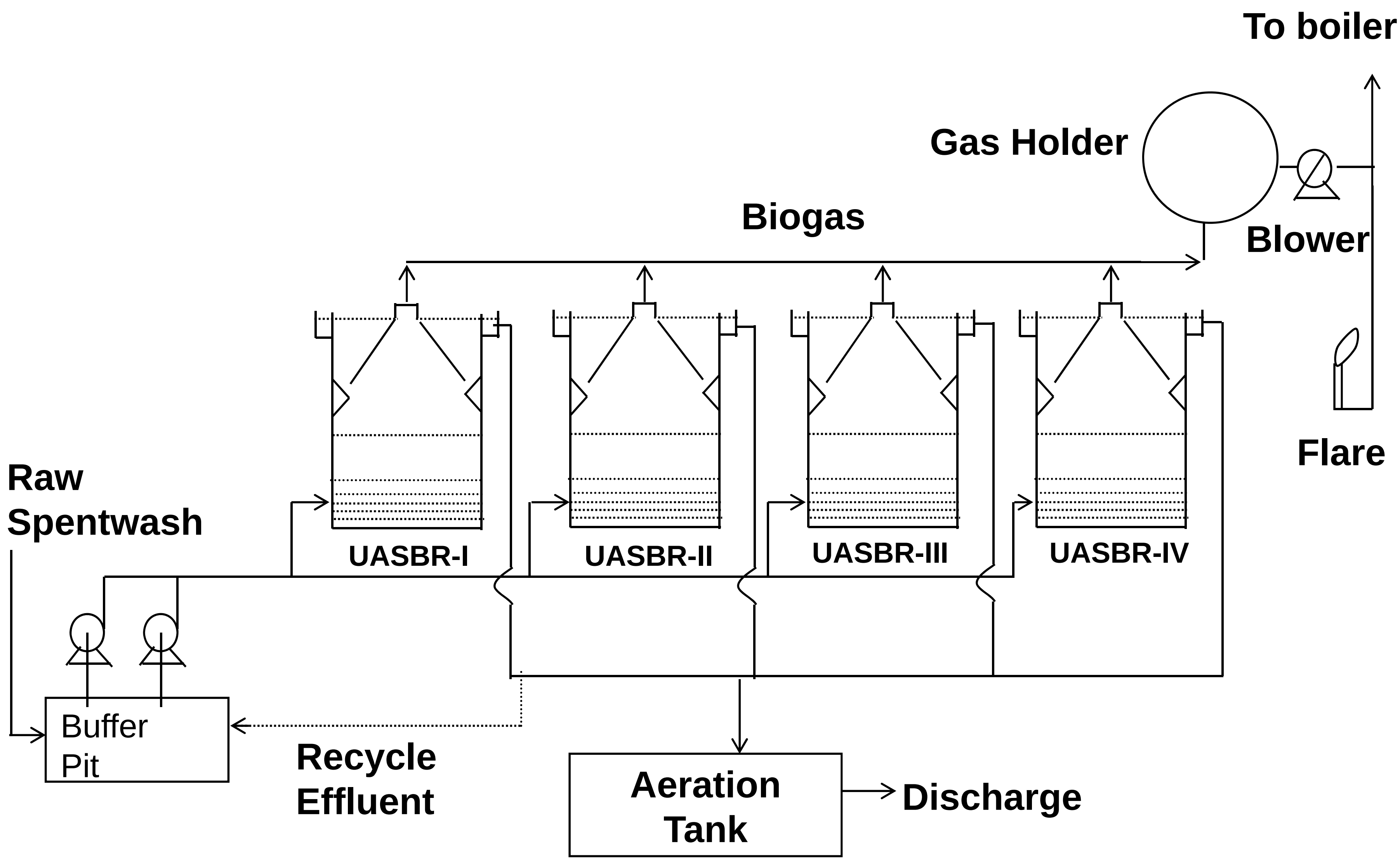
- The recent trend in design of anaerobic systems is towards the use of a “hybrid” reactor. The removal of the lower 50 – 75% of the media in anaerobic filters could produce a hybrid reactor configuration consisting of a lower sludge blanket zone and an anaerobic filter on the top.

Case Studies

- **Spentwash Characteristics Of Batch and Continuous Fermentation Processes**
- **Schematic Of UASB System (Sanjivani SSKL, Kopargaon)**
- **Profiles of Weekly Average Feed and Final Values, Feed Rate and Biogas Generation Rates. (UASB System, Somaiya Organo Chemicals Ltd. Sakarwadi) (March 2000 – Feb 2001**
- **Comparative Features and Performances of Biomethanation Plants at Pudumjee and Satia Paper Mills**

