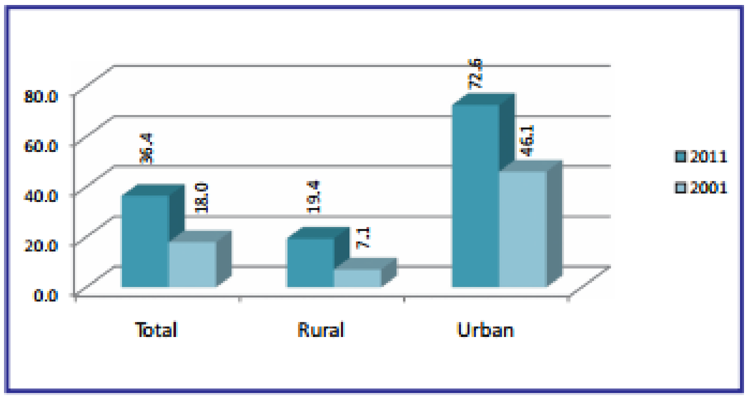
Septage and Fecal Sludge Management: Work carried out at IIT Madras

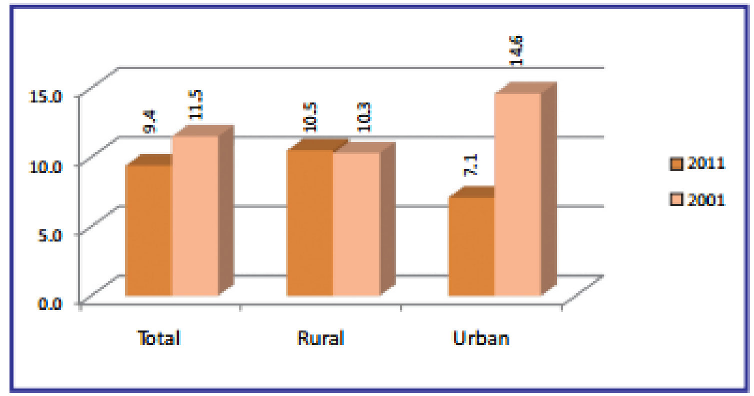
Dr. Ligy Philip
Professor
Department of Civil Engineering
IIT Madras
Email: ligy@iitm.ac.in

Sanitation in India

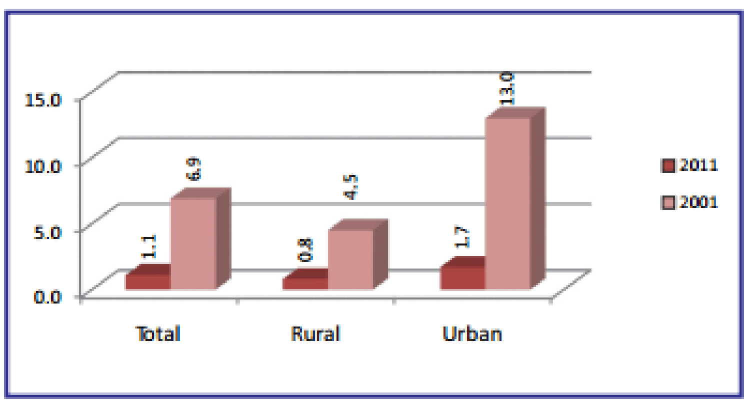
PERCENTAGE OF HOUSEHOLDS HAVING WATER CLOSET
INDIA, 2001-2011



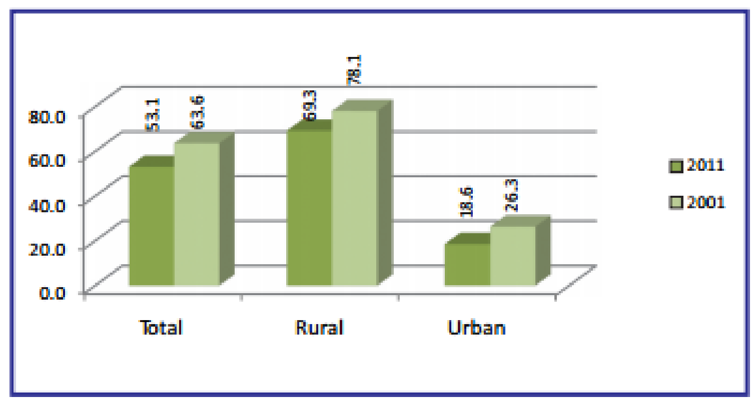
PERCENTAGE OF HOUSEHOLDS HAVING PIT LATRINE
INDIA, 2001-2011



PERCENTAGE OF HOUSEHOLDS HAVING OTHER LATRINE
INDIA, 2001-2011

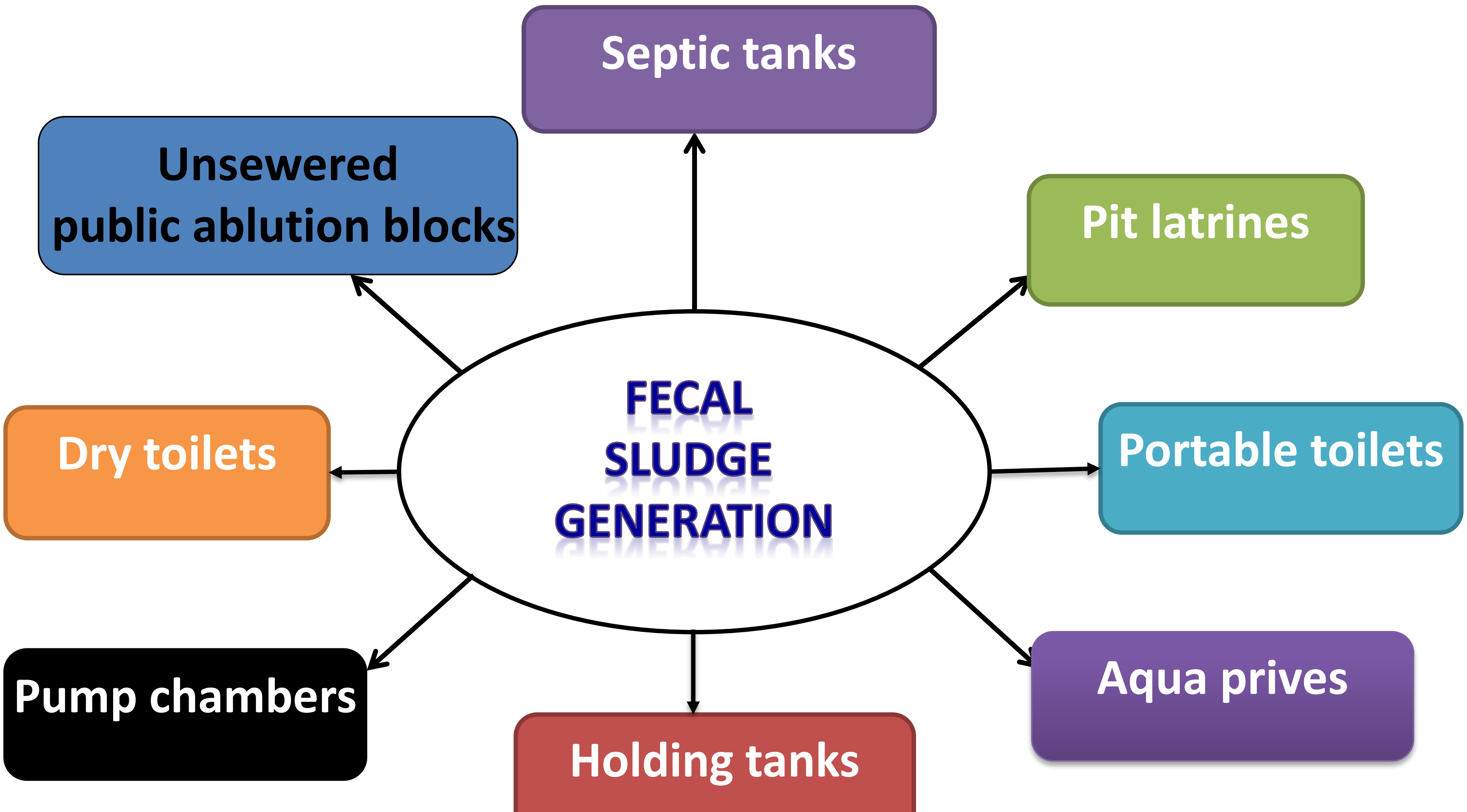


PERCENTAGE OF HOUSEHOLDS HAVING NO LATRINE
INDIA, 2001-2011



Source: Census of India 2011

Sources of fecal sludge ??

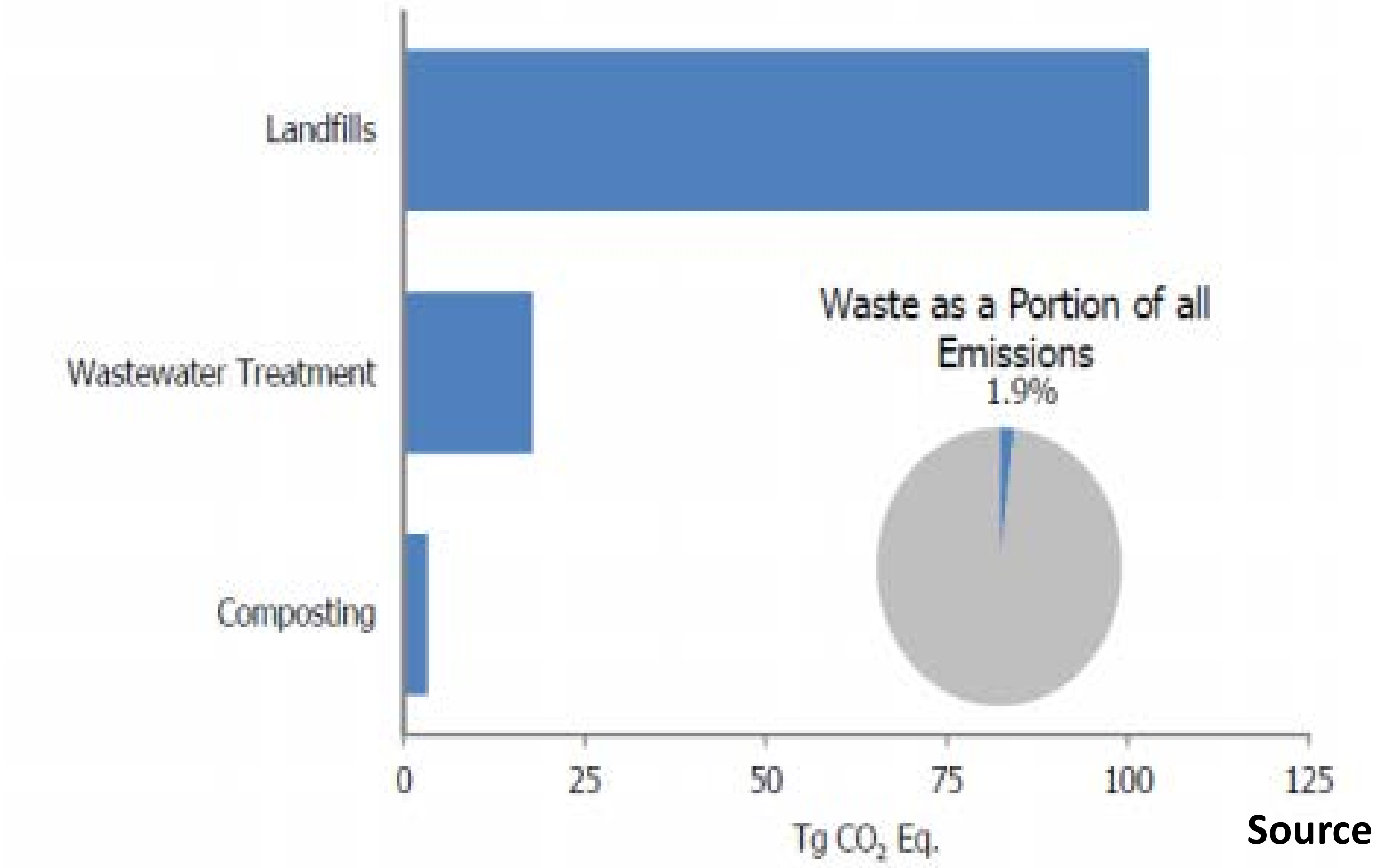


Composting : Sustainable option ???

- Controlled aerobic decomposition of organic matter by microorganisms into stable, humus like soil amendment
- Natural process
- Can control the system to enhance & accelerate process
- Produce fresh, stable , odour-free COMPOST
- Used as soil conditioner and can store easily

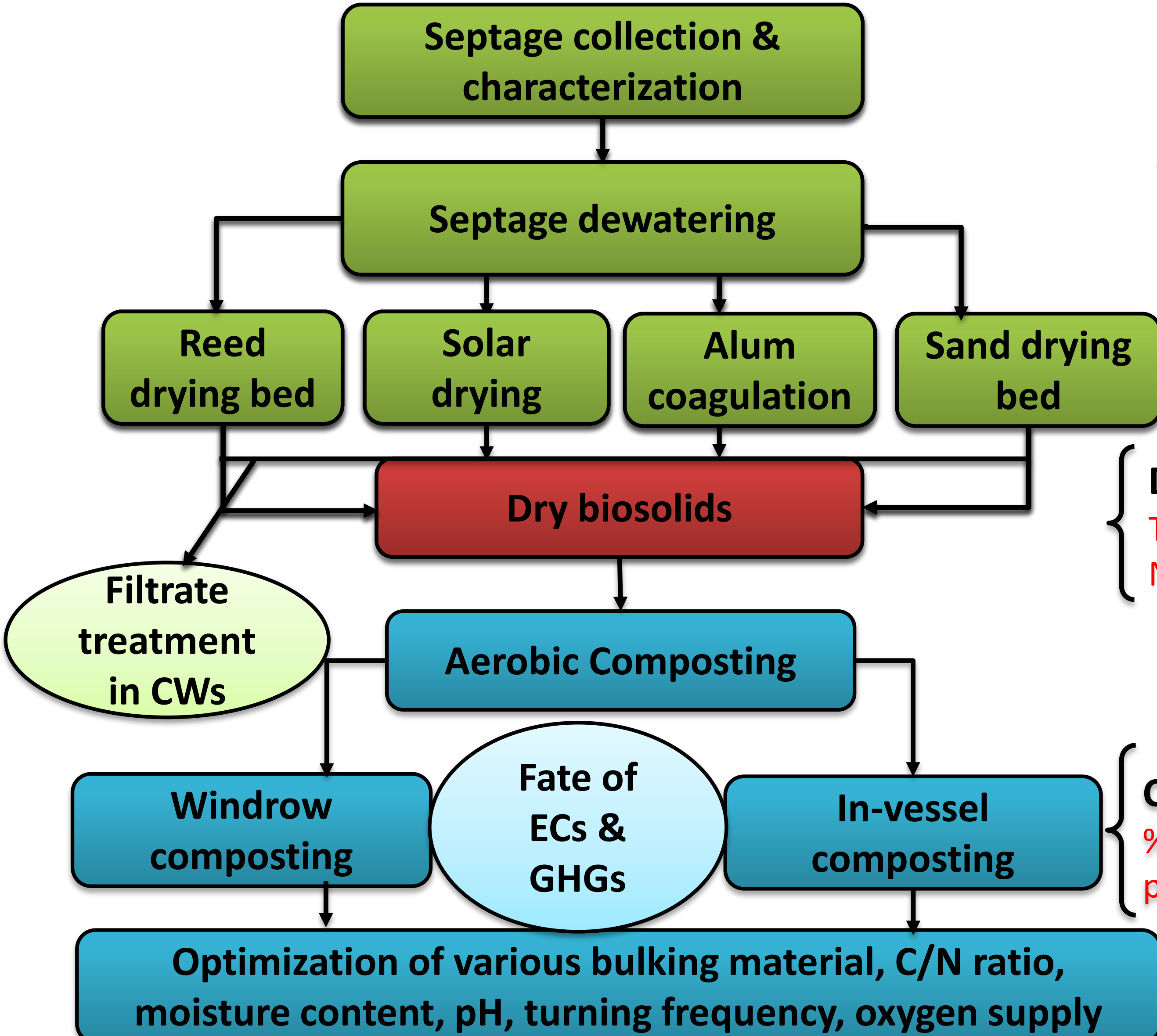
Source : USCC

Composting : Sustainable option ???



Source : USCC

Methodology

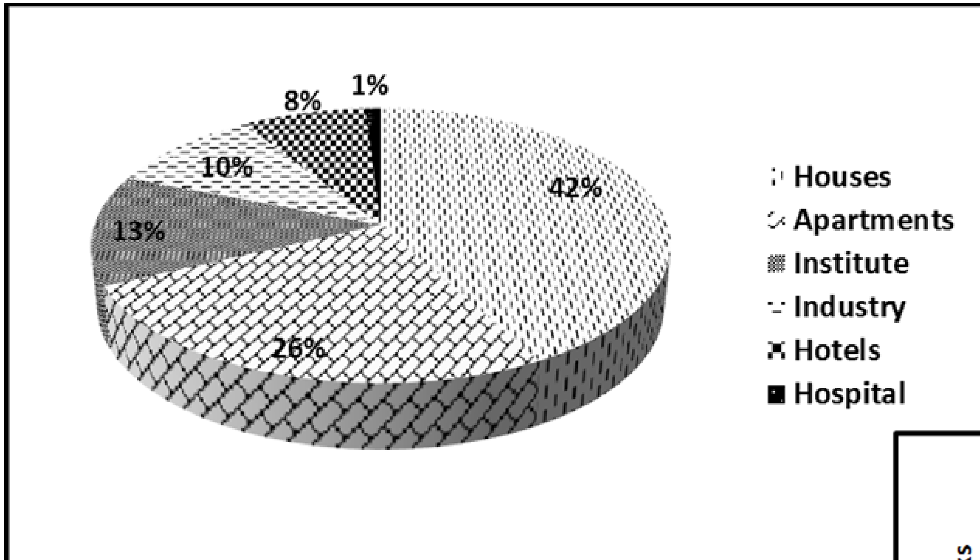


Parameters: TS,VS, TSS,VSS, BOD,COD, TN,TP, Sulphates, Ammonia, Nitrates, Helminth eggs, Micropollutants

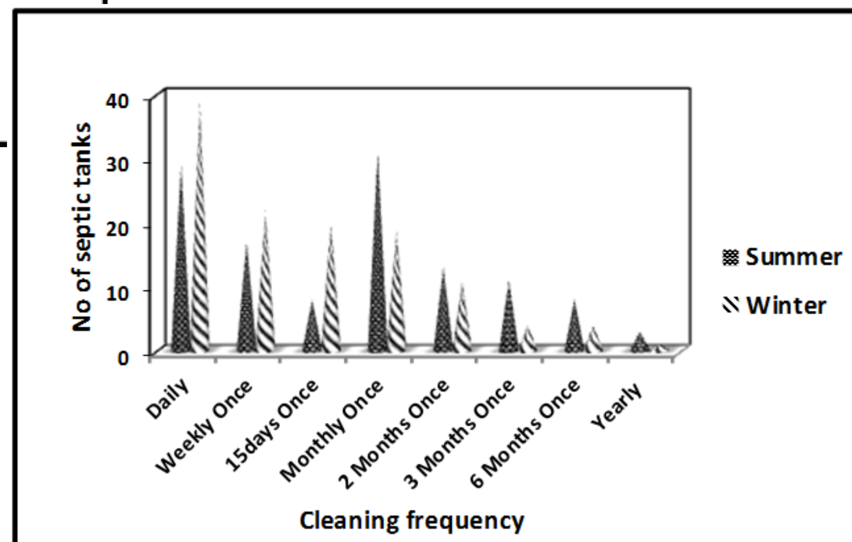
Dewatering Parameters: TOC, TN, BOD, COD, TS, TP, Nitrates

Composting Parameters: %C,%N, VS, temperature, pH, moisture, helminth eggs

Sources of Chennai septage samples



Source distribution of the collected septage samples



Frequency of cleaning during summer and winter seasons

Composition of Chennai septage samples

Parameters	No: of Samples	Concentration (mg/L)							
		Pre Monsoon				Post Monsoon			
		Maximum	Minimum	Average	SD	Maximum	Minimum	Average	SD
Total Solids	120	6940	1000	2185	1070	17467	1010	3555	2935
Volatile Solids		4753	307	1414	657	14400	10	1541	2157
TSS	120	4010	105	712	602	11200	27	1103	1908
VSS	120	2337	57	463	382	9760	10	842	1566
SS	120	850	50	288	170	850	0	94	116
sBOD	120	240	30	117	54	1896	40	211	220
COD	120	2400	80	905	603	6656	160	1460	1295
sCOD	120	1064	16	336	272	4296	64	427	485
Ammonia	120	84	3	16	13	129	2	32	24
TN	120	313	19	94	65	500	4	58	65
TP	120	236	7	77	43	182	5	54	36
Sulphate	120	209	16	76	41	612	2	99	118
Sulphide	120	28	0	10	6	61	0	10	12

Solid Liquid Separation in Septage

- Septage has both liquid and solid fraction

resembles sewage

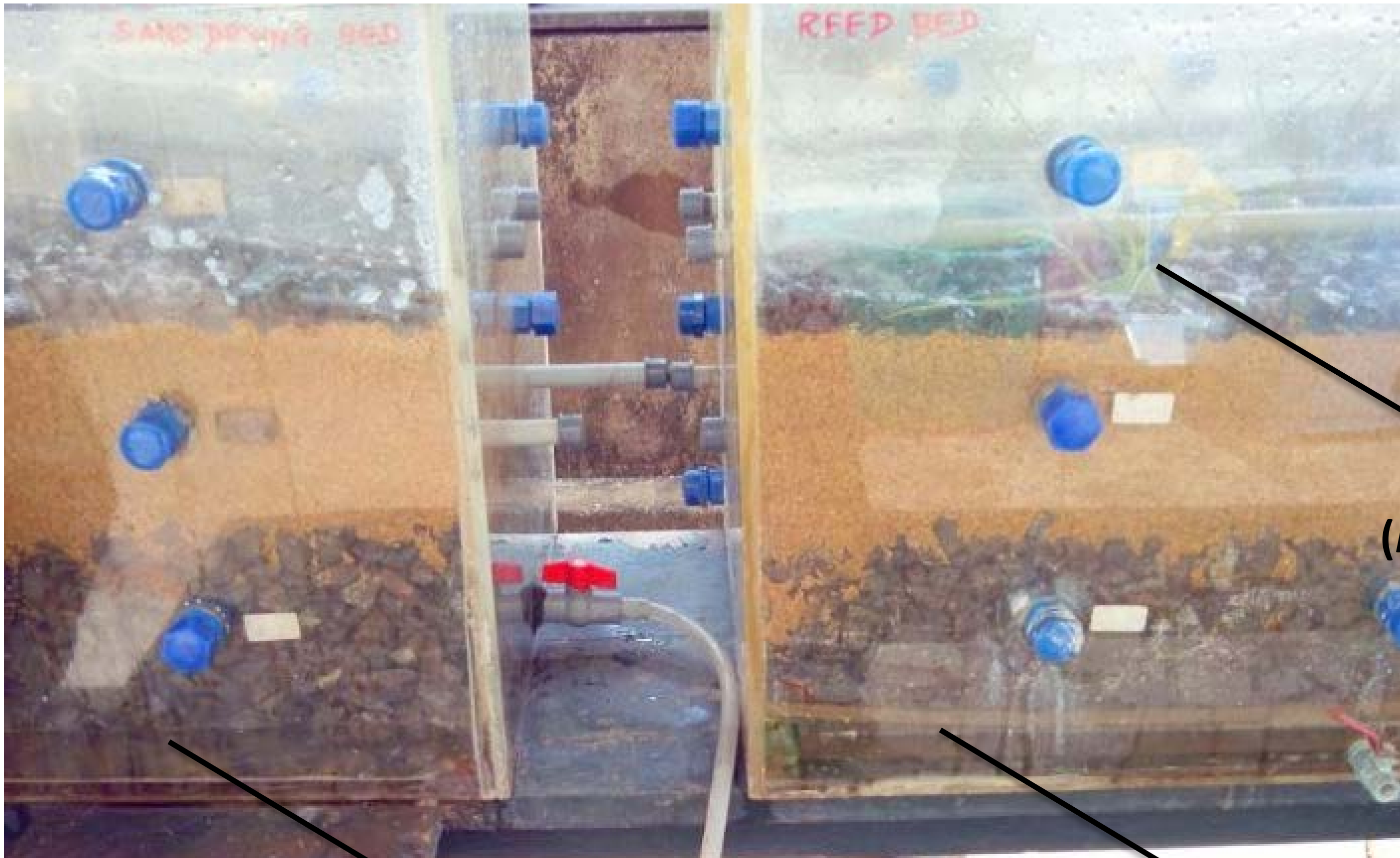
- SS concentration in FS is 10-100 times higher than sewage
- Segregate and treating : a good option
- Volume reduction
- Easiness in handling
- Cost effective

Septage Dewatering options

- Sustainable methods include
  - ❑ Solar drying
  - ❑ Planted drying bed (Reed bed)
  - ❑ Unplanted drying bed (Sand bed)
  - ❑ Coagulation using Alum

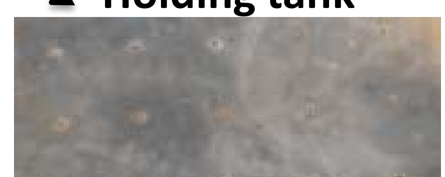
- Well mixed septage samples were dewatered
- Alum coagulation : dosage 20-120mg/L (USEPA 1986)

Dewatering setup



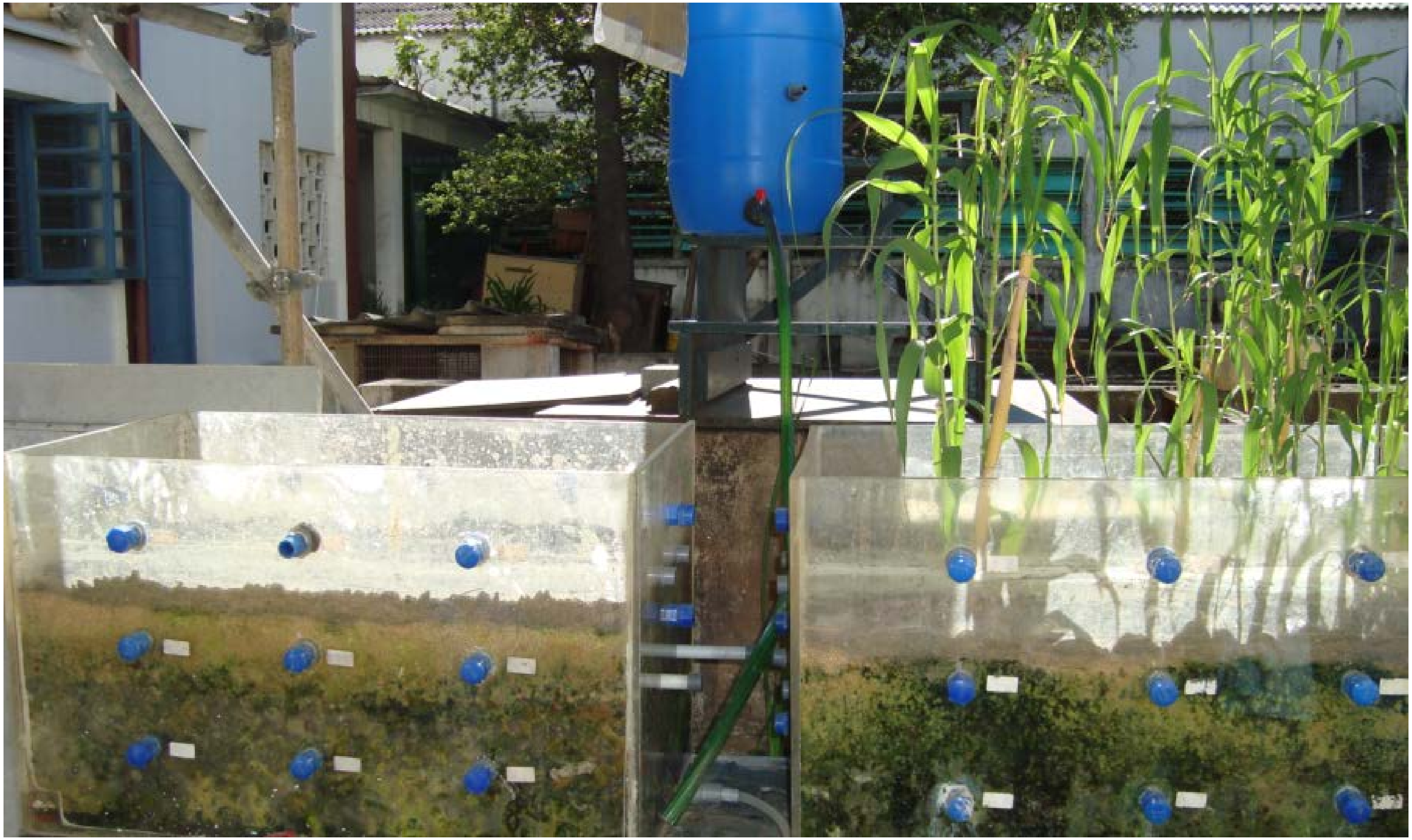
Reed
(*Phragmites australis*)

Under drain pipe



Holding tank

Dewatering setup



Filtrate Quality

Parameters	Concentration in mg/L		
	Raw septage quality	Reed bed percolate quality	Sand bed percolate quality
Total solids	12733	1716	2003
Volatile solids	7013	1770	1397
Total Suspended Solids	10787	133	267
Volatile Suspended Solids	5313	123	213
BOD	1150	510	540
Soluble BOD	990	300	330
COD	9920	3520	4800
Soluble COD	5440	2280	960

Biosolids Quality

Reed Drying Bed

Biosolids quality	Concentration
Total Carbon	72.23 g /kg septage
Total Organic Carbon	67.92 g /kg septage
Inorganic Carbon	4.31 g/kg septage
Average Moisture content	35%
C/N ratio	8.81

Sand Drying Bed

Biosolids quality	Concentration
Total Carbon	93.33 g/kg septage
Total Organic Carbon	84.38 g/kg septage
Inorganic Carbon	8.95 g/kg septage
Average Moisture content	40%
C/N ratio	10.61

Inferences

- Four sustainable dewatering methods are studied
- Since the septage is highly variable, the optimum alum dosage always varies depending on the TS concentration
- Solar drying can be an option where there is enough land space and sunlight
- In case of filter beds, irrespective of TS concentration, it separates the solid and liquid fractions
- Also the filter beds showed better efficiency in removing organic pollutants and nutrients
- Filter beds will be a good option for highly variable septage treatment

Available bulking agents in Tamil Nadu

Groundnut shells | Palm dry leaves | Rice husk | Dry leaves | Coir fibre

Coir pith | Rice straw | Saw dust | Sugarcane bagasse | Wood chips

Source: Thomas et al, "Optimization of bulking material for co-composting of septage", Proceedings of Indo-German Conference on Sustainability, 2016, pp. 25-27.

