

# SBT TECHNOLOGY OF IIT BOMBAY



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# APPLICATIONS OF SBT

- Rain water harvesting
- Drinking water
- Swimming pool
- Sewage treatment
- Industrial wastewater treatment,
- Industrial air purification
- Municipal solid waste Processing
- Commercial production of Soil
- Animal House waste processing
- Hospital waste treatment

# Why This Technology

**Agriculture**

**Animal Husbandry**

**Fisheries**

**Sewage Treatment**

**Water Supply& Sanitation**

**Waste Water Treatment**

**Rain water Harvesting**

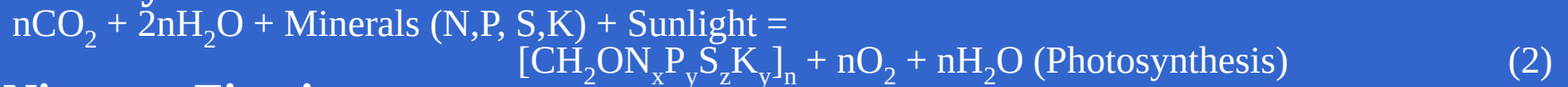
**Restoration of Rivers and Lakes**

# Process Chemistry

## Respiration



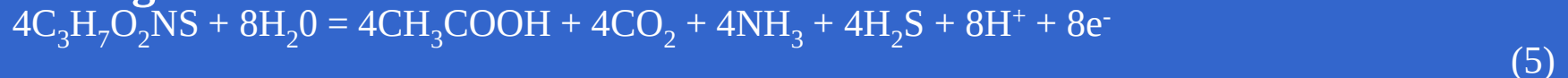
## Photosynthesis



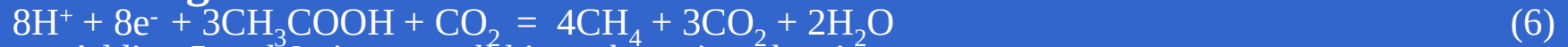
## Nitrogen Fixation



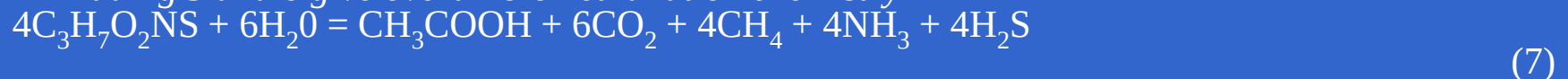
## Acidogenesis



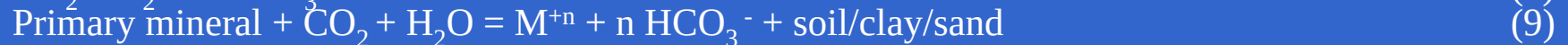
## Methanogenesis



*Adding 5 and 6 give overall biomethanation chemistry*



## Mineral weathering



## Nitrification



## Denitrification

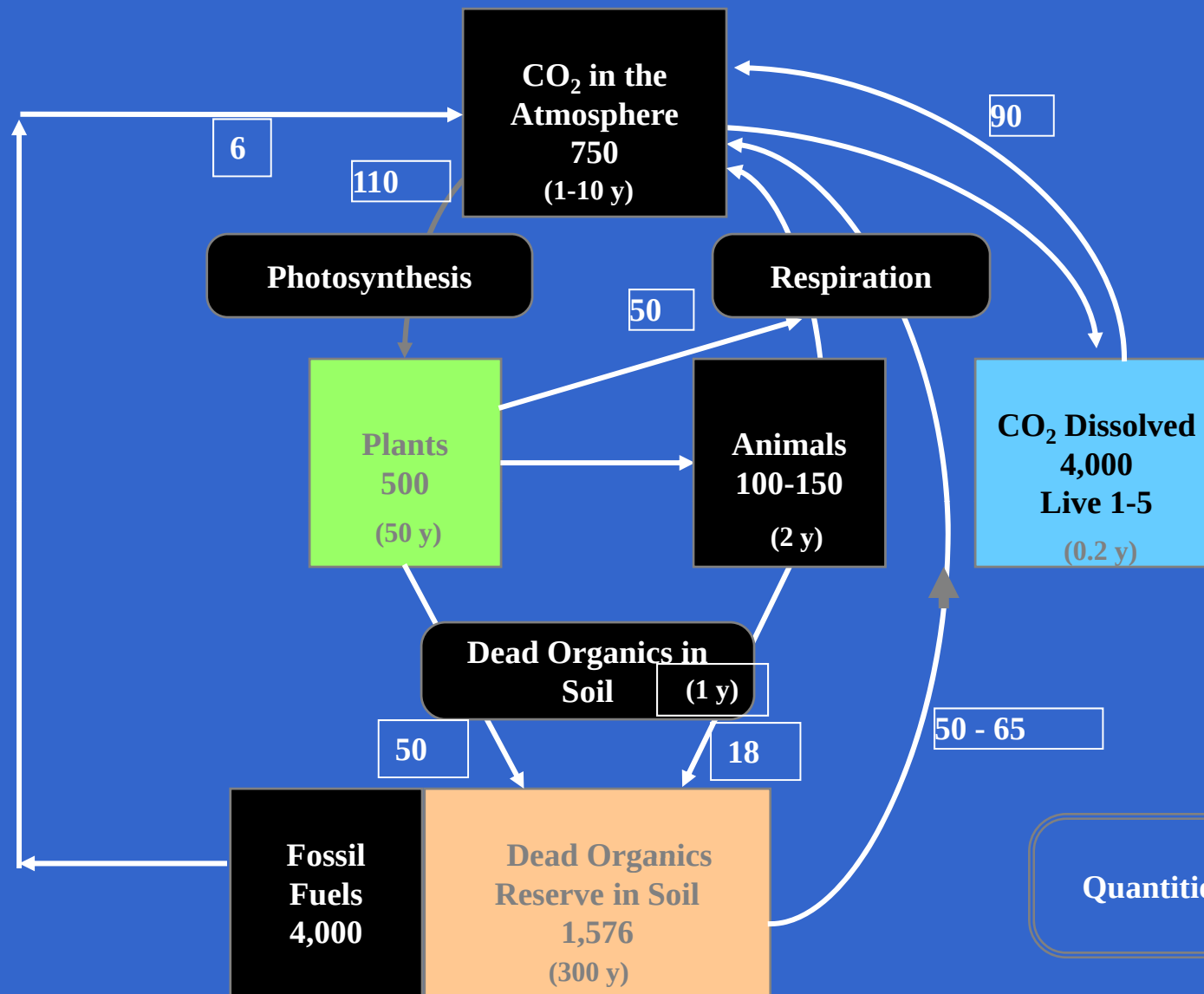




**A Natural Water body near Mumbai, India**



**A natural water body near Mumbai, India now converted to marsh land due to nutrient overload**



Quantities in  $10^{15}\text{g}$

## Global Carbon Cycle (Meilli, 1995)

Source: Encyclopedia of Environmental Biology, Vol.1, Academy press, 1995, pp.235-248

# Energy Consumption in Different Habitats

1. Water

500 kJ/g live C. yr

✓ 2. Land

3 kJ/g live C. yr

Source: Global Carbon Cycle , Meili, 1995, Encyclopedia of Environmental Biology, Vol.1, Academy press, 1995, pp.235-248



## Lessons from Carbon Cycle

Global carbon cycle shows that terrestrial ecosystems reveal high population densities compared to aquatic ecosystems indicating very high oxygen availability in terrestrial ecosystems

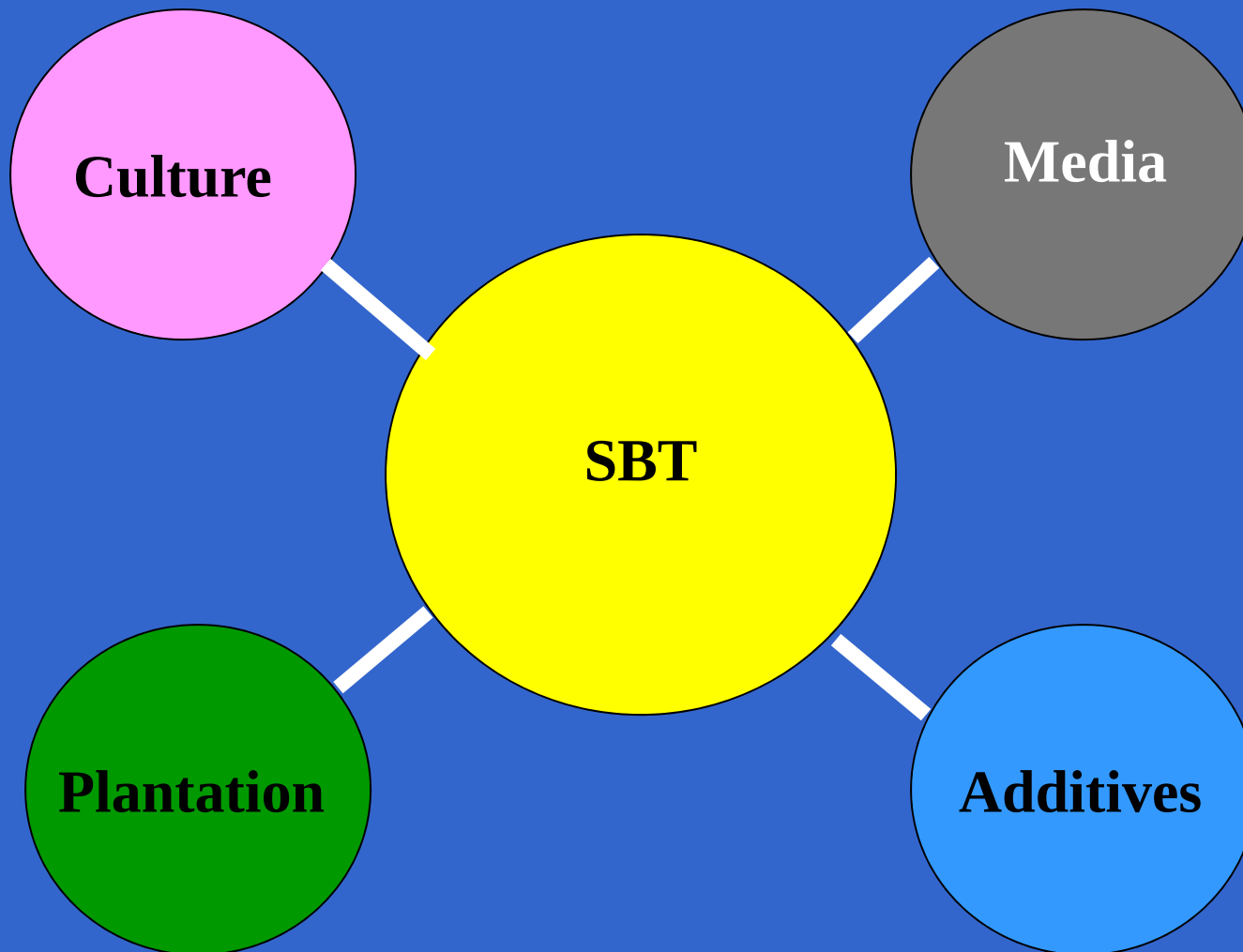
Current Technologies for waste treatment engage aquatic ecosystems needing much mechanical energy for oxygen transfer .

Hence the interest in terrestrial engineered ecosystems for waste treatment- a design consistent with carbon cycle

# Media and Culture

1. Partially weathered soil-like primary minerals of suitable particle size , composition, liquid hold up, hydraulics
2. Geophagus worm such as *Pheretima Elongata* and bacterial culture. Appropriate culture for special situations.
3. Selected Green plants particularly with tap root system

# Elements of SBT



## SBT Media And Culture

1. Partially weathered soil-like primary minerals of suitable particle size , composition, liquid hold up, hydraulics
2. Geophagus worm such as Pheretima Elongata and bacterial culture. Appropriate culture for special situations.
3. Selected Green plants particularly with tap root system

### Source

US Patent: 6890438 B2 (May 2009) *Process for treatment of organic wastes;*

US Patent 7604742 ( October 2009) *Soil Conditioning Products from Organic wastes*

# Schematic of Water Renovation

Recycle (vr )

Feed (vf )

1.Raw water

2.Raw Water slurry

3. Air scrubbing

4. Leachates of solids

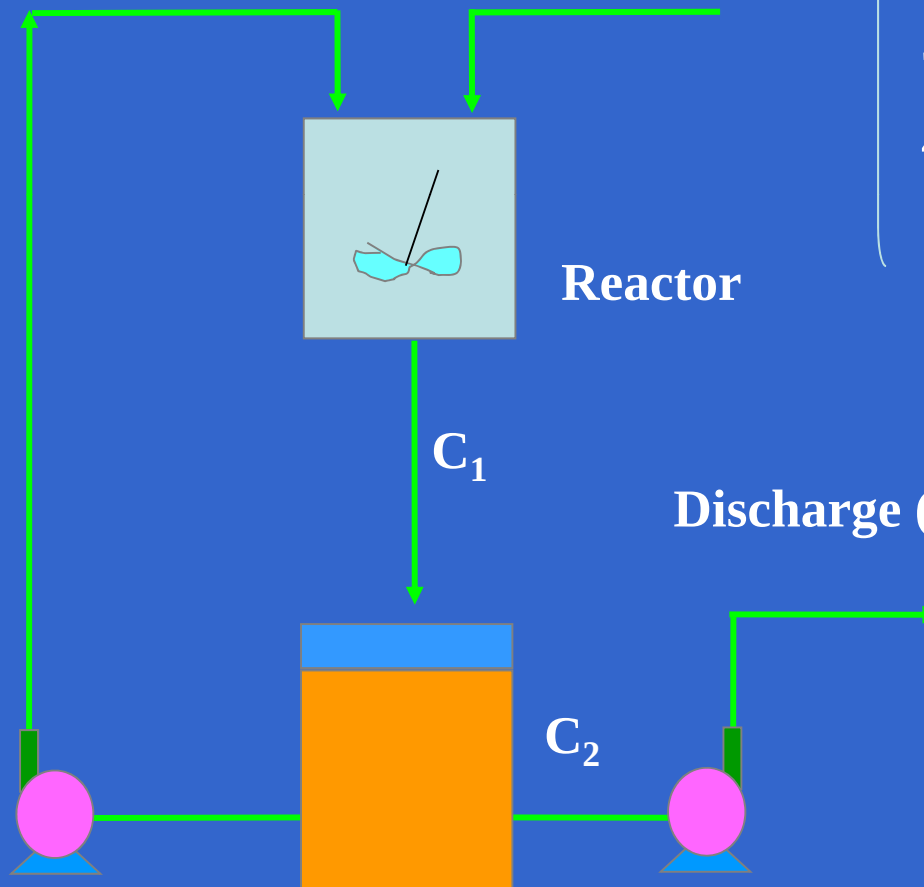
5. Waste water

Reactor

$C_1$

Discharge (vf )

