BITS, PILANI – K. K. BIRLA GOA CAMPUS

Recycling of wastewater resources for sustainable cities of the future

Srikanth Mutnuri

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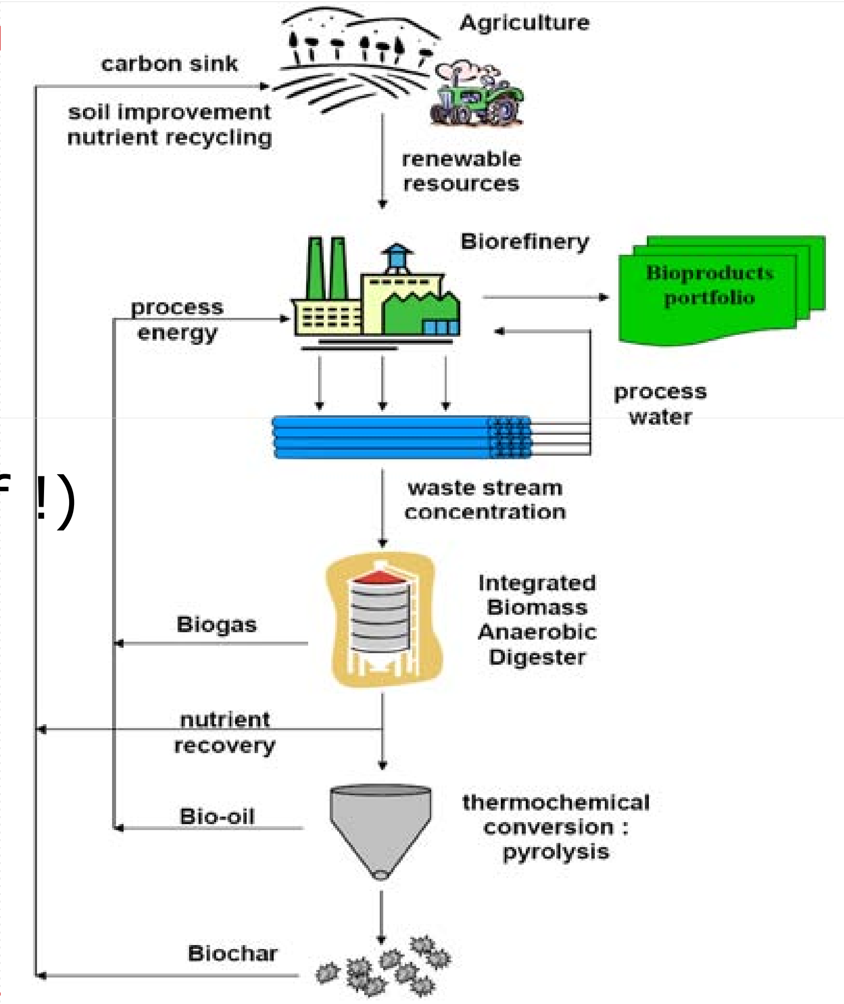
The new societal wave & water

More need for water

→ The bio-economy

→ Various cleansing, bathing, relaxing, aqua sports (golf !)