Estimation of Physical properties

Composting materials	Moisture content (%)	Organic matter (%)	C/N ratio	Water holding capacity (g of water/ g of material)	Bulk density (kg/m^3)	Air filled Porosity (%)
Bulking agent for composting						
Bagasse	5.14	81.18	62	6.79	200	85.03
Straw	6.83	65.50	54	4.30	220	82.37
Wood chips	7.17	70.20	500	2.03	120	89.41
Saw dust	11.04	75.20	779	4.35	95	90.95
Dry leaves	5.29	62.96	60	2.15	70	93.96
Coir fibre	8.06	64.29	26	3.38	84	92.88
Coir pith	19.66	64.08	53	5.07	70	93.78
Rice husk	8.02	48.20	47	1.82	75	93.11
Groundnut shells	8.88	49.37	24	1.97	130	88.17
Palm dry leaves	7.34	45.12	20	1.42	92.8	91.48
Substrate for composting						
Dewatered septage solids	5.14	81.18	10	0.72	300	85.03

Source: Thomas et al, “Optimization of bulking material for co-composting of septage”, Proceedings of Indo-German Conference on Sustainability, 2016, pp. 25-27.

Factors effecting compostin

Factor	Range	
	Acceptable	**Preferred**
C:N	15:1 – 40:1	25:1 – 30:1
Moisture	40 – 65 %	50 – 60 %
Oxygen	> 5 %	>> 5 %
Free air space	>30%	>30%
Particle size	1/8 – 1/2 in	Variable
pH	5.5 – 9.0	6.5 – 8.0
Temperature	43-66^{o}C	55-60^{o}C

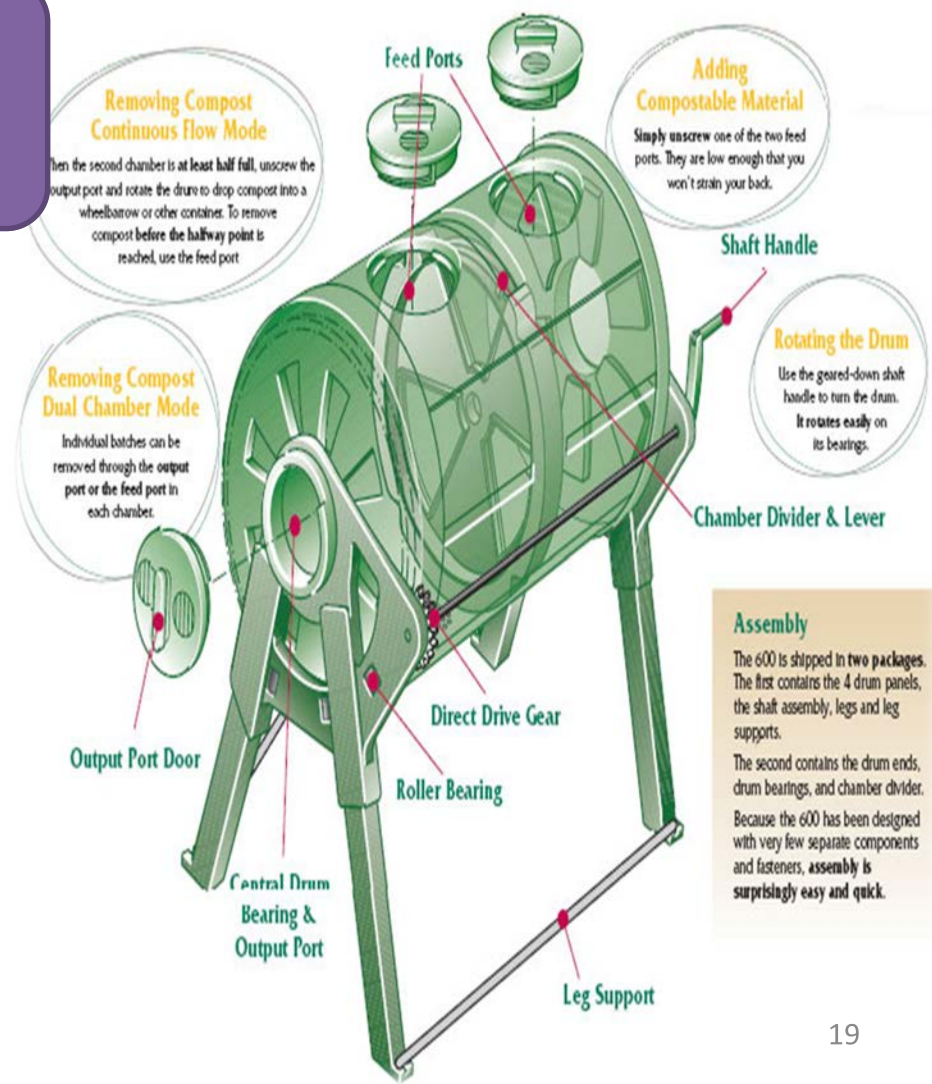
Source: Rynk et al, 1992

Types of Aerobic composting

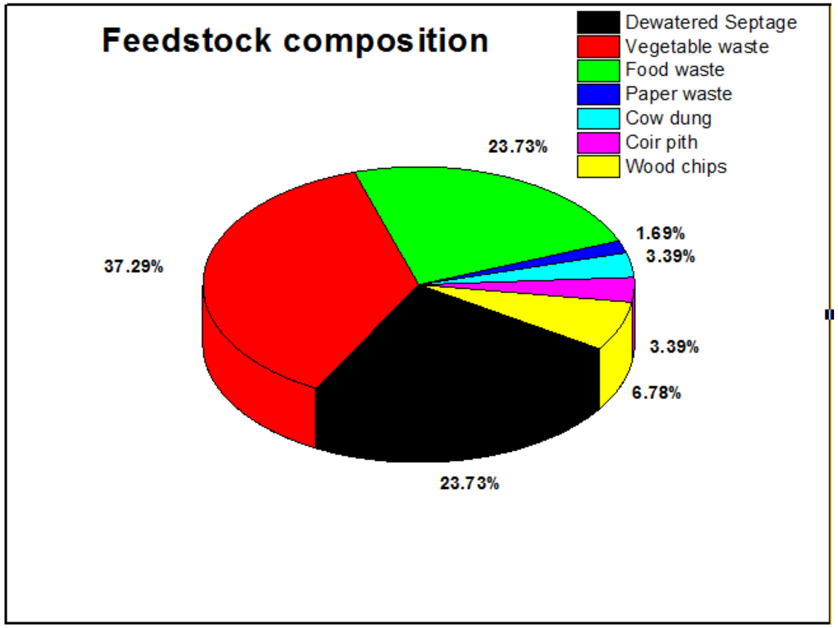
Windrow composting

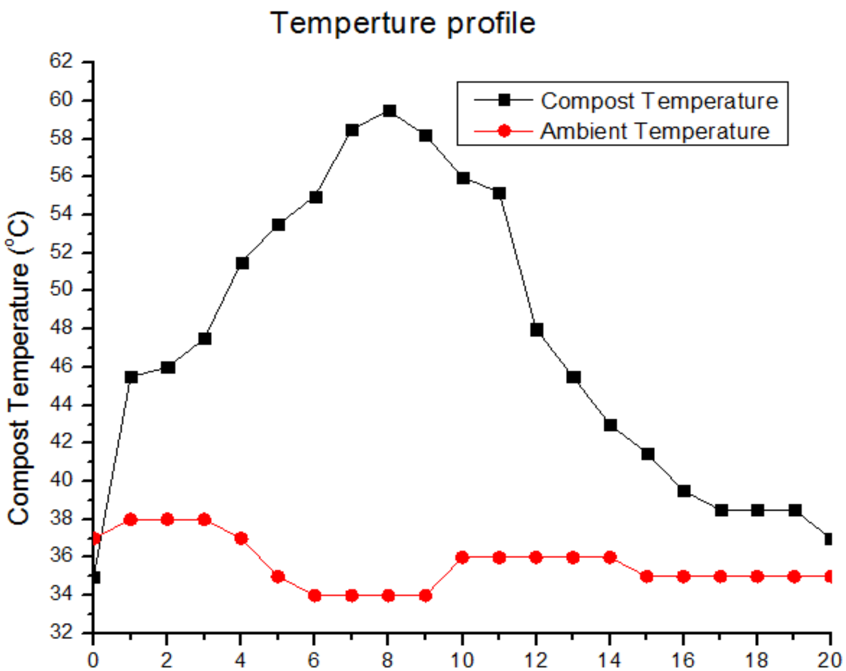
Using passive and active aeration

Rotary drum composting



In-vessel co-composting of septage





- Mixed organic waste : septage ratio is 3:1 (at initial C/N ratio of 23.4)
- Bulking material: Coir pith (Water holding capacity=5.07g water/g coir pith)
- Temperature profile has 3 phases : mesophilic, thermophilic and curing stage
- Major organic matter transformation occur at thermophilic phase
- Retention at >55°C for more than 3 days ensured significant pathogen inactivation

Conclusion

- The selected feedstock composition is suitable for the effective co-composting of septage.
- Close monitoring of in-vessel system helped in the detailed understanding of compost dynamics during septage co-composting.
- Proper mixing of feedstock materials resulted in obtaining the final ripened compost within 20 days of composting operation
- Final compost have a TOC content of 30.2±0.5%, TN value of 2.92±0.3% and a TP value of 0.31±0.01%.
- The low temperature (37^{o}C) and low C/N ratio (11.4±0.5) confirms the stability of final compost.
- The final product is suitable for the application as a soil conditioner.

In-vessel co-composting of Septage in passive & active aeration systems

Characteristics of initial mix (feedstock composition)

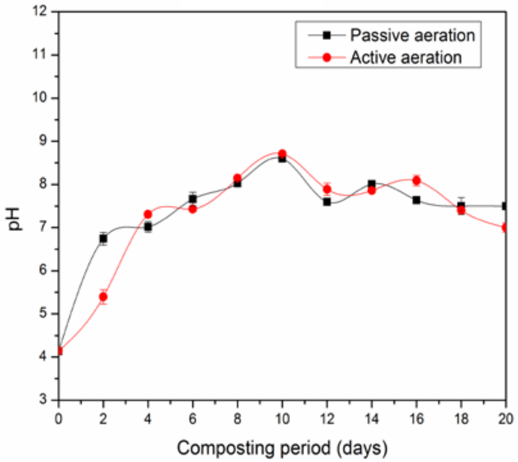
Substrate	Moisture Content (%)	C/N ratio	Mass used (kg)
Vegetable waste	92.6 ± 1.8	15.6±1.5	11.0
Food waste	81.4±2.5	20.4±0.7	2.0
Dewatered septage	60.2±2.7	8.2±0.8	6.5
Coir pith	33.3±1.2	34.5±2.7	1.0
Wood chips	55±0.9	40.9±1.8	2.5
Cow dung	94.3±2.2	9.4±0.9	1.0
Overall Moisture Content (%)			76.8
Overall C/N ratio			15.7

C-mole formulae of initial compost [$CH_{1.70}O_{1.34}N_{0.05}$] matrix revealed that the main component in organic matter (OM) is carbohydrates [$CH_{1.8}O_{0.9}$] rather than fats [$CH_{0.75}O_{0.25}$] and proteins [$CH_{0.86}O_{0.5}N_{0.14}$] hence results faster degradation

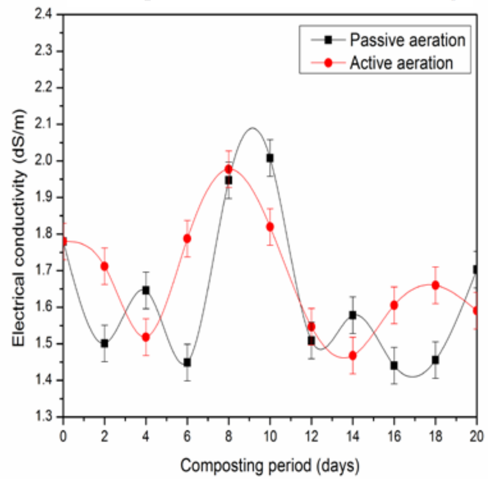
The C/N ratio was made at 15.7 which is at lower optimum range in order to treat more septage (having low C/N ratio 8.8) and reduce the net bulking material consumption

Compost dynamics

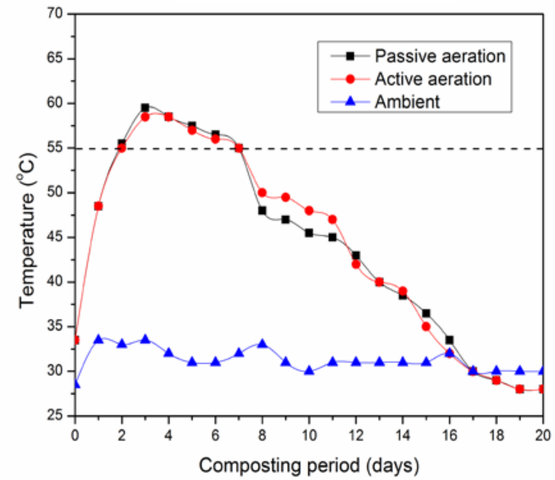
pH profile



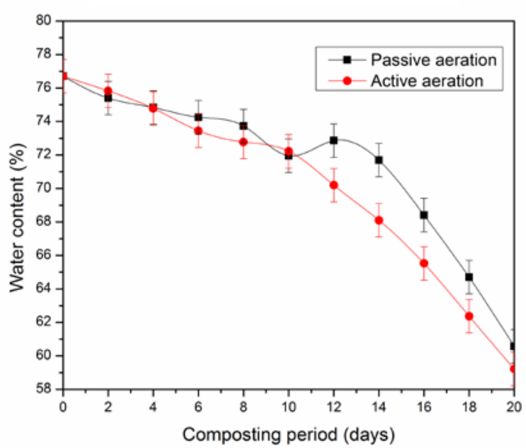
Change in Electrical conductivity



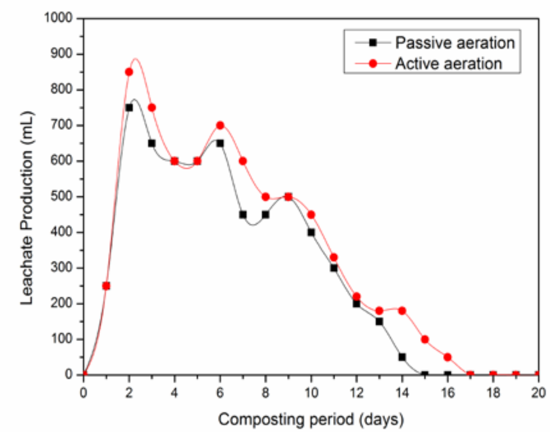
Temperature profile



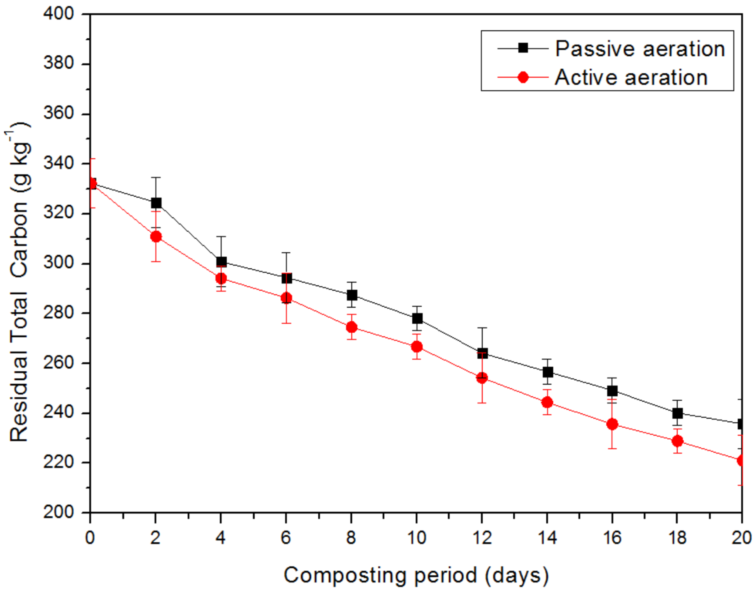
Change in Moisture content

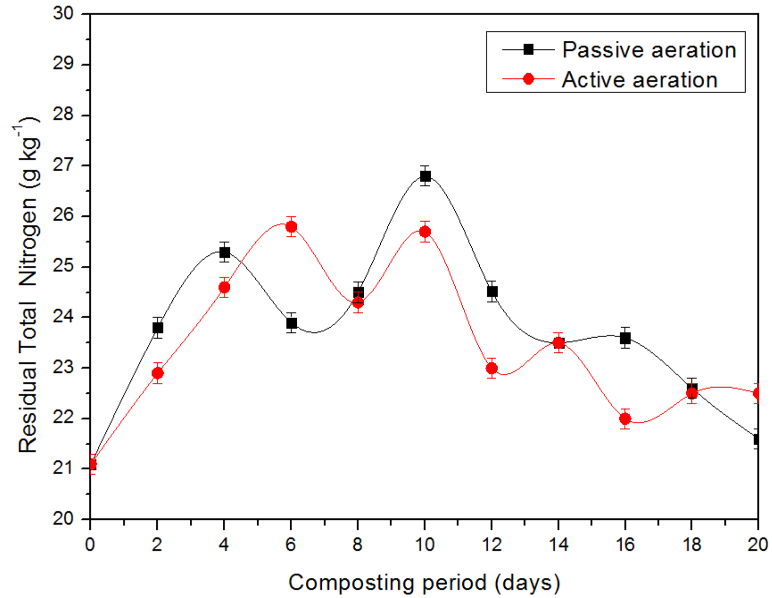


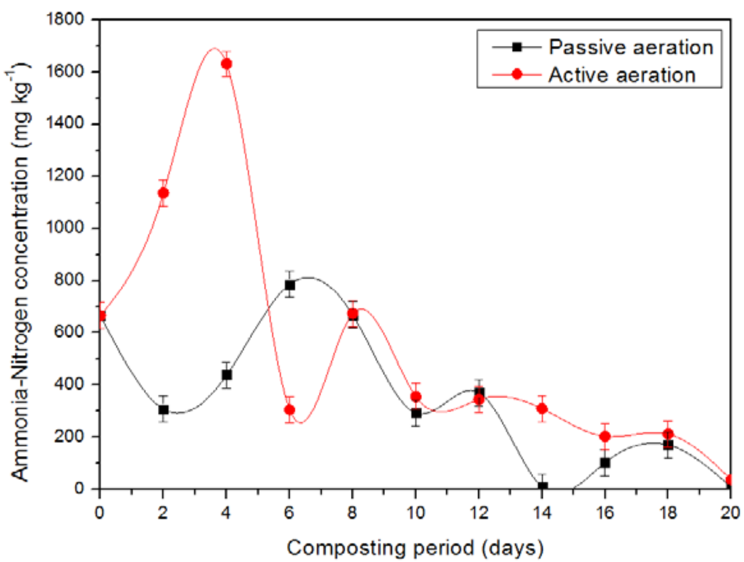
Leachate production

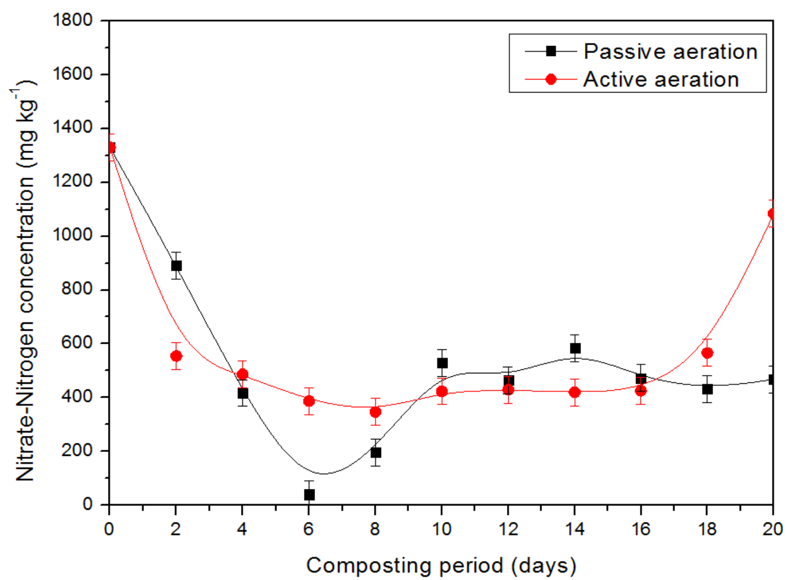


Carbon & Nitrogen decomposition







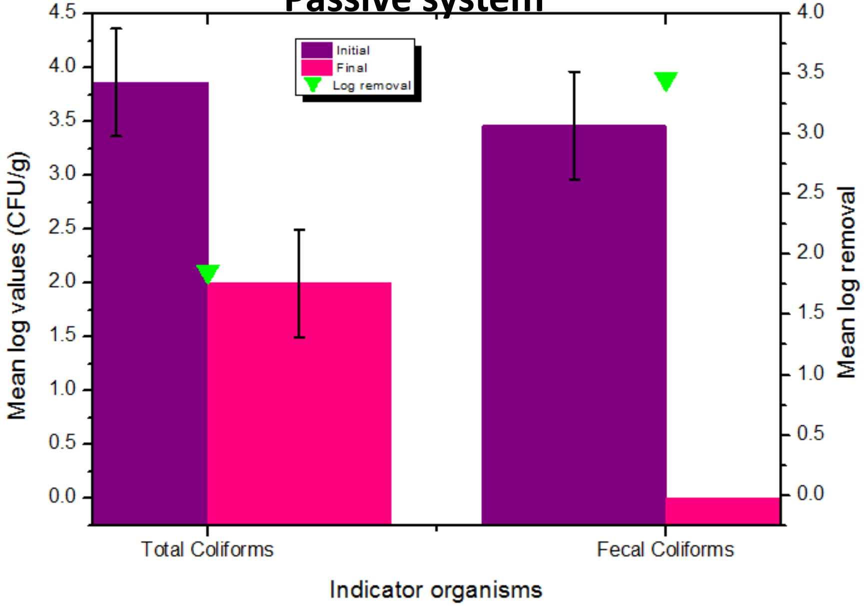


Pathogen reduction

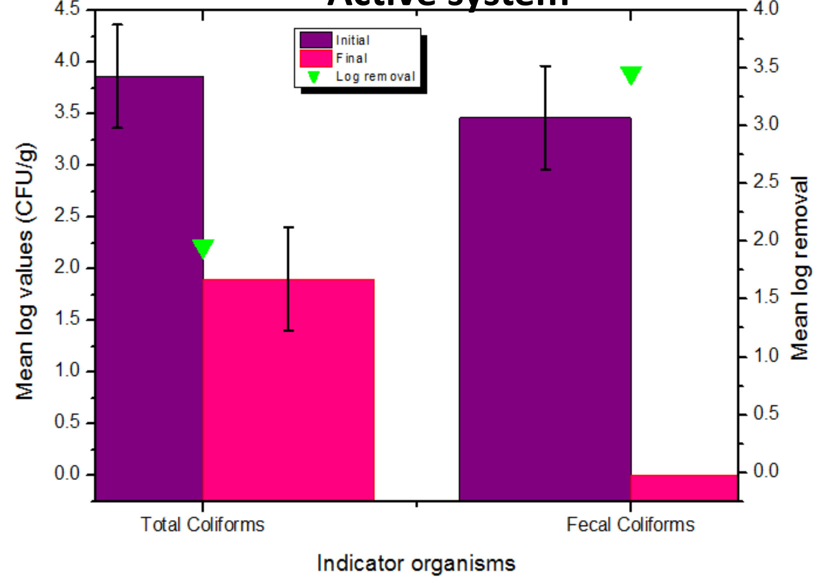
Time-Temperature relation for pathogen killing in composting (Source: EPA 1992)

Time (Days)	Temperature (°C)
0.02 (30 min)	70
0.04 (1 hour)	68
0.08 (2 hours)	66
1	58
2	56
3	55

