Anaerobic Digestion-Pasteurization Latrine (ADPL): Sanitation in Multiple Contexts

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Duke UNIVERSITY

University of Eldoret
flame of knowledge and innovation

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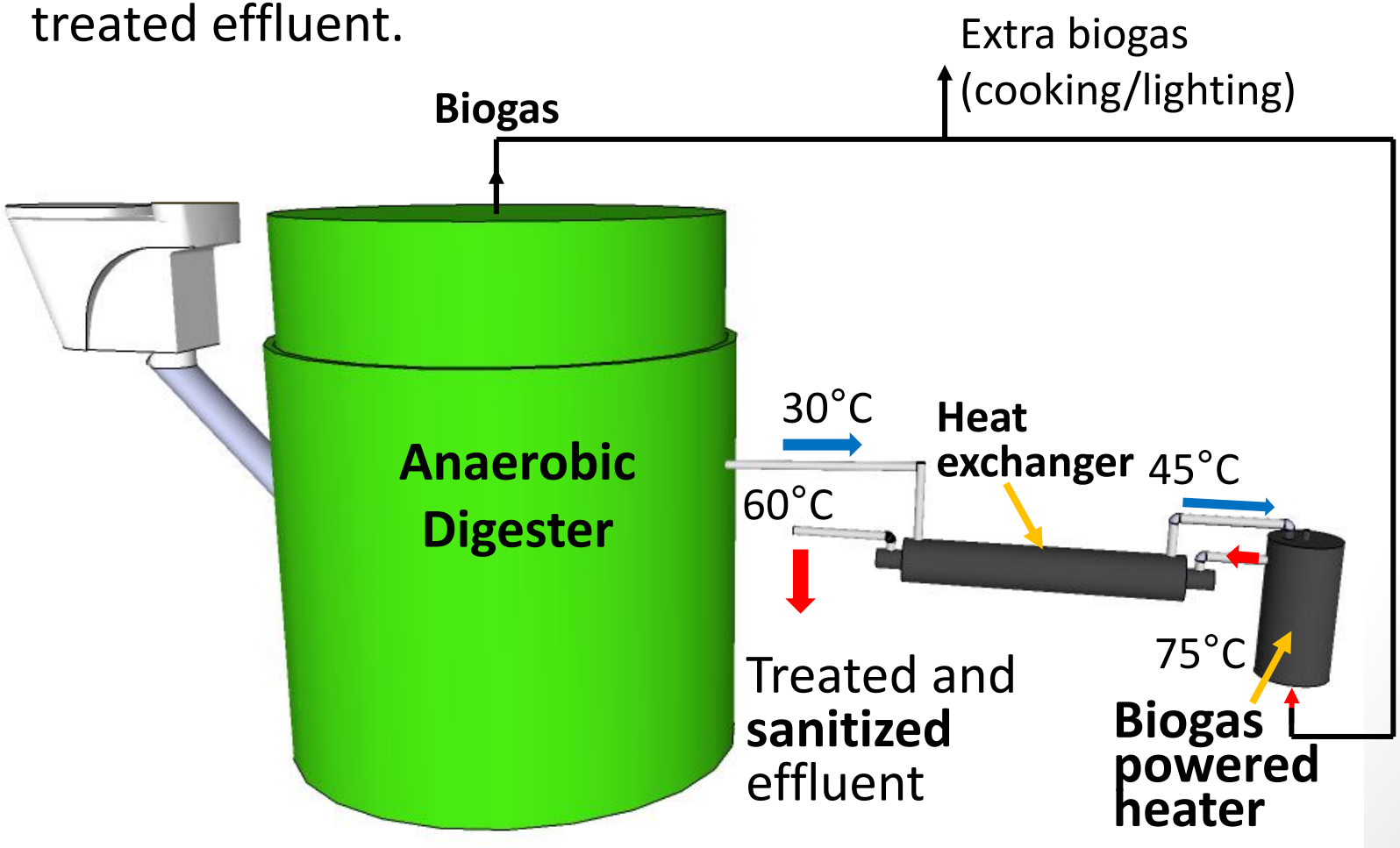
Eram Scientific

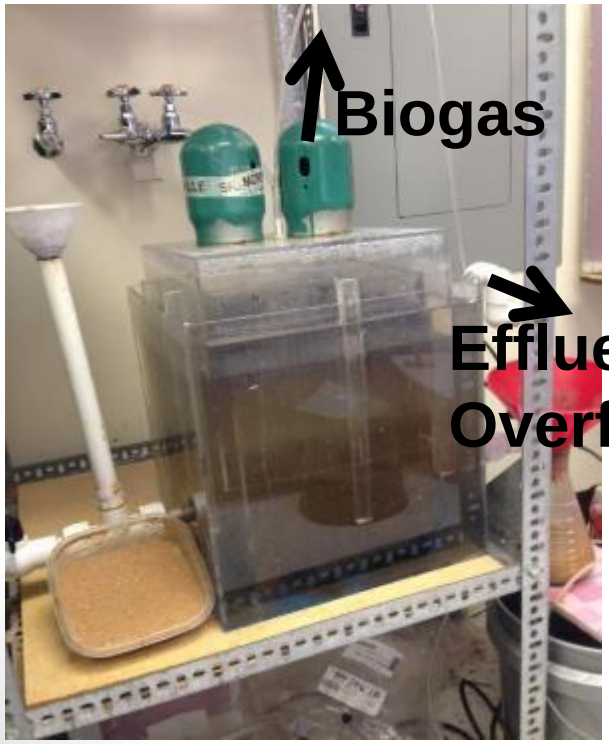
The ADPL: A Self-Sanitizing Toilet

Our objective is to develop a **self-contained** and **energy neutral** sanitation technology that relies on anaerobic digestion to generate biogas then used to **heat-sterilize** the treated effluent.