→ No acceptance of dry toilet



The global IWA concept

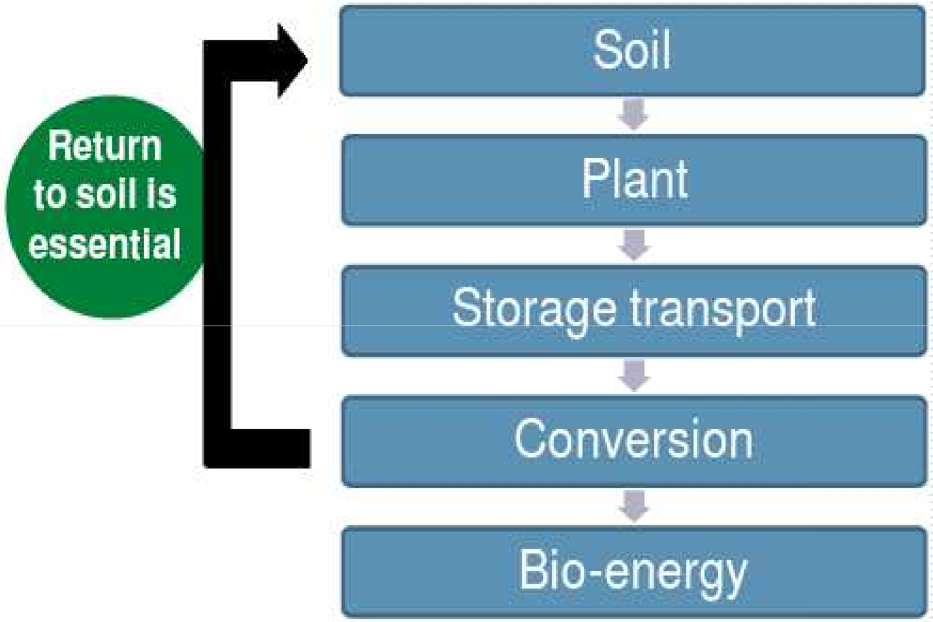
Rockström, 2009; Nature 461:472-474

PLANETARY BOUNDARIES

Earth-system process	Parameters	Proposed boundary	Current status	Pre-industrial value
Climate change	(i) Atmospheric carbon dioxide concentration (parts per million by volume)	350	387	280
	(ii) Change in radiative forcing (watts per metre squared)	1	1.5	0
Rate of biodiversity loss	Extinction rate (number of species per million species per year)	10	>100	0.1–1
Nitrogen cycle (part of a boundary with the phosphorus cycle)	Amount of N_2 removed from the atmosphere for human use (millions of tonnes per year)	35	121	0
Phosphorus cycle (part of a boundary with the nitrogen cycle)	Quantity of P flowing into the oceans (millions of tonnes per year)	11	8.5–9.5	~1
Stratospheric ozone depletion	Concentration of ozone (Dobson unit)	276	283	290
Ocean acidification	Global mean saturation state of aragonite in surface sea water	2.75	2.90	3.44
Global freshwater use	Consumption of freshwater by humans (km^3 per year)	4,000	2,600	415
Change in land use	Percentage of global land cover converted to cropland	15	11.7	Low
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis		To be determined	
Chemical pollution	For example, amount emitted to, or concentration of persistent organic pollutants, plastics, endocrine disrupters, heavy metals and nuclear waste in, the global environment, or the effects on ecosystem and functioning of Earth system thereof		To be determined	

Boundaries for processes in red have been crossed. Data sources: ref. 10 and supplementary information

Soil is losing its nutrients



(Hanegraaf et al., 2006; Rapport 1183 TCB 1-56)

Ode to the soil

(After Frans Barends, KIVI – NIRIA Congress 2008)

Yearly Loads kg/(P*year)	Greywater	Urine	Feaces
Volume l/(P*year)	25.000 -100.000	~ 500	~ 50 (option: add biowaste)
N ~ 4-5	~ 3 %	~ 87 %	~ 10 %
P ~ 0,75	~ 10 %	~50 %	~ 40 %
K ~ 1,8	~ 34 %	~ 54 %	~ 12 %
COD ~ 30	~ 41 %	~ 12 %	~ 47 %
S, Ca, Mg and trace elements	Treatment → Reuse / Water Cycle	Treatment → Fertiliser	Biogas-Plant Composting → Soil-Conditioner

Flushwater can be saved 6.000 - 25.000

Geigy, Wiss. Tabellen, Basel 1981, Vol. 1, LARSEN and GUJER 1996, FITSCHEN and HAHN 1998

Toilets and resulting Dilution

Type of Toilet	Daily Flow per P.	Pro and Con's
Flushing toilet	25-40 l	+ widely accepted - waste of water - high dilution
Vacuum-toilet	9 l	+ low water demand + well developed (ships) - high-tec / expensive
Separating toilet	6 l 1,5 l	+ little water / little diluti + simple fertiliser reuse - little experience
Waterless Urinal	1,2 l	+ no water / no dilution - maintenance required
Composting-toilet Desi	1,5 l	+ no water needed - high space demand - maintenance needed ++ Desiccation for hot climates

Wastewater generation in India

Structured urban & Industrial Database 2007

Name of the zone	City classification	Wastewater generated (Mld)	Wastewater collected (Mld)
South	Very big	669.53	
	Big	58.22	
	Medium	640.42	
	Small	1532	
		2911	1812
North	Very big	1935	
	Big	394	
	Medium	948.26	
	Small	2250	
		5578	3932
Western	Very big	978	
	Big	437	
	Medium	780.525	
	Small	1269	
		3469	2275
Eastern	Very big	55	
	Big	297	
	Medium	631	
	Small	2461	
		3434	2151

Pathways for a water efficient future:

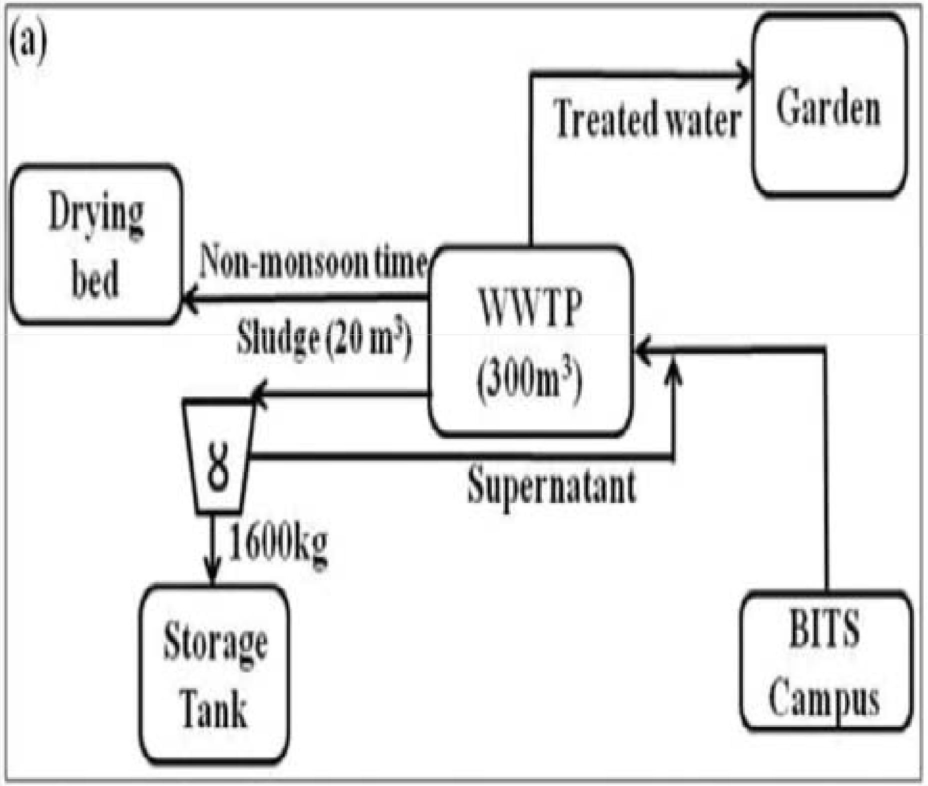
a. Dry sanitation / Low Cost solutions

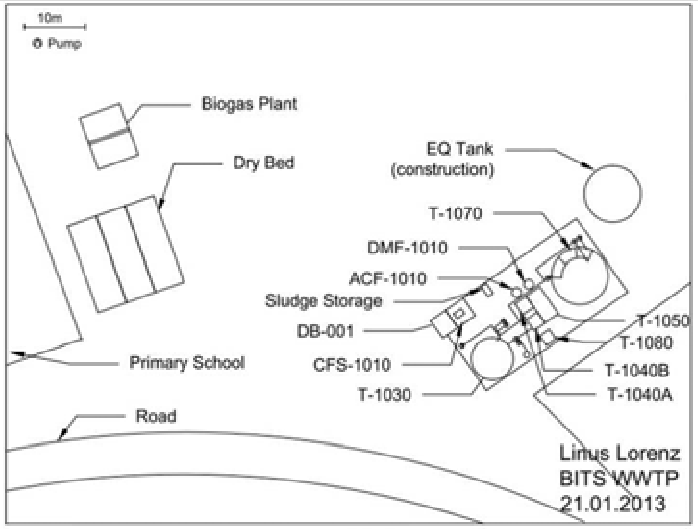
b. Urine-Diversion with flush sanitation

c. Blackwater and integrated systems design

Poor soil can become highly fertile with clever management of biowaste and sanitation

Schematic picture of WWTP





Terra Preta set up

Content	Exp. setup1	Exp. setup 2	Exp. setup 3	Exp. setup 4	Exp. setup 5
Sludge [kg]	7	5.6	5.5	5.37	5.15
Charcoal [kg]	0	1.4	1.4	1.4	1.4
EMa (concentrated) [l]	0	0	0.1	0.1	0.1
Soil [kg]	0	0	0	0.13	0.13
$CaCO_3$ [kg]	0	0	0	0	0.22

Terra Preta set up

Figure 4.3: Terra Preta samples

pH of experimental set ups

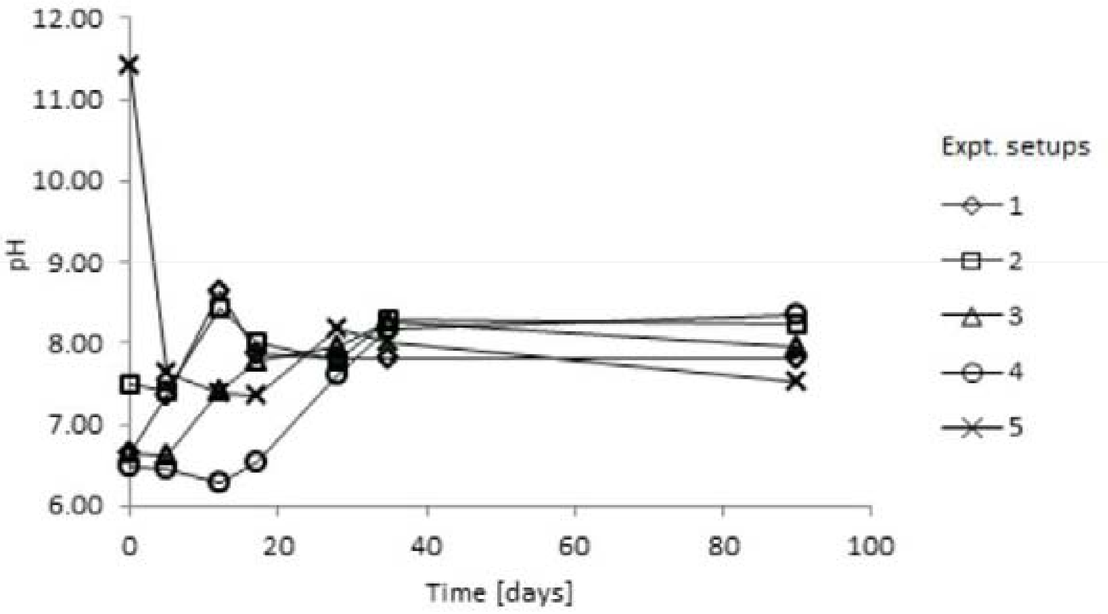


Figure 1. pH of experimental setups 1-5. Day 0 - 28 cover the phase of LF. VC was performed between day 28 - 90.