Passive system

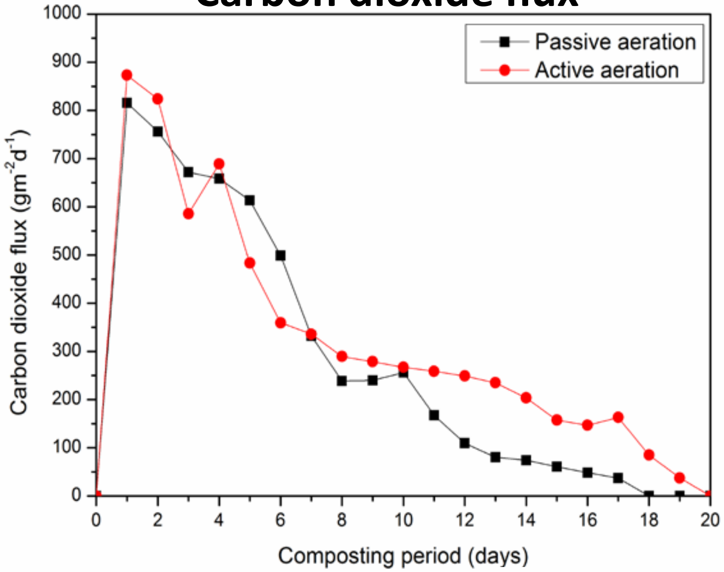


Active system

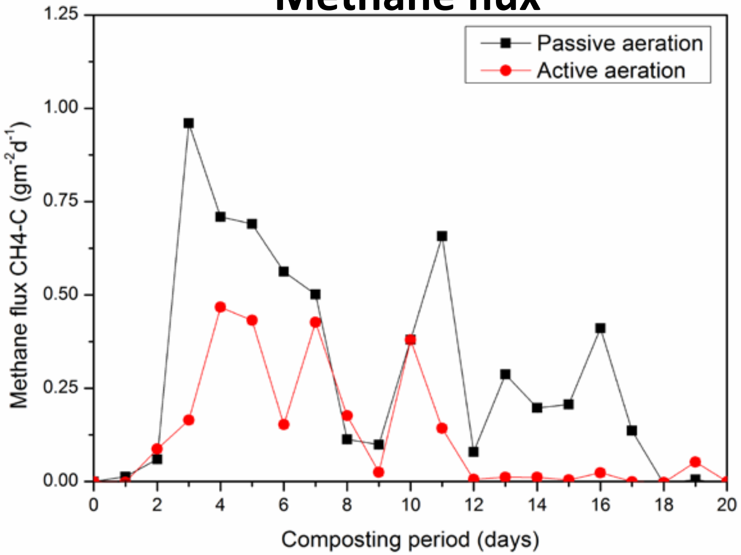


Greenhouse gas emission from septage co-composting

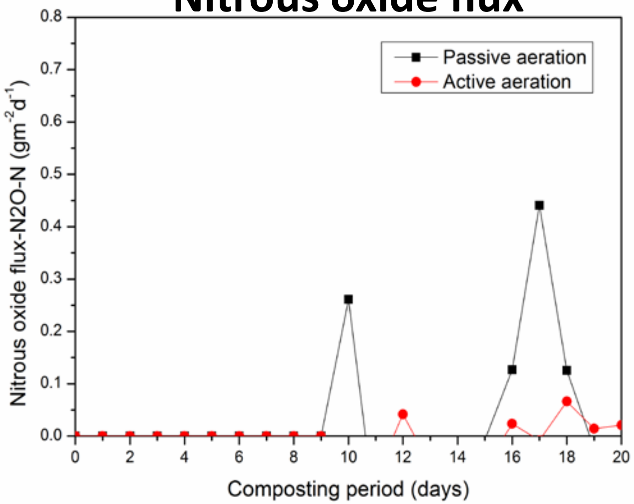
Carbon dioxide flux



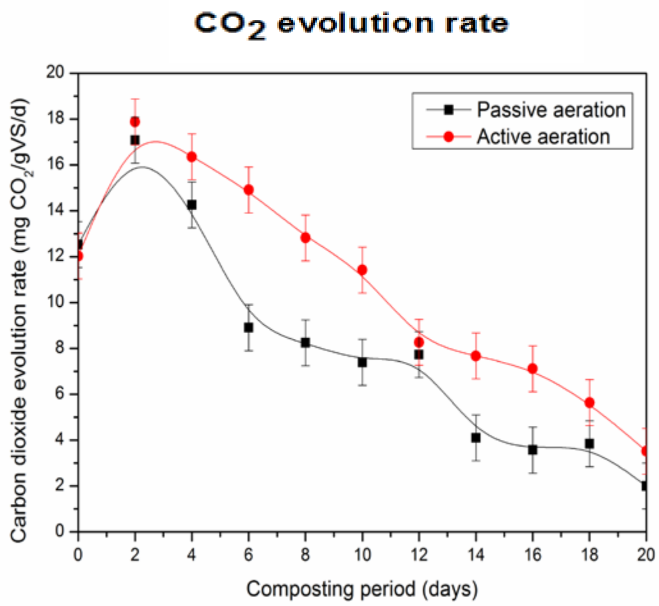
Methane flux

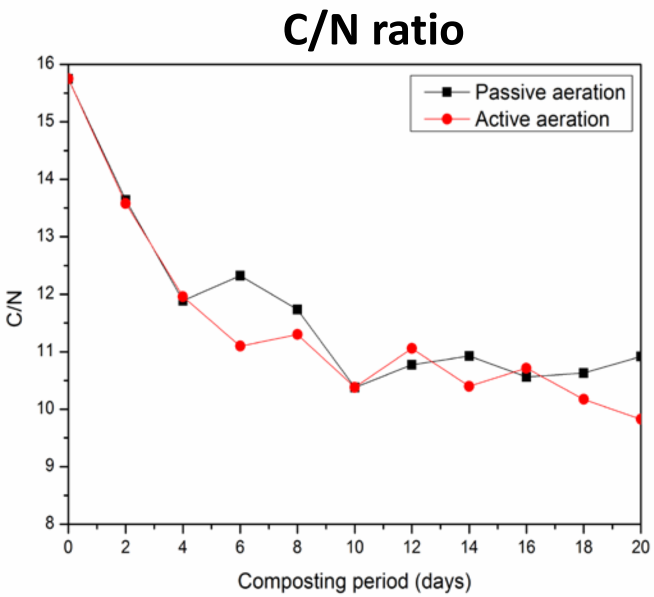


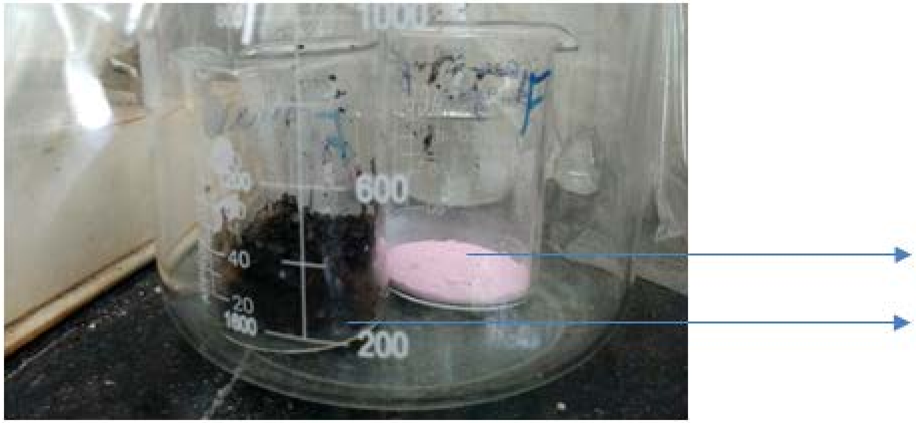
Nitrous oxide flux



Compost maturity



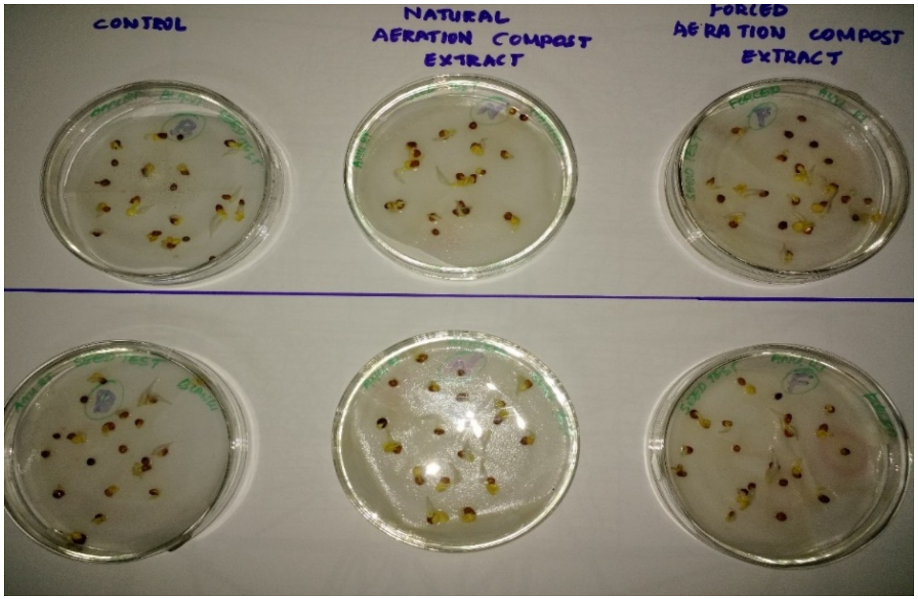


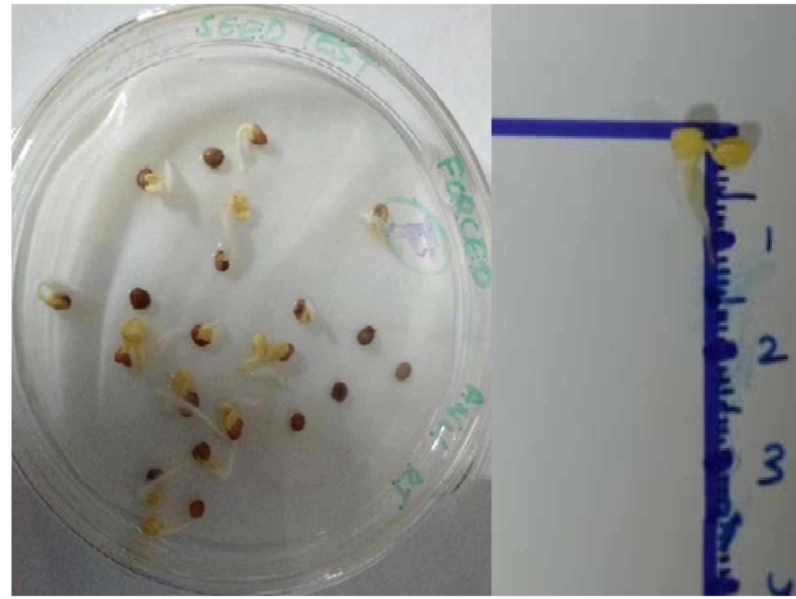


Soda lime

Compost sample

Seed germination test





Outcomes of Seed germination test

Item/Parameter	Control Test	Compost extract from passive aeration system	Compost extract from active aeration system
Total seeds	40	40	40
Germinated seeds	29	32	30
Mean root length (cm)	0.79	1.09	1.22
Relative seed germination (%)	-	110	103
Relative root growth (%)	-	123	137
Germination index (%)	-	135	141

Ripened compost product quality

Parameters	Standard values		Passive aeration system	Active aeration system
	HKORC[a]	TMECC[b]/ CCME[c]		
Ammoniacal-N (mg/kg dw)	< = 700	75-500	10.3 ±5.3	37.2± 4.8
CO_2 evolution rate (g C/kg VS/day)	< = 2	2-4	2.0 ± 0.18	3.5 ± 0.20
C:N ratio	≤ 25	≤ 25	10.9 ± 0.8	9.8 ± 0.5
pH Value	5.5 - 8.5		8.2 ± 0.02	7.4 ± 0.10
Organic matter (% dw)	> 20	>40	61 ± 0.5	58 ± 0.5
Seed germination index (%)	≥ 80	80–90	135	144
Total N, P, K	≥ 4% dw		4.37±0.5	4.5±0.5

[a]HKORC (2005): *Compost and Soil Conditioner Quality Standards for General Agricultural Use*.
[b]TMECC (2002): *Test Methods for the Examination of Composts and Composting*.
[c]CCME (2005): *Guidelines for Grade A Compost Quality*.

Conclusion

- The retention at higher temperature (>55^{o}C) for more than 5 days ensured three log pathogen reduction in both systems.
- The selected feedstock composition is suitable for septage co-composting even at low C/N ratio with relatively lower GHG emissions when compared with various treatment options.
- The active system was found to be better than passive system especially in terms of GHG emissions.
- Maturity wise, both systems produced stable ripened compost meeting the necessary standards for agricultural purposes.
- The ripened compost can also serve the purpose of carbon sequestration as the initial carbon content in both systems was higher than the total GHG emissions in terms of CO_2-C equivalent.

Evaluation of DRDO Onsite Wastewater Treatment System

Objective & Scope of the project

- To test and evaluate existing sanitation technologies
- Testing the DRDO wastewater treatment system: Assessing system performance, usability and acceptability/demand in urban settings in India
- *TEAM:* IIT Madras, Sanitary Technology Platform (STeP) managed by RTI International

Performance evaluation of DRDO toilets with anaerobic biodigesters

15 units	in TN /AP / Telangana/ Karnataka

Startup and monitoring of onsite biodigesters

7 units	In IIT Madras

Questionnaire

Evaluation of the socio - economic and institutional condition on the selected existing onsite biodigesters

Main assessment approach adopted

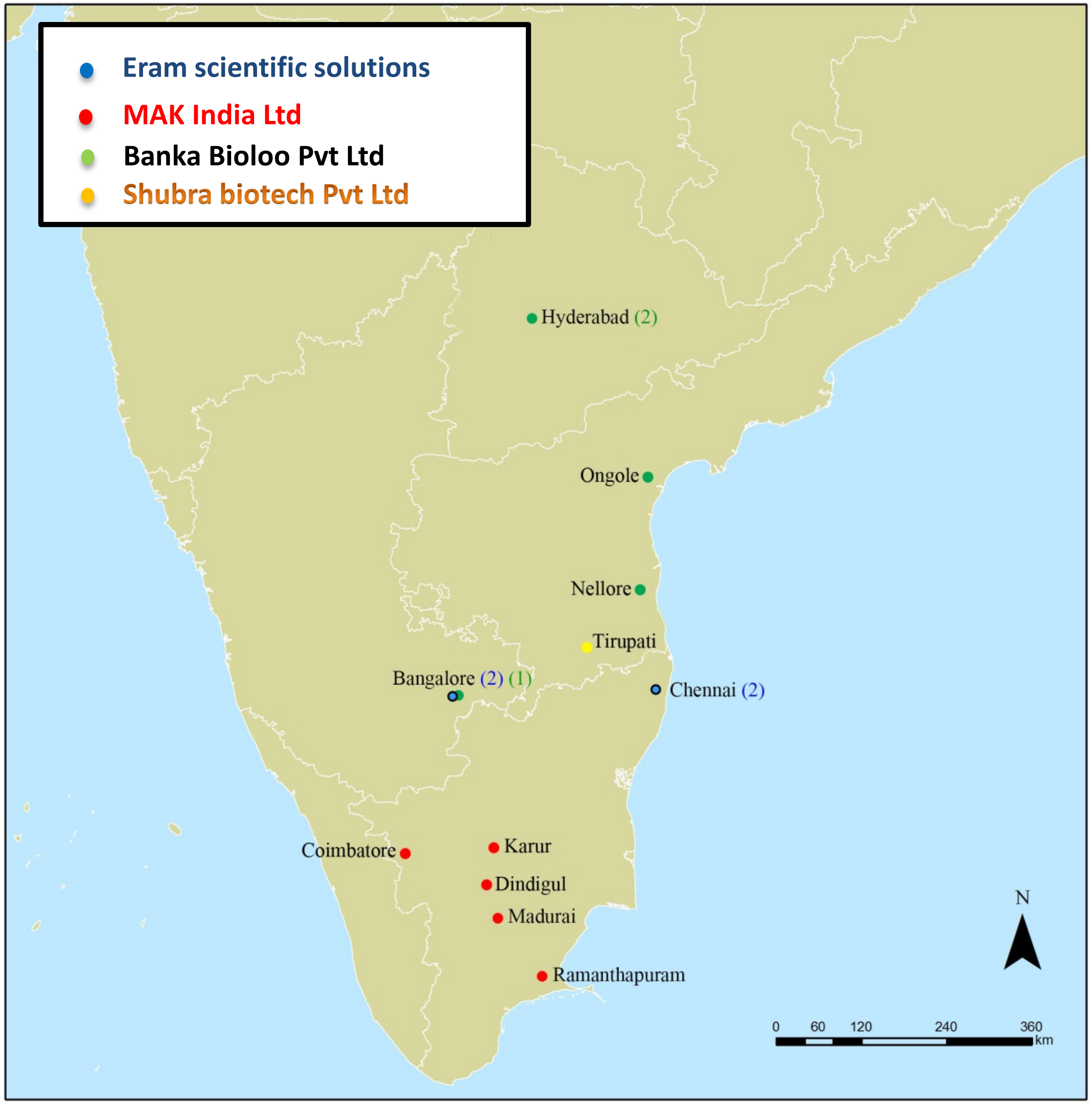
-Carry out the appraisal of different onsite biodigester treatment technologies

-Means and ways of attaining it

-Timely sampling and investigation

Distribution of 15 DRDO toilets selected for this study

- **Eram scientific solutions - 4**
  - Chennai (2)
  - Bangalore (2)
- **MAK India Ltd - 5**
  - Dindigul (1)
  - Karur (1)
  - Coimbatore (1)
  - Madurai (1)
  - Ramanathapuram (1)
- **Banka Bioloo Pvt Ltd - 5**
  - Bangalore (1)
  - Hyderabad (2)
  - Nellore - Gudur (1)
  - Ongole (1)
- **Shubra biotech - 1**
  - Seva Tirupati (1)



Details of the sampling points, frequency, type and location

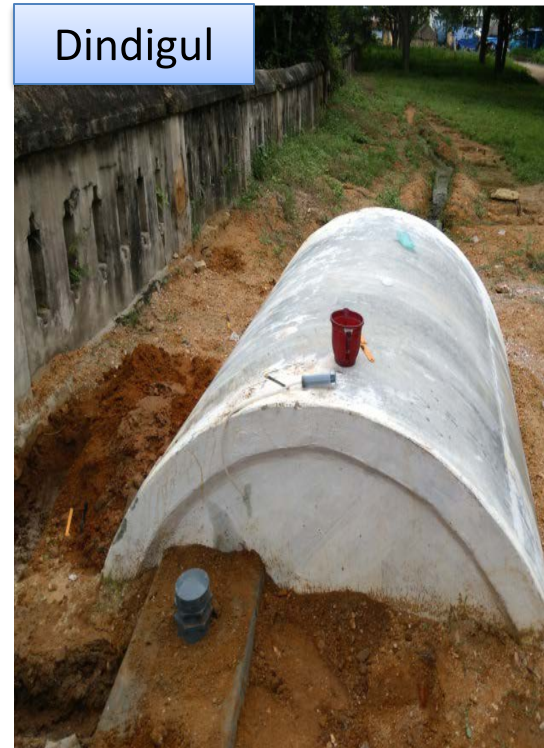
Type of biodigesters	SamplingL ocation	No of biodigesters	Sampling frequency	Sample type	Sample points	Licensee / Vendor
DRDO based biodigester installations in Field	TN / AP / Telangana/ Karnataka	15	Once in a month	Grab sampling	Raw wastewater and Treated water, tap water	Banka BioLoo, MAK & Eram
			Once during the 6 months	Composite sampling		
Onsite Biodigester treatment technology; Duke University	Krishna hostel, IIT Madras	1	Once in a week (till week 13)	Grab sampling	Raw wastewater, Digester effluent, Treated water	Eram scientific & Duke University
			Once in a week (from week 14)	Composite sampling		
DRDO based Biodigester monitoring under varying operating conditions	IIT Madras	4	Once in a week (till week 12)	Grab sampling	Raw wastewater and Treated water	Banka Bioloo
			Once in a week (from week 13)	Composite sampling		
DRDO based Biodigester monitoring	IIT Madras	2	Once in a week (till week 9)	Grab sampling	Raw wastewater and Treated water	MAK
			Once in a week (from week 10)	Composite Sampling		

MAK Sites

Karur

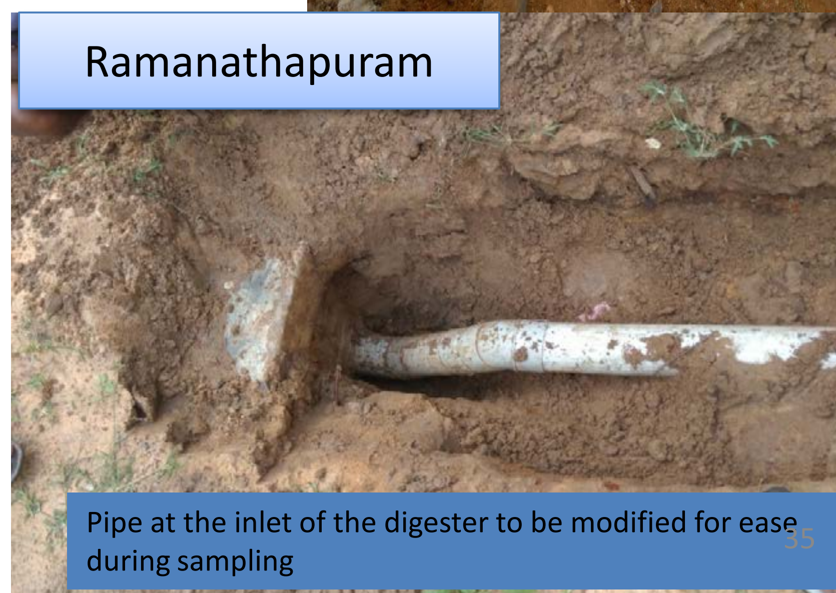
Madurai

Dindigul



Coimbatore

Ramanathapuram



Pipe at the inlet of the digester to be modified for ease during sampling

Banka BioLoo Sites

Bangalore

Ongole

Hyderabad 2

Hyderabad 1

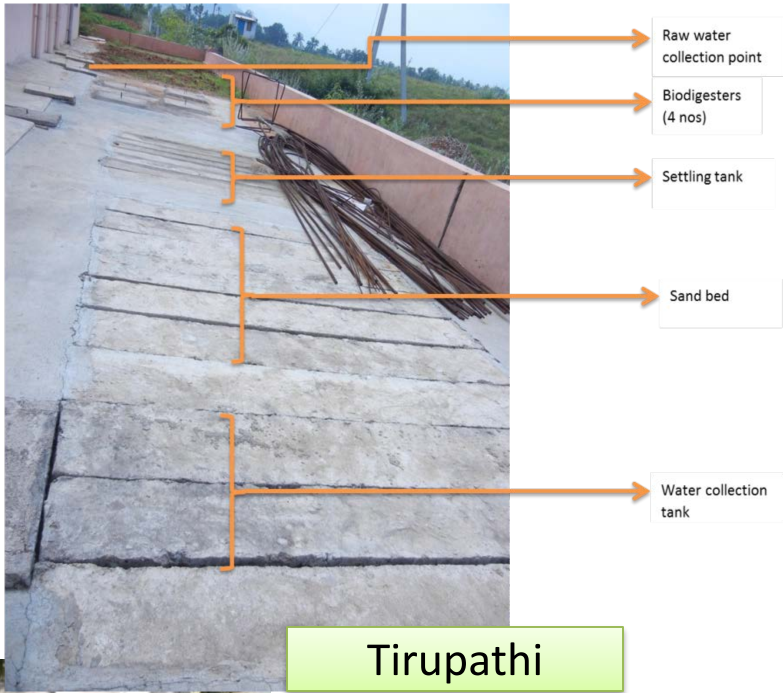
Nellore

[Link photographs of all site\Photographs of Banka Bialoo.pptx]

Eram Scientific & Shubra Biotech sites

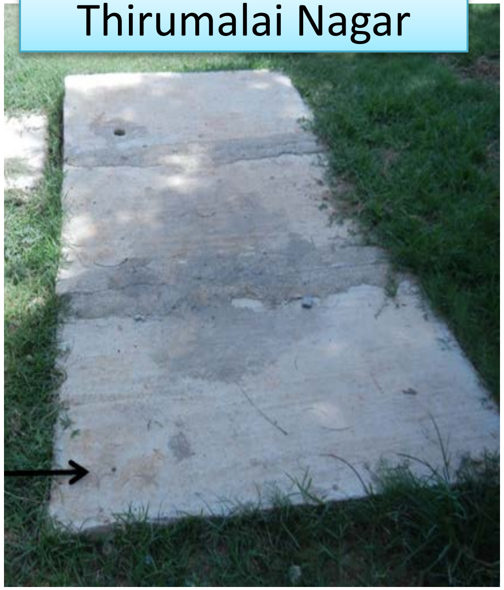
Rajiv Nagar

ELCITA-1



Tirupathi

Link_photographs of all site\Photographs of Shubra Biotech.pptx



Thirumalai Nagar

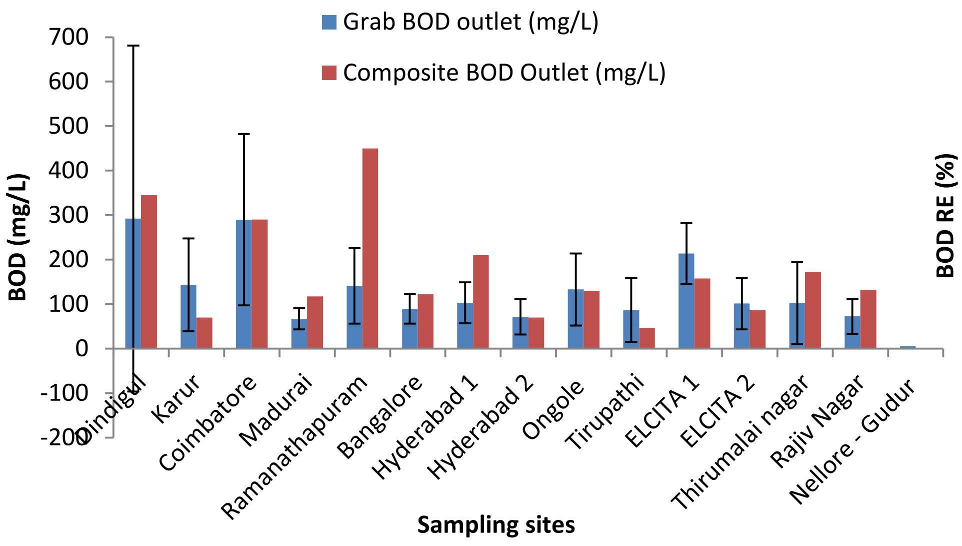
ELCITA-2

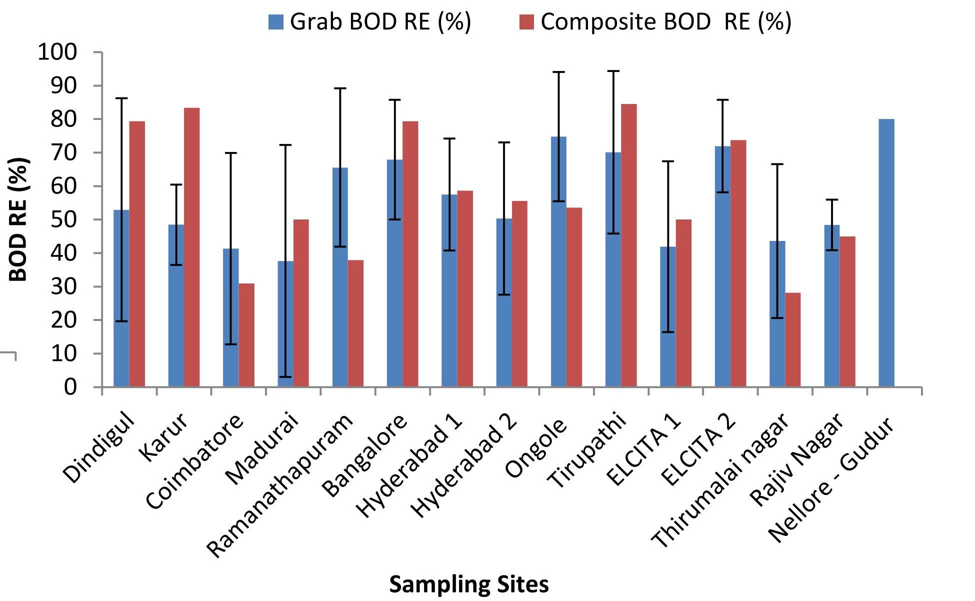
Link_photographs of all site\Photographs of Eram Scientific.pptx