$C_2$



# 120 Cu M Plant at M P. Airport, AAI, Udaipur, Rajasthan





# Plant



3MLD Sewage purification in Corporation Of Bombay



***Some of our plants***



***25 KLD plant at Godrej, Pondicherry***



***75 KLD plant at FRLHT Hospital,  
Bengaluru***



***3000 KLD plant at BMC (Worli), Mumbai***





**Renovation of wastewater from toilet, bath, wash, kitchen etc. for a handicapped rehabilitation centre**





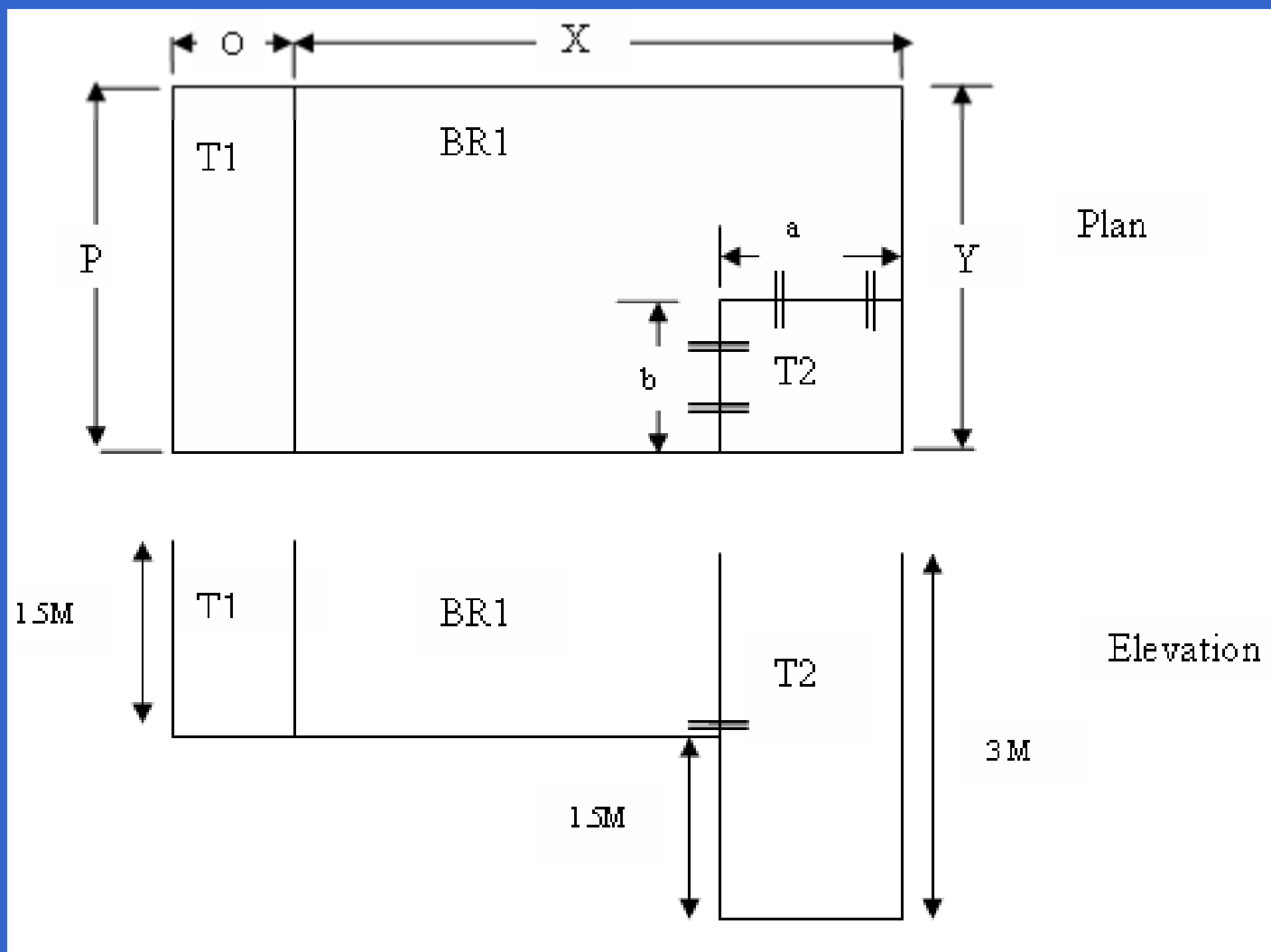
**Renovation of septic tank waste water for irrigation in a  
Research Center**



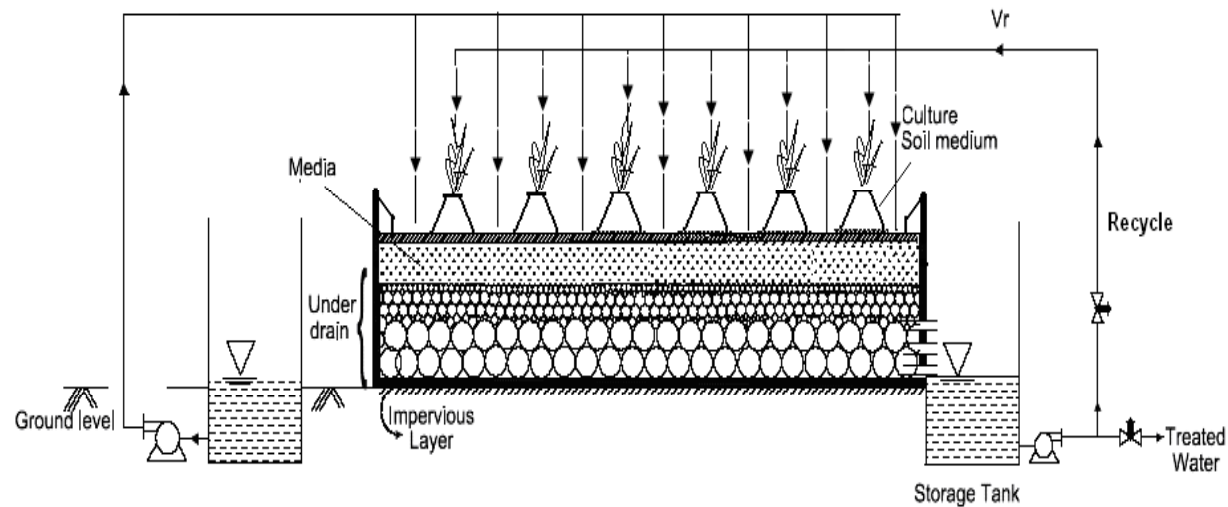
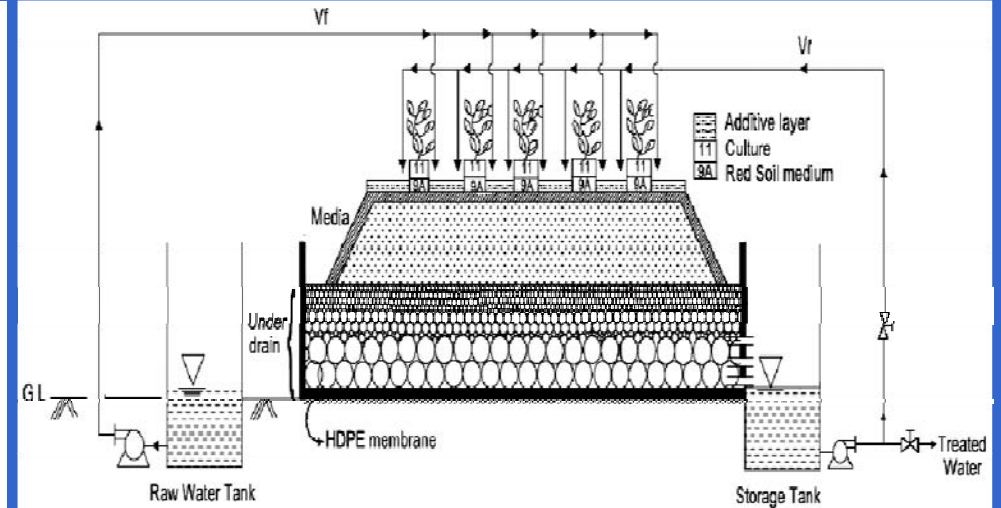
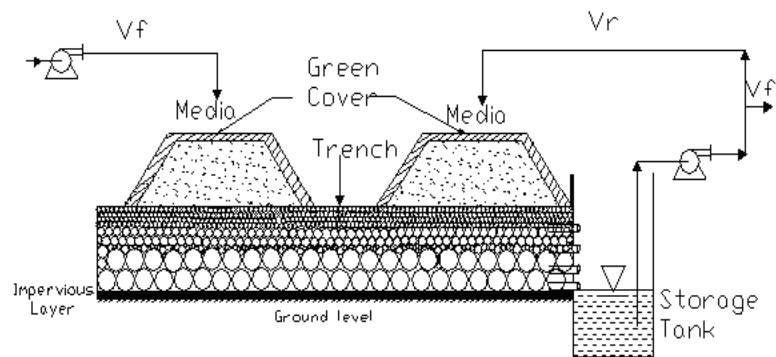
**Storage Tank – treated water at BMC being used for race course and marine outfall pump cooling**



# Typical Sketch of Plant

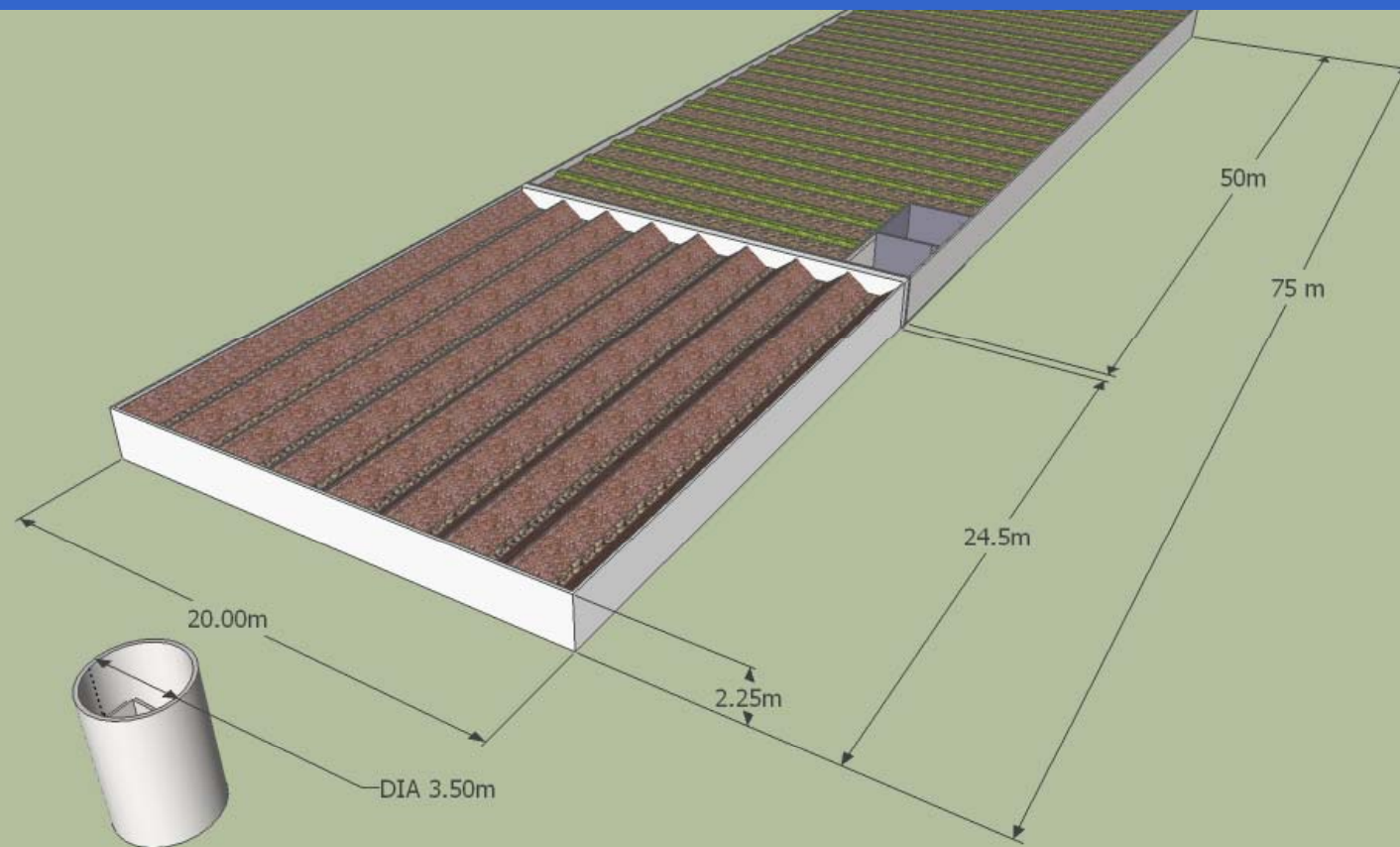


## Sectional view of Plants





## 3D VIEW OF SBT PLANT



MUNICIPAL CORPORATION OF BRIHANMUMBAI  
DADAR LABORATORY

Subject: Analytical report of samples collected from  
soil based technology plant at LGP.

SBT plant at LGP is monitored regularly for assessing its performance in terms  
its effluent quality. So 2 nos. of samples were collected from SBT plant at LGP. The raw  
Sample & the sample after treatment were analyzed for the following parameters.

The results are tabulated as follows.

Date of sampling: 31/08/2007

| Sr.No. | PARAMETERS           | RAW    | FINAL  |
|--------|----------------------|--------|--------|
| 1      | COLOUR               | Sewage | Clear  |
| 2      | pH                   | 7.3    | 7.3    |
| 3      | TSS                  | N.D.   | N.D.   |
| 4      | D.O.                 | B.D.L. | 6.4    |
| 5      | BOD                  | 75     | 1.4    |
| 6      | COD                  | 344    | 16     |
| 7      | CHLORIDES            | 156    | 114    |
| 8      | FREE NH <sub>3</sub> | 10.64  | B.D.L. |
| 9      | OIL & GREASE         | B.D.L. | B.D.L. |

All parameters except PH are expressed in mg/L.

B.D.L. - Below detection limit.

N.D. - Not done due to some technical reason.

Submitted for your information please.