COD in mg/g dry mass

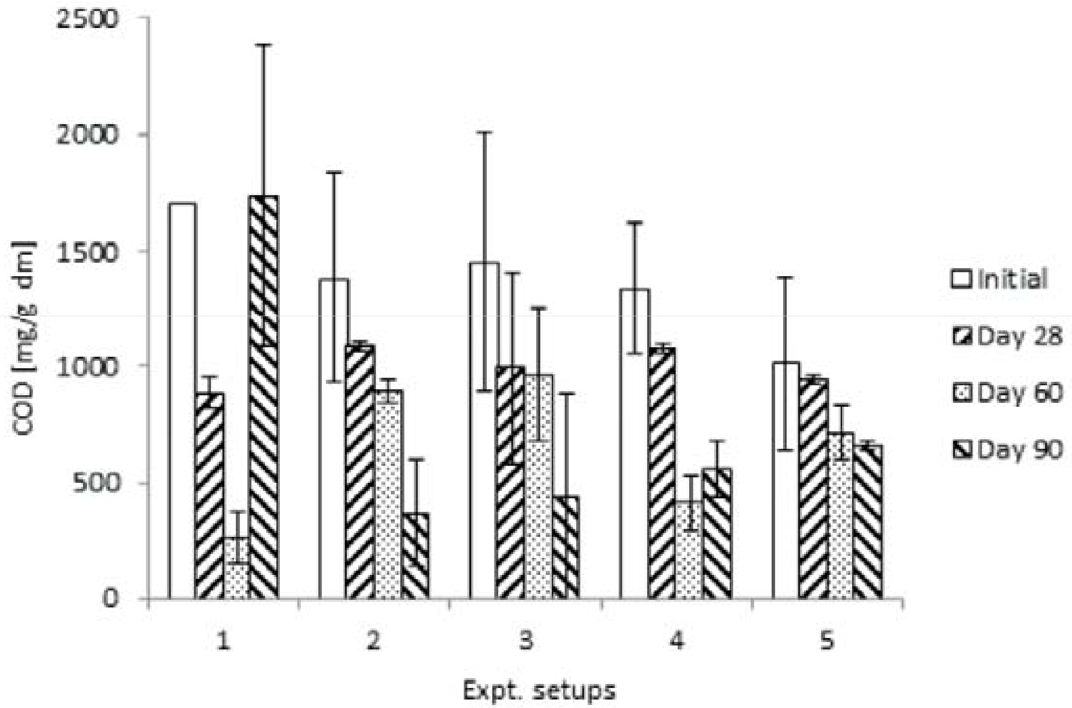


Figure 2. COD in mg/g dry mass, of experimental setups 1-5. Day 0 - 28 cover the phase of LF. VC was performed between day 28 - 90.

Total N in mg/kg wet mass

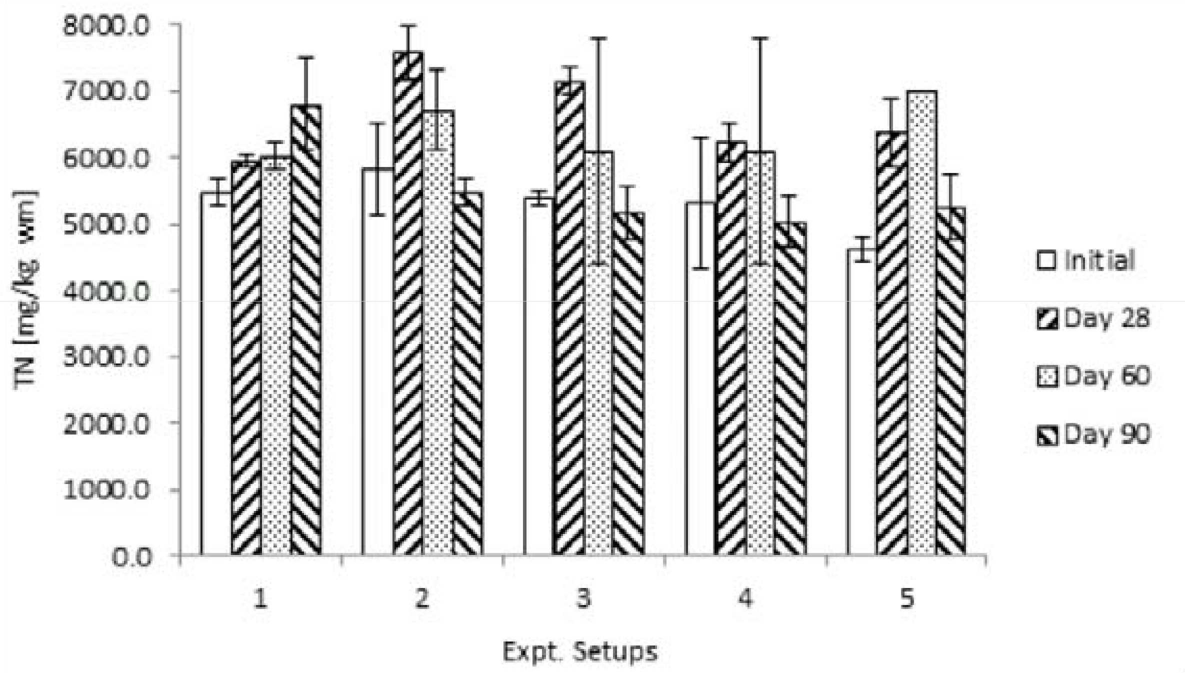


Figure 5. Total N **in mg/kg wet mass of experimental setups 1-5 during LF (day 0 - 28) and VC (day 28 - 90)**.