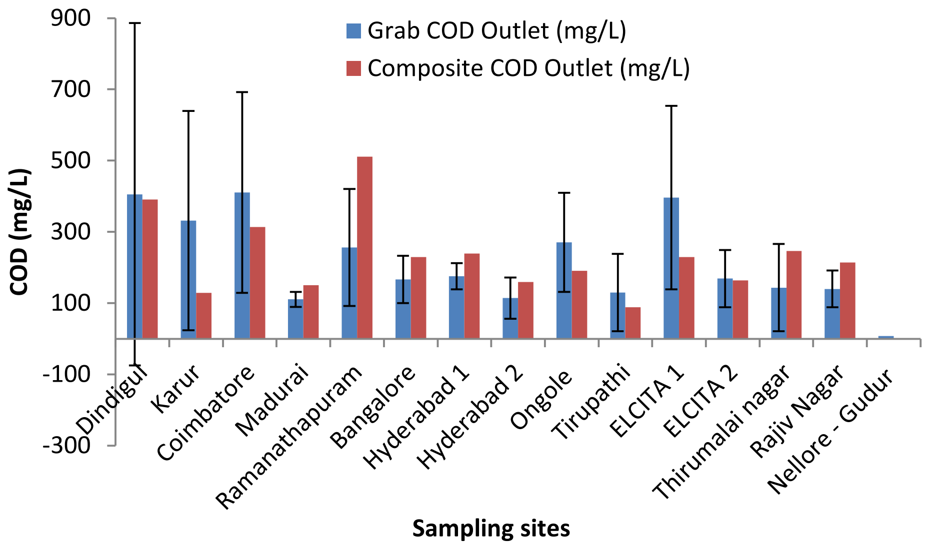
SAMPLING AND ANALYSES METHODS

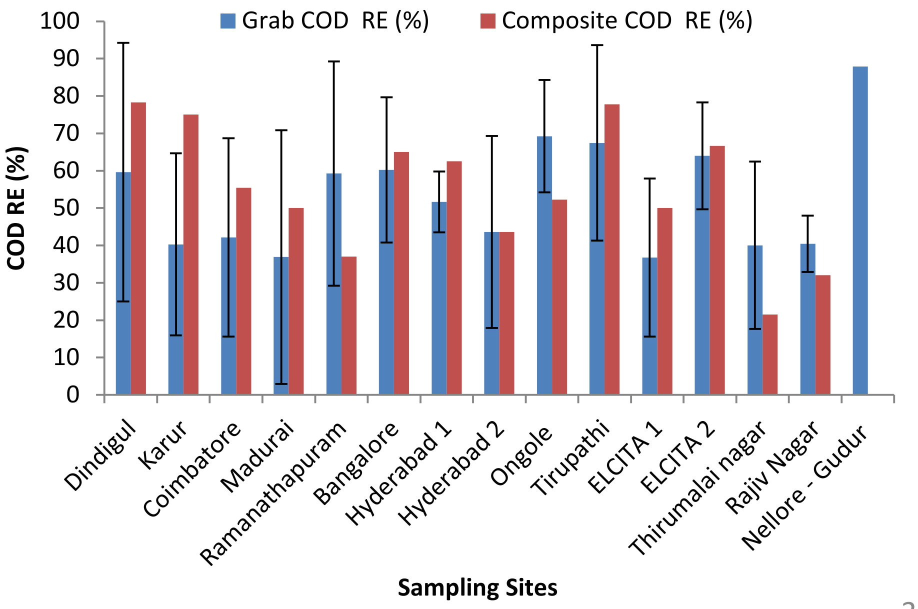
Parameters	Method	Instrument used	Reference (APHA 2005)
pH	Potentiometry	Cyberscan series 600 PCD 650 Waterproof portable meter(Eutech instruments)	4500 H
Temperature (^{0}C)			2550 B
Dissolved oxygen (mg/L)			4500 – O G
Turbidity (NTU)	Nephelometry	Turbidimeter TN – 100 (Eutech instruments)	2130 B
Total Chemical Oxygen Demand (tCOD)	Dichromate digestion	COD digester (HACH)	5220 C
Soluble Chemical Oxygen Demand (sCOD)			
Total biological Oxygen Demand (tBOD)	Azide addition	BOD Incubator (Rands Instruments)	5210 – B
Soluble biological Oxygen Demand (sBOD)			
Total Suspended Solids (TSS)	Gravimetry	Oven (Remi Instruments), balance (A&D GR 202) and muffle furnace (Inlab equipments)	2540 D
Volatile suspended solids (VSS)			2540 E
Ammoniacal nitrogen	Colorimetry	Spectrophotometer (Shimadzu)	4500 NH_4^+-N F
Nitrite nitrogen			4500 NO_2^--N B
NitrateNitrogen			4500 NO_3^--N B
Total Phosphate			4500 – P D
Faecal Coliform (MPN / 100 mL)	MPN method-Presumptive CFU method	Incubator (Remi Instruments)	9221 E (MPN method)
Total Kjeldhal Nitrogen (TKN)	Digestion and distillation method	Distillation apparatus	4500 – N_{org}B

Comparison between Grab and Composite sampling

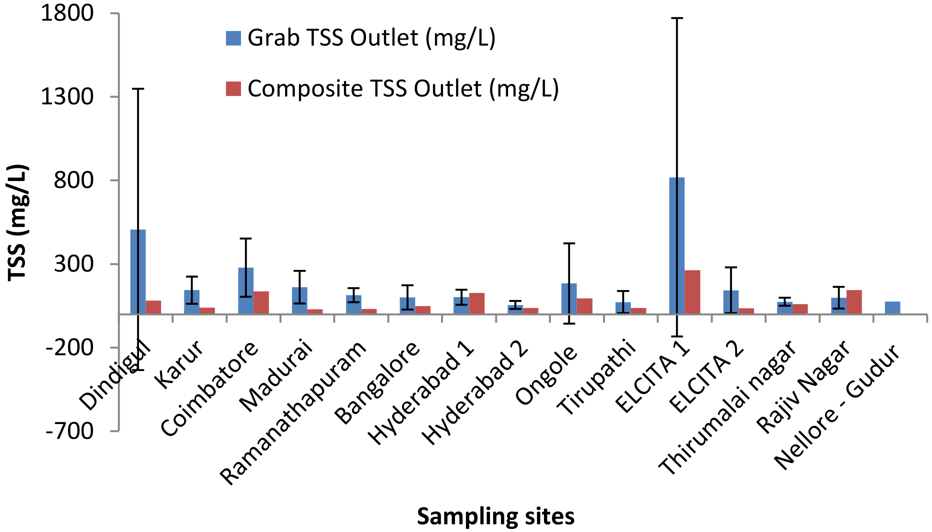


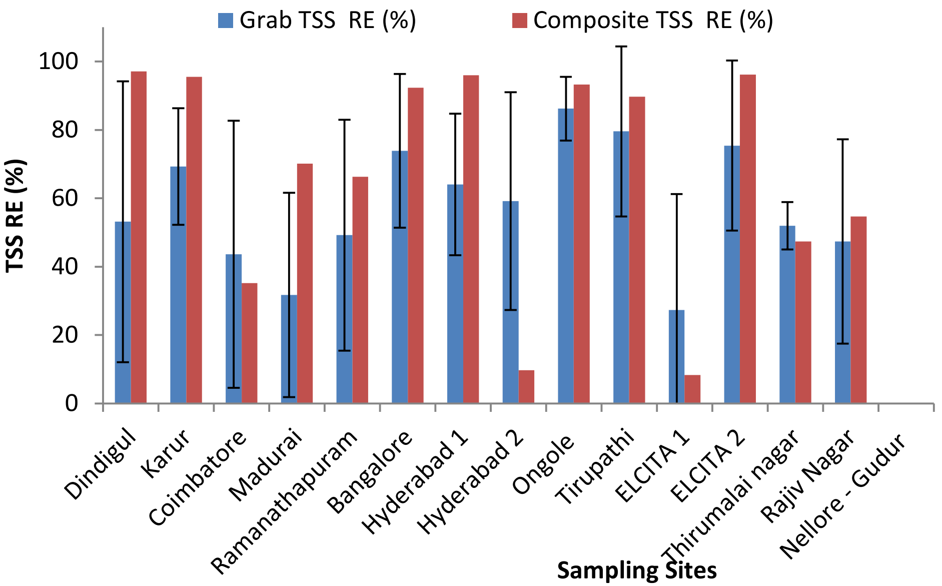


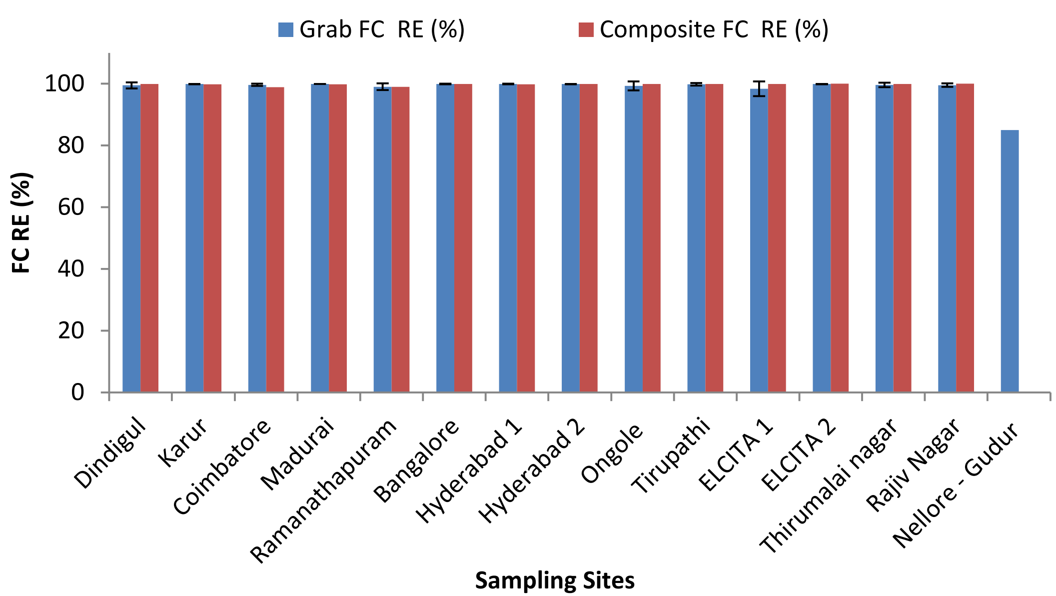




Comparison between Grab and Composite sampling







Evaluation details on the onsite biodigester in IIT Madras (Cauvery & Krishna hostel)

Banka Bioloo (Cauvery hostel)	Digester label	Operation strategy
Site 1	Digester A	Control
	Digester B	Control + inoculation
Site 2	Digester C	Frequent inoculation
	Digester D	Addition of chemicals Eg: Phenyls, Bleach etc

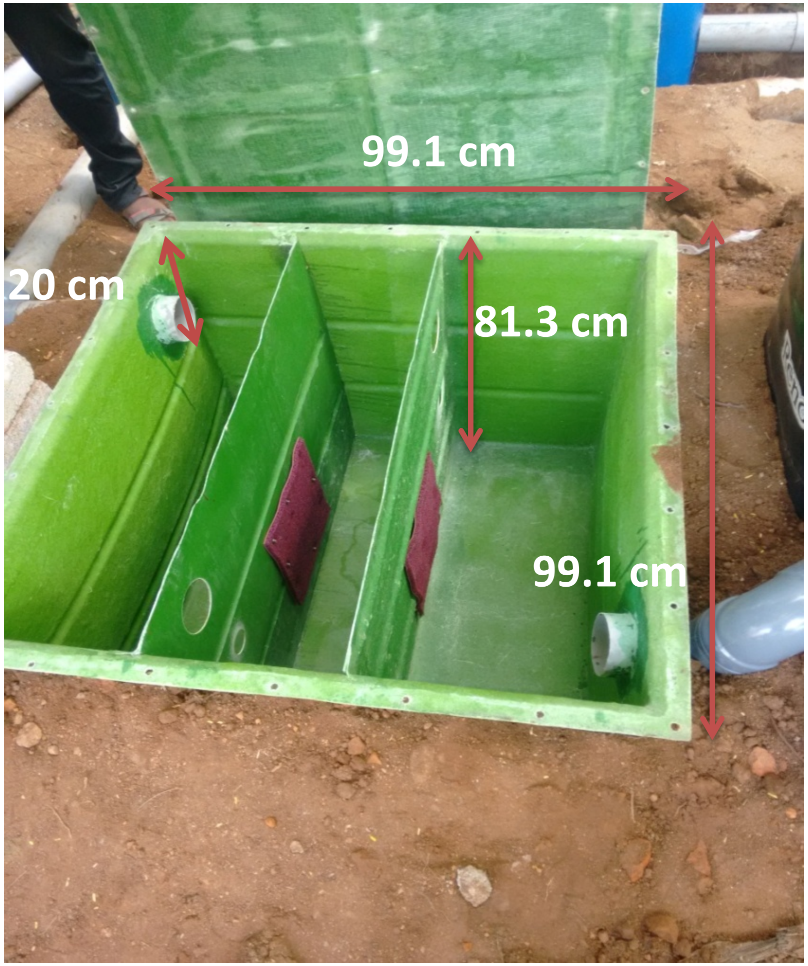
Simple septic t
without inocul

Septic tank with inoculum

Cauvery hostel - MAK	Digester label	Operation strategy
Site 3	Digester E	Based on licensee's procedure
	Digester F	

Krishna hostel	Digester label	Operation strategy
Site 4	Duke unit	Strategy developed by Duke university

FRP biodigester used by DRDO licensee

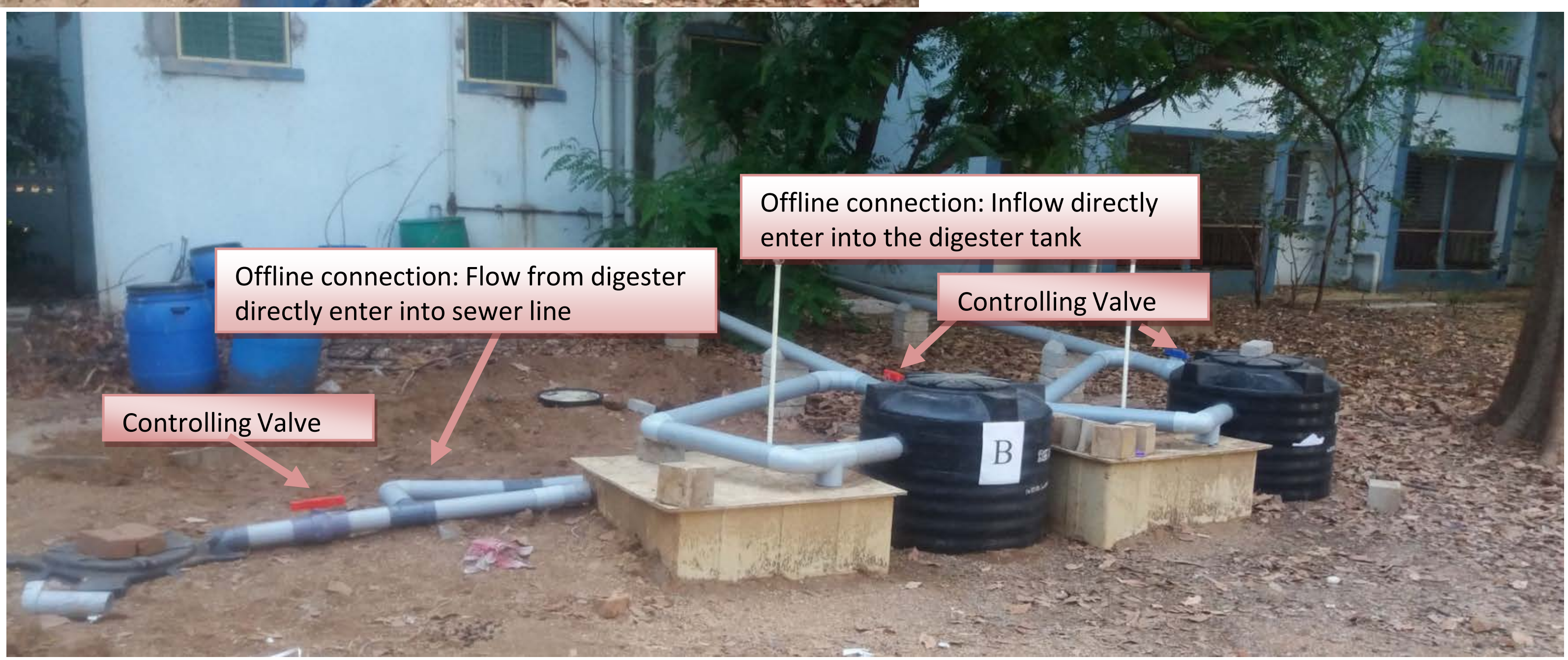


- The chief components of biodigester : anaerobic microbial consortium and fermentation vessel.
- The provision of immobilization material (PVC) is provided to afford attachment site for bacteria, reduce wash out and to enhance the rate of waste fermentation.

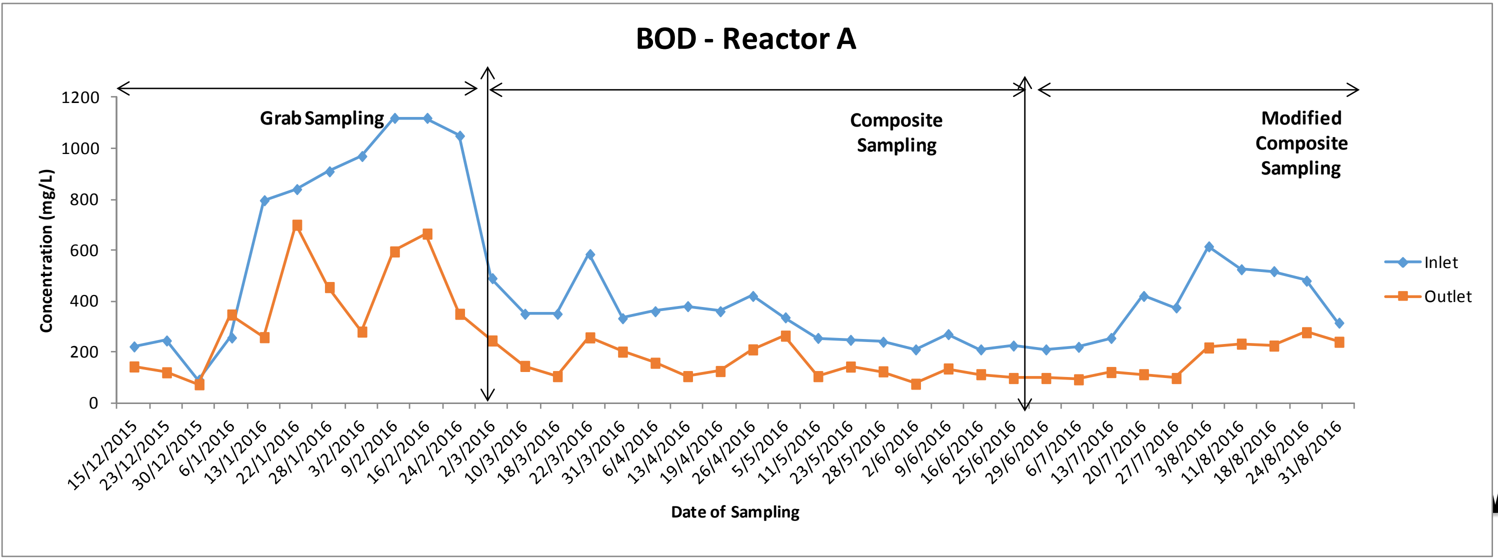
IIT Madras Cauvery & Krishna sites

Composite sampling & Offline pipe connections in Cauvery site

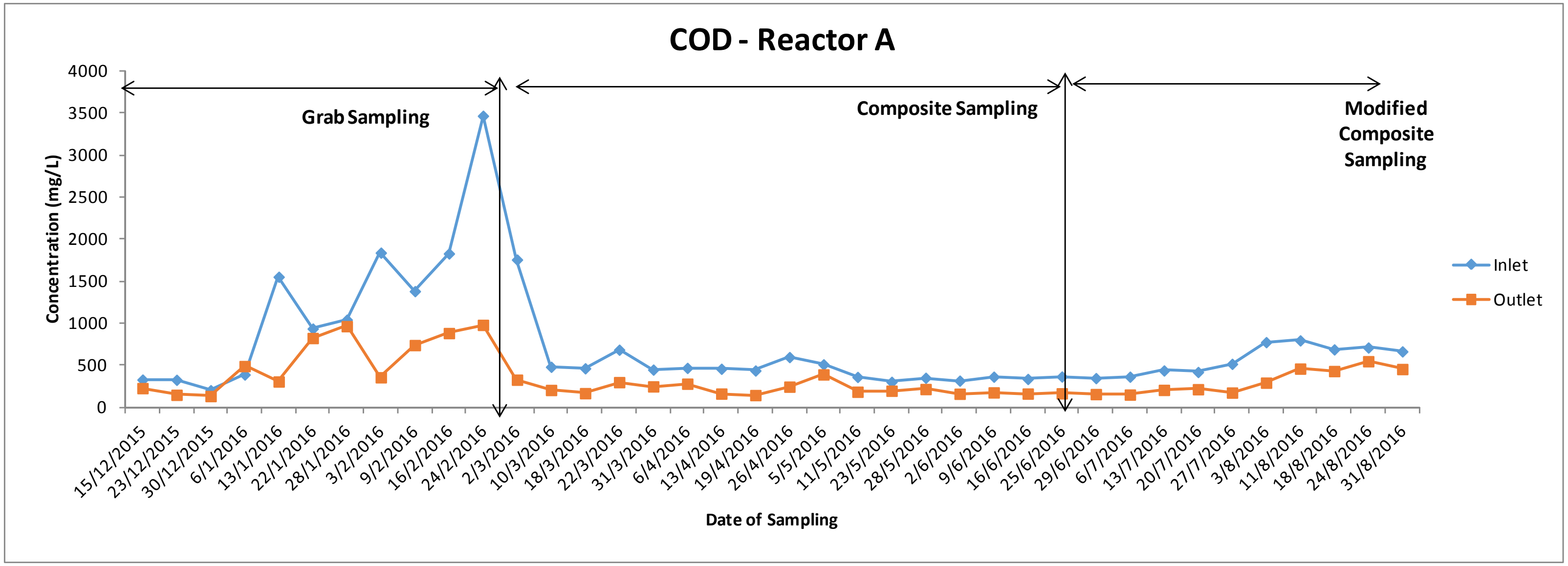
- The content of the inlet and outlet tanks were pumped out to the main sewer line using 1 HP pump.
- After 24 hrs the inlet and outlet sample is collected.