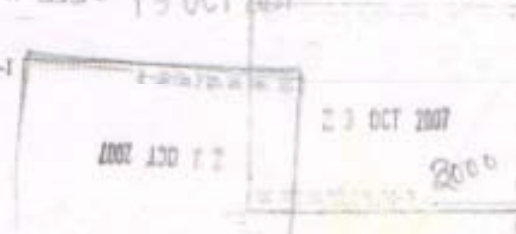
Supdt. Chemist (Dadar Lab)

Ex. Eng. Mech. (S) City-I

वर्ग. सं. सं. (सं.) सं-1/ 353 6 19 OCT 2007

Ch.E.(S.O)  
CC to E.E.Mech.(S)City-I  
E.E.Mech.(S)City-II  
O.C. Laboratory

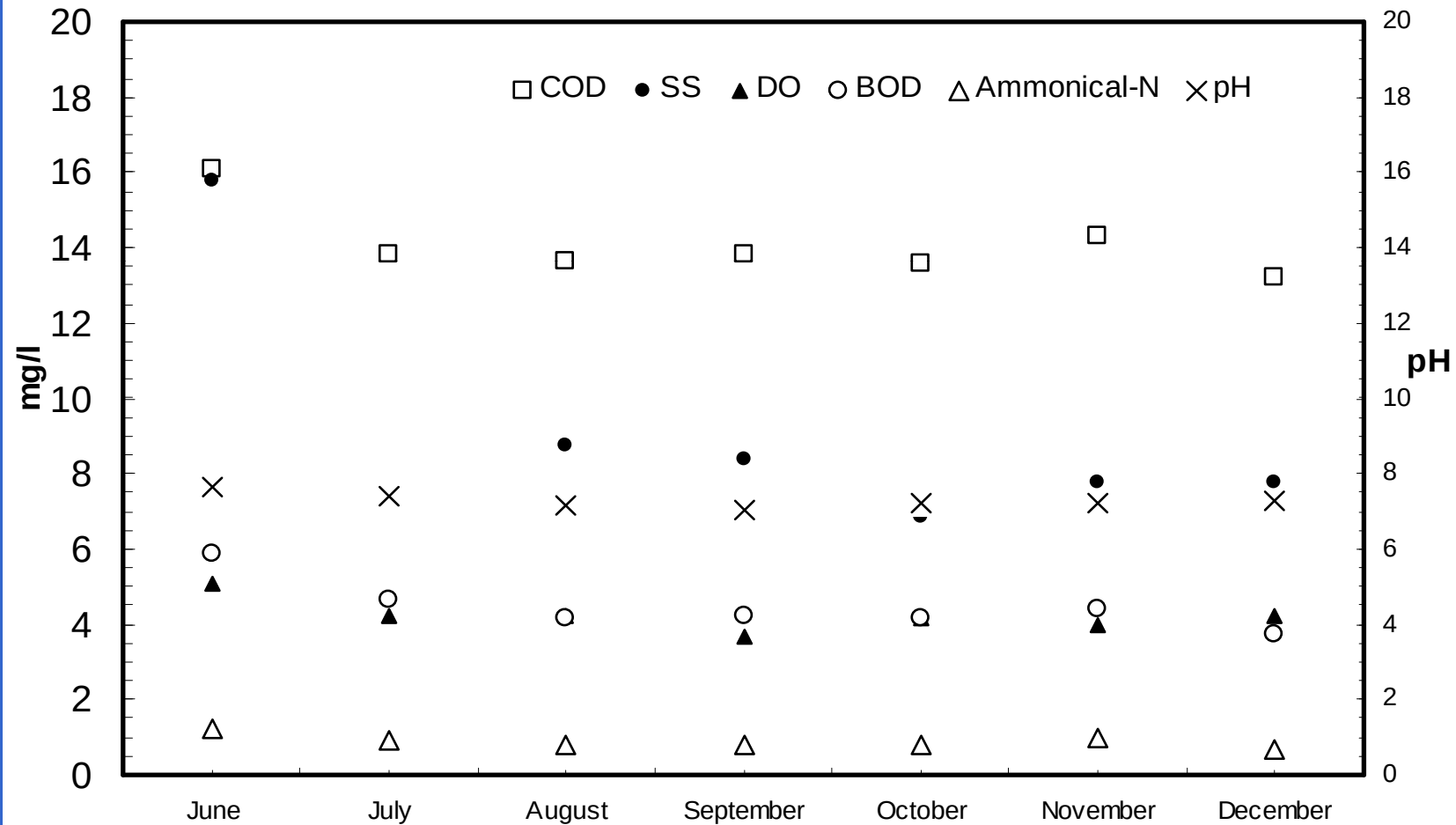
A.E. (LGP) I  
A.E. (LGP) II  
A.E. (Dadar Lab)  
H.C. (LGP)



# Physicochemical Performance of Plant

| Parameters              | Influent    | Effluent |
|-------------------------|-------------|----------|
| pH                      | 6.8 - 7.1   | 7.3      |
| SS (mg/l)               | 78 - 293    | 9.0      |
| DO (mg/l)               | ND - 2.8    | 4.2      |
| COD (mg/l)              | 186 - 360   | 14.1     |
| BOD (mg/l)              | 64 - 130    | 4.4      |
| Turbidity (NTU)         | 46 - 148    | 0.4      |
| TDIS (mg/l)             | 1030 - 1786 | 644.1    |
| Ammoniacal-N (mg/l)     | 9.3 - 3.4   | 0.9      |
| TKN (mg/l)              | 11.2 - 23.1 | 1.6      |
| Orthophosphate-P (mg/l) | 0.47 - 3.44 | 0.05     |

# Performance Variation of Plant



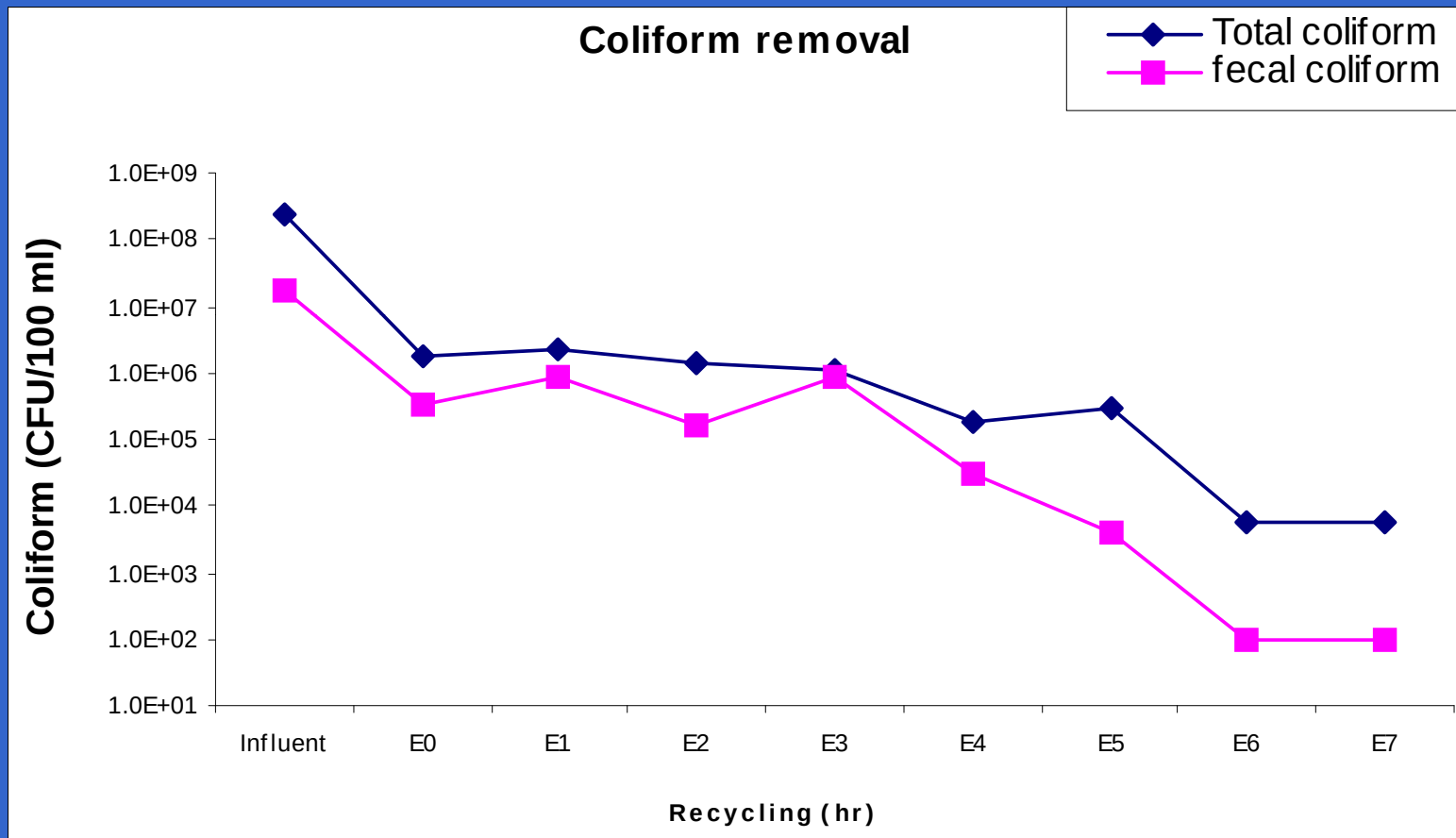
**Performance of plant over a period of six months**



# Microbial Performance of Plant

|       | Total coliform                                  |                            | Fecal coliform                                |                            |
|-------|-------------------------------------------------|----------------------------|-----------------------------------------------|----------------------------|
| Month | Influent<br>CFU/<br>100 ml                      | Effluent<br>CFU/<br>100 ml | Influent<br>CFU/<br>100 ml                    | Effluent<br>CFU/<br>100 ml |
| Jun   |                                                 | 110                        |                                               | 55                         |
| July  |                                                 | $4.4 \times 10^4$          |                                               | $2.5 \times 10^3$          |
| Aug   |                                                 | $8.2 \times 10^3$          |                                               | $3.5 \times 10^3$          |
| Sep   | $3.5 \times 10^8$<br>to<br>$1.5 \times 10^{10}$ | $7.9 \times 10^3$          | $1.7 \times 10^6$<br>to<br>$1.45 \times 10^7$ | $3.3 \times 10^3$          |
| Oct   |                                                 | $1.7 \times 10^4$          |                                               | $1.3 \times 10^3$          |
| Nov   |                                                 | $1.5 \times 10^4$          |                                               | $1.1 \times 10^3$          |
| Dec   |                                                 | $3.7 \times 10^4$          |                                               | $1.9 \times 10^3$          |
| Avg   |                                                 | $2.6 \times 10^4$          |                                               | $1.5 \times 10^3$          |

# Coliform Removal



**Effect of recycling on micro-organism removal;  
E0: Effluent 0 hr, E1: Effluent 1 hr etc Kadam., (2005)**

# Nitrogen Removal

| Process | COD<br>(mg/l) |     | NH <sub>4</sub> -N<br>(mg/l) |     | NO <sub>2</sub> -N<br>(mg/l) |     | NO <sub>3</sub> -N<br>(mg/l) |     | Total Nitrogen<br>(mg/l) |      |
|---------|---------------|-----|------------------------------|-----|------------------------------|-----|------------------------------|-----|--------------------------|------|
|         | Inf           | Eff | Inf                          | Eff | Inf                          | Eff | Inf                          | Eff | Inf                      | Eff  |
| IA      | 250           | 80  | 43                           | 9   | 0                            | 0.1 | 0                            | 2   | 43                       | 11.1 |
| IB      | 137           | 9.4 | 25                           | 2.9 | 0.1                          | 0.0 | 2                            | 0.7 | 27.1                     | 3.6  |
| IIA     | 250           | 80  | 43.5                         | 9   | 0                            | 0.1 | 0                            | 3   | 43.5                     | 12.1 |
| IIB     | 102           | 3.5 | 15                           | 2.2 | 0.05                         | 0.0 | 3                            | 0.7 | 18.0                     | 2.9  |
| IIIA    | 250           | 80  | 43.5                         | 8   | 0                            | 0.1 | 0                            | 2   | 43.5                     | 10.1 |
| IIIB    | 170           | 15  | 33                           | 3.8 | 0.04                         | 0.0 | 2                            | 0.5 | 35.0                     | 4.3  |

# Iron Removal

| Initial iron (mg/l) | Residual iron (mg/l) | Total dissolved solids (mg/l) | EC ( $\mu$ S/cm) | pH   |
|---------------------|----------------------|-------------------------------|------------------|------|
| 5.0                 | 0.128                | 113                           | 170              | 7.45 |
| 5.0                 | 0.09                 | 111                           | 168              | 7.36 |
| 5.0                 | 0.08                 | 110                           | 163              | 7.28 |
| 5.0                 | 0.07                 | 109                           | 162              | 7.20 |
| 5.0                 | 0.06                 | 109                           | 162              | 7.12 |

\*Drinking water Standard is 0.3 mg/l



# Arsenic Removal

| Initial Arsenic (µg/l) | Initial Phosphate (mg/l) | Residual As(V) µg/l | Residual Phosphate mg/l | Arsenic Removal % |
|------------------------|--------------------------|---------------------|-------------------------|-------------------|
| 300                    | 5                        | 7                   | 0.31                    | 98.3              |
| 300                    | 5                        | 6                   | 0.28                    | 98.3              |
| 300                    | 5                        | 7                   | 0.30                    | 98.6              |
| 300                    | 5                        | 6                   | 0.26                    | 98.3              |
| 300                    | 5                        | 7                   | 0.27                    | 98.6              |
| 300                    | 5                        | 7                   | 0.26                    | 98.6              |

\*WHO, Drinking water Standard is < 10 µg/l; < 50 µg/l (India)