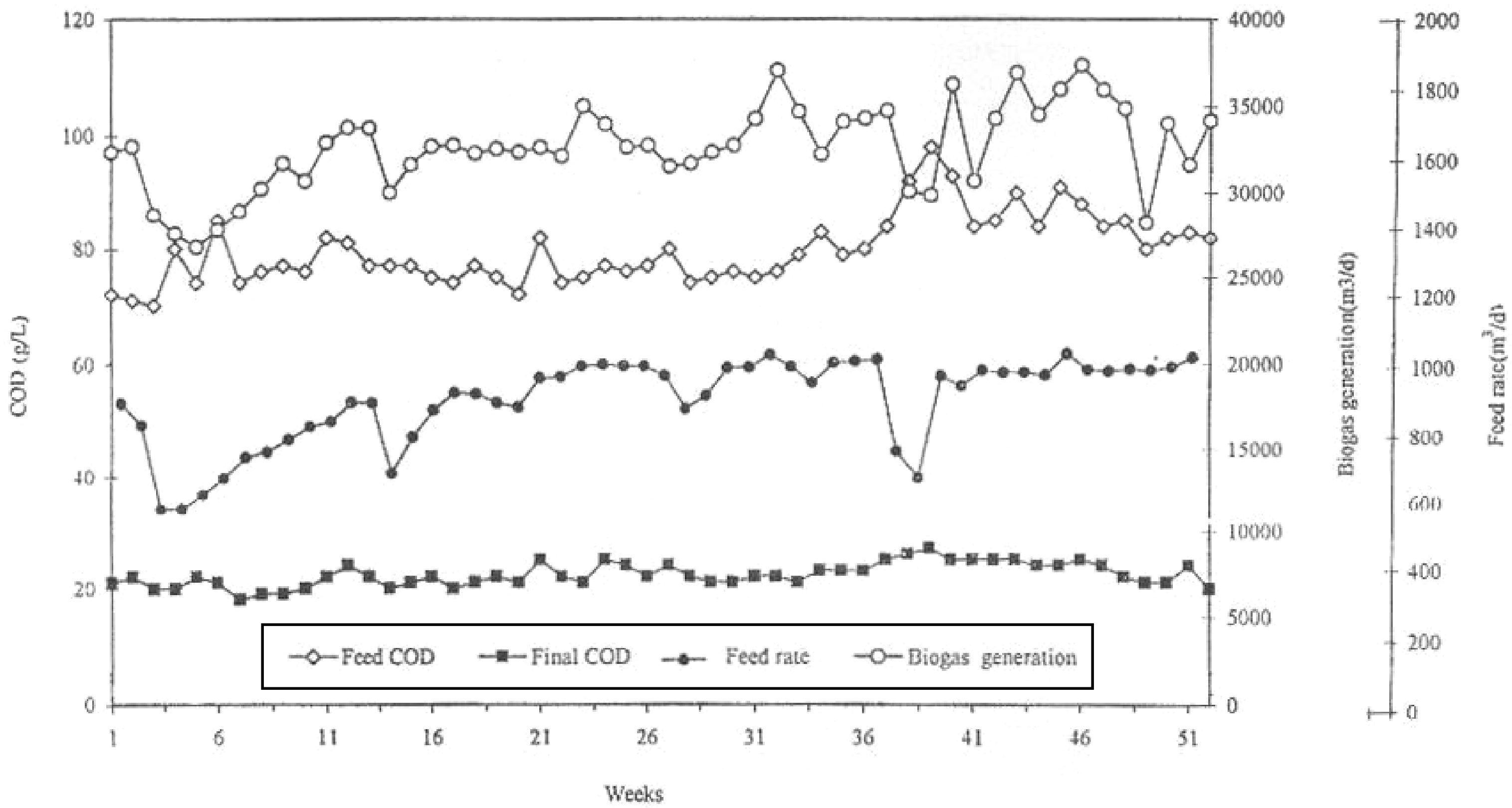
Average Spentwash Characteristics

Sr. No.	Parameter (mg/L)	Batch process	Continuous process
1	**Volume (L/L Alcohol)**	**14--15**	**10-12**
2	**Color**	**Dark brown**	**Dark brown**
3	**pH**	**3.7-4.5**	**4.0-4.3**
4	**COD**	**80,000-1,00,000**	**1,10,000-1,30,000**
5	**BOD**	**45,000-50,000**	**55,000-65,000**
6	**Total solids**	**90,000-1,00,000**	**1,30,000-1,60,000**
7	**Total Volatile**	**60,000-70,000**	**60,000-75,000**
8	**Inorganic dissolved**	**30,000-40,000**	**35,000-45,000**
9	**Chlorides**	**5,000-6,000**	**6,000-7,500**
10	**Sulphates**	**4,000-8,000**	**4,500-8,500**
11	**Total Nitrogen**	**1,000-1,200**	**1,000-1,400**
12	**Potassium**	**8,000-12,000**	**10,000-14,000**
13	**Phosphorus**	**200-300**	**300-500**
14	**Sodium**	**400-600**	**1,400-1,500**
15	**Calcium**	**2,000-3,500**	**4,500-6,000**



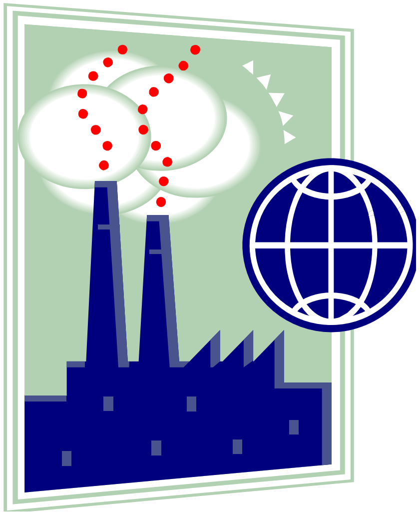
UASB SYSTEM (At SANJIVANI SSKL, KOPARGAON) **(Biradar)**