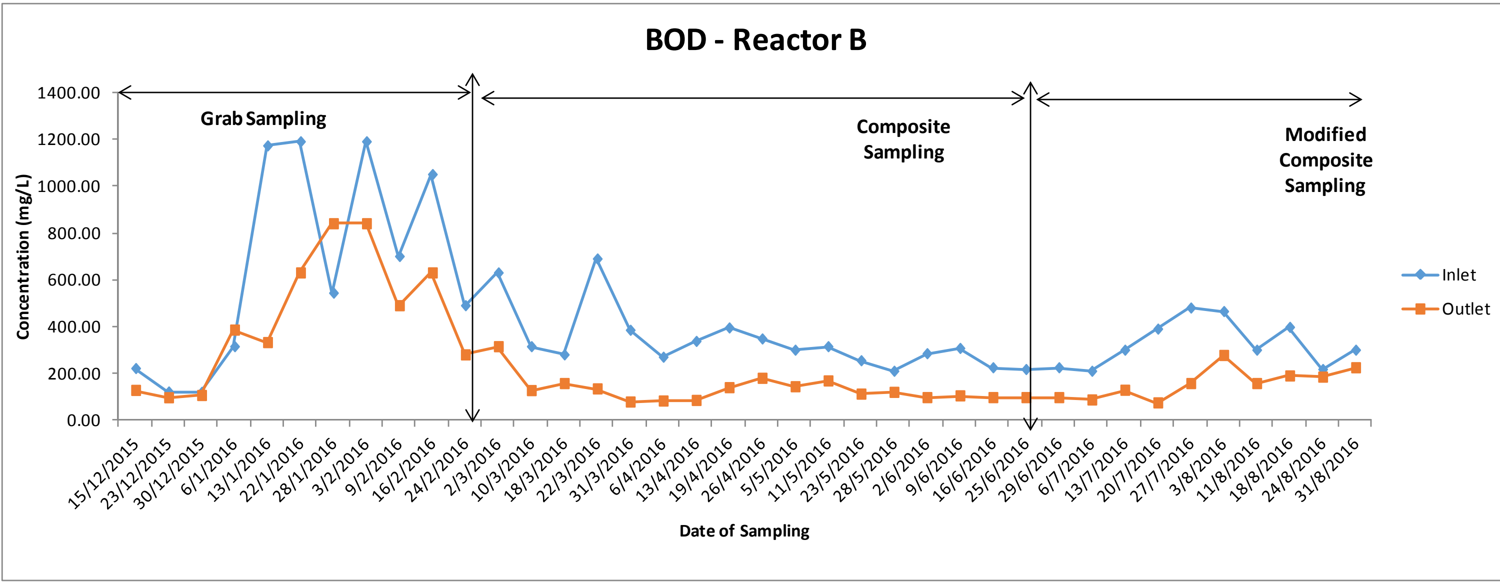
BOD & COD values of Reactor A



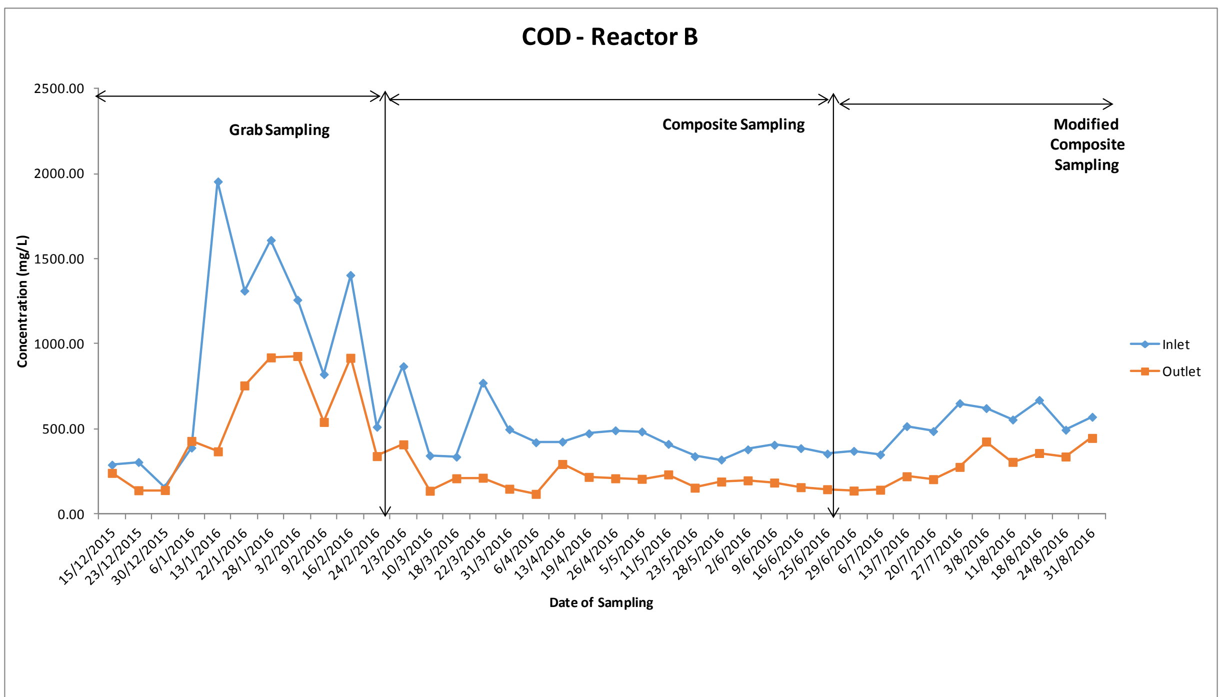
Reactor A – Without inoculum



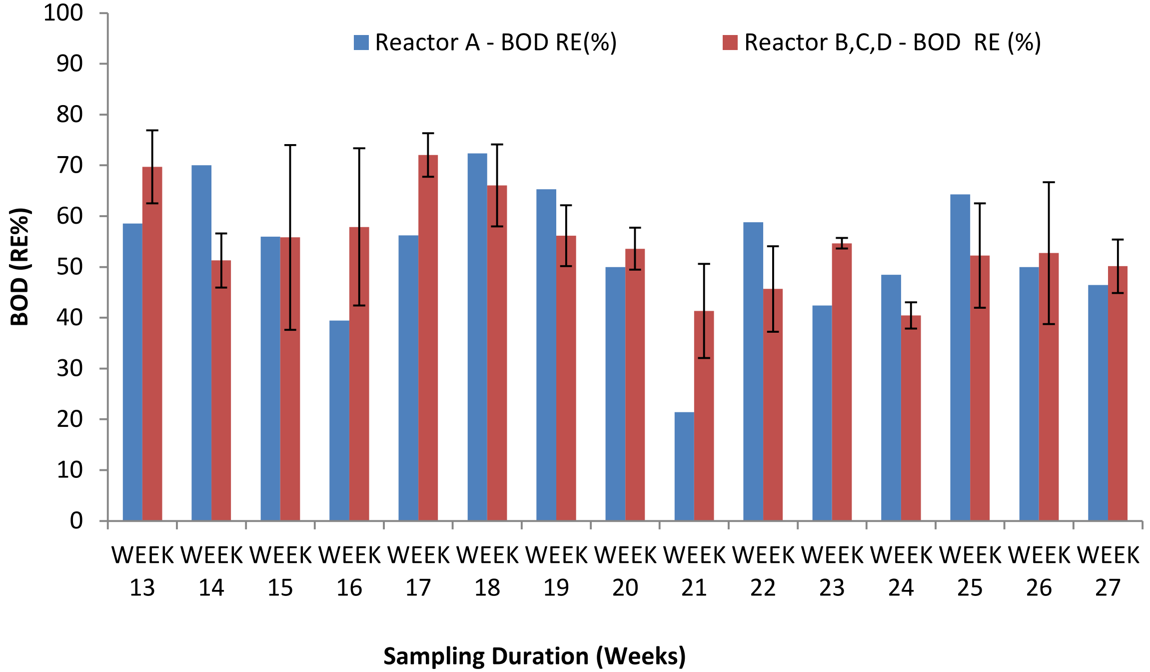
BOD & COD values of Reactor B

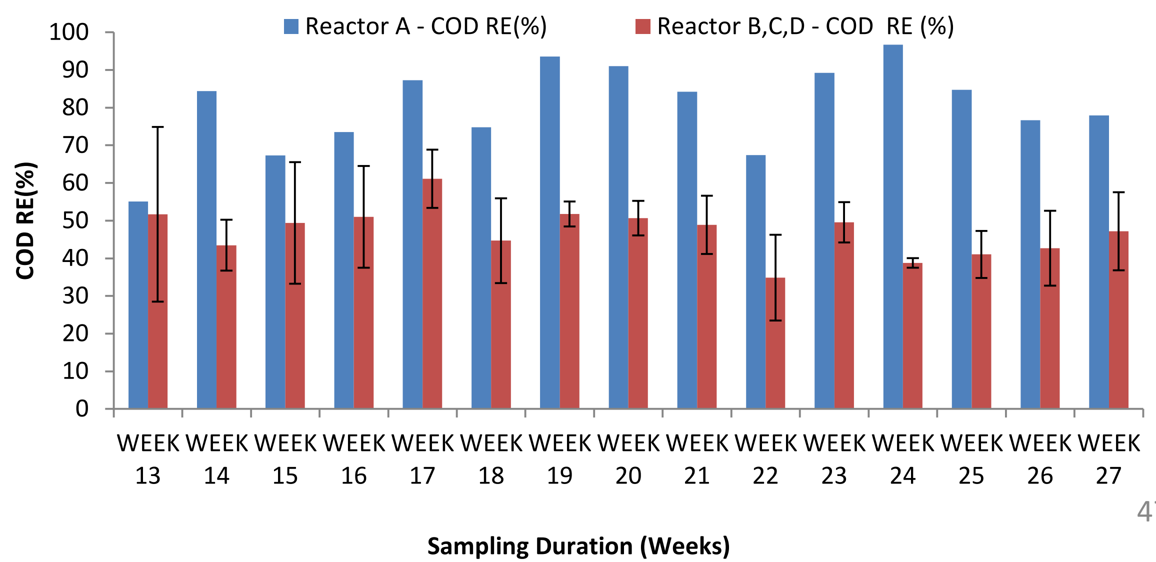


Reactor B – With inoculum

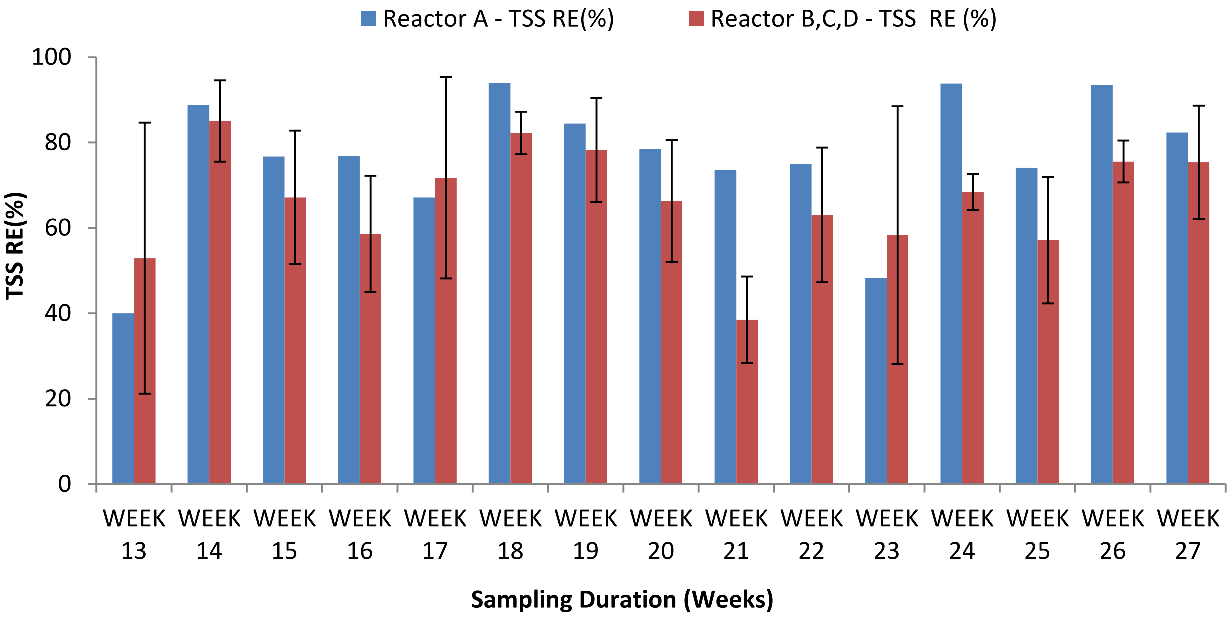


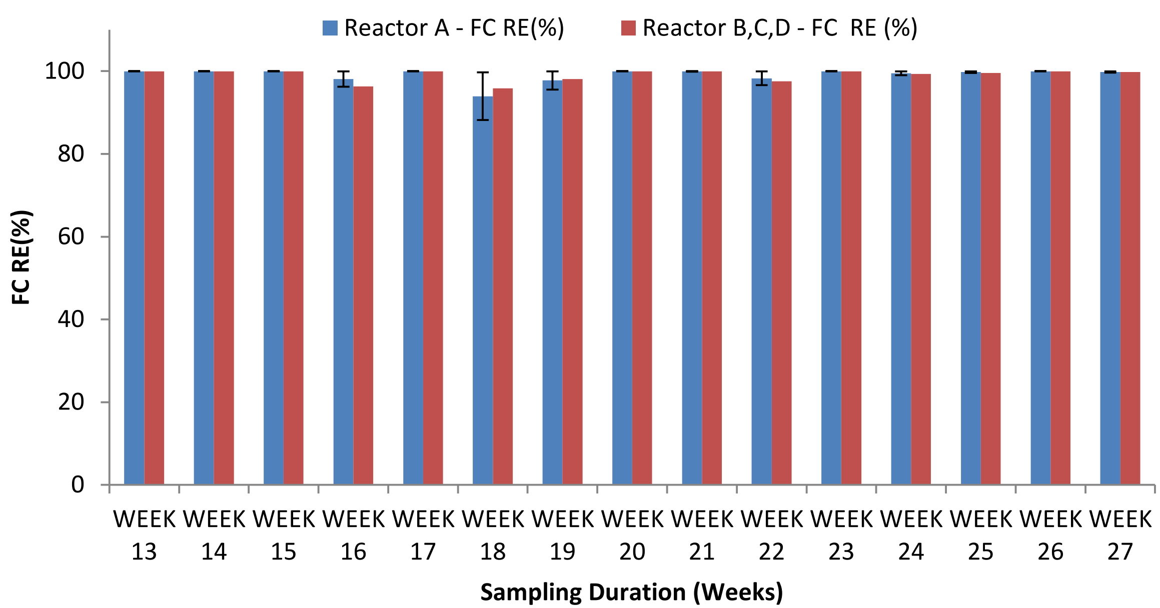
Removal performance Reactor A Vs B,C,D



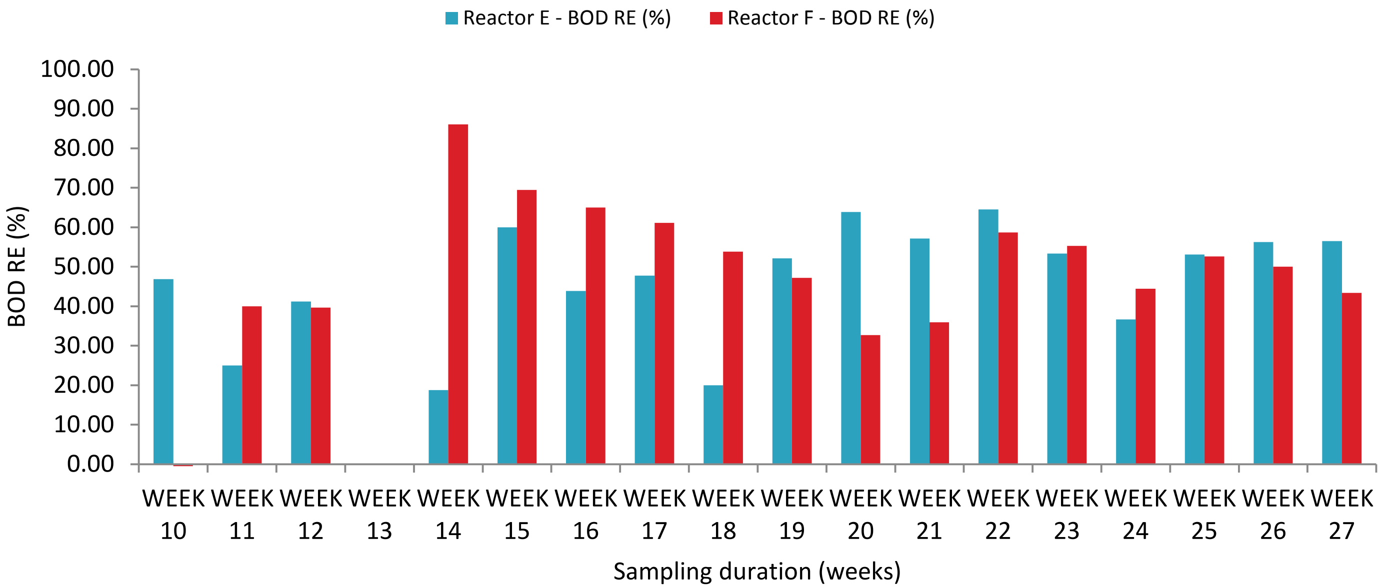


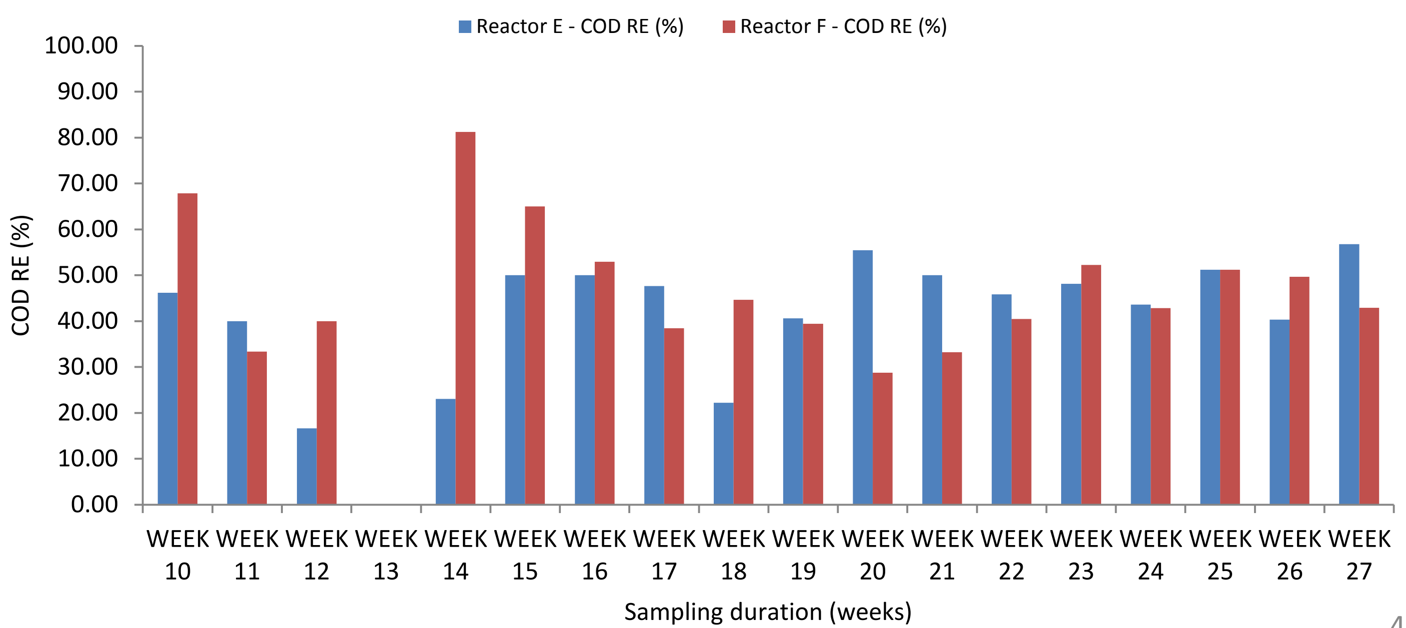
Removal performance Reactor A Vs B,C,D



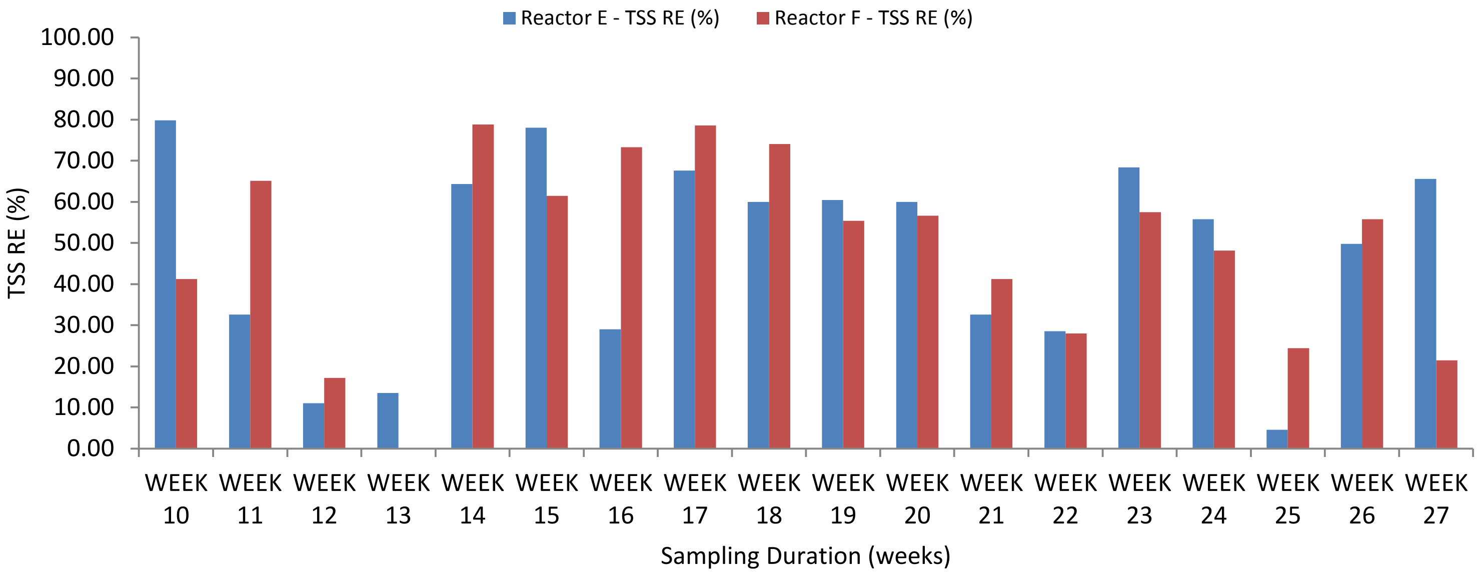


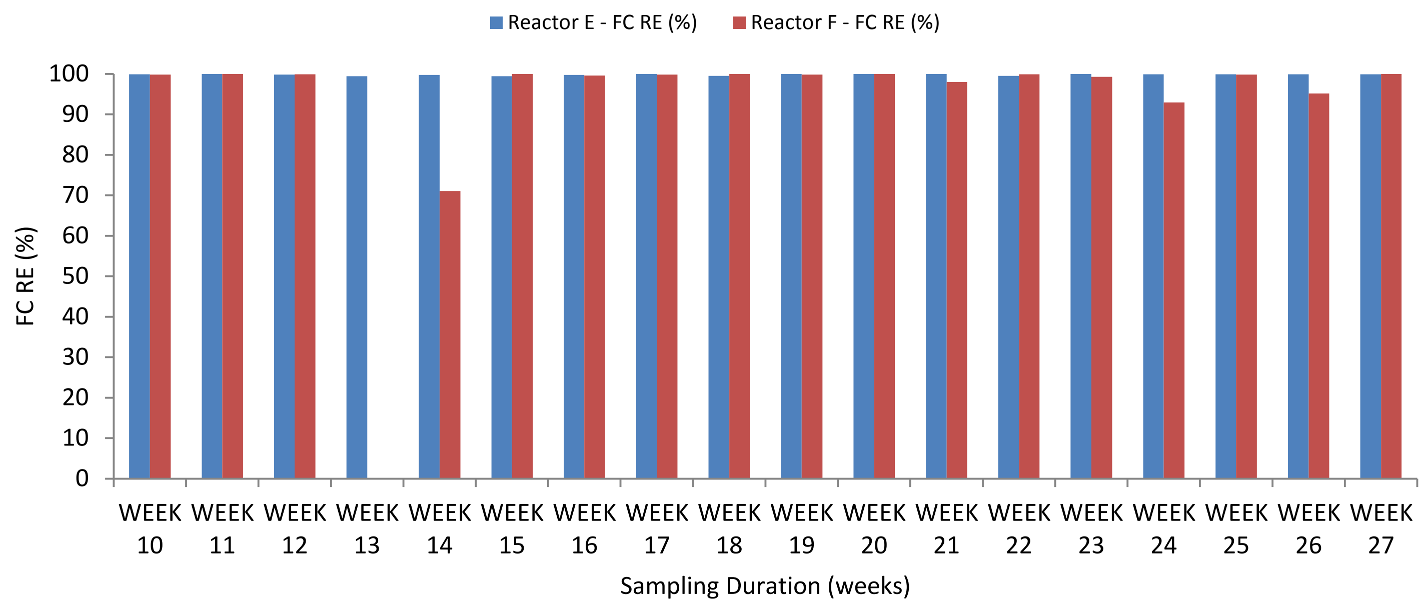
Removal performance Reactor E Vs F



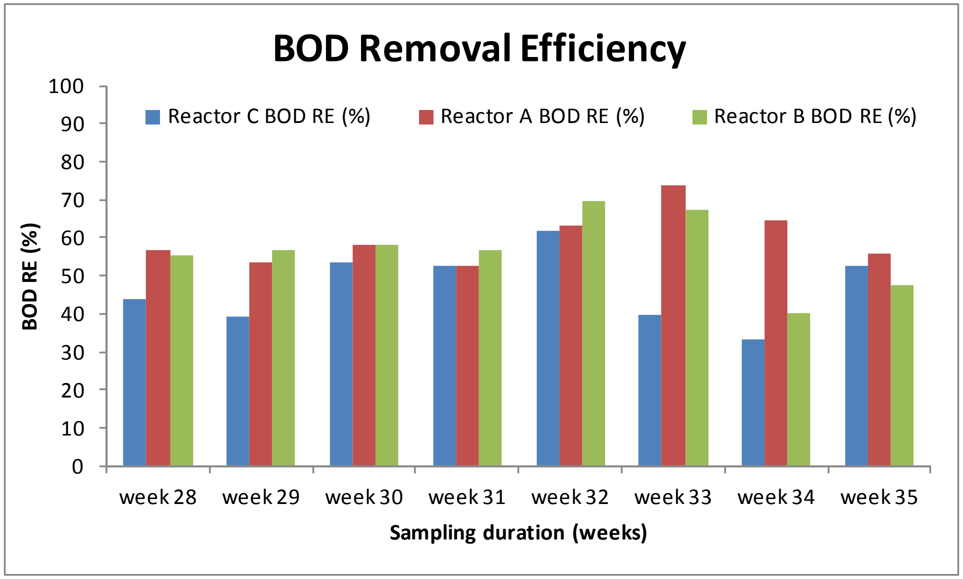


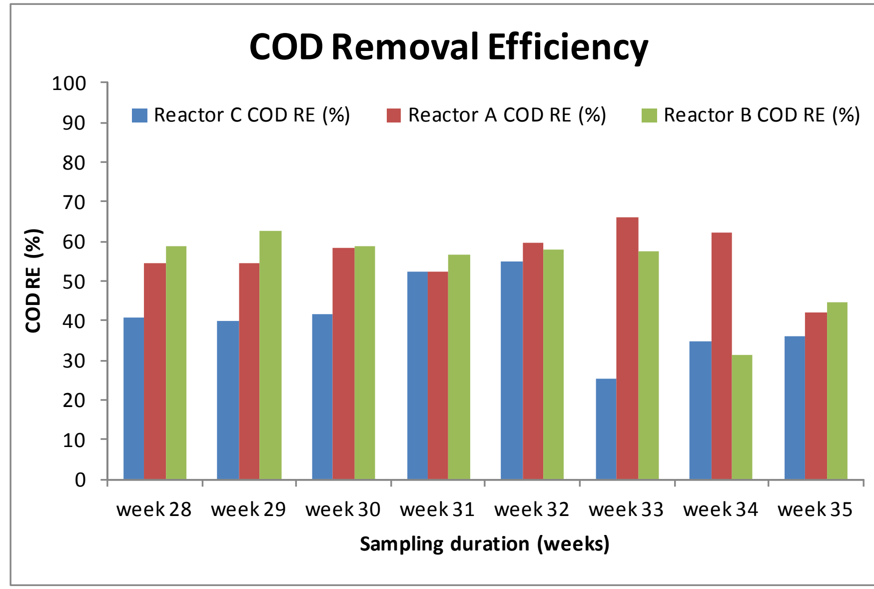
Removal performance Reactor E Vs F

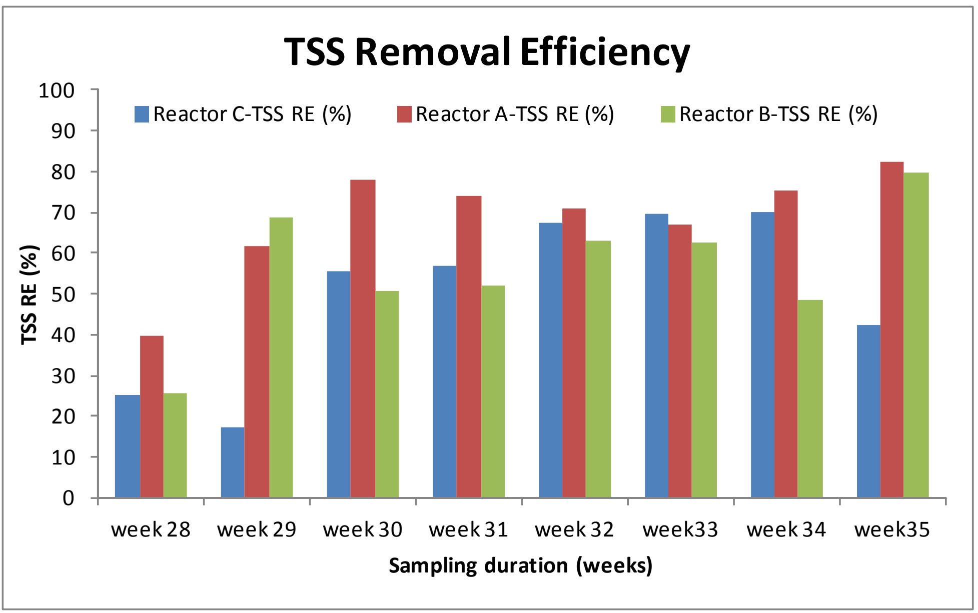


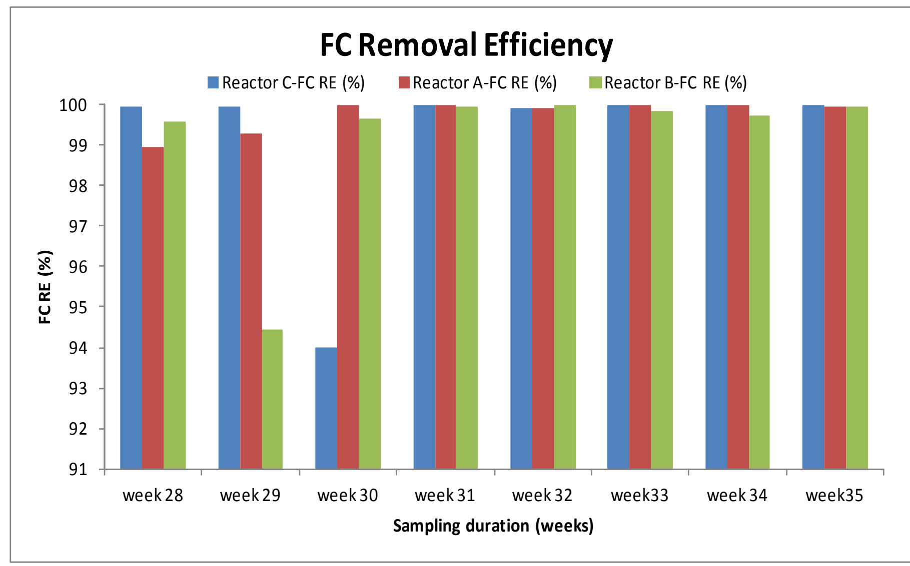


Variation of Reactor C with respect to A and B

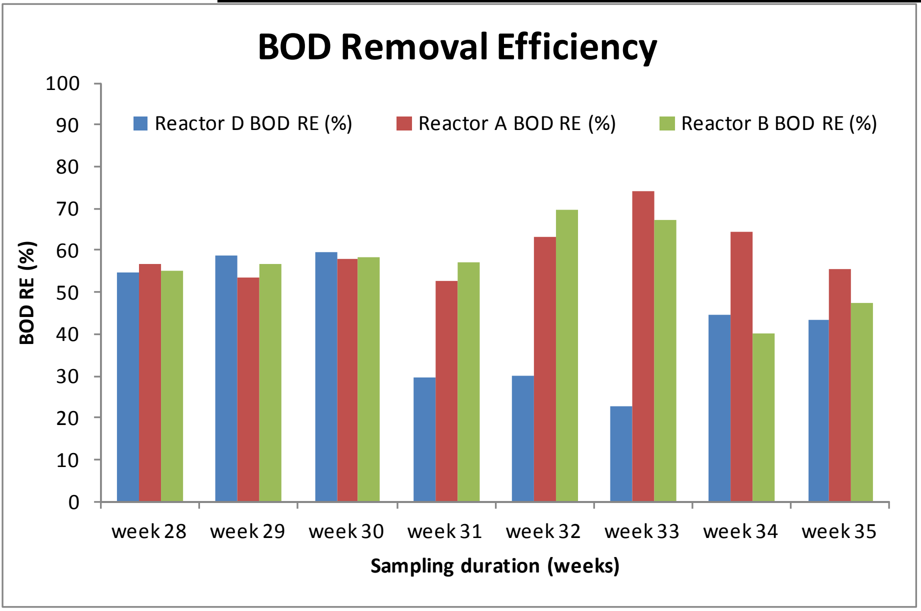


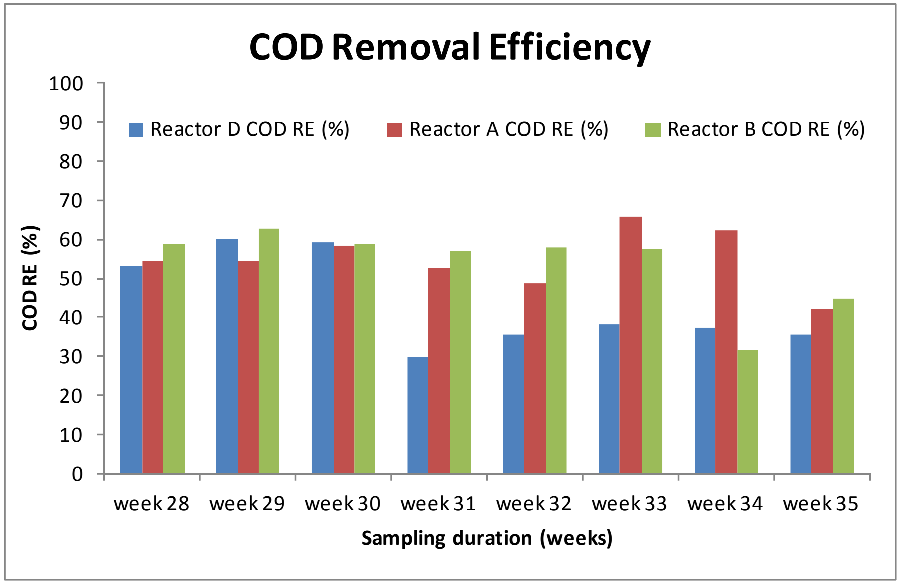


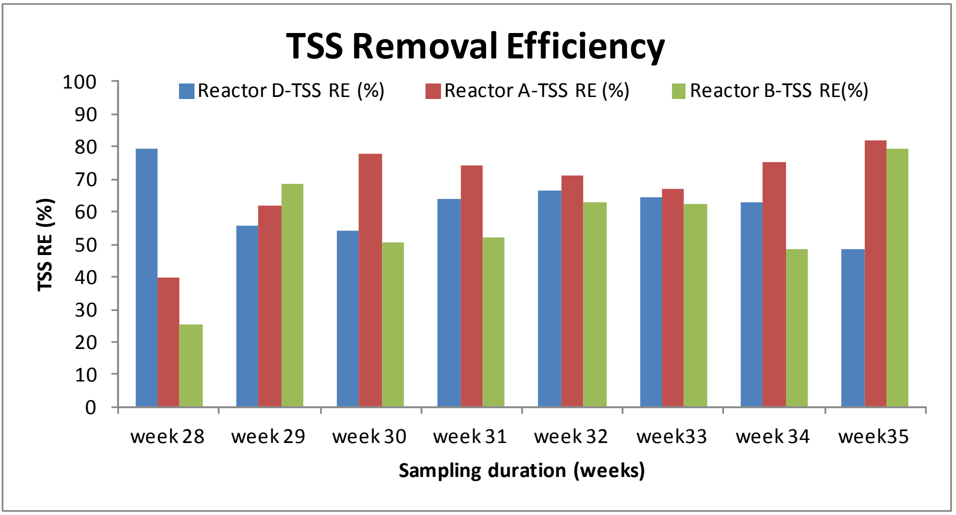


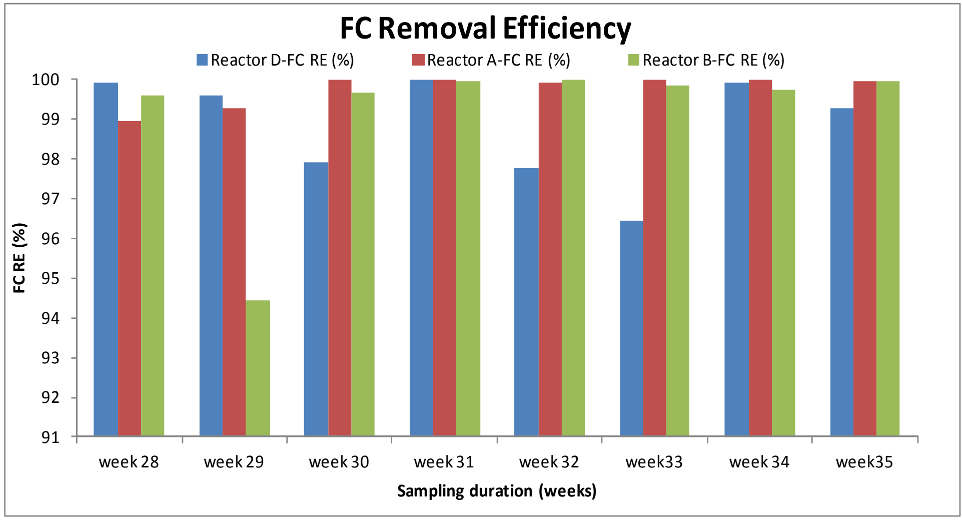


Variation of Reactor D with respect to A and B









Sludge Measurement in Onsite IITM units

- Scum layer on top and mixed liquor suspended solids at the bottom was observed in all the digesters
- Hence, sludge depth measurement was difficult