# **ABOUT VISION EARTHCARE**

**A company in SINE**

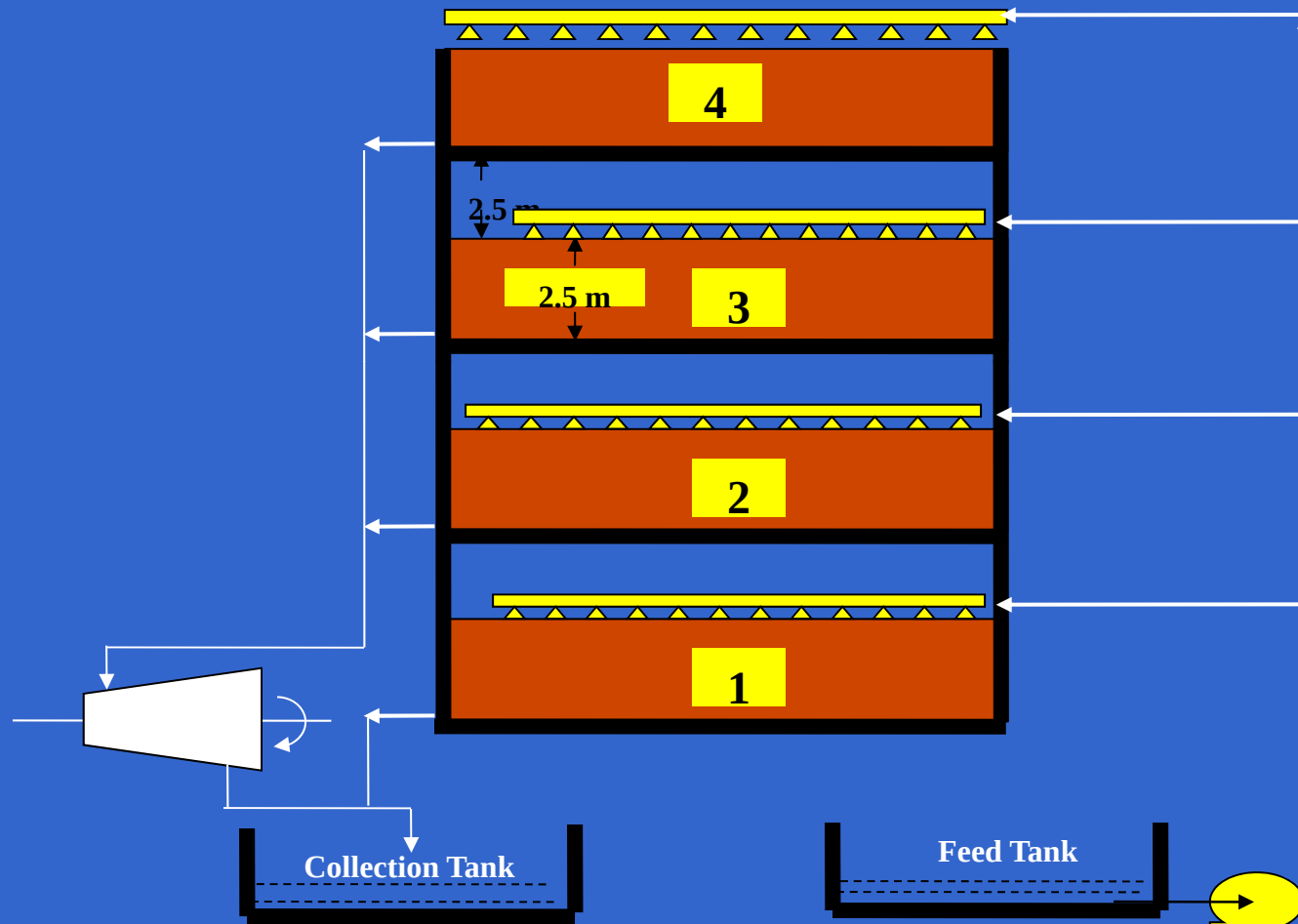
**SINE is Innovation Centre of IITB**

**SINE Was Set Up 2005**

**SINE is Supported by GOI**

**Other Offerings ?**

# Multistage Operation



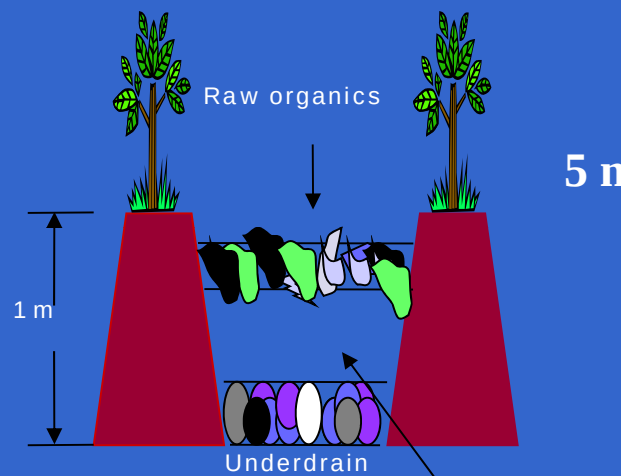
# Plant



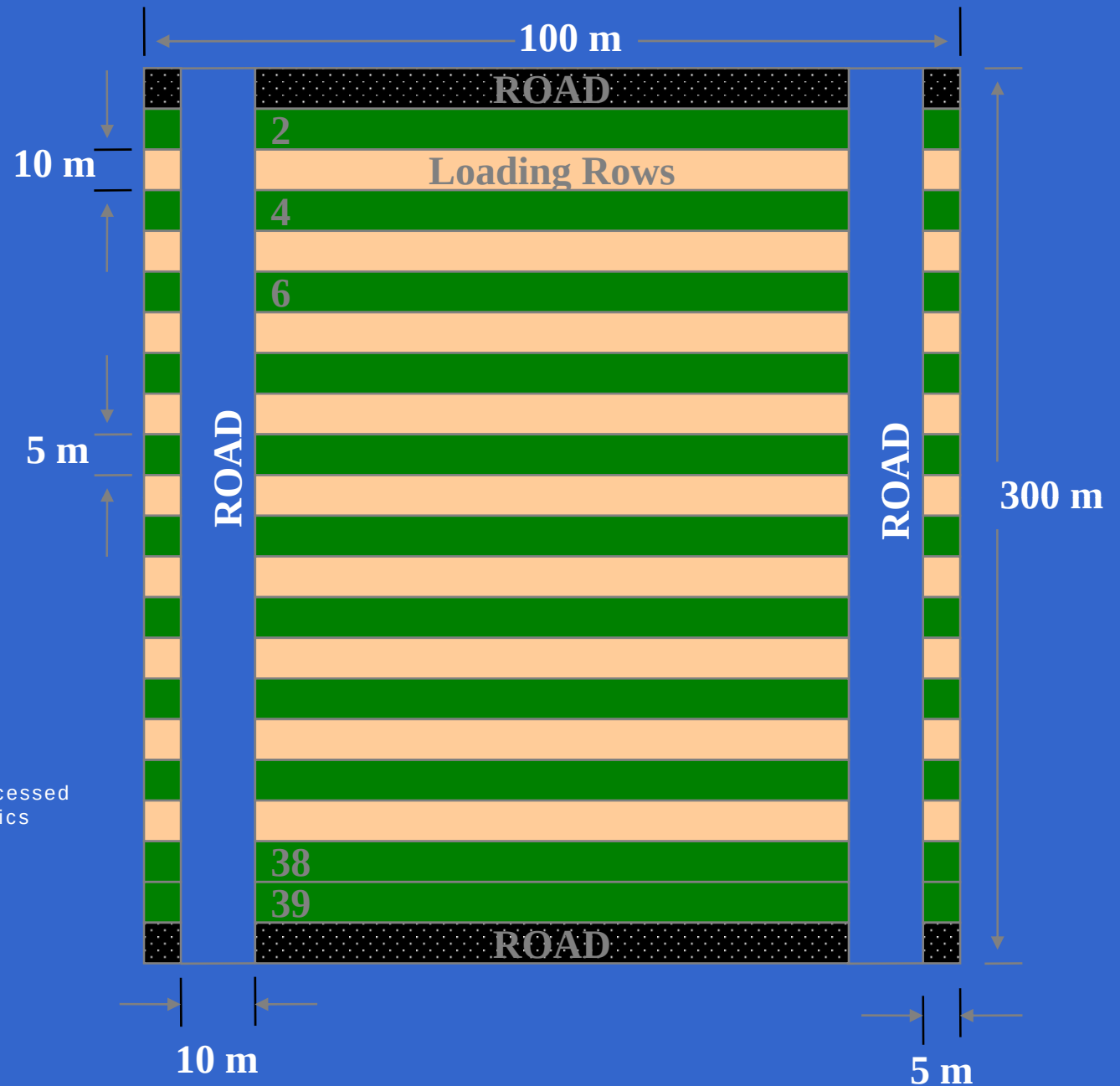
**Close up of hospital solid waste  
processing**



# ORGANIC RESIDUE PROCESSING

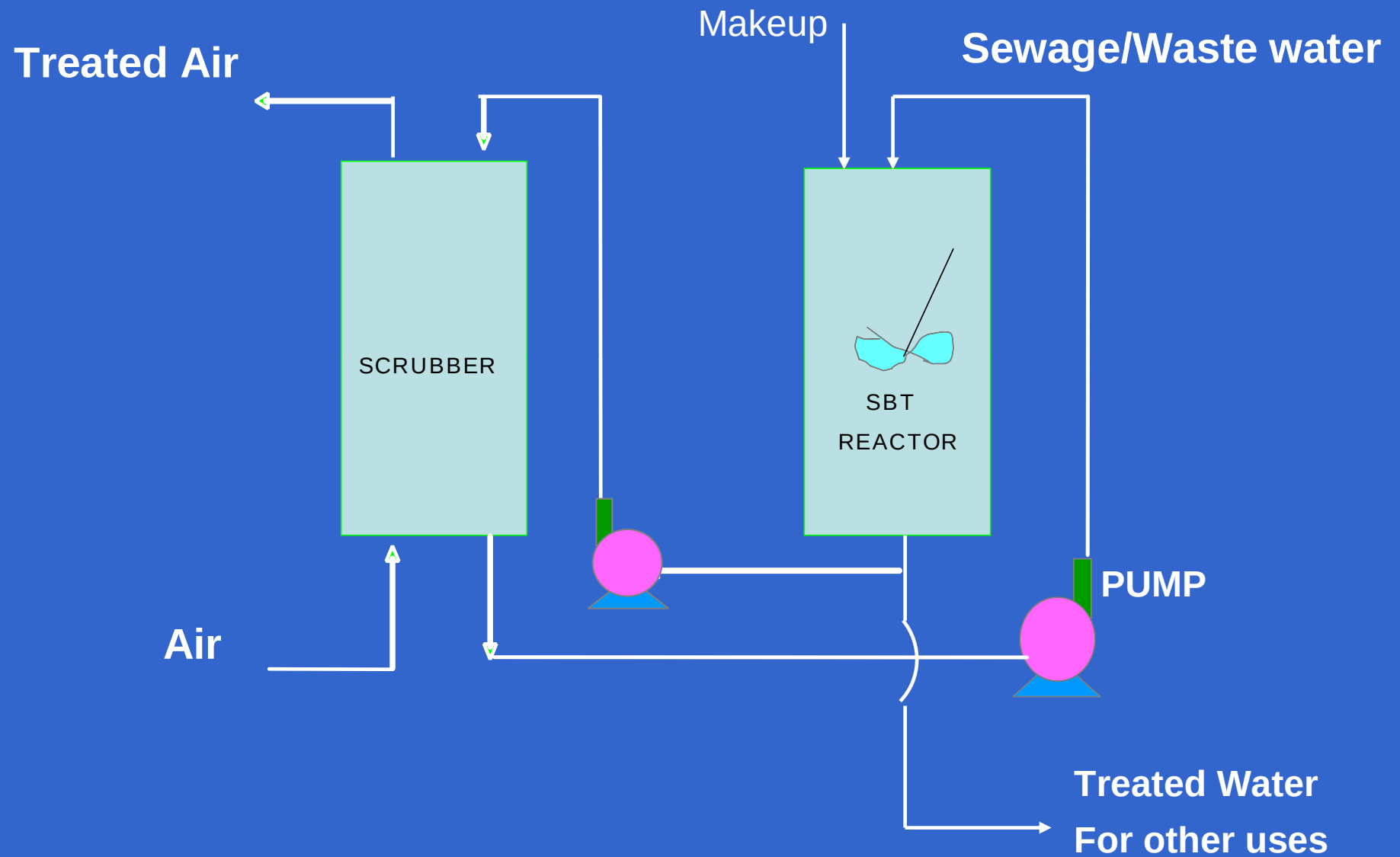


A



**Schematic of organic residue processing.**

# AIR PURIFICATION



# **Selection of Completed Works**

**MJP ( GOM 95 Villages under tender)**

**GOV GUJARAT( In Progress)**

**Bangalore Municipal Corporation( In Progress)**

**Ganga Action Plan Uttarakhand (In Progress)**

**AAI Lucknow Airport 2012**

**Mumbai Rail Vikas Nigam 2012**

**BPGC Ltd Bombay 2012**

**Air Force Hospital Bangalore 2011**

**FRLHT Hospital Bangalore 2010**

**AIDS Rehabitalization Bangalore 2010**

# Selection of Completed Works

Air Force Hospital Bangalore 2011

FRLHT Hospital Bangalore 2010

AIDS Rehabitalization Bangalore 2010

- o Airports Authority of India (AAI) – 2008
- o BrihanMumbai Municipal Corporation, 2008, 2007, 2005  
(Upgradation,O&M, 3000 cu.m/d plant)
- o VazirSultan Tobacco, Hyderabad, 2004
- o Delhi Travel Tourism Dev Corporation, 2004
- o Bombay Presidency Golf Club, 2002 (500 cu. m/day), 1996
- o Naval Housing Colony, Mumbai, 2002

# **ABOUT VISION EARTHCARE**

**A company in SINE**

**SINE is Innovation Centre of IITB**

**VEC Commenced operation 2006**

**Based on SBT Technology of IITB**

**About 30 plants in operation**

**Revenue 2010 INR 14 million**

**Order on hand 2011 INR 40 million**

**CEO is Dr. Chandrashekar ( PhD UMICH)**



# Film : India Innovates

*(Min. of Ext. Affairs)*

<http://www.youtube.com/watch?v=dKWVtZ81mY0>

**Thank You**

# 120 Cu M Plant at M P. Airport, AAI, Udaipur, Rajasthan



# Patents

- ✂ US Patent No: 6890438 " Process for treatment of organic wastes" H.S.Shankar, B.R.Patnaik, U.S.Bhawalkar, issued 10 May 2005
- ✂ US Patent No 7604742 B2 Soil Conditioning products from organic waste H.S.Shankar, B.R.Patnaik, U.S.Bhawalkar, issued October 2009
- ✂ Indian patent no 203425 " Process for Water and waste waterwaste water renovation " , H.S.Shankar, B.R.Patnaik, U.S.Bhawalkar , issued 12 December 2006
- ✂ Indian patent no 203744 Process for treating organicsolid wastes, Patnaik, B.R., Bhawalkar, U.S., Shankar, H.S., issued 8 January 2007

# SBT Preliminary Financial Highlights

Smaller capacities capex scales capacity  $\times 0.5$

Smaller capacities Opex scales inversely as capacity  $\times 0.5$

Smaller capacities space scales as capacity  $\times 0.5$

| Capacity (MLD)                     | 1                    | 5                    |
|------------------------------------|----------------------|----------------------|
| Outlet water quality<br>**(mg/lit) | BOD < 10<br>COD < 60 | BOD < 10<br>COD < 60 |
| Investment (Rs Cr)                 | 1.4                  | 5.5                  |
| O&M (Rs/1000 Litres)               | 3                    | 2                    |
| Area (ha) **                       | 0.15                 | 0.60                 |
| Process Power<br>( kWh/1000 Lit)   | 0.02                 | 0.02                 |

\*\* or as desired per site ; space landscaped green as desired  
Earthbundh Civil Structures /equivalent  
ha = 10000 sqm ; MLD million Litres per day



# Comparison of Power Consumption

| Process                   | kWh/1000 gallons |
|---------------------------|------------------|
| ❖ SBT **                  | 0.12             |
| Activated sludge Process* | 2.00             |
| ❖ Membrane Bioreactor*    | 5.00             |
| Moving Bed Bioreactor*    | 2.00             |
| Fluidized Bed Bioreactor* | 3.00             |

❖ \*Aquatic environment

❖ \*\*terrestrial environment

## OTHER TECHNOLOGIES

Moving Bed Bio Reactor

Sequencing Batch Reactor

Fluidized Aerobic Bioreactor

Membrane Bioreactor

Activated Sludge Process

Oxidation Pond

Upflow Sludge Blanket Bioreactor

# Recent Publications

- ✂ Kadam,AM,Ojha,Goldie.,Nemade,P.D.,Shankar,H.S(2009).Waste water treatment using laterite based constructed soil filter, Ecological Engineering 35(7) 1051-1061
- ✂ Nemade,P.D.,Kadam,A.M.,Shankar,H.S.(2009),Remediation of arsenic and iron contaminated ground water using novel constructed soil filter system, Ecological Engineering , 35, 1152-1157
- ✂ Kadam,A.M.,Oza,G.H.,Nemade,P.D.,Dutta,S.,Shankar,H.S.,Shankar,H.S .(2008) Municipal waste water treatment using novel constructed soil filter system,Chemosphere,975-981
- ✂ Kadam,A.M.,Oza,G.H.,Nemade,P.D.,Shankar,H.S.,Shankar,H.S.(2008) Pathogen removal from municipal waste water treatment using novel constructed soil filter system,Ecological Engineering, 33(1)37-44

# Recent Publications

- ✂ Patnaik, B.R., Bhawalkar, U.S., Gupta, A., Shankar, H.S., “*Residence Time Distribution model for Soil Filters*, *Water Environment Research*, 76(2), 168-174, 2004
- ✂ Patnaik, B.R., Bhawalkar, U.S., Shankar, H.S., “*Waste Processing in Engineered Ecosystems*”, 4th World Congress on Chemical Engineering, 23-27, September 2001, Melbourne, Australia
- ✂ Patnaik, B.R., Bhawalkar, U.S., Kadam, A, Shankar, H.S., “*Soil Biotechnology for Waste Water Treatment and utilization*”, 13th ASPAC 2003, International Water Works Association Conference 13-18, October, 2003, Quezon City, Philippines



**Chickoo plant after SBT restoration of soil**





**Chickoo plant affected by fungal disease**

# SBT Features

- **Very Low Life Cycle Cost**
- **Very Long Life**
- **Very Low Energy Consumption**
- **Very Low Operating Cost**
- **All Green Ambience**
- **Modular & Multi-level and greenhouse Designs**
- **Water ,waste water, solid waste and air purification**
- **Reusable Water (Products)**
- **Green Technology Carbon Credits**