Profiles of Weekly Average Feed and Final Values, Feed Rate and Biogas Generation Rates. (UASB System, Somaiya Organo Chemicals Ltd. Sakarwadi) (March 2000 – Feb 2001 **(Biradar)**



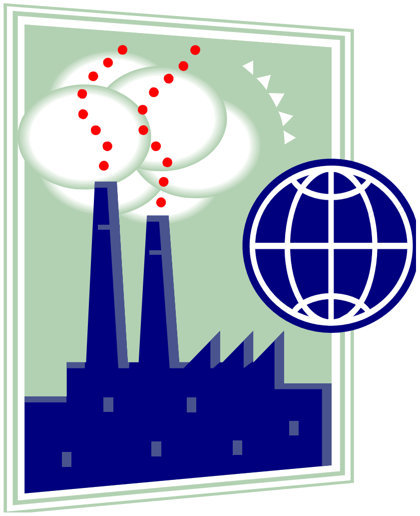
PROFILES OF WEEKLY AVERAGE FEED AND FINAL VALUES, FEED RATE AND BIOGAS GENERATION RATES (UASB SYSTEM, SOMAIYA ORGANO CHEMICALS Ltd.,SAKARWADI) (MARCH 2000-FEB 2001)

Comparative Features and Performances of Biomethanation Plants at Pudumjee and Satia Paper Mills.



Pudumjee

Vs



Satia

1. Pulping

Sr. No.		Pudumjee	Satia
a	**Plant Capacity (TPD)**	**40**	**45/50**
b	**Raw material**	**Bagasse**	**Bagasse/Wheat straw**
c	**Pulping Process**	**Chemi Mechanical**	**Alkaline Sulphite (changed to Soda)**

2. Black Liquor

		Pudumjee	Satia	Satia
			Design	**Revised**
a	**PH**	**9-9.5**	**8.5-9**	**8.5-9**
b	**TDS mg/L**	**-**	**-**	**30000-40000**
c	**BOD mg/L**	**3000-3500**	**3200**	**8000-9000**
d	**COD mg/L**	**9000-10000**	**12000**	**26000-27000**
e	**COD/BOD**	**3**	**3.8**	**3**
f	**Flow cum/d**	**2200**	**4580**	**2000**
g	**Temp deg C**	**$36^{O}C$**	**-**	**-**

3. Biomethanation Plant

		Pudumjee	Satia
a	**Technology**	**Sulzer (AN-OPUR-P)**	**Paques**
b	**Bioreactor**	**Contact with integral lamella clarifiers**	**UASB**
c	**Start-up**	**1988**	**1997**
d	**Feed**	**Segregated black liquor**	**Segregated soda black liquor (bleach plant effluent excluded)**
e	**Funding**	**IREDA + (others)**	**MNES (UNDP/GEF)**
f	**Tech Support**	**-**	**CPPRI**

4. Reactor details

		Pudumjee	Satia
a	**No. of reactors**	**2**	**2**
b	**Volume (m3) (each)**	**6200**	**2623**
c	**Arrangement**	**Parallel**	**Parallel**
d	**Retention time (h)**	**50 (each)**	**24 (each)**

5. Reactor Performance

		Pudumjee	Satia
a	COD loading (kg/m3.d)	5 (max)	10 (actual:12)
b	Reactor pH	6.8-7.6	6.5-7.5
c	Temperature (deg C)	35-37	35-37 (winter: heating of feed)
d	BOD removal (%)	90	75-80
e	COD removal (%)	70	45-50
f	MLVSS (mg/L)	6000-7000	-
g	Biogas generation (m3/d)	9000-10000	11000 – 12500
h	Specific biogas production (m3/kg COD)	0.45-0.5	-
i	Biogas methane (%)	75	80-85
j	Boiler Fuel	LSHS/Biogas	Rice husk/Biogas
k	Boiler fuel replacement (%)	15	15-20

6. Treated effluent characteristics

		Pudumjee	Satia
	PH	**7.4-7.6**	**-**
	Temperature (deg C)	**36-37**	**-**
	BOD (mg/L)	**300-350**	**-**
	COD (mg/L)	**2700-3000**	**-**
	COD/BOD	**9**	**-**

7. Downstream treatment

		Pudumjee	Satia
		Activated sludge Process	**Activated sludge process (?)**

Summary

- The selection of an appropriate bioreactor configuration is a critical factor determining the successful implementation and sustained operation of a total biomethanation system.
- Several bioreactor designs and configurations have been utilized in the implementation of biogas systems operating in the country.

Summary Contd…

- Engineering know-how for the full-scale plant design has been acquired through technical collaborations with leading international organizations.
- Engineering companies, consultants, institutional experts and R & D personnel together can offer total expertise necessary for turnkey execution of biomethanation projects.

Thank You