Hydraulic Retention Time of the Biodigesters

Reactor	Vendor	Reactor liquid volume (L)	Sludge depth (m)	Mean Water Depth in reactor (m)	Inlet collection tank volume (L)	Flow rate (L/d)	HRT(h)
A	Banka Bioloo	584.30 - 585.83	0.206 – 0.250	0.595 -0.597	500	279.70 - 292.80	48.15 -49.92
B	Banka Bioloo	628.50 - 647.65	0.206 – 0.250	0.664 -0.660	500	284.70 - 285.60	52.80 -54.35
C	Banka Bioloo	594.10 - 666.30	0.206 – 0.230	0.610 -0.679	500	269.80 - 297.60	52.80 - 53.57
D	Banka Bioloo	559.70 - 684.94	0.206 – 0.210	0.570 -0.698	500	279.70 - 283.20	48.00 -57.88
E	MAK	548.54 - 559.70	0.200 - 0.224	0.570 -0.559	500	244.80 - 235.20	54.72 -62.94
F	MAK	571.11 - 510.60	0.224 – 0.229	0.520 -0.582	500	239.80 - 247.20	50.88-62.22

Comparison of performance

Reactor	Operational strategy	BOD RE (%)	COD RE (%)	TSS RE (%)	FC Concentration		$NH4^+$ (mg/L)	
					Inlet	Outlet	Inlet	Outlet
A	Control (No inoculum)	54.2 ± 13.2	51.3 ± 11.2	73.1 ± 14.0	8.22E+08	6.18E+05	34.8	48.02
B	External inoculum addition(once)	56.1 ± 15.7	47.5 ± 12.9	64.5 ± 22.2	7.47E+08	3.03E+05	35.11	50.12
C	Frequent inoculum addition	48.5 ± 15.8	41.9 ± 12.8	59.3 ± 20.1	3.49E+08	3.99E+05	38.48	54.92
D	Addition of extra chemicals	41.2 ± 14.7	46.7 ± 12.6	66.7 ± 14.4	4.20E+08	3.27E+05	43.47	51.19
E	External inoculum addition(once)	49.6 ± 14.1	44.6 ± 15.8	54.3 ± 22.4	4.76E+08	4.31E+05	41.25	44.29
F	External inoculum addition(once)	54.9 ± 14.2	50.0 ± 14.8	55.2 ± 19.4	4.91E+08	3.65E+06	37.55	47.01

Specific Methanogenic activity test results for Banka BioLoo Inoculum, MAK Inoculum, MAK Coimbatore Inoculum and Control Anaerobic sludge

S.No	Organic Loading rate (kg COD /kg MLVSS)	Banka BioLoo Inoculum		MAK Inoculum		MAK Coimbatore Inoculum		Control Anaerobic Sludge	
		Methane production rate (L/h)	Specific methanogenic activity (L/kg/h at STP)	Methane production rate (L/h)	Specific methanogenic activity (L/kg/h at STP)	Methane production rate (L/h)	Specific methanogenic activity (L/kg/h at STP)	Methane production rate (L/h)	Specific methanogenic activity (L/kg/h at STP)
1.	0.5	0.096	77.50	0.12	99.03	0.03	12.64	0.168	50.36
2.	1.0	0.254	**116.02**	0.19	112.07	0.12	**50.14**	0.384	**272.33**
3.	1.5	0.044	43.85	0.21	**136.12**	0.02	8.36	0.216	35.99
4.	2.0	0.084	31.15	0.12	62.46	0.04	15.38	0.072	42.94

SMA results :

Banka BioLoo - 0.140 g CH_4-COD/g VSS/d;
MAK - 0.132 g CH_4-COD/g VSS/d;
MAK Coimbatore - 0.105 g CH_4-COD/g VSS/d;

Control Anaerobic Sludge - 0.193 g CH_4-COD/g VSS/d

SMA values:

Industrial &laboratory digesters: **0.1 and 1.0 g COD/g VSS/ d;**
Pure or enriched methanogenic cultures≈**10 g COD/g VSS/d**
Septic tanks - **0.09 g CH_4-COD/g VSS/d**

(Dolfing and Bloemen, 1985; Guiot, 1991;Soto et al., 1992; Harper and Pohland, 1986; Korsak and Moreno 2006)

Specific Methanogenic activity test results for Banka BioLoo Inoculum

S.No	Organic Loading rate (kg COD /kg MLVSS)	Banka BioLoo Inoculum	
		INITIAL SMA	
		Methane production rate (L/h)	Specific methanogenic activity (L/kg/h at STP)
1.	0.5	0.096	77.50
2.	1.0	0.254	**116.02**
3.	1.5	0.044	43.85
4.	2.0	0.084	31.15

SMA results :
Banka BioLoo - 0.140 g CH_4-COD/g VSS/d

S.No	Organic Loading rate (kg COD /kg MLVSS)	Banka BioLoo Inoculum	
		SMA before addition in Reactor C	
		Methane production rate (L/h)	Specific methanogenic activity (L/kg/h at STP)
1.	0.5	0.156	71.63
2.	1.0	0.240	**112.31**
3.	1.5	0.071	33.13
4.	2.0	0.072	26.13

SMA results:
Banka BioLoo - 0.133 g CH_4-COD/g VSS/d

SMA values:
Industrial &laboratory digesters: **0.1 and 1.0 g COD/g VSS/ d;**
Pure or enriched methanogenic cultures≈**10 g COD/g VSS/d**
Septic tanks - **0.09 g CH_4-COD/g VSS/d**

(Dolfing and Bloemen, 1985; Guiot, 1991;Soto et al., 1992; Harper and Pohland, 1986; Korsak and Moreno 2006)

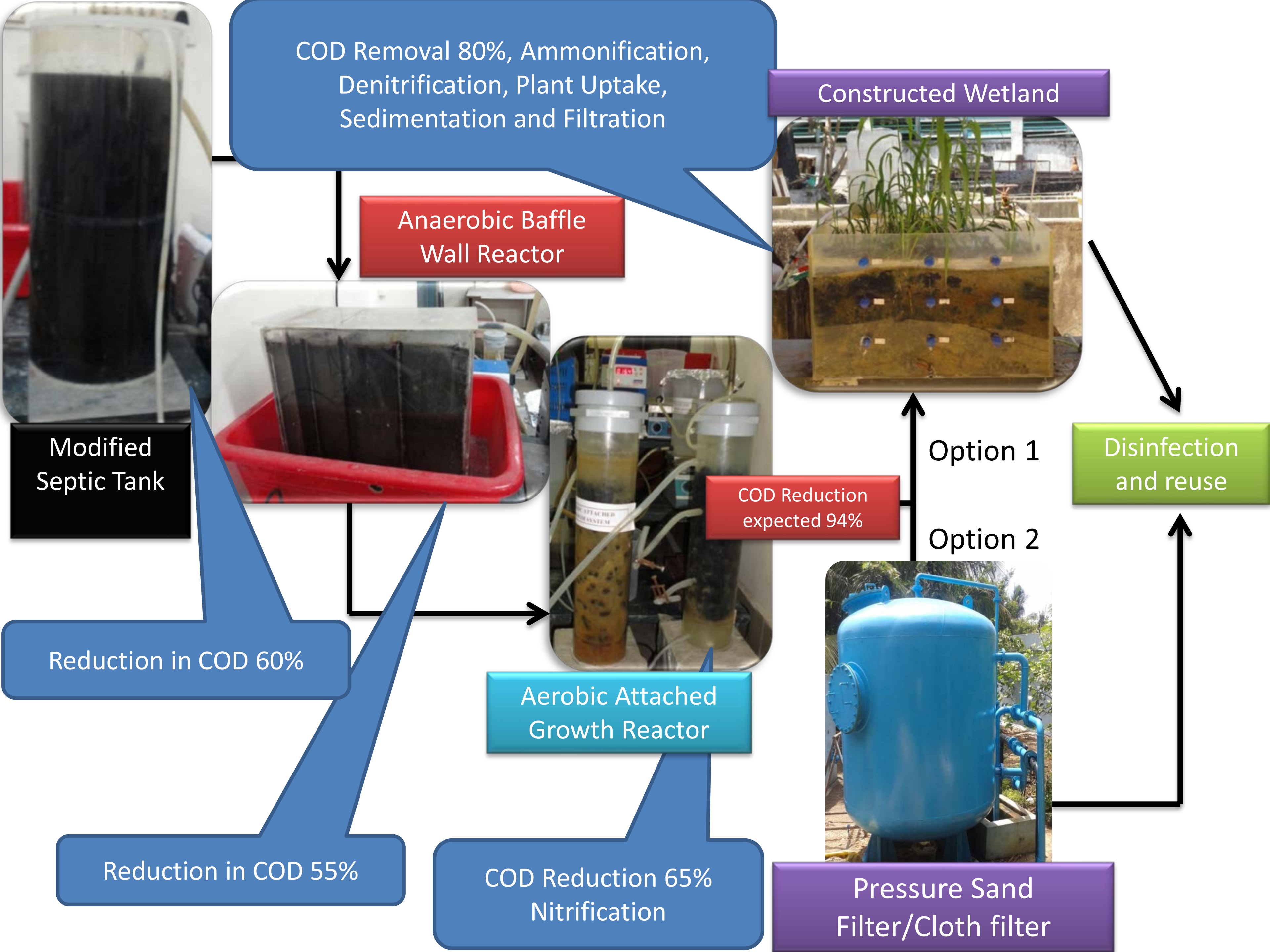

Thank you
www.keralatourism.org
Photo : Kuttiyapillai

Onsite wastewater management systems

- Minimum use of pumps or other electrical equipment

- Minimum level of monitoring and process control

- Aeration to be carried out for part of 24 hour cycle to simulate power interruptions or use of non-conventional energy sources



COD Removal 80%, Ammonification, Denitrification, Plant Uptake, Sedimentation and Filtration
Constructed Wetland
Anaerobic Baffle Wall Reactor
Modified Septic Tank
Option 1
Disinfection and reuse
COD Reduction expected 94%
Option 2
Reduction in COD 60%
Aerobic Attached Growth Reactor
Reduction in COD 55%
COD Reduction 65% Nitrification
Pressure Sand Filter/Cloth filter

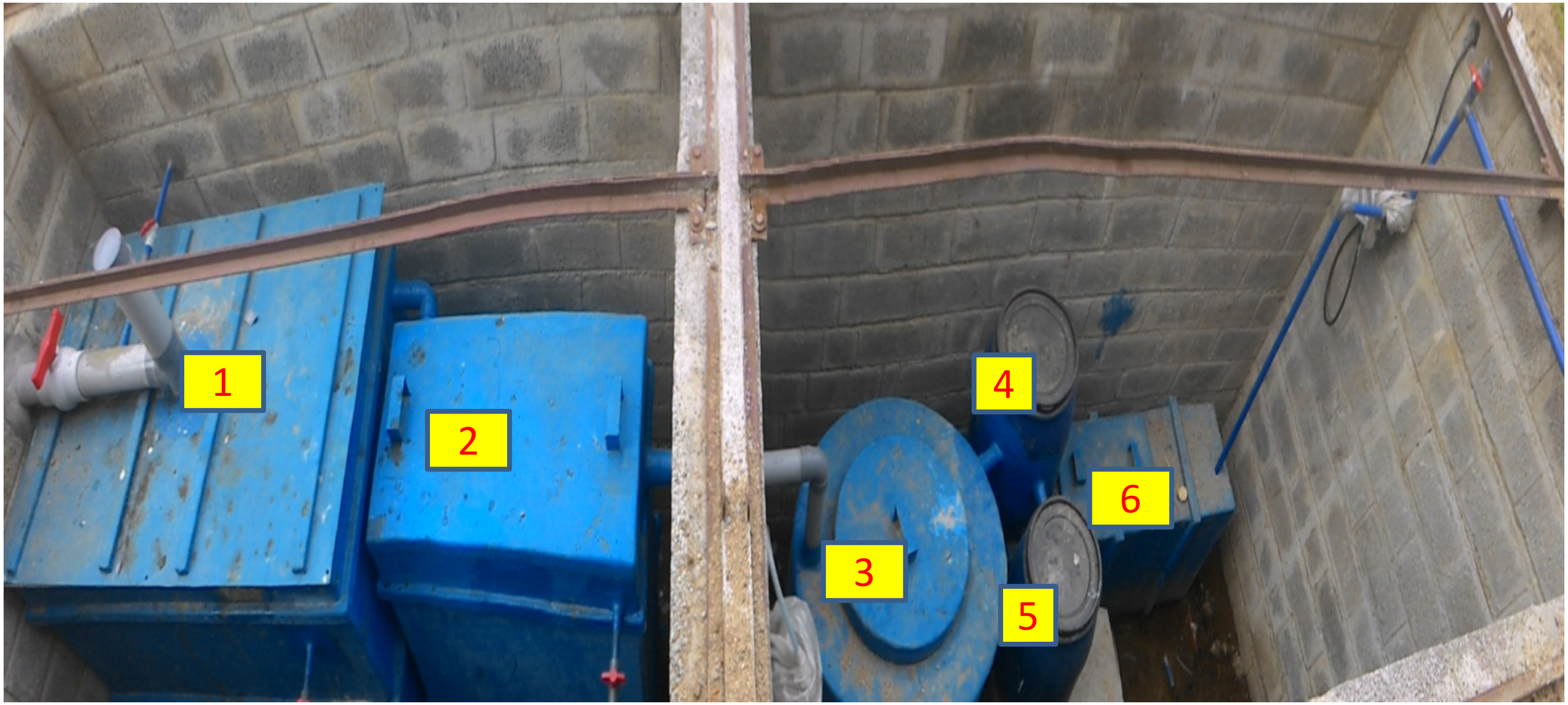
Pilot Scale system: Nellavathi Illam, Mullai Street, Medavakkam, Chennai

SOLAR PANEL

Generating 1.5 HP has three mode of operation

1. From Direct solar.
2. From UPS.
3. From household electricity supply.

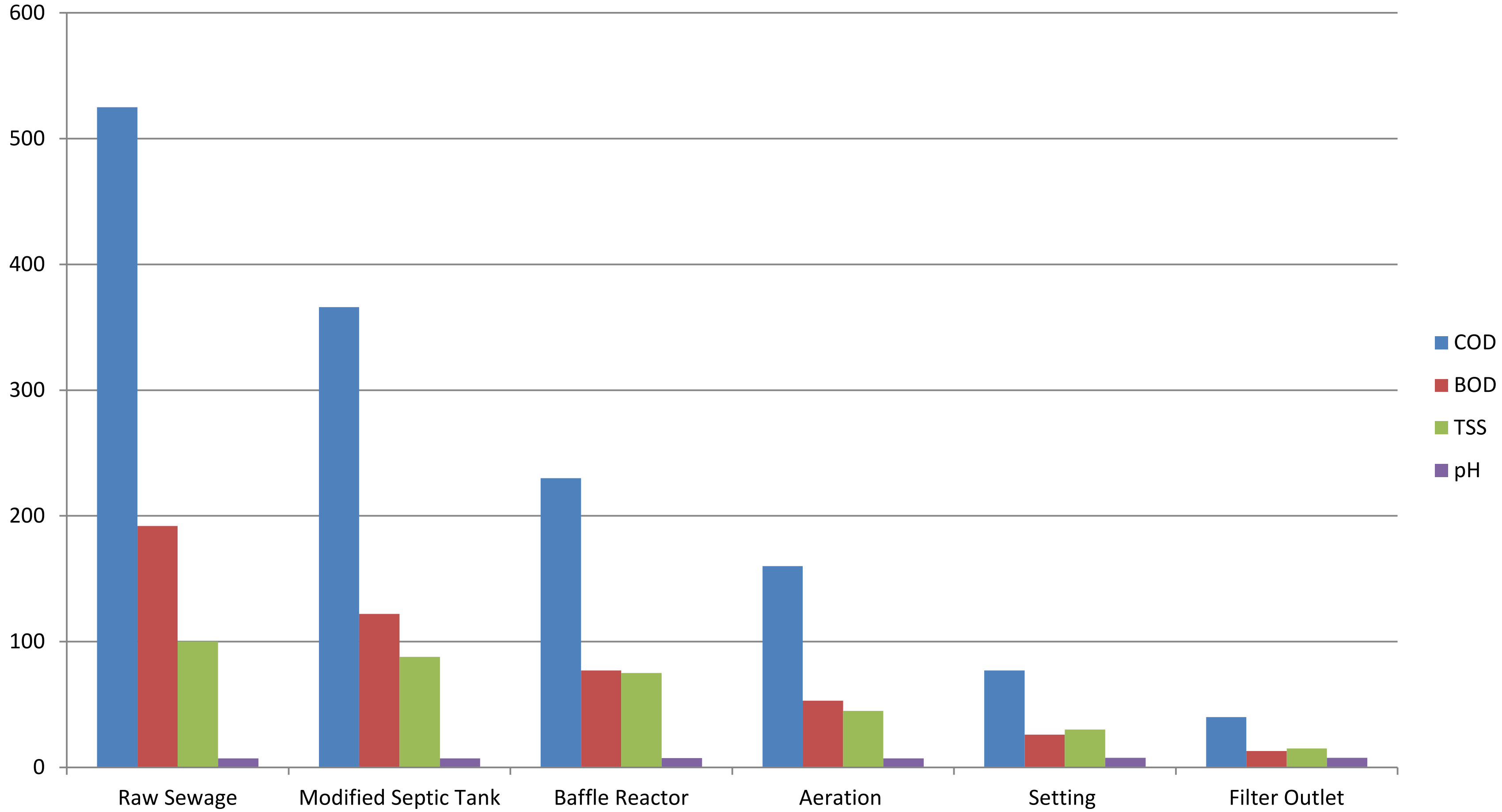
REACTORS IN PILOT PLANT



1. Modified septic tank
2. Anaerobic Baffle reactor
3. Aeration tank

4. Settling tank
5. Sand filtration tank
6. Holding tank

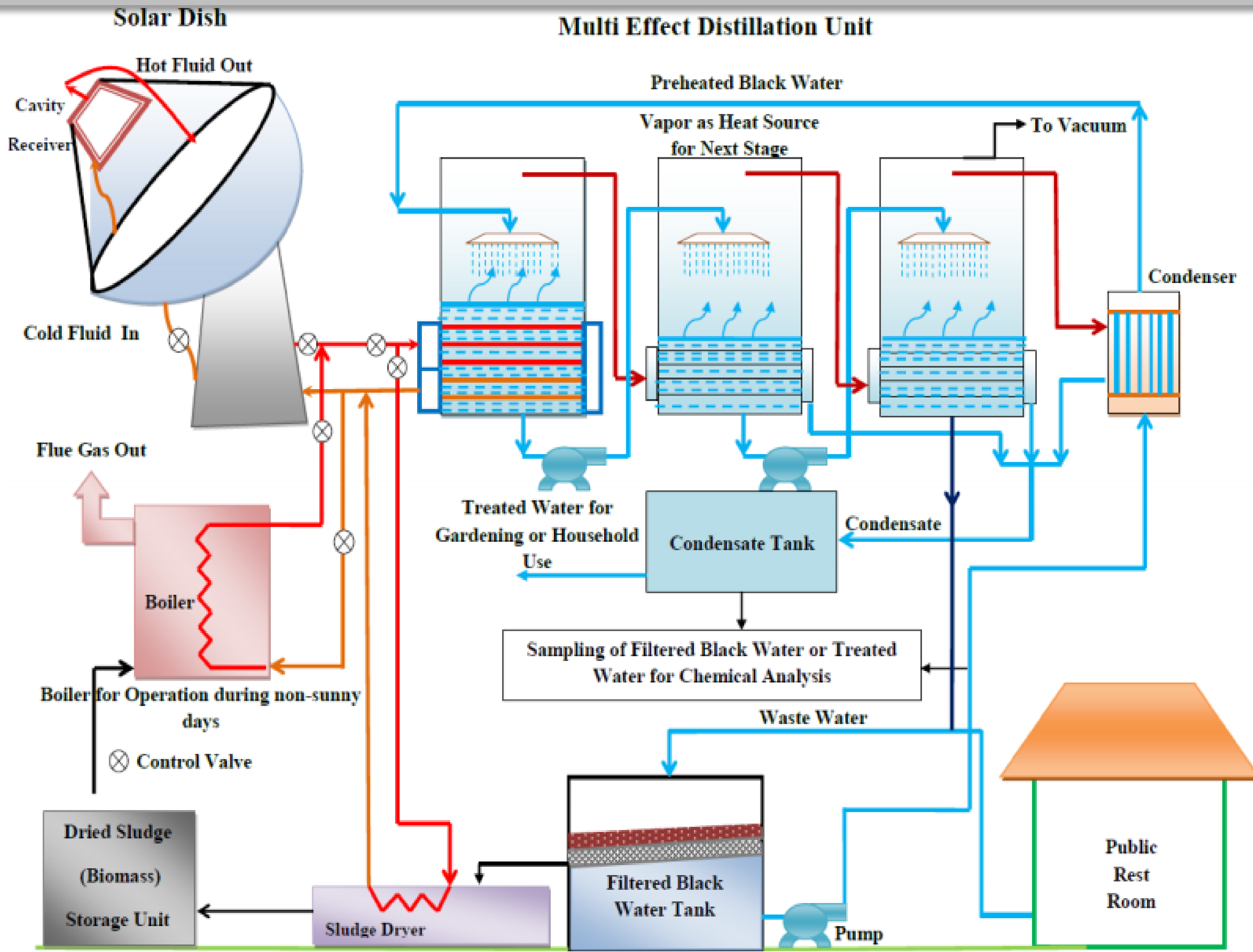
Performance of the system



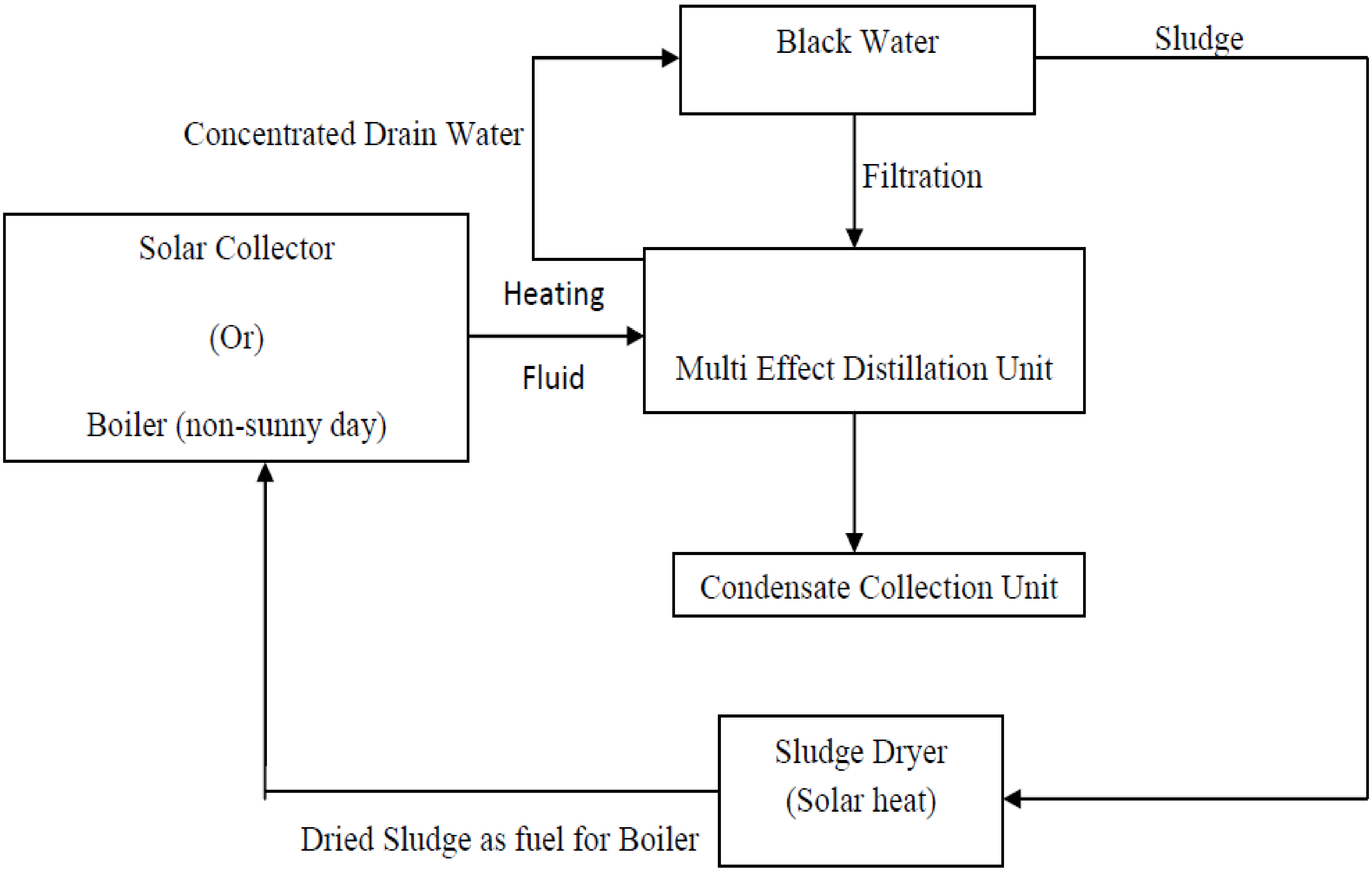
Water Quality Photos

Design and Development of Solar Thermal Energy System for Domestic Sewage (Black Water) Treatment