# PRESENTATION SUMMARY

Lessons from Carbon Cycle

Process chemistry

Media Layout

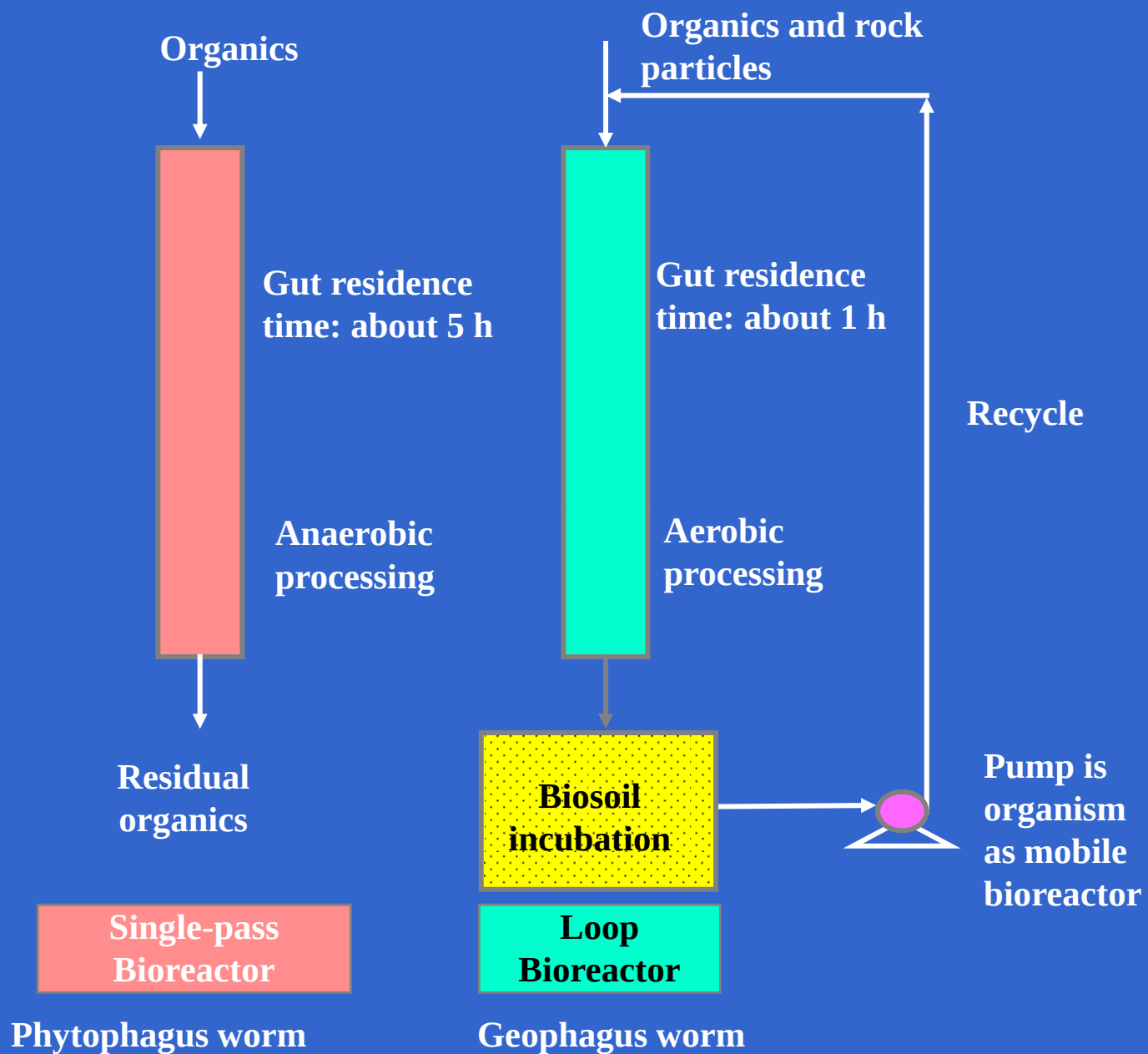
Media design for waste water

SBT Performance in sewage Treatment

Other offerings

Vision Earthcare

SBT Film of GOI



Bioprocessing by the two types of organisms

Source: Bhawalkar (1996)

# Media Features

Oxygen Transfer

Residence Time Distribution

Liquid Hold up

Hydraulic Loading

Organic Loading

Nitrogen Fixation

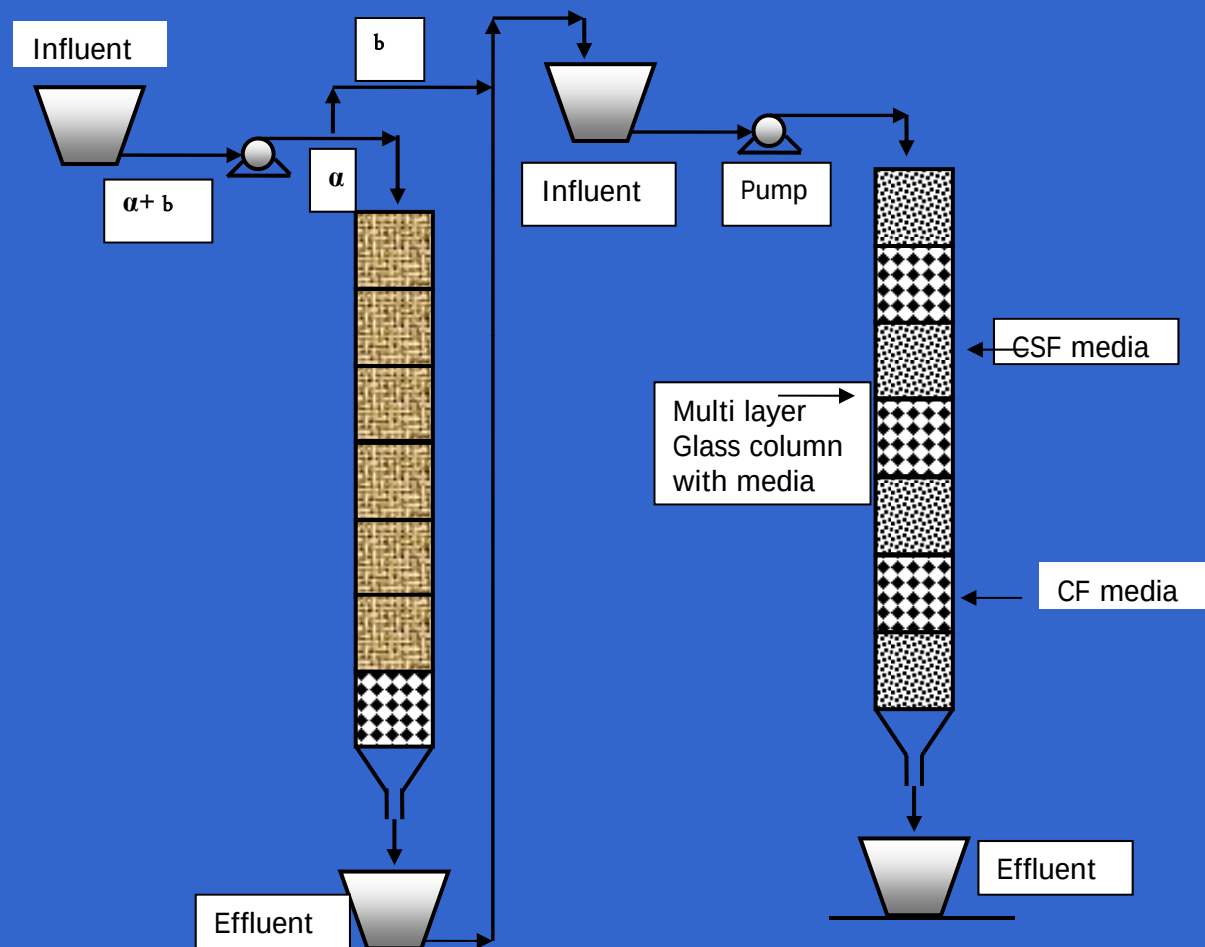
C & N Removal

Efficacy of % media in Bioreactor bed

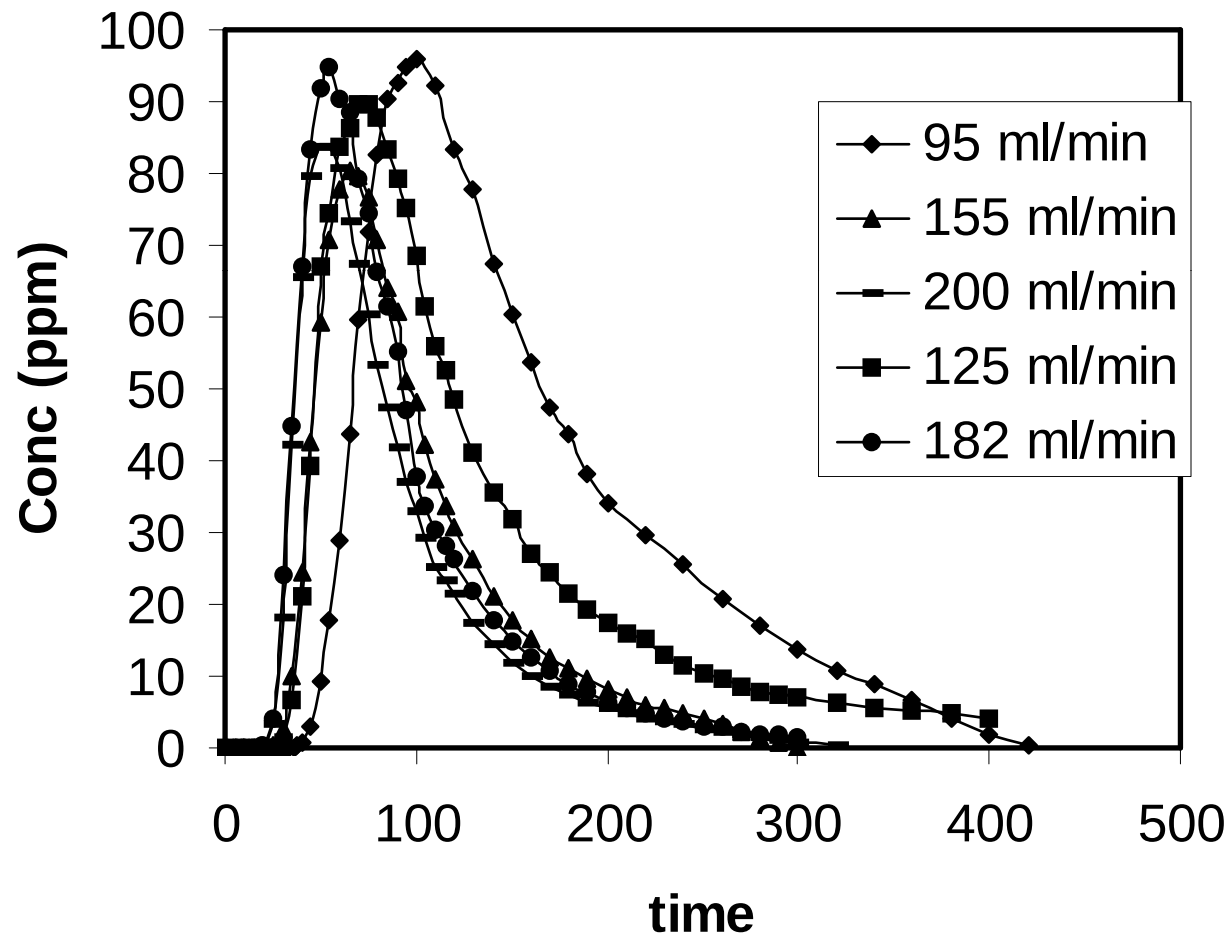


# Experimental Equipment

## CSF & CF



**Fig. Plot of concentration of tracer versus time of  
2m CSF column of 0.285m diameter , 100 L bed volume,  $d_n = 9\text{mm}$**



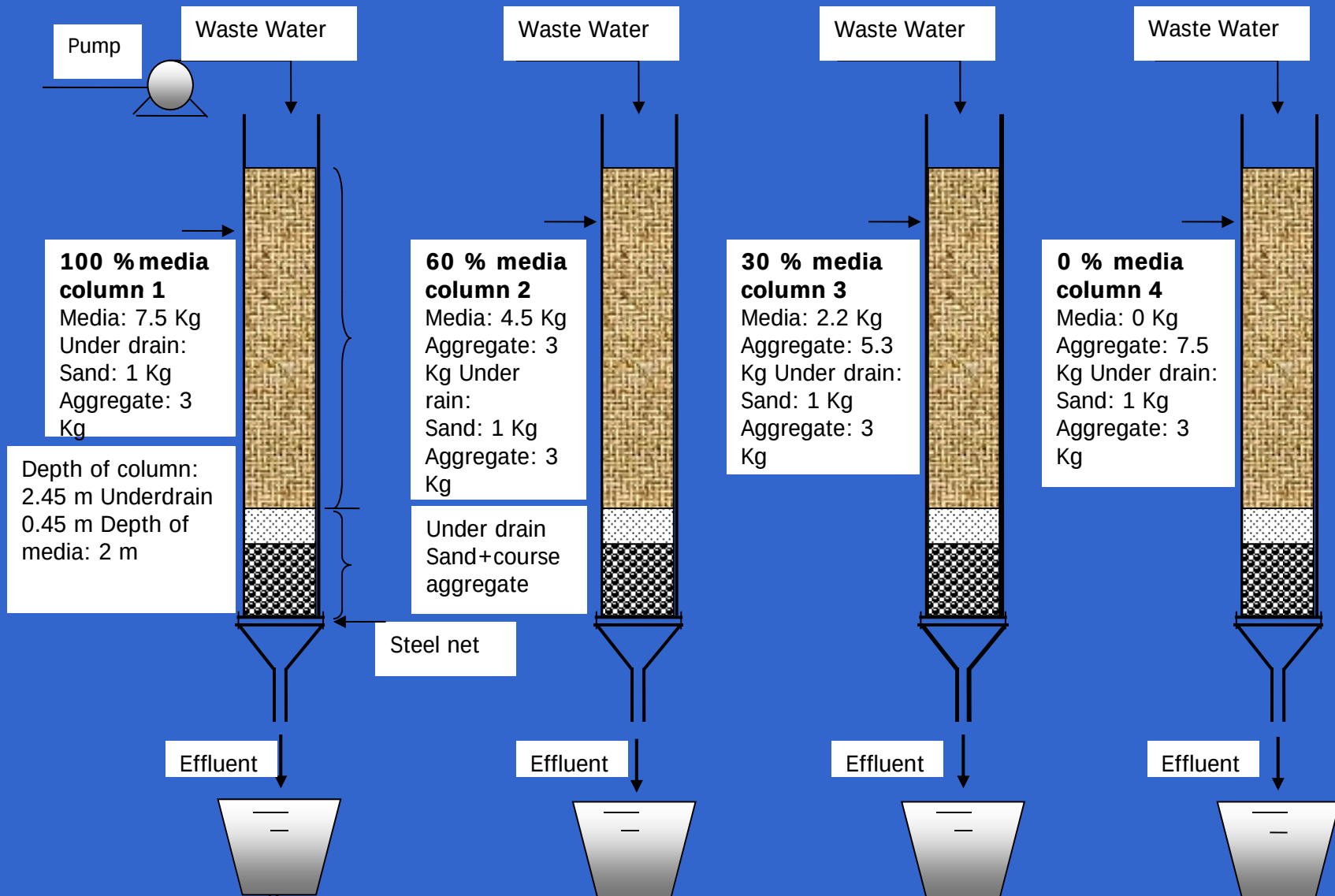
## Media Features

To understand features Experiments are performed in 4 CSF reactors each of volume 9L (2 m length and 0.00762m diameter)

| Column | % of media |
|--------|------------|
| 1      | 100        |
| 2      | 60         |
| 3      | 30         |
| 4      | 0          |

This study is helpful in the selection of proper media required for the treatment.