Anaerobic Digestion Results (Lab)

Load	OLR ($kg_{COD}/(m^3 d)$)	N in ($g/L_{influent}$)	Yield (m^3_{biogas}/kg_{COD})	CH_4 (%)	COD Removal (%)	NH_3-N out (g/L)	pH
Lower N	1.78	5.20	0.42	63.0	71.1	3.80	7.6
High N	1.80	7.20	0.33	64.5	61.9	4.98	8.1



Lab system: scaled-down 1/3 person

17 L vol.
HRT 40 days
T= 30 °C
No mixing

Daily feed:
300 mL urine/d
120 g feces/d
Intermittent feed

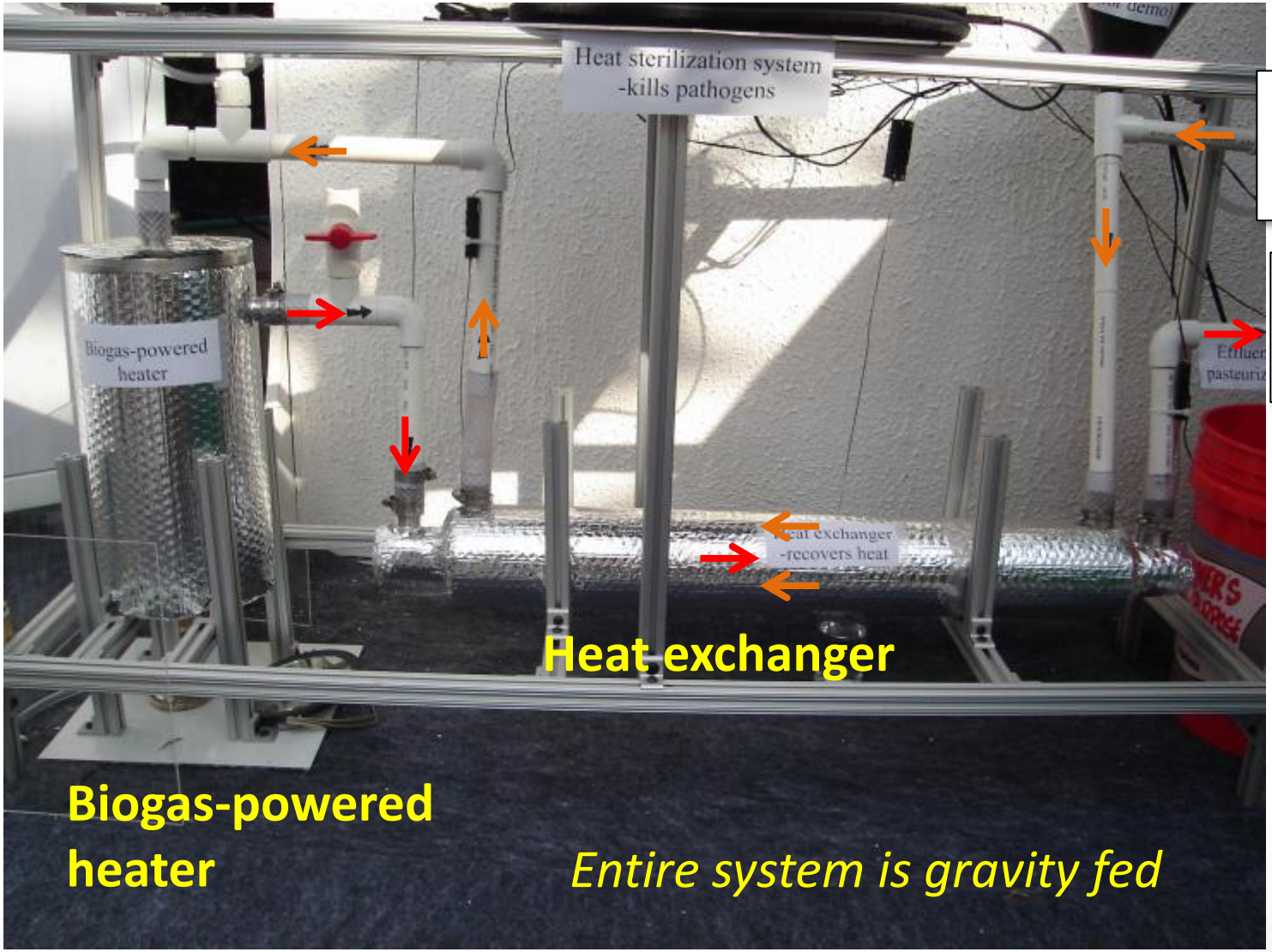
Per person biogas yield
42 $L_{biogas}/(p\ d)$ at lower N
33 $L_{biogas}/(p\ d)$ at high N

The Effluent is NOT Clean Water But it is Safe!

Lab unit (fed simulant)

Field systems

Pasteurization System