Solar Thermal Energy Unit for Sewage Treatment



FLOW DIAGRAM



LAB SCALE ELECTRICAL DRYER UNIT FOR FAECES & URINE

ELECTRICAL DRIER

ELECTRICAL DISTILLATION UNIT

Elemental analysis

TESTS	C%	H%	N%	S%
Synthetic faeces with E.Coli	39.62	5.944	4.49	0.305
Synthetic faeces without E.Coli	41.70	6.336	4.24	0.284

Plate count test

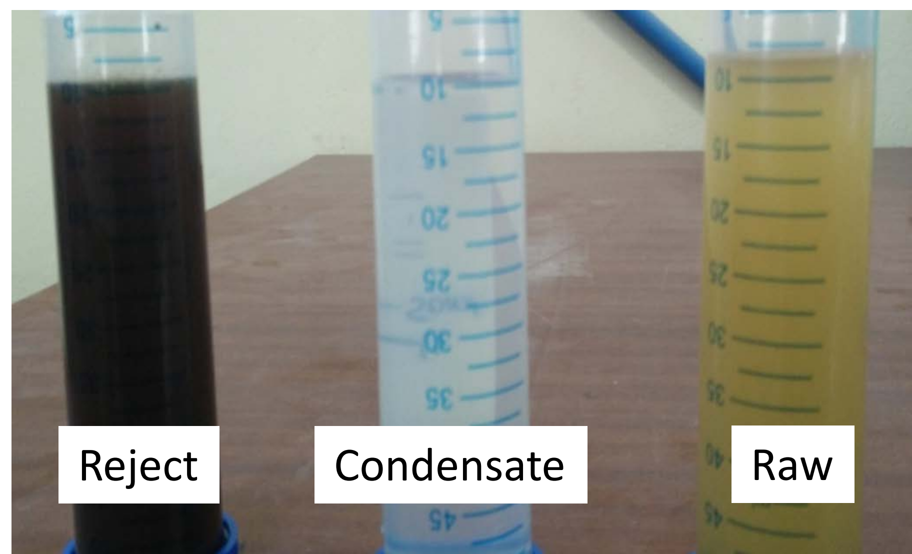
	Before drying(CFU/100mL)	After drying(CFU/100mL)
Synthetic faeces with E.Coli	4*10^5	0
Synthetic faeces without E.Coli	-	

Synthetic Faeces made artificially in lab

Synthetic Faeces After Drying

Synthetic Urine made artificially in lab

Synthetic Urine After Distillation

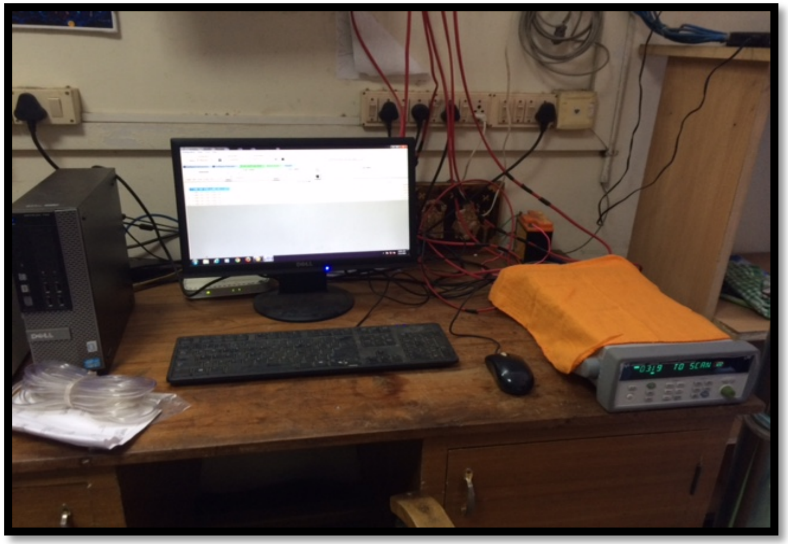


Pilot scale solar thermal black water system includes:

- **Automated separator cum conveyor system**- which separates solid and liquid directly from toilet
- **Solar Inclined still**-for treating liquid waste(urine)
- **Solar dryer**- for treating solid waste(Faeces)
- **Data logger**- for continuous monitoring of temperature of the system
- **Pyranometer**-To measure the solar radiation

Photographs of Individual Treatment Units

Separator system

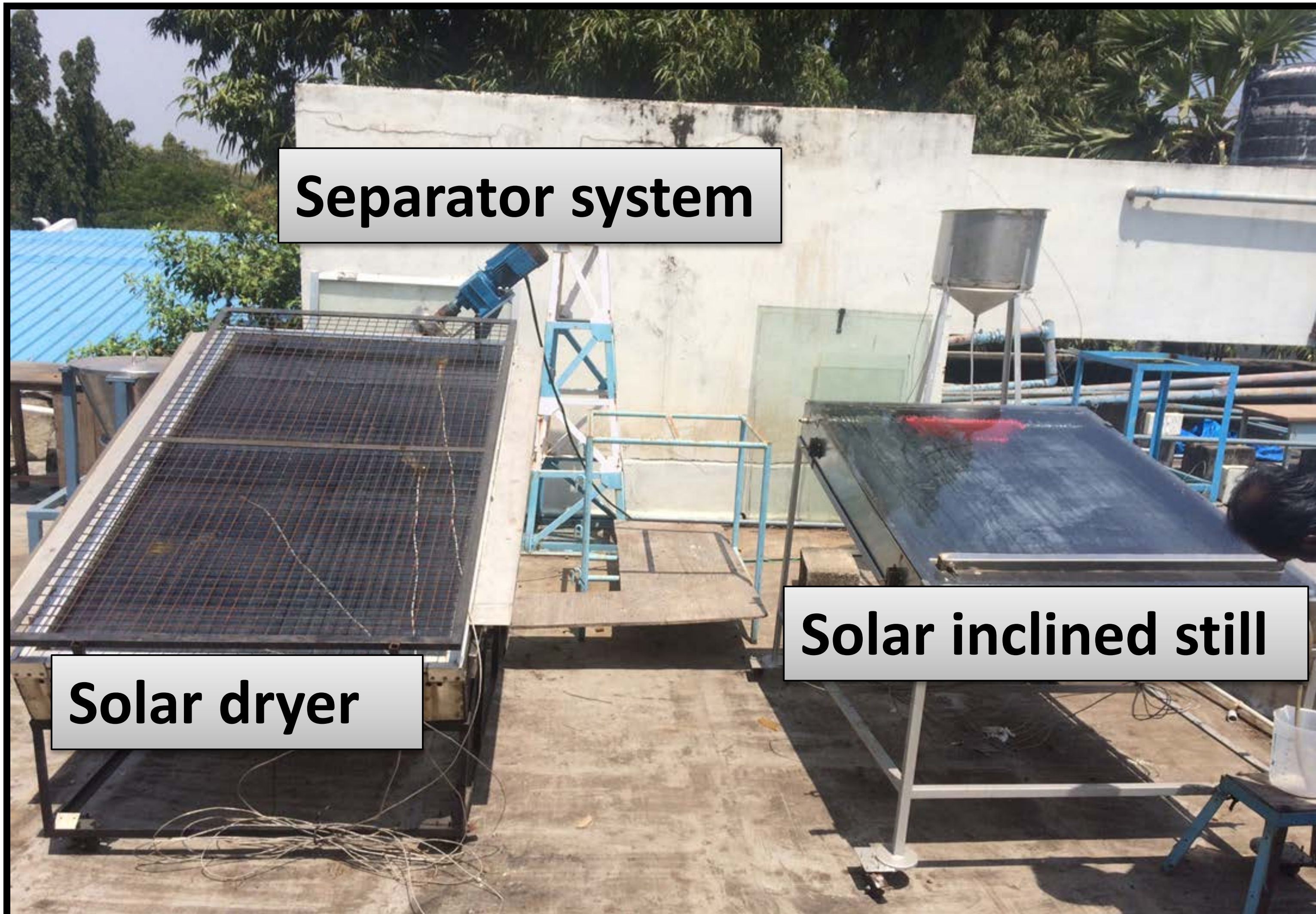


System with Data Logger

Solar Dryer

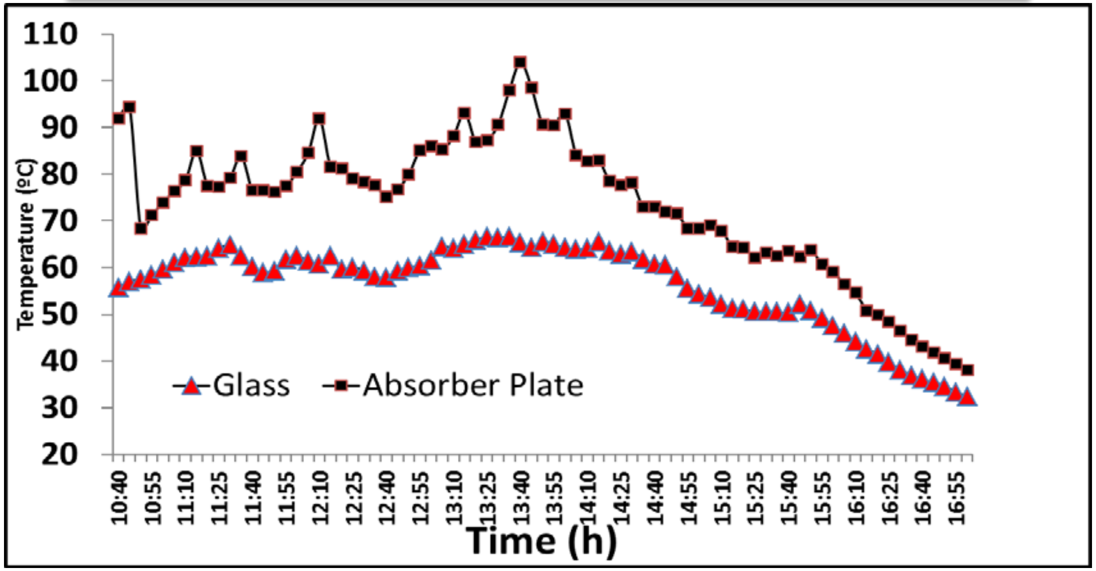
Solar Inclined Still

Integrated Pilot Scale System



Experiments on Inclined solar still

Temperature profile for solar inclined still

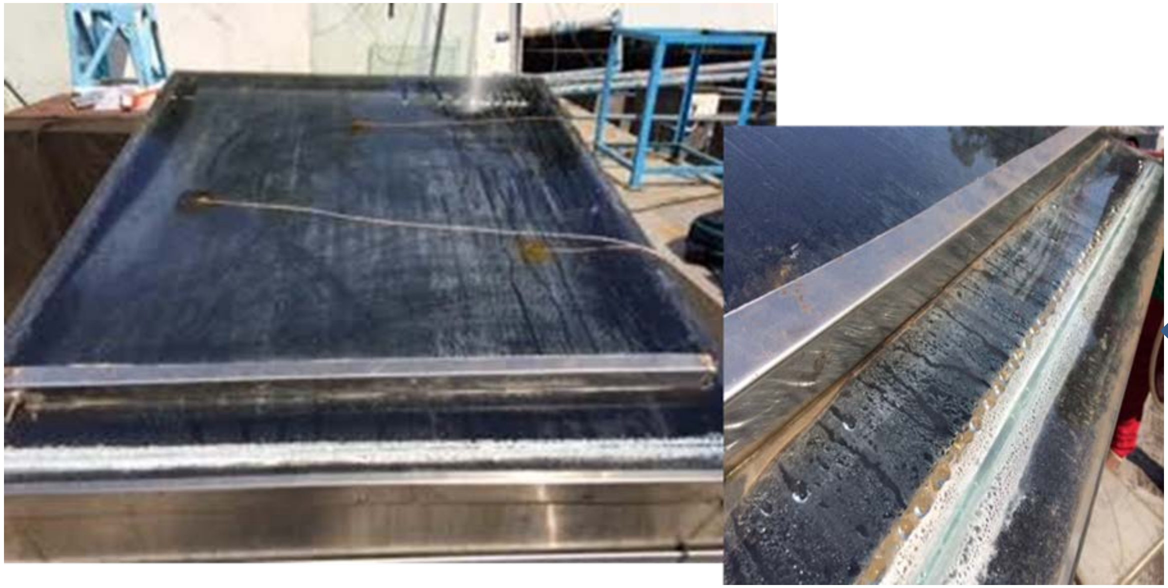


Maximum plate temperature- 105ºC

Maximum glass temperature - 65 ºC

Ambient temperature -30ºC

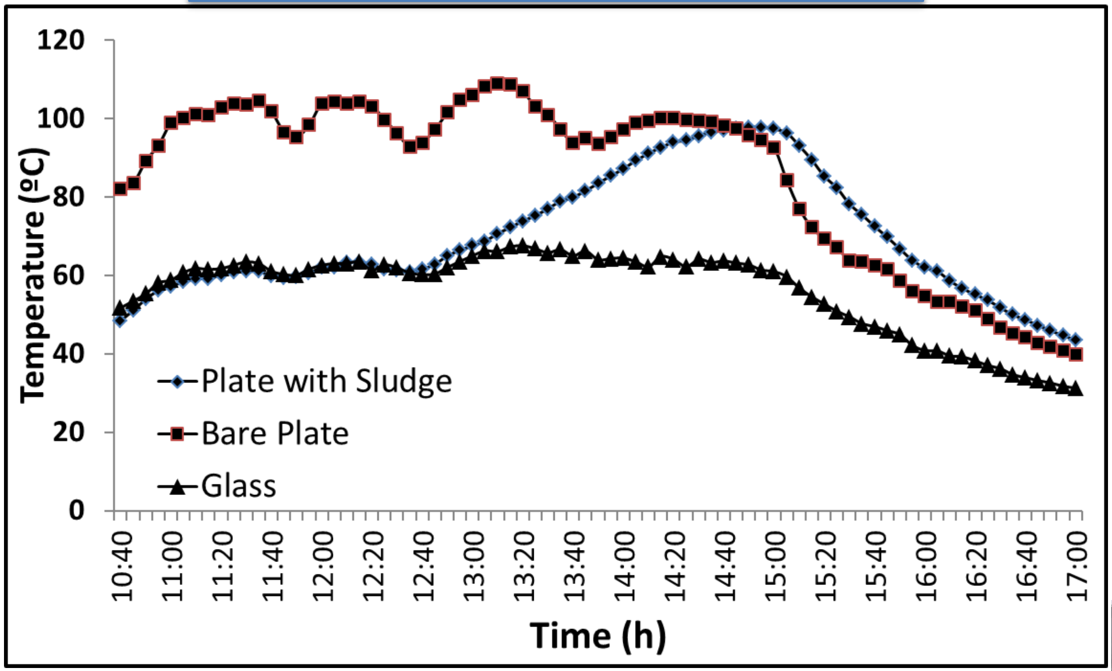
Maximum solar radiation 920W/m2



Solar Inclined Still during Condensation

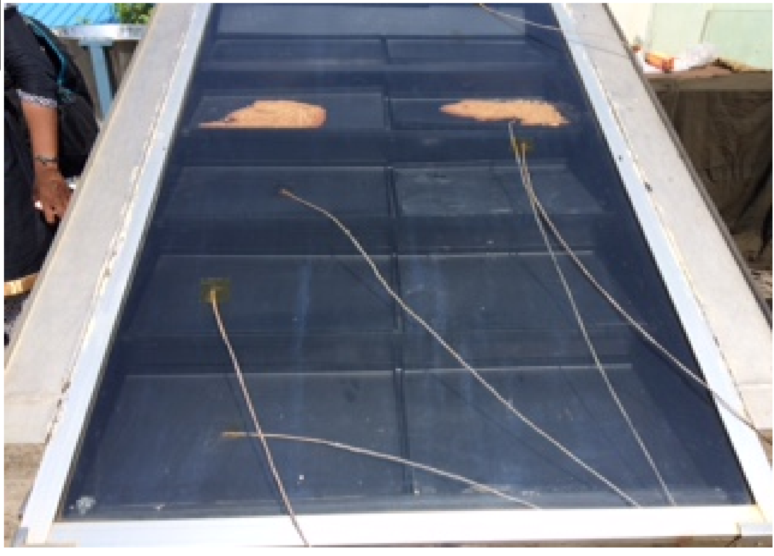
Experiments on Solar Dryer

Temperature profile for solar dryer



Maximum temperature for Plate with sludge 97.8ºC
Bare plate 109ºC
Glass-67ºC

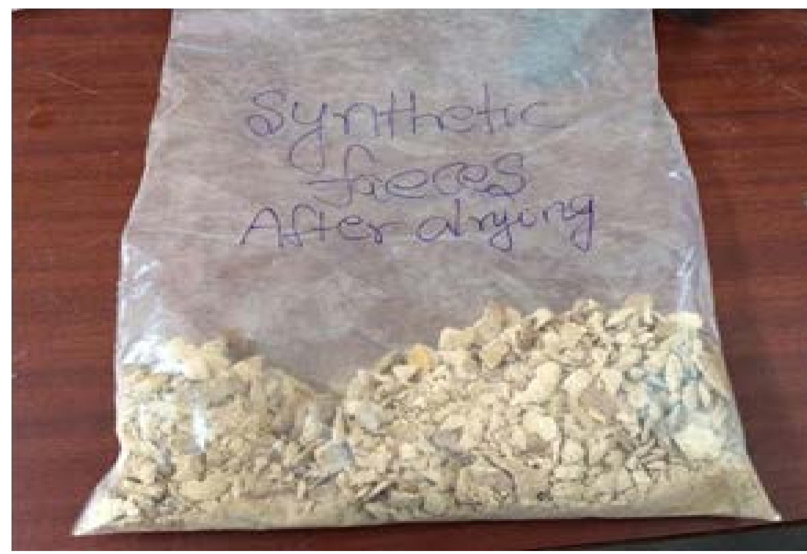
Solar Dryer loaded with synthetic faeces



Quality of dryed Faeces

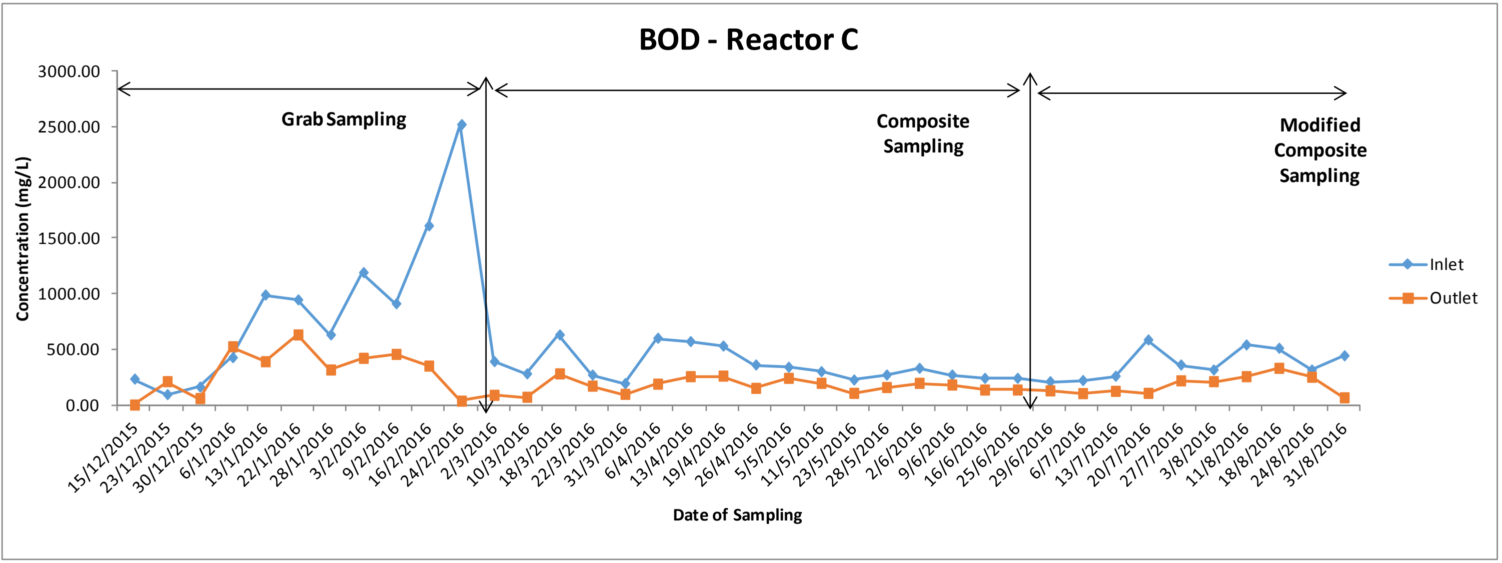
Parameters		
Moisture content (%)	90.2%	
Bacterial content (CFU/100 mL)	Initial 5*10^6	Final Nil

Synthetic faeces before drying



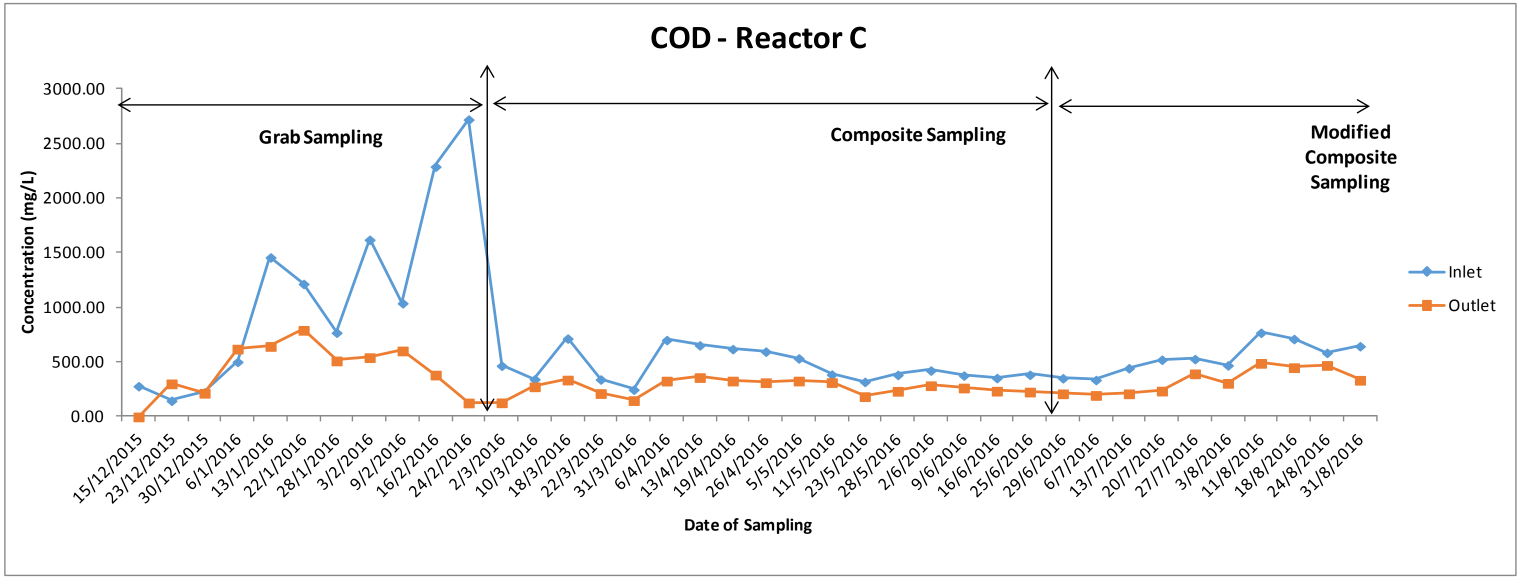
Synthetic faeces after drying

BOD & COD values of Reactor C



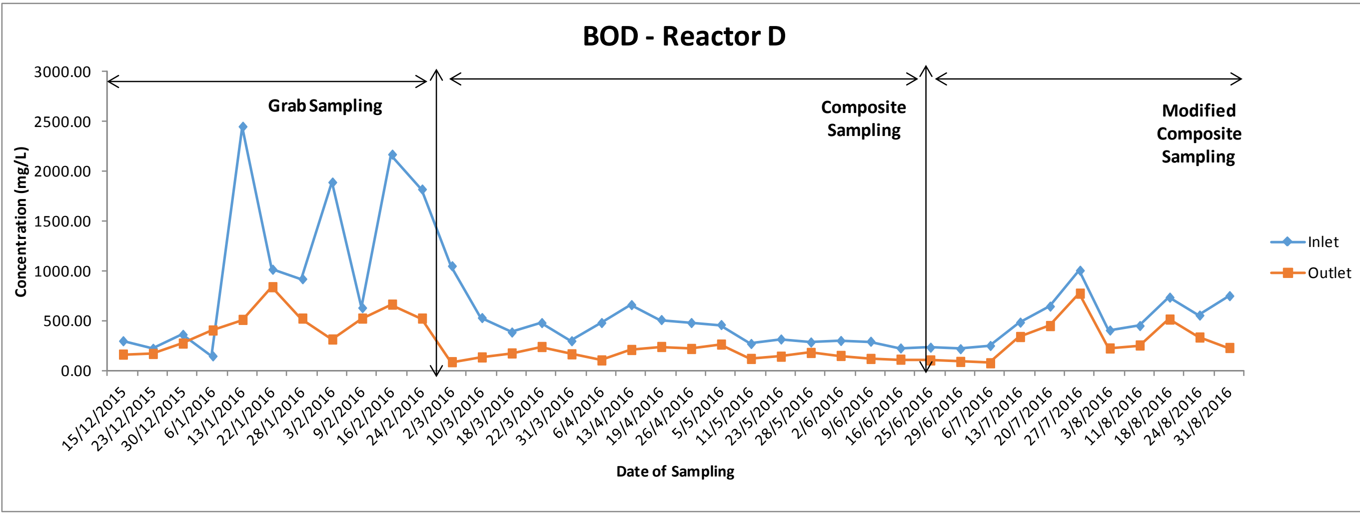
Reactor C –With inoculum

Second Inoculum addition (220 L) on June 25th, 2016 (Week 28)