# Experimental Equipment



## N Fixation

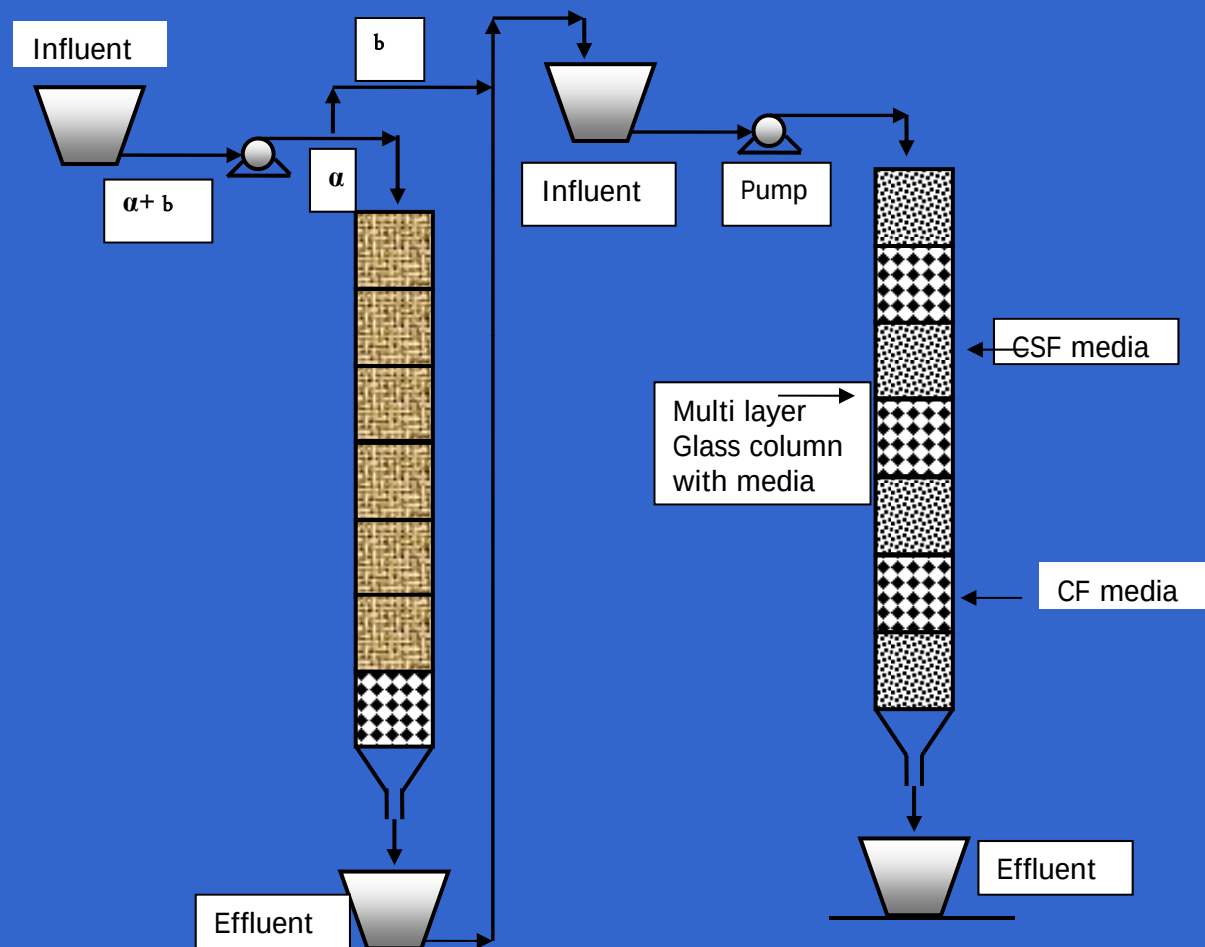
Carbon removal in 9L vessel with 100 % media zero N in feed Showing nitrate production so the considerable ammonia production so considerable oxygen supply at the 4 hr residence time and 0.06 m/hr superficial velocity

| Flow rate                       | 60 mL/min |       | 30 mL/min |       | 4 mL/min |     |
|---------------------------------|-----------|-------|-----------|-------|----------|-----|
| Parameter                       | Inf       | Eff   | Inf       | Eff   | Inf      | Eff |
| $\text{NH}_4^+\text{-N}$ (mg/L) | 0         | 1.5   | 0         | 0.21  | 0        | 2.6 |
| $\text{NO}_3^-\text{-N}$ (mg/L) | 0         | 2.4   | 0         | 3     | 0        | 9.5 |
| $\text{NO}_2^-\text{-N}$ (mg/L) | 0         | 0.07  | 0         | 0.36  | 0        | 0.3 |
| COD (mg/L)                      | 250       | 177.4 | 250       | 145.1 | 250      | 5   |



# Experimental Equipment

## CSF & CF



# Carbon and Nitrogen removal in 9L CSF

with varying media

| Column   | Flow rate<br>(ml/min) | COD<br>(mg/L) |     | NH <sub>4</sub> <sup>+</sup> -N<br>(mg/L) |     | NO <sub>2</sub> <sup>-</sup> -N<br>(mg/L) |      | NO <sub>3</sub> <sup>-</sup> -N<br>(mg/L) |      |
|----------|-----------------------|---------------|-----|-------------------------------------------|-----|-------------------------------------------|------|-------------------------------------------|------|
|          |                       | Inf           | Eff | Inf                                       | Eff | Inf                                       | Eff  | Inf                                       | Eff  |
| 1 (100%) | 50                    | 250           | 44  | 21.3                                      | 2.4 | 22.5                                      | 0.3  | 0                                         | 11   |
| 2 (60 %) | 50                    | 250           | 176 | 21.3                                      | 3.5 | 22.5                                      | 0.49 | 0                                         | 10.5 |
| 3 (30 %) | 50                    | 250           | 198 | 21.3                                      | 4.1 | 22.5                                      | 0.56 | 0                                         | 10.8 |
| 4 (0 %)  | 50                    | 250           | 237 | 21.3                                      | 7.8 | 22.5                                      | 1.06 | 0                                         | 11.6 |
| 1 (100%) | 5                     | 250           | 1.5 | 21.3                                      | 1.1 | 22.5                                      | 0.1  | 0                                         | 41   |
| 2 (60 %) | 5                     | 250           | 32  | 21.3                                      | 1.5 | 22.5                                      | 0.15 | 0                                         | 19.5 |
| 3 (30 %) | 5                     | 250           | 52  | 21.3                                      | 1.9 | 22.5                                      | 0.72 | 0                                         | 38.5 |
| 4 (0 %)  | 5                     | 250           | 201 | 21.3                                      | 7.0 | 22.5                                      | 0.87 | 0                                         | 16   |

**Result of oxygen transfer experiment by sodium sulfite oxidation experimental of 2m CSF column, 0.285m diameter, 100 L bed,  $d_p = 9\text{mm}$**

| Run | Q<br>(ml<br>min <sup>-1</sup> ) | Hydraulic<br>Loading<br>(cm h <sup>-1</sup> ) | Run<br>Time<br>(min<br>) | Initial conc<br>of sodium<br>sulfite (mol<br>L <sup>-1</sup> ) | Final conc of<br>sodium<br>sulfite (mol<br>L <sup>-1</sup> ) | Oxygen<br>Transfer<br>Rate (g L <sup>-1</sup><br>s) | Rate<br>constant<br>(s <sup>-1</sup> ) |
|-----|---------------------------------|-----------------------------------------------|--------------------------|----------------------------------------------------------------|--------------------------------------------------------------|-----------------------------------------------------|----------------------------------------|
| RS1 | 80                              | 7.5                                           | 80                       | 0.72                                                           | 0.28                                                         | $4 \times 10^{-4}$                                  | $2.16 \times 10^{-5}$                  |
| RS2 | 125                             | 11.8                                          | 80                       | 0.69                                                           | 0.29                                                         | $3.2 \times 10^{-4}$                                | $2.67 \times 10^{-5}$                  |
| RS3 | 180                             | 16.9                                          | 70                       | 0.55                                                           | 0.29                                                         | $2.9 \times 10^{-4}$                                | $2.16 \times 10^{-5}$                  |
| RS4 | 220                             | 20.7                                          | 70                       | 0.46                                                           | 0.26                                                         | $1.6 \times 10^{-4}$                                | $2.24 \times 10^{-5}$                  |

**Result of physical oxygen transfer experiment by DO  
experimental of 2m CSF column, 0.285m diameter , 100 l bed,  
dp = 9mm**

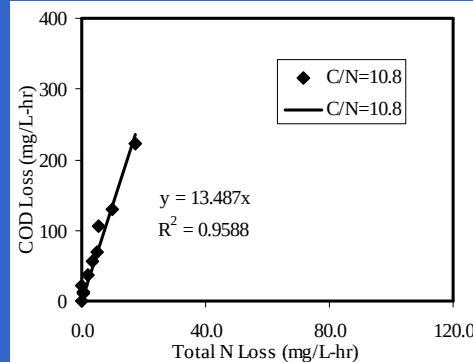
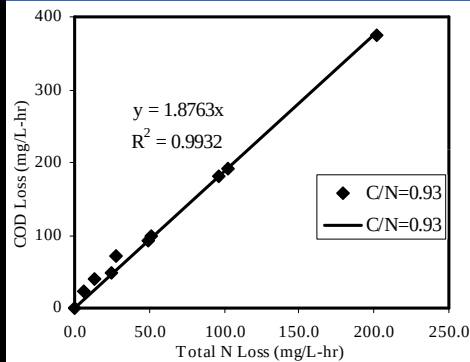
| Run | Q<br>(mL min <sup>-1</sup> ) | Hydrau.<br>Loading<br>(cm h <sup>-1</sup> ) | Run<br>Time<br>(min) | Inlet<br>DO<br>(mgL <sup>-1</sup> ) | Outlet<br>DO<br>(mgL <sup>-1</sup> ) | Oxygen<br>Transfer<br>Rate (g L <sup>-1</sup> s) | Rate<br>constant<br>(s <sup>-1</sup> ) |
|-----|------------------------------|---------------------------------------------|----------------------|-------------------------------------|--------------------------------------|--------------------------------------------------|----------------------------------------|
| RP1 | 80                           | 7.5                                         | 90                   | 0.55                                | 5.85                                 | $7.1 \times 10^{-8}$                             | $1.69 \times 10^{-5}$                  |
| RP2 | 105                          | 9.9                                         | 90                   | 1.04                                | 5.33                                 | $7.5 \times 10^{-8}$                             | $1.70 \times 10^{-5}$                  |
| RP3 | 140                          | 13.2                                        | 90                   | 1.13                                | 5.62                                 | $1.1 \times 10^{-7}$                             | $2.63 \times 10^{-5}$                  |
| RP4 | 185                          | 17.4                                        | 90                   | 0.22                                | 5.82                                 | $1.7 \times 10^{-7}$                             | $3.91 \times 10^{-5}$                  |

## Experimental results and model parameters for RTD studies of 2m CSF column with 0.285m diameter, 100 L bed, $d_p = 9\text{mm}$

| Run No | Bed (L) | Q (mL min <sup>-1</sup> ) | Hydrau. Load (cm h <sup>-1</sup> ) | $\tau$ (min) | Tracer Recovery % | Hold up (L) | Total Hold up $H=Q \tau$ (L) | $\alpha$ | Pe   |
|--------|---------|---------------------------|------------------------------------|--------------|-------------------|-------------|------------------------------|----------|------|
| R1     | 100     | 95                        | 8.93                               | 155          | 94.3              | 4.4         | 14.72                        | 0.7      | 12.1 |
| R2     | 100     | 125                       | 11.76                              | 133          | 96.6              | 5           | 16.62                        | 0.6      | 9.7  |
| R3     | 100     | 155                       | 14.58                              | 102          | 94.1              | 5.3         | 15.81                        | 0.7      | 10.1 |
| R4     | 100     | 182                       | 17.12                              | 91           | 90.2              | 5.5         | 16.56                        | 0.6      | 12.3 |
| R5     | 100     | 200                       | 18.81                              | 90           | 93.0              | 5.7         | 18                           | 0.6      | 11.5 |

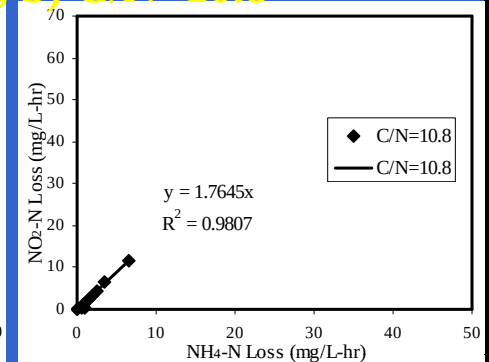
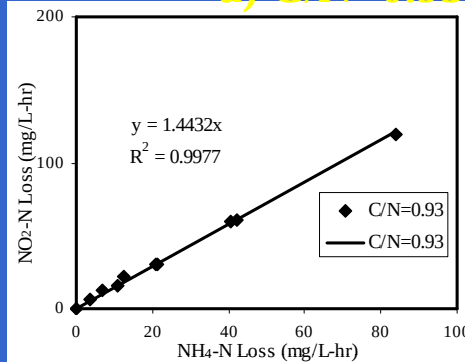
## Relationship between Total N loss to COD Loss.

a) C/N=0.93, b) C/N=10.8



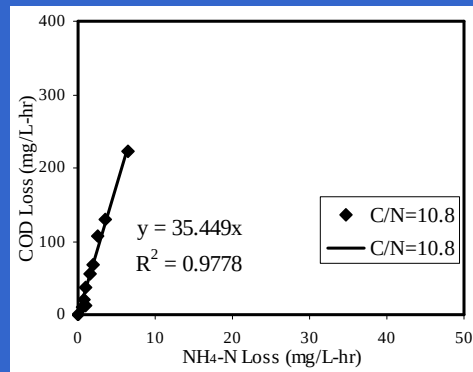
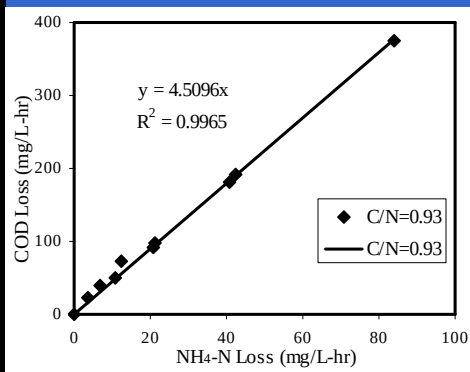
## Relationship between $\text{NH}_4\text{-N}$ loss to $\text{NO}_2\text{-N}$ loss

a) C/N=0.93, b) C/N=10.8



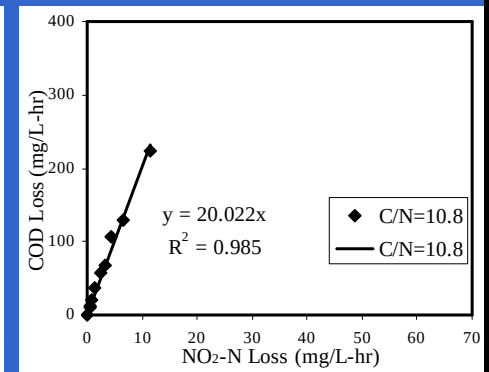
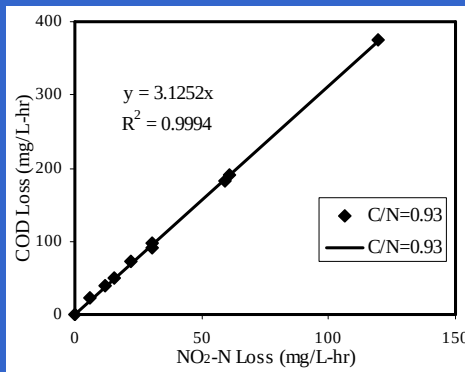
## Relationship between $\text{NH}_4\text{-N}$ Loss to COD Loss