Total phosphate in mg/g dry mass

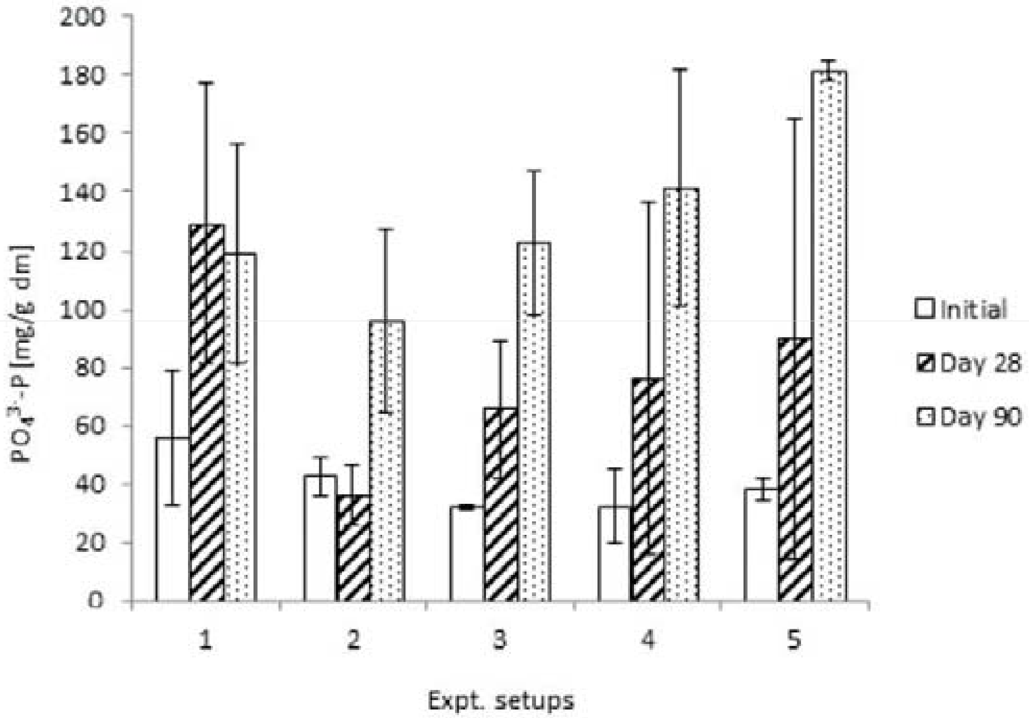
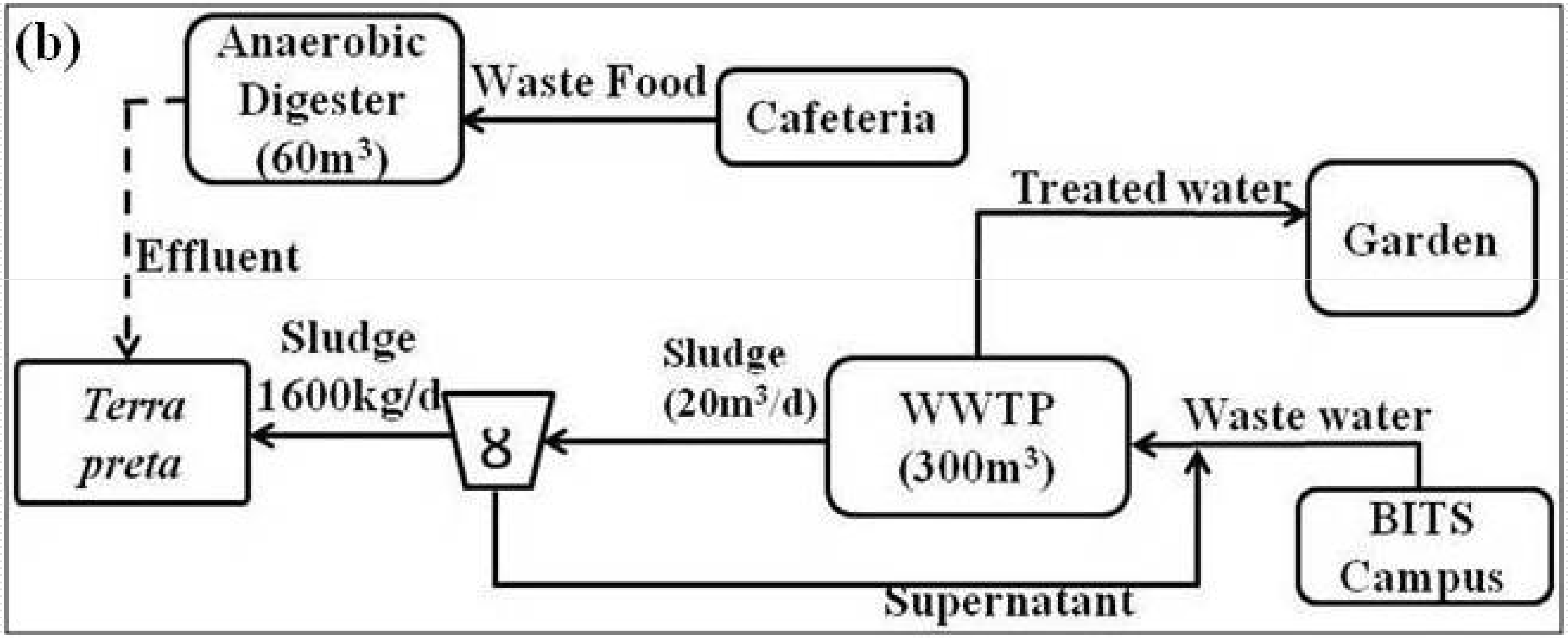


Figure 6. Total phosphate in mg/ g dm of experimental setups 1-5 during LF (day 0 - 28) and VC (day 28 - 90).