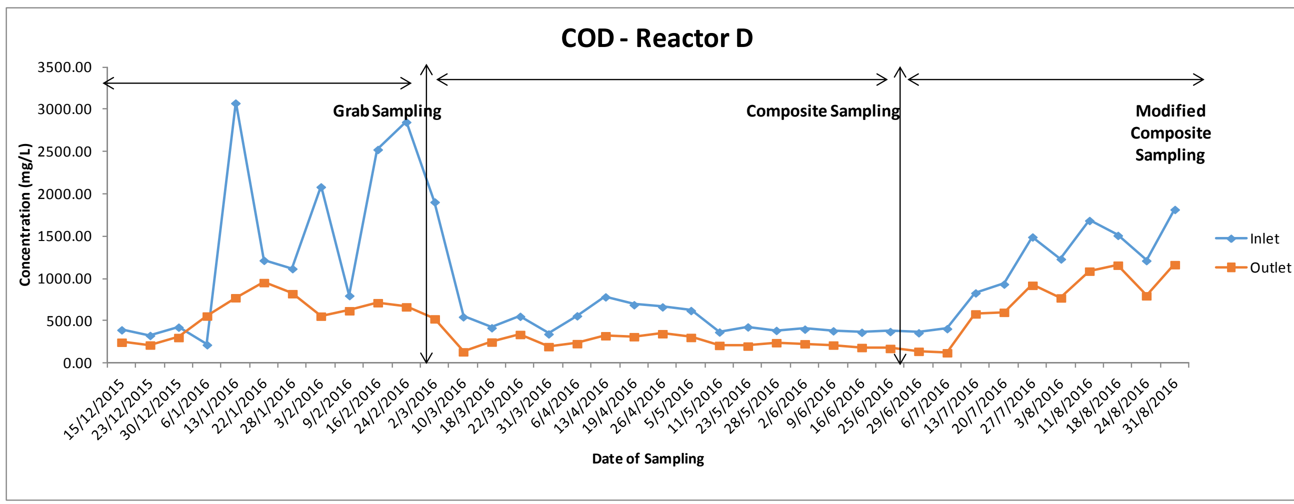
BOD & COD values of Reactor D

actor D – With Inoculum

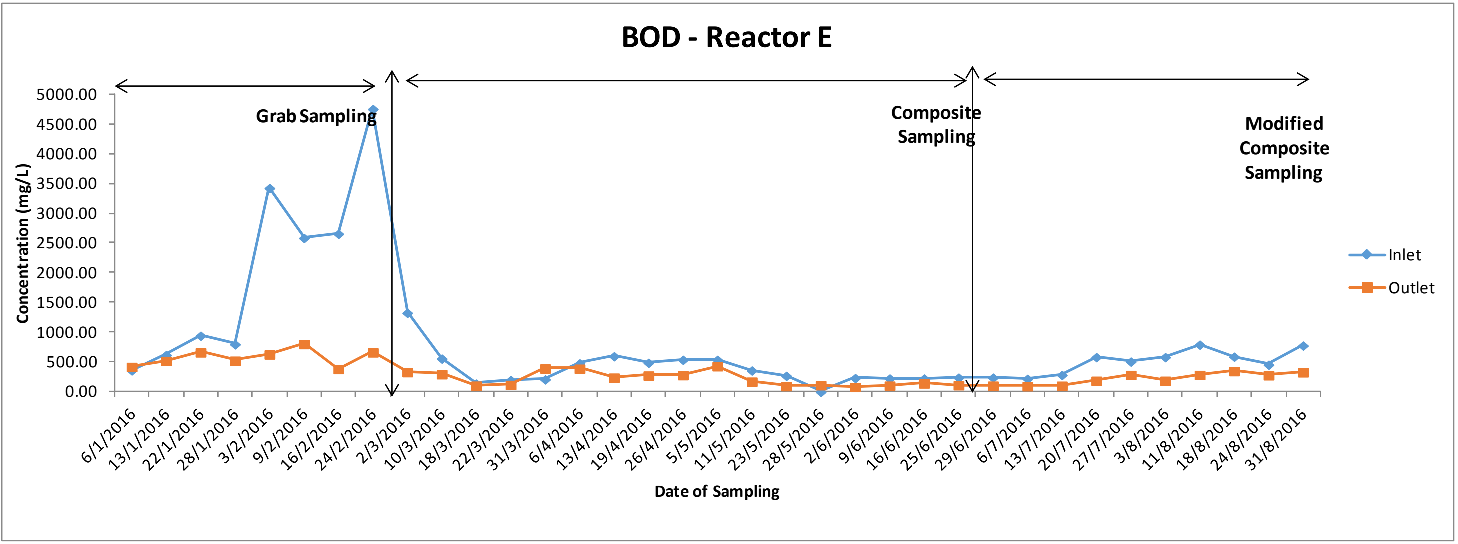


Everyday addition of chemicals (2x) from June 25th 2016 (Week 28)

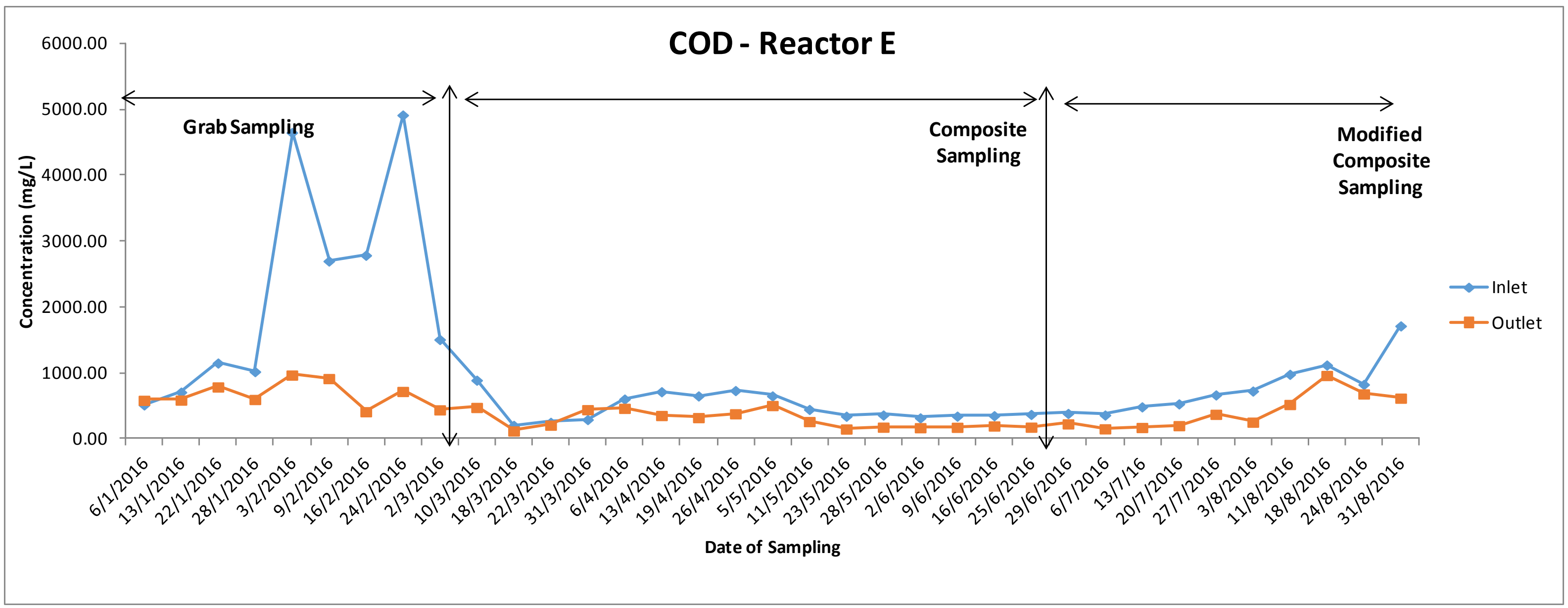
200 mL of Soap solution
200 mL Phenyl solution



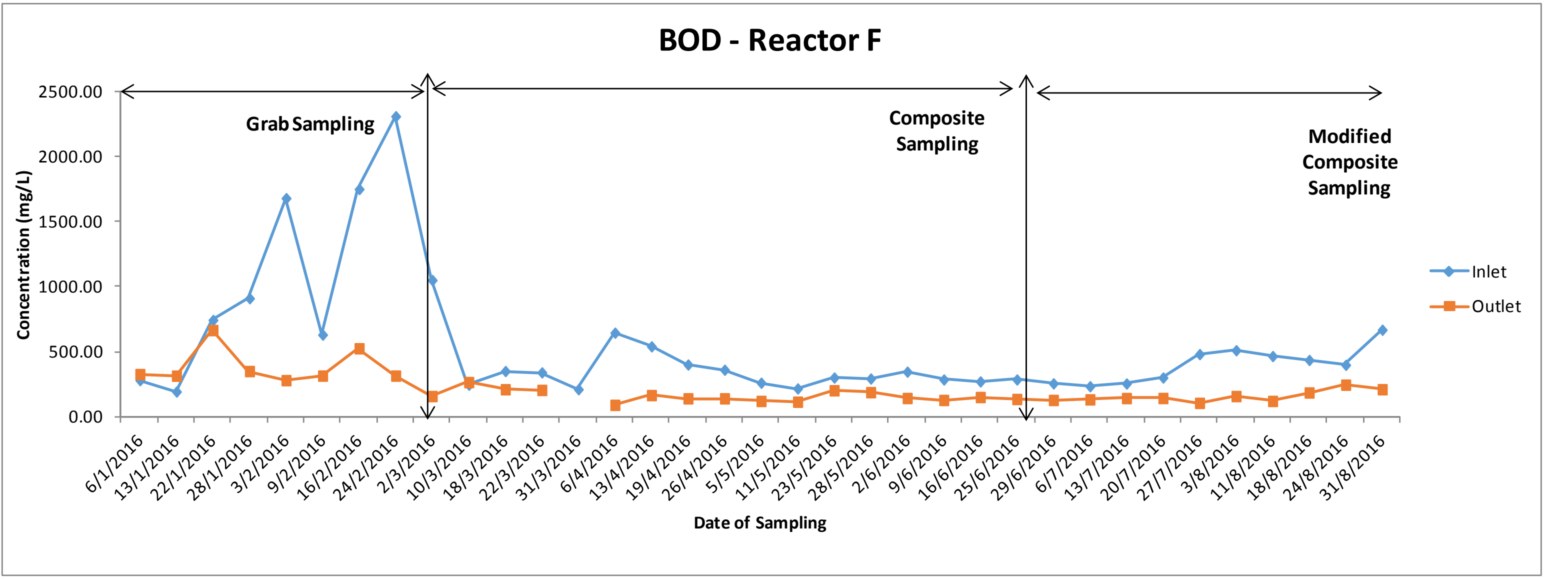
BOD & COD values of Reactor E

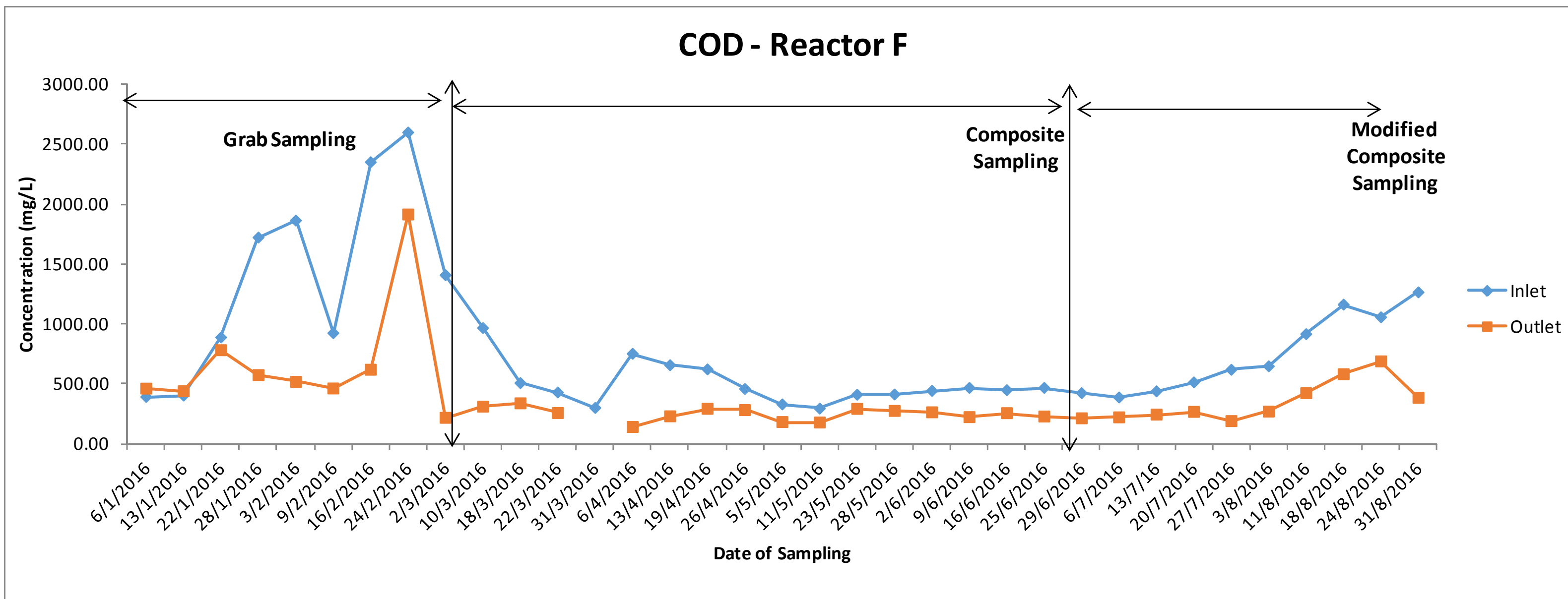


Reactor E – With inoculum

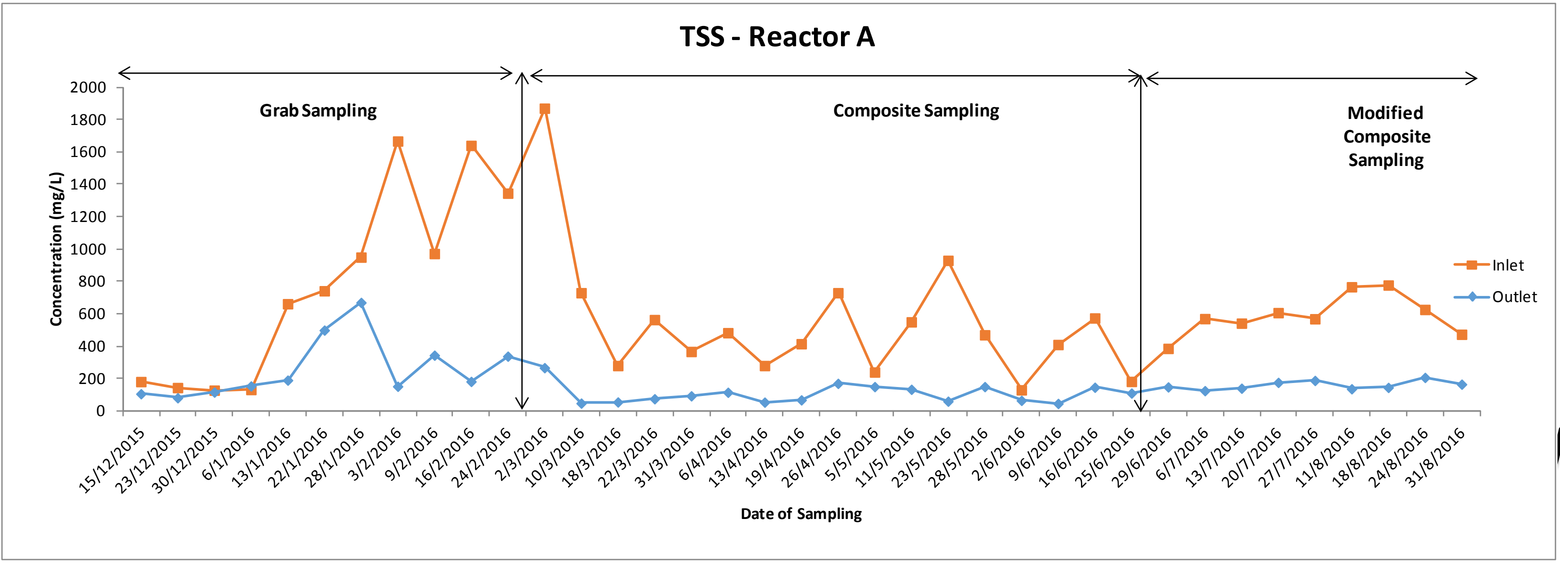


BOD & COD values of Reactor F

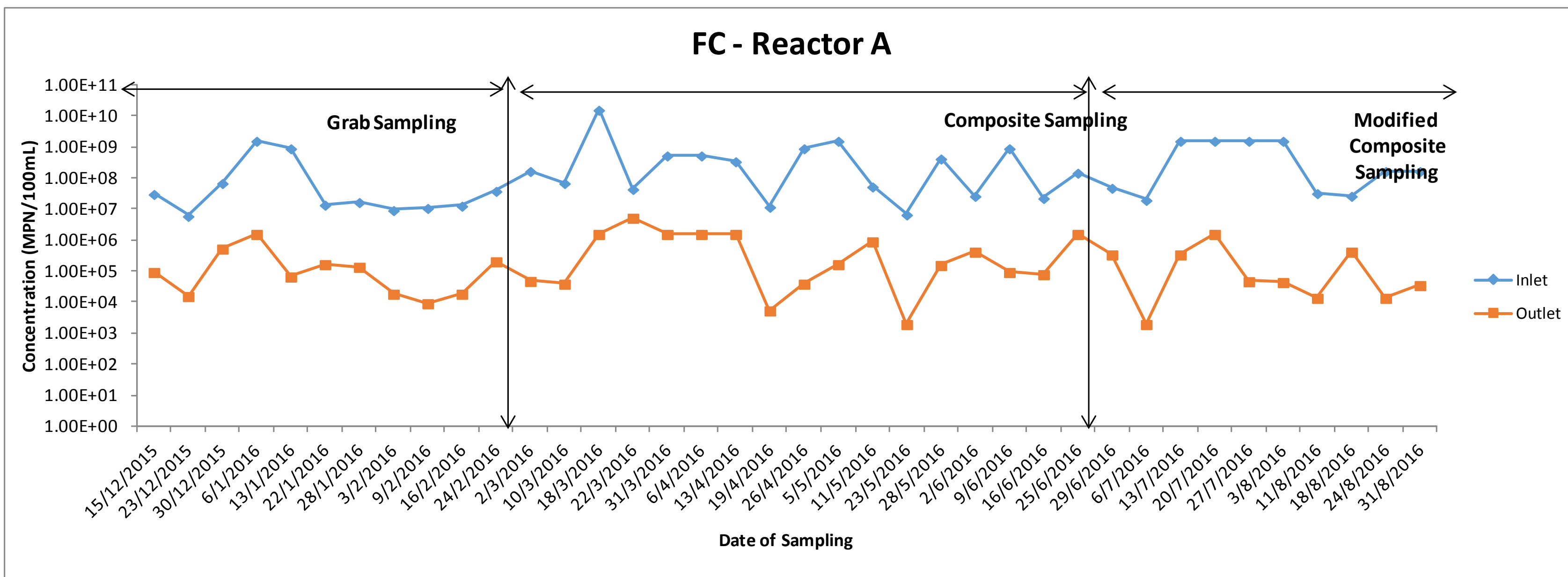




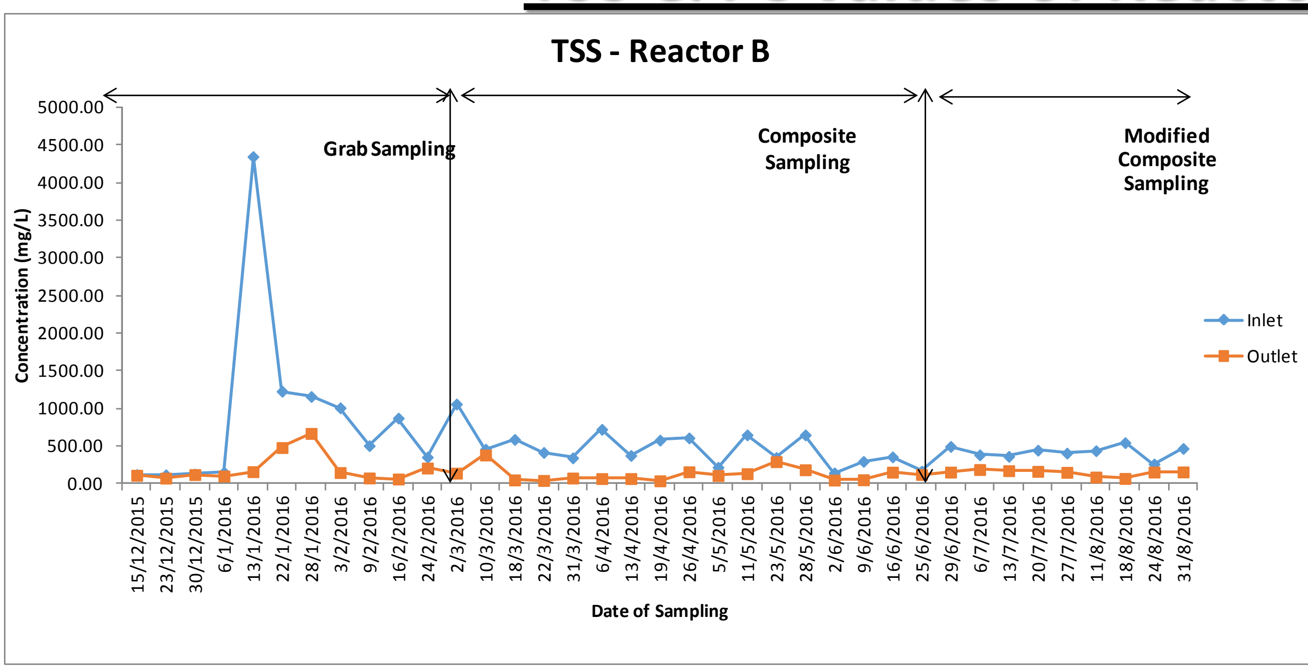
TSS & FC values of Reactor A

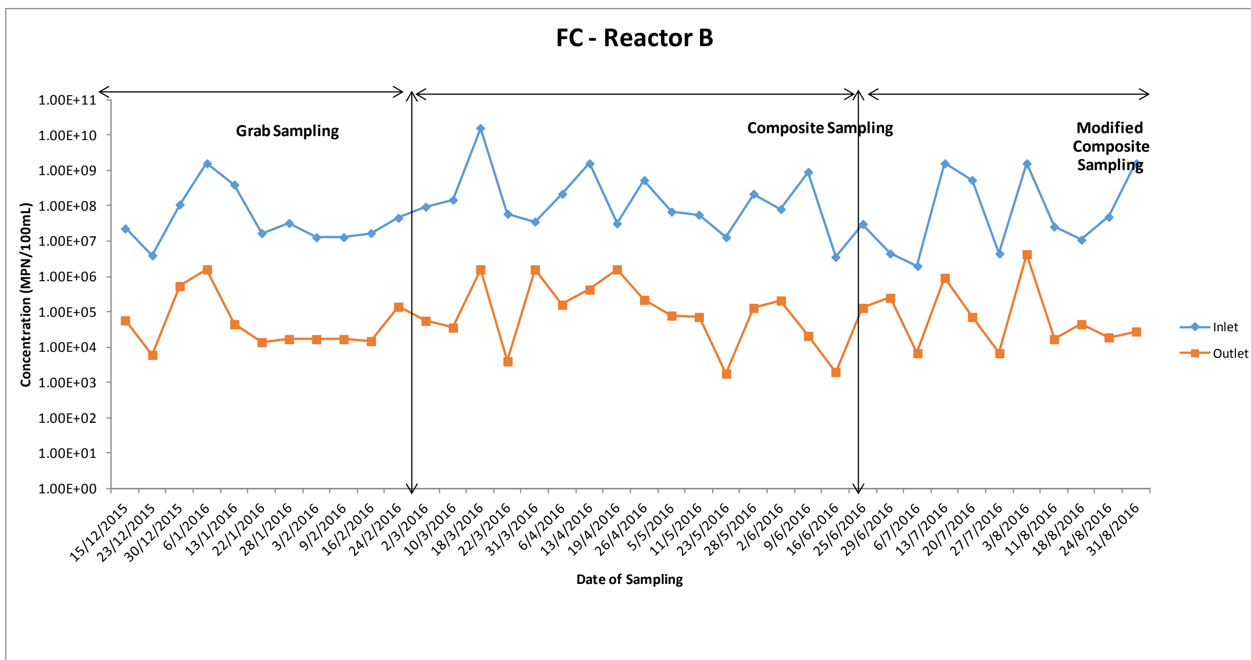


Reactor A –
/ithout inoculu

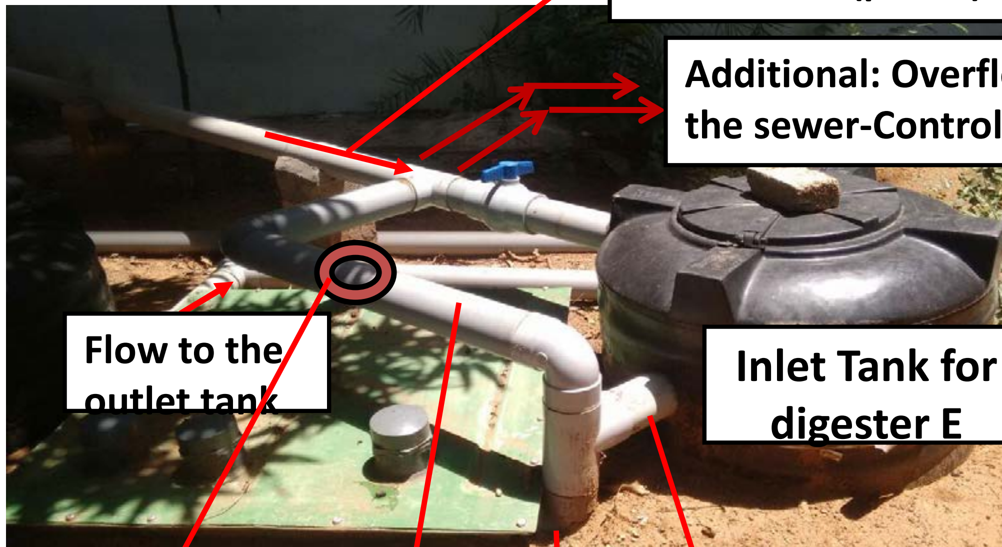


TSS & FC values of Reactor B



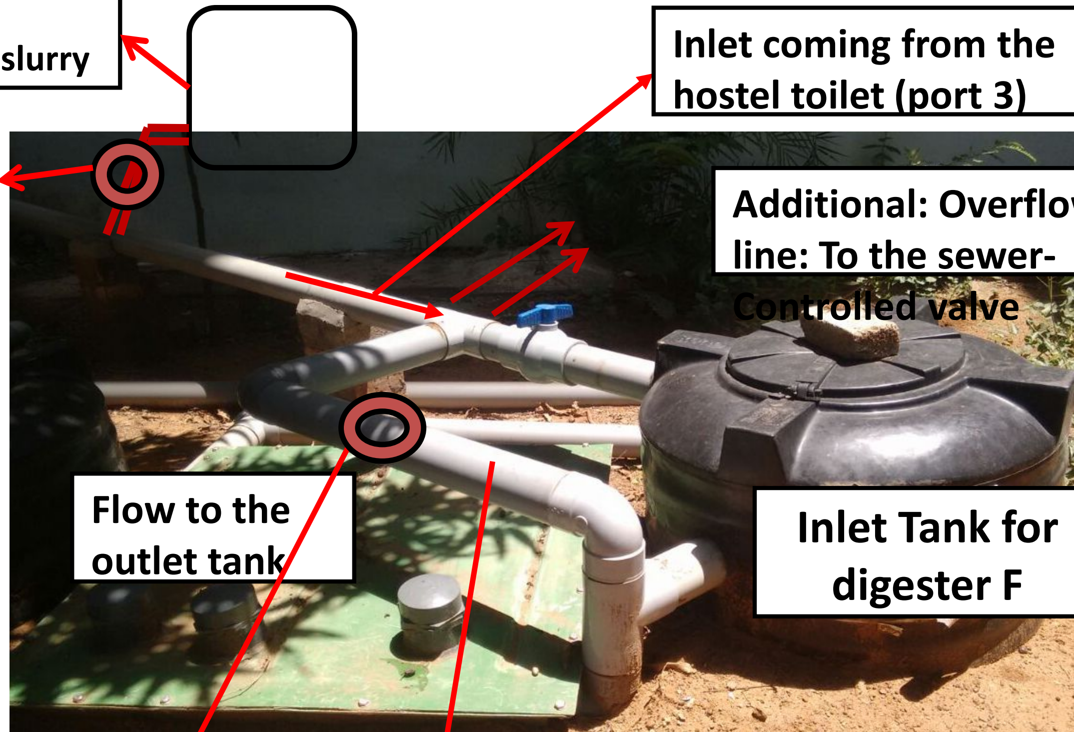


Reactor E-Modified Plan: Inlet Tank & Digester setup



- **Flow to the digester will be controlled from the through gate valve shown according to the HRT**
- **Reactor operation will be completely in continuous mode**
- **Sampling frequency will be according to the fixed HRT**
- **Each HRT will be maintained for a period till pseudo steady state will be achieved**
- **Continued for a period of next 6 months**

Reactor F-Modified Plan: Inlet Tank & Digester setup



- Need to maintain the flow rate and influent COD
- Influent COD maintained through: Vegetable waste in a slurry form mixed to influent using overhead tank
- Flow rate will change according to the HRT: OLR will change
- Each OLR can be maintained till pseudo steady state which will be continued for a period of next 6 months

FUTURE WORK – Fieldunits

Performance evaluation of DRDO toilets with anaerobic biodigesters

12 units	in TN /AP / Telangana/ Karnataka

Monitoring of Field units (Composite Sampling – 24h)

Old sites - 6	New sites - 6

Questionnaire

Evaluation of the socio - economic and institutional condition on the selected existing onsite biodigesters

Old Sites
Tirumalai Nagar park, Perungudi
Rajiv Nagar park, Perungudi
Kappalore community toilet block
K.Paramathy, community toilet at MAK company premises
Community toilet at old age home, Ongole
Common toilet at construction site, Bellandhur

New Sites
Raj classic Foods, Hyderabad
Mantri Developers Pvt Ltd., Nagawara
G-Block, Western side of the Shapoorji Pallonji Construction site, Panorama Brigade
Site Office block, Shapoorji Pallonji Construction site, Panorama Brigade
Mandal Parishad Primary School, Talamanchipatnam village
Mandal Praja Parishad School , Chinnakomerla village