a) C/N=0.93, b) C/N=10.8



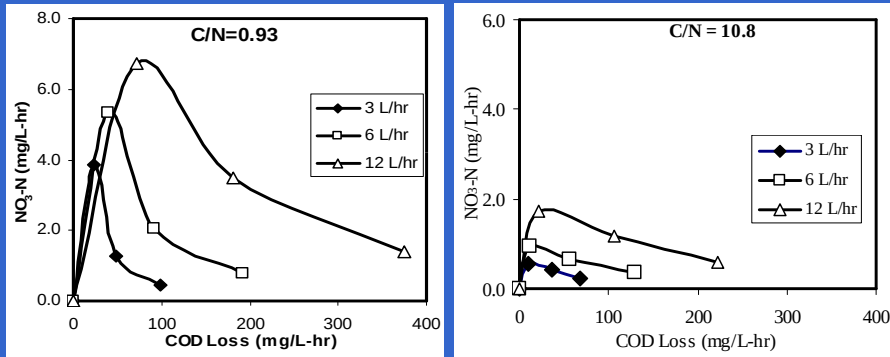
## Relationship between $\text{NO}_2\text{-N}$ Loss to COD Loss

a) C/N=0.93, b) C/N=10.8

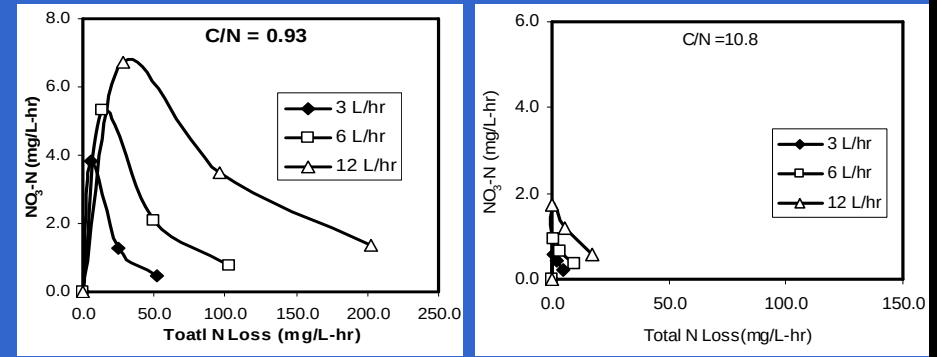




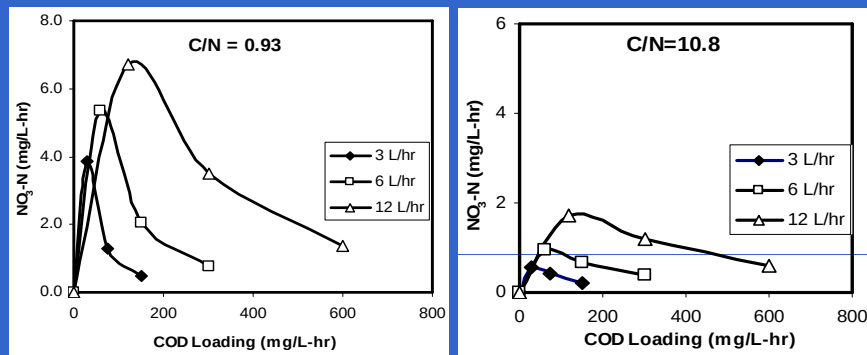
## Relationship between COD Loss and $\text{NO}_3^-$ Production a) $\text{C/N}=0.93$ , b) $\text{C/N}=10.8$



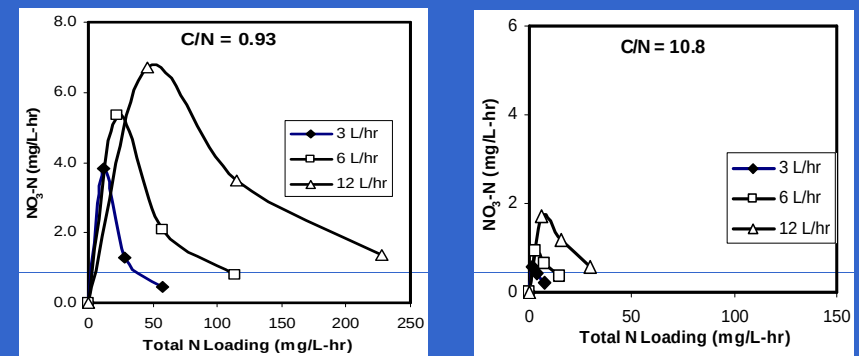
## Relationship between Total N Loss and $\text{NO}_3^-$ Production a) $\text{C/N}=0.93$ , b) $\text{C/N}=10.8$



## Relationship between COD loading and $\text{NO}_3^-$ Production a) $\text{C/N}=0.93$ , b) $\text{C/N}=10.8$



## Relationship between Total N Loading and $\text{NO}_3^-$ Production a) $\text{C/N}=0.93$ , b) $\text{C/N}=10.8$



## Model

The likely reactions are as follows;



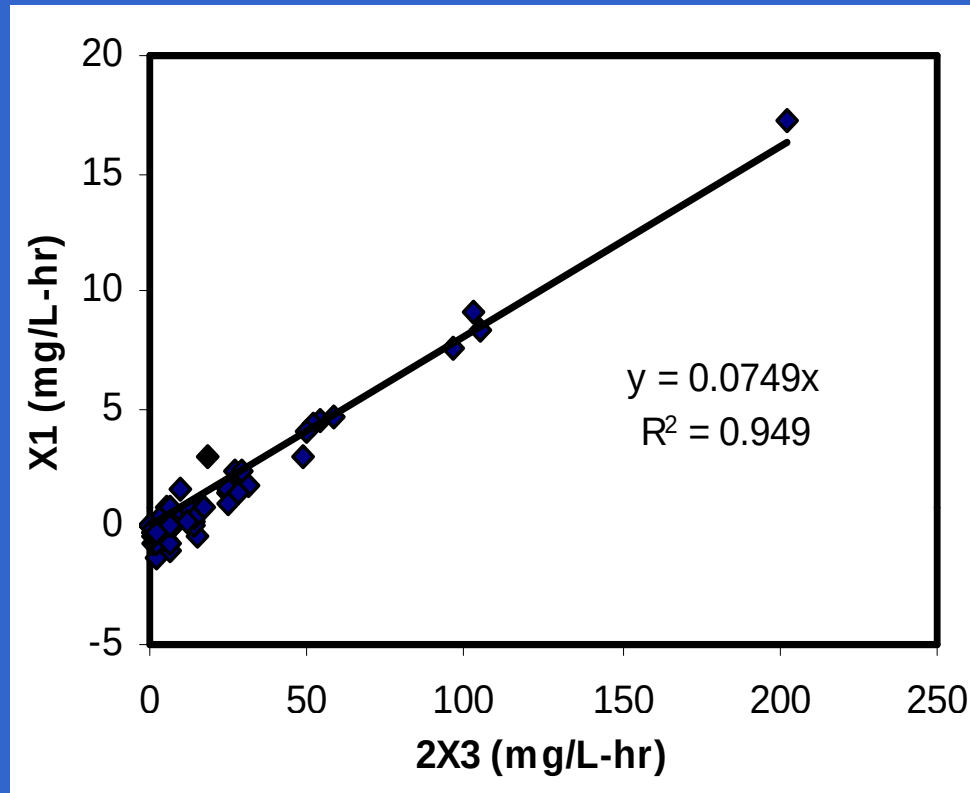
For the above reactions, we get from stoichiometry

$$\text{X1} = 0.5 * F * [(\text{Ao}-\text{A}) - (\text{Bo} - \text{B}) + (\text{Co}-\text{C})] / \text{Vr},$$

$$\text{X2} = F * (\text{C} - \text{Co}) / \text{Vr};$$

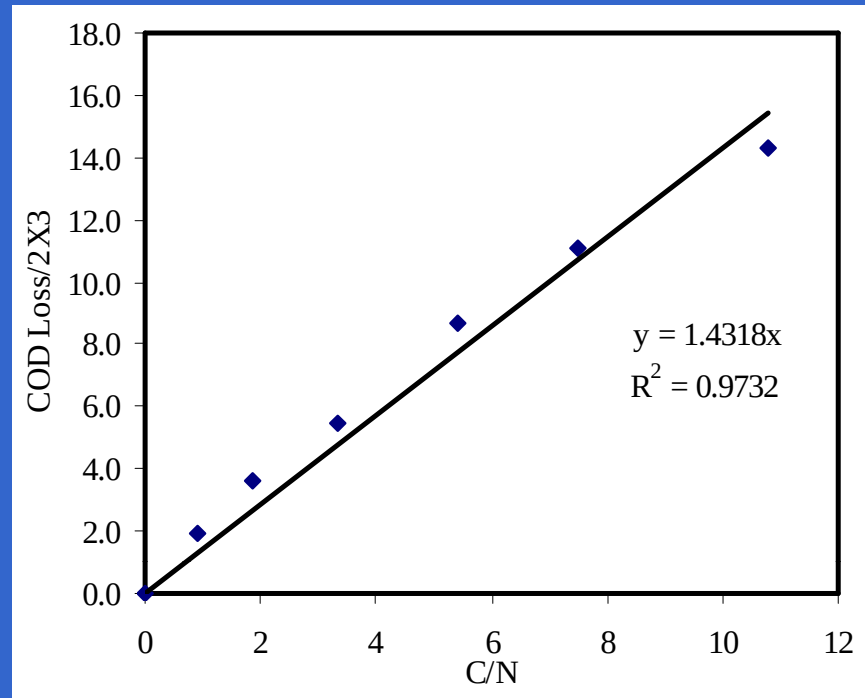
$$\text{X3} = 0.5 * F * [(\text{Ao}-\text{A}) + (\text{Bo}-\text{B}) + (\text{Co}-\text{C})] / \text{Vr}$$

where, Ao (Nitrite), Bo (Ammonium), Co (Nitrate) are feed concentrations and A, B, C outlet concentrations, F feed flow, Vr reactor volume,  $\alpha$  is (g. COD / g. N content of cells)



**Relationship between anammox nitrogen loss (2X3) and predicted ammonia production (X1)**

$$X3 / X1 = 6.67 (= \lambda)$$



$$\frac{COD_{Loss}}{2X3} = 1.43 \frac{C}{N}$$

It is well known that ammonium-N (X1) of nitrite reduction leads to cell synthesis; accordingly we can write cell mass X4 as

$$X4 = \alpha X1$$

where  $\alpha$  of cell is g.COD / g N .

$$\frac{COD_{Loss}}{X4} = \frac{2.86 \lambda C / N}{\alpha}$$

## UNDERSTANDING YIELDS IN AGRICULTURE

- i)  $\text{COD Loss}/X_4 = 2.86 \text{ (C/N)} \lambda / \alpha$  ( From Model)
- ii) Solar Input = 320 GJ/ha.yr = 20 ton/ha.yr
- iii) Corn USA with  $\alpha = 74$ ,  $\text{C/N} = 18$  ,  $\lambda = 7$  gives  
 $X_4 = 4.1 \text{ ton/ha.yr}$  ; observed  $X_4 = 4 \text{ ton/ha.yr}$
- iv) 200 kg/ha.yr urea-N Corn USA with  $\alpha = 74$ ,  
 $\text{C/N} = 9$  ,  $\lambda = 7$  gives  $X_4 = 8.2 \text{ ton/ha.yr}$ ;  
observed  $X_4 = 8 \text{ ton/ha.yr}$
- v) Wheat India with  $\alpha = 60$  ,  $\text{C/N} = 60$  ,  $\lambda = 7$   
gives  $X_4 = 1 \text{ ton/ha.yr}$ ; observed  
 $X_4 = 0.82 \text{ ton/ha.yr}$

# Thermodynamics

- Assuming exergonic reactions supply energy for endergonic reactions

$$\sum X_i \Delta G_i = 0$$

Simplifying

$$\Delta G_4 = - [ X_2 \Delta G_2 + X_3 \Delta G_3 + X_5 \Delta G_5 ] / \alpha X_1 - \Delta G_1 / \alpha$$

- $X_3 ( \lambda * \Delta G_1 + \Delta G_3 + \alpha * \Delta G_4 / \lambda ) = - X_5 * \Delta G_5$

$\Delta G_1$ - Free Energy change of Nitrite reduction

$\Delta G_2$ - Free Energy change of Nitrite oxidation

$\Delta G_3$ - Free Energy change of Anammox reaction

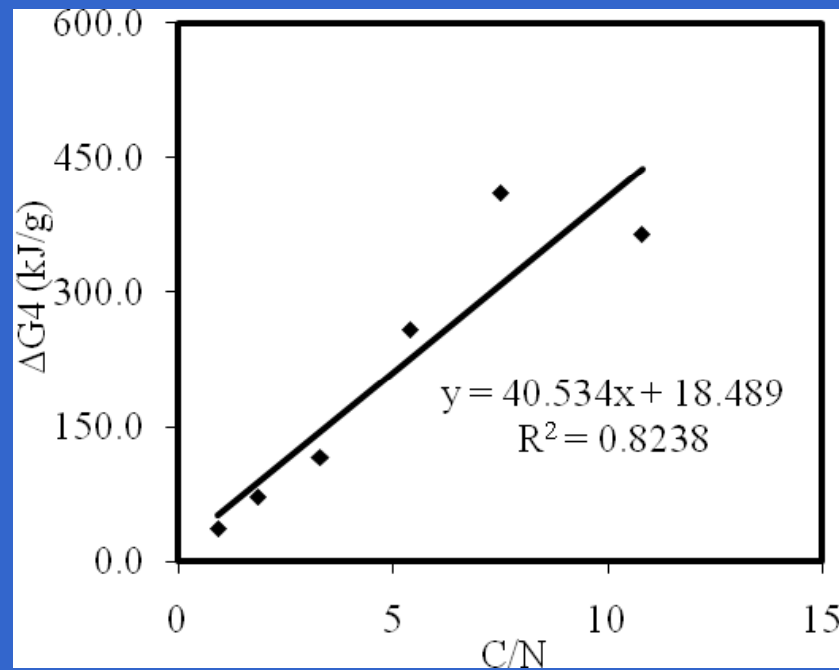
$\Delta G_4$ - Energy required for cell synthesis

$\Delta G_5$  – Energy of Carbohydrate oxidation

$X_4 = \alpha X_1$

$X_5 = \text{COD Loss}$





**Fig.** Relationship of C/N to  $\Delta G4$  (kJ/g) with  $\alpha = 10$

Shows a way of understanding energy needs of productions from soils

## ENERGY CONSUMPTION IN AGRICULTURE

- i)  $\text{COD Loss}/X_4 = 2.86 \text{ (C/N)} \lambda / \alpha$  ( From Model)
- ii) Solar Input = 320 GJ/ha.yr = 20 ton/ha.yr
- iii) Corn USA with  $\alpha = 74$ ,  $\text{C/N} = 18$  ,  $\lambda = 7$  gives  
 $X_4 = 4.1 \text{ ton/ha.yr}$  ; observed  $X_4 = 4 \text{ ton/ha.yr}$   
energy consumption 98MJ/kg
- iv) 200 kg/ha.yr urea-N Corn USA with  $\alpha = 74$ ,  
 $\text{C/N} = 9$  ,  $\lambda = 7$  gives  $X_4 = 8.2 \text{ ton/ha.yr}$ ;  
observed  $X_4 = 8 \text{ ton/ha.yr}$ ; energy  
consumption 49MJ/kg
- v) Wheat India with  $\alpha = 60$  ,  $\text{C/N} = 60$  ,  $\lambda = 7$   
gives  $X_4 = 1 \text{ ton/ha.yr}$ ; observed  
 $X_4 = 0.82 \text{ ton/ha.yr}$