Proposed modification plan for WWTP



Plant growth experiments using TP produced

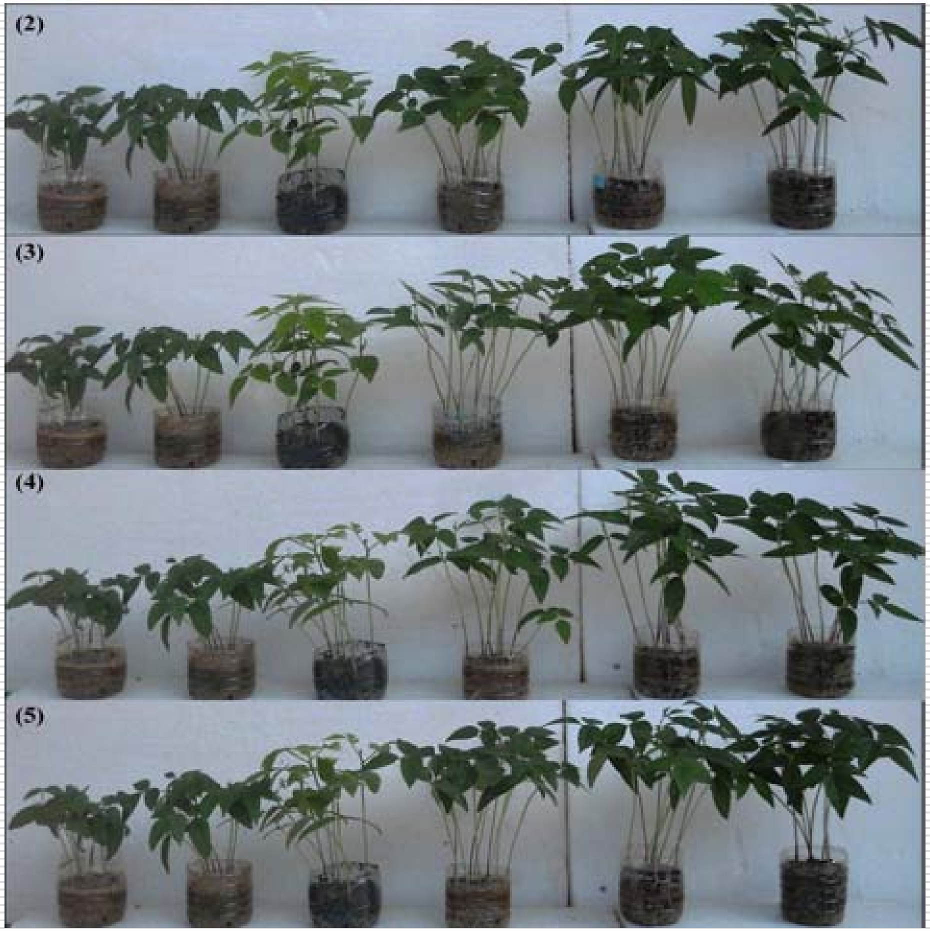


Figure 1. Growth status of *Vigna radiata* on day 30 in Plant growth experiment. Numbers (2-5) in the vertical order indicate the TP setup (setup 2-5) used. The six pots in each row are (from left to right) control only soil (C1), soil and charcoal (C2), only TP (C4), 10% TP, 25% TP and 50% TP. (Pot with soil and organic manure (C3) is not included in picture as that setup was started one week later).

Worms from the Terra Preta experiment compared to worms from normal earth

Waste To Energy Project in Nashik

- GIZ-ASEM under the thrust area “Sustainable Urban Environment” is currently supporting 6 municipal corporations (Shimla, Varanasi, Nashik, Raipur, Kochi and Tirupathi) under the JNNURM reform project. In addition GIZ-ASEM is also extending its technical support to promote sustainable urban sanitation solutions.
- Within the framework of the “International Climate Change Initiative” of the Federal Ministry of Environment, Nature Conservation and Nuclear Safety of Germany, GIZ-ASEM is demonstrating an waste to energy project.

Process Flow Sheet

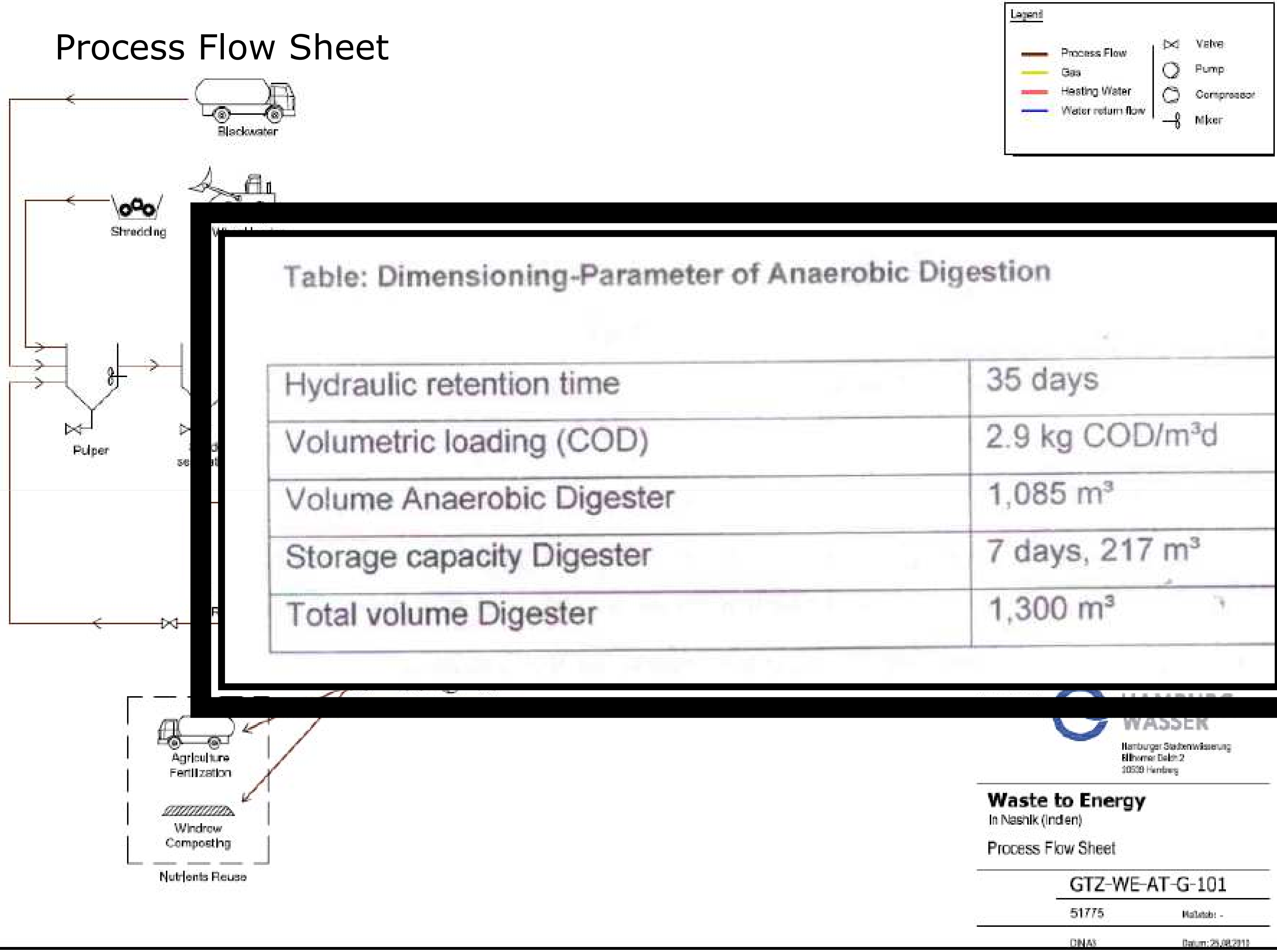


Table: Dimensioning-Parameter of Anaerobic Digestion

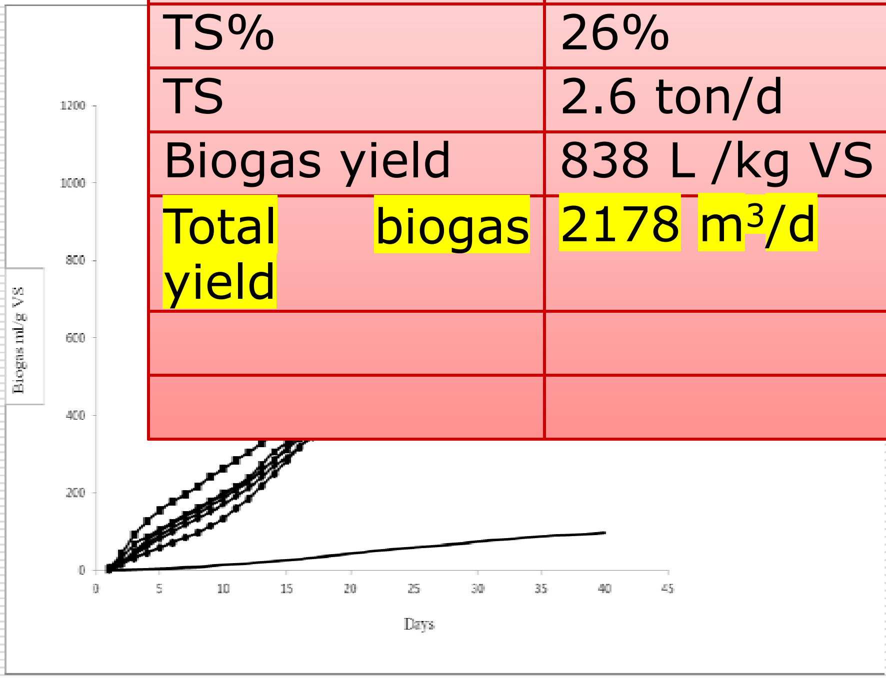
Hydraulic retention time	35 days
Volumetric loading (COD)	2.9 kg COD/m³d
Volume Anaerobic Digester	1,085 m³
Storage capacity Digester	7 days, 217 m³
Total volume Digester	1,300 m³

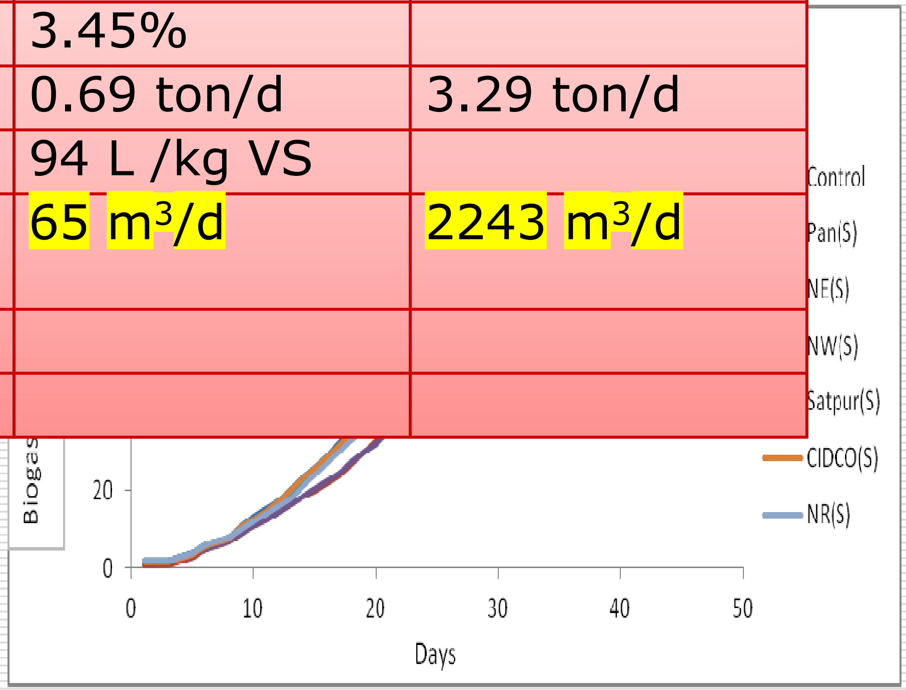
Physical and chemical composition of the food waste and septage

Parameters	Panchavati		NE		NW		Satpur		CIDCO		NR	
	Food	Septage	Food	Septage	Food	Septage	Food	Septage	Food	Septage	Food	Septage
pH	7.5	7.5-8	7.5	7.0-7.5	6.5	7.5	6.5	7.5	7.0-7.5	7	7	7
TS (%)	32.01	5.69	25.92	1.78	23.72	4.71	27.70	4.85	28.02	2.67	18.08	1.10
VS (%)	27.46	3.97	24.47	1.36	22.58	3.59	26.03	3.47	24.84	1.75	16.81	0.82
VS/TS	0.854	0.697	0.944	0.761	0.952	0.762	0.940	0.715	0.888	0.655	0.927	0.740
TN(%)	0.471	0.168	0.722	0.082	0.436	0.028	0.834	0.133	0.883	0.025	0.672	0.049
T NH3-N (mg/kg, L)	205	45.92	77	12.32	49	15.68	175	28	210	16.8	82.35294	22.4
COD (mg/kg, L)	240000	1800	341800	3240	348000	4280	320000	5040	345000	1280	344000	1720

Biogas production from food waste and septage

	Food waste	Septage	Total
Input	10 ton/d	20 ton/d	30 ton/d
TS%	26%	3.45%	
TS	2.6 ton/d	0.69 ton/d	3.29 ton/d
Biogas yield	838 L /kg VS	94 L /kg VS	
Total biogas yield	2178 m^3/d	65 m^3/d	2243 m^3/d





1:02	Food waste	Septage	Total input	Total output
Input (t/d)	10	20	30	30
Specific Dry Solids (TS) %	26.87	3.95		2.11
Dry Solids (tons)	2.69	0.79	3.48	0.63
Specific Organic Dry solids (VS) %	88.62	70.10		37.54
Organic dry solids (tons)	2.38	0.55	2.93	0.24
Degradability of Organic Solids (%)	[illegible]	[illegible]		
specific C[illegible]	[illegible]	[illegible]	[illegible]	[illegible]33.33
Biogas Yi[illegible]	[illegible]	[illegible]	[illegible]	[illegible]48.04
Specific G[illegible]	[illegible]	[illegible]	[illegible]	[illegible]48.83

Biogas yield (m^3/day) at different ratios of food waste and septage

	1:1	1.5:1	2:1	1:1.5	1:2
1st sampling	2272	2128	1555	2269	2248
2nd sampling	1372	1423	1415	1326	1643

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]al output
Input (t/[illegible]	[illegible]	[illegible]	[illegible]	30
Specific Dry Solids (TS) %	25.06	1.67	13.33	2.49
Dry Solids (tons)	2.51	0.33	2.84	0.75
Specific Organic Dry solids (VS) %	94.37	77.71	68.80	60.09
Organic dry solids (tons)	2.36	0.26	2.62	0.45
Degradability of Organic Solids (%)	94	77	68.8	
specific COD (mg/L)	250000 (mg/kg)	3400 (mg/L)		2560
Biogas Yield (m3/day)				1643.3
Specific Gas yield (methane (m3/day))				986.0

Conclusions

- We have to redesign the sewage System entirely
  - Separation at source (NoMix is not an option)
  - Separation at STP
- Up-concentration is a crucial step

  Several lines of up-concentration are under development
  - Management
  - Physical/chemical
  - Biological
- AD is a key process in the recovery of Energy and Nutrients
- We must work towards a “Zero Waste”-Water Technology both at decentralized and centralized level
- Thus we can truly deal with the environmental burdens of the water cycle

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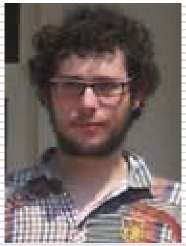

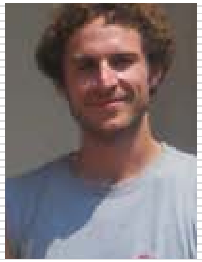

Meghanath Prabhu   Malte Esra Horvat   Linus Lorenz