Hydrogen production 160 MJ/kg;  
Ammonia production 32 MJ/kg  
American Soil C/N 3.5 to 35

# **Film : India Innovates**

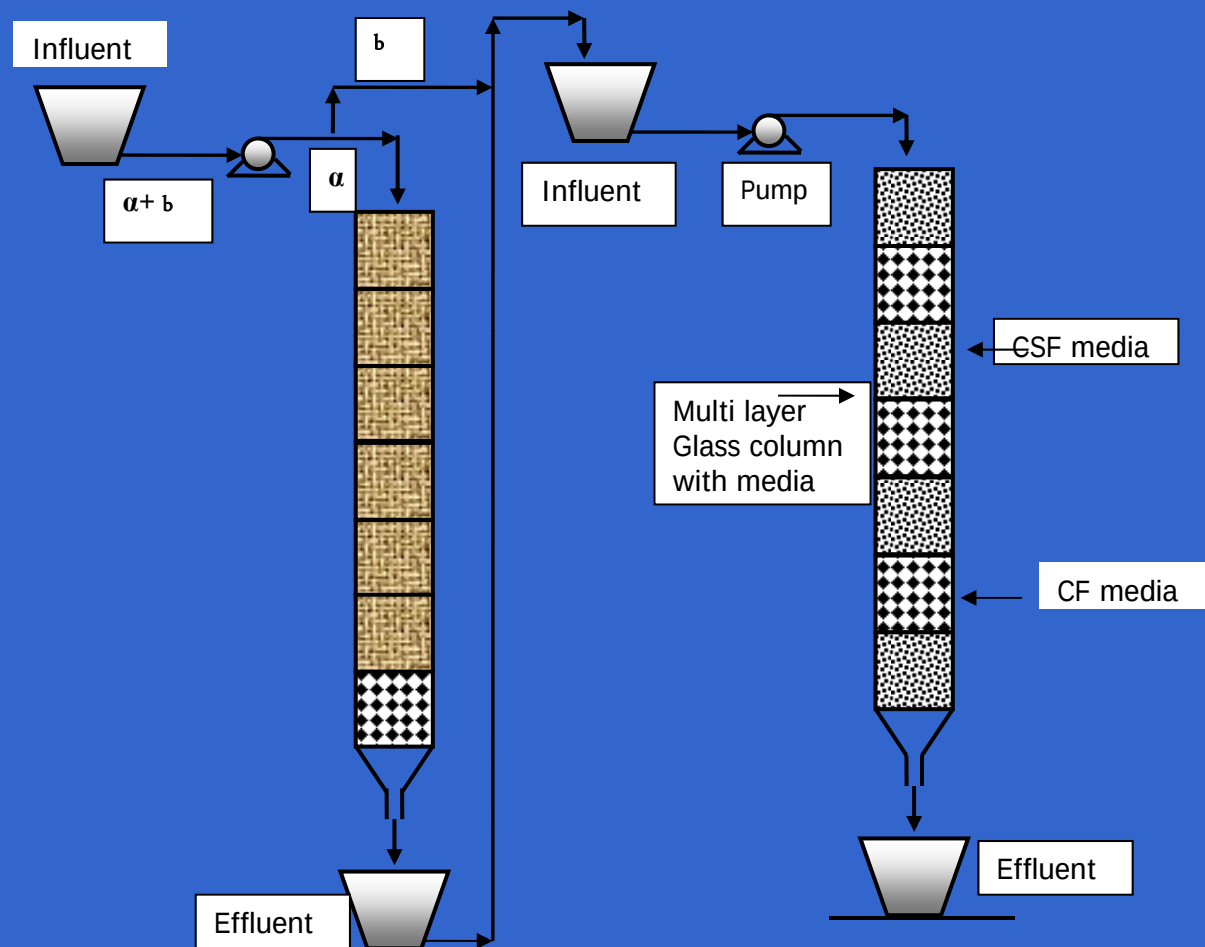
## ***(Min. of Ext. Affairs)***

<http://www.youtube.com/watch?v=dKWVtZ81mY0>

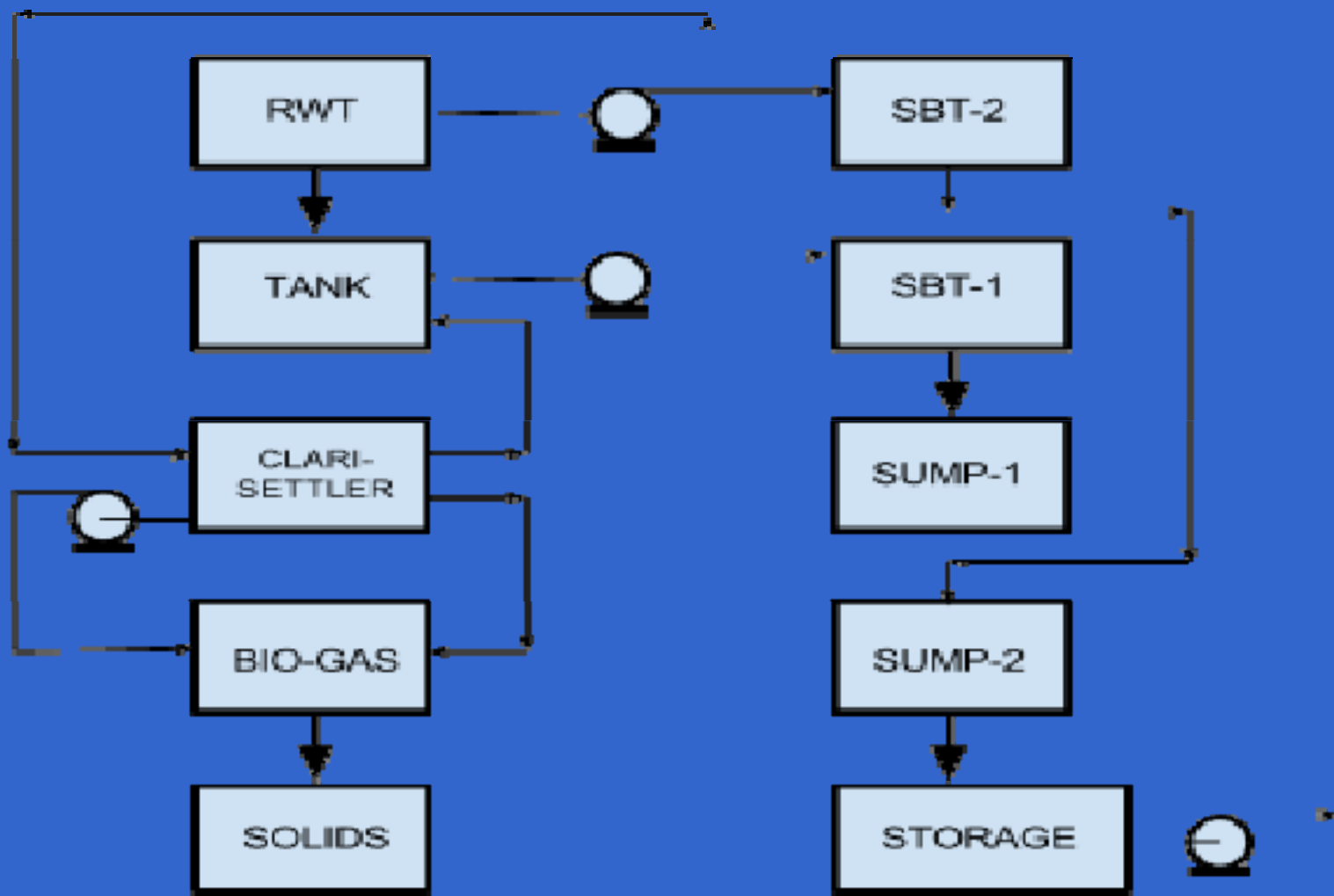
<http://www.che.iitb.ac.in/faculty/hss/hss-web.html>.

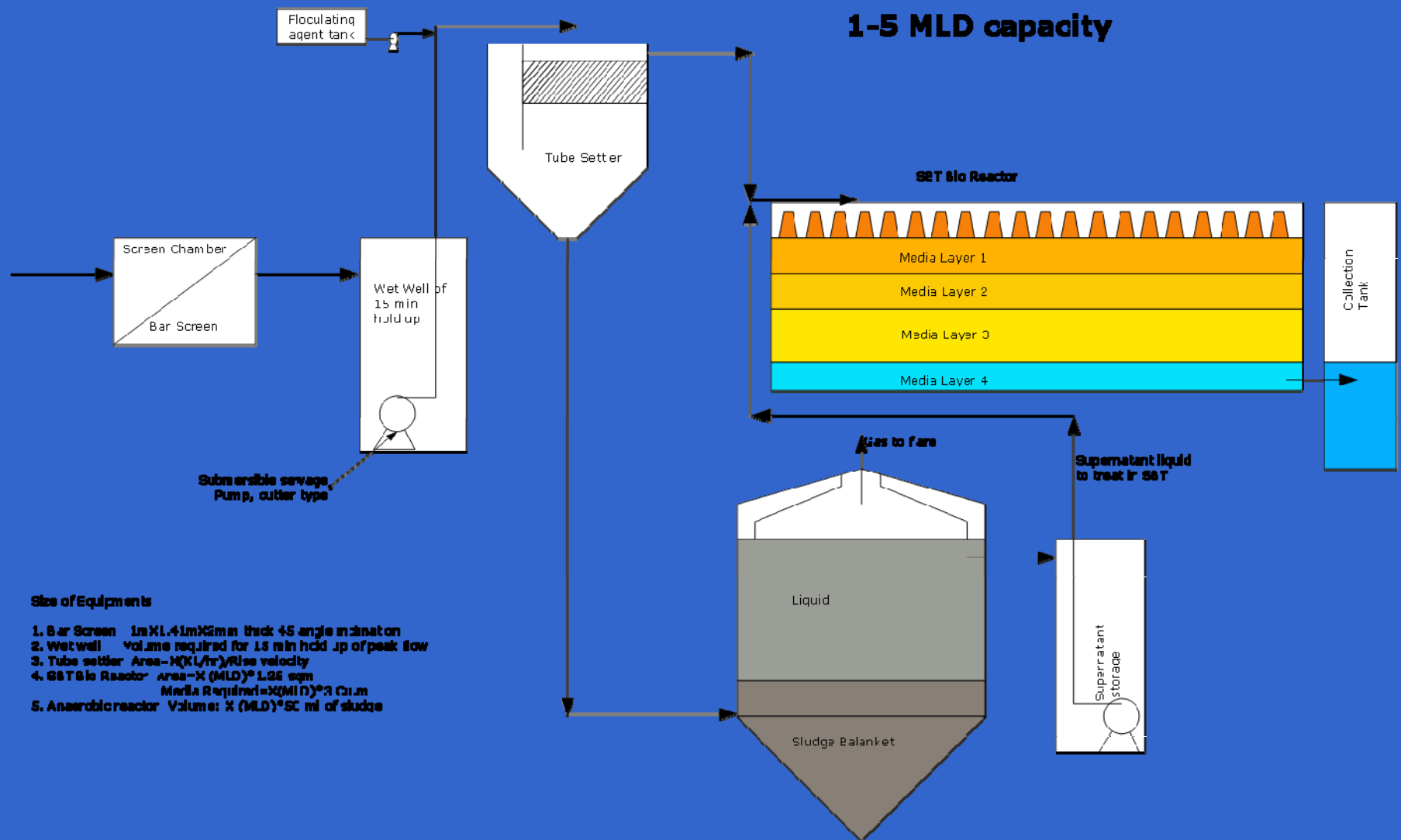
# Experimental Equipment

## CSF & CF



# Typical Process Flow

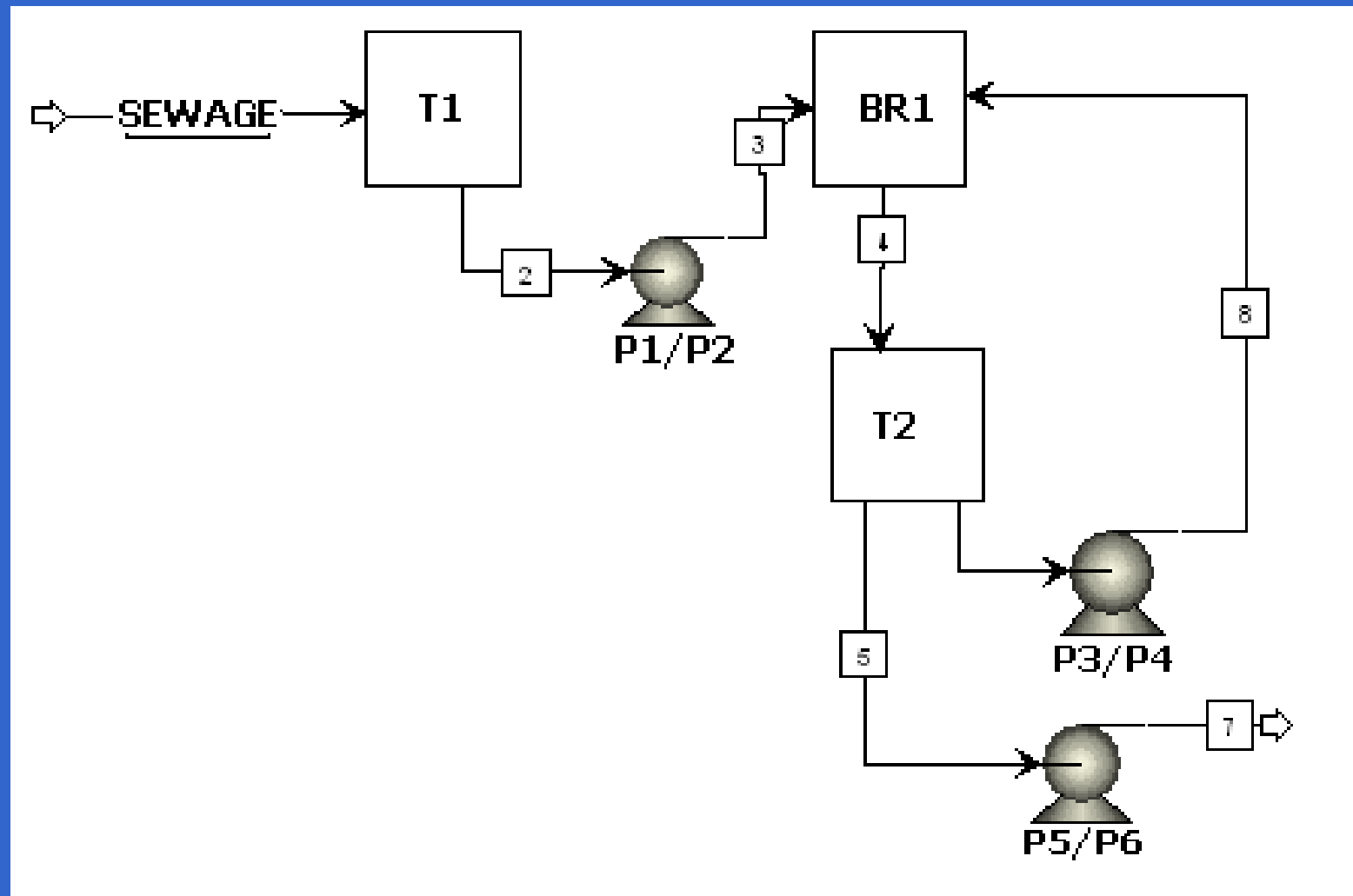






## Schematic Layout

Generally just one feed pump is adequate



# PRESENTATION SUMMARY

Lessons from Carbon Cycle

Process chemistry

Media Layout

Media design for waste water

SBT Performance in sewage Treatment

Other offerings

Vision Earthcare

SBT Film of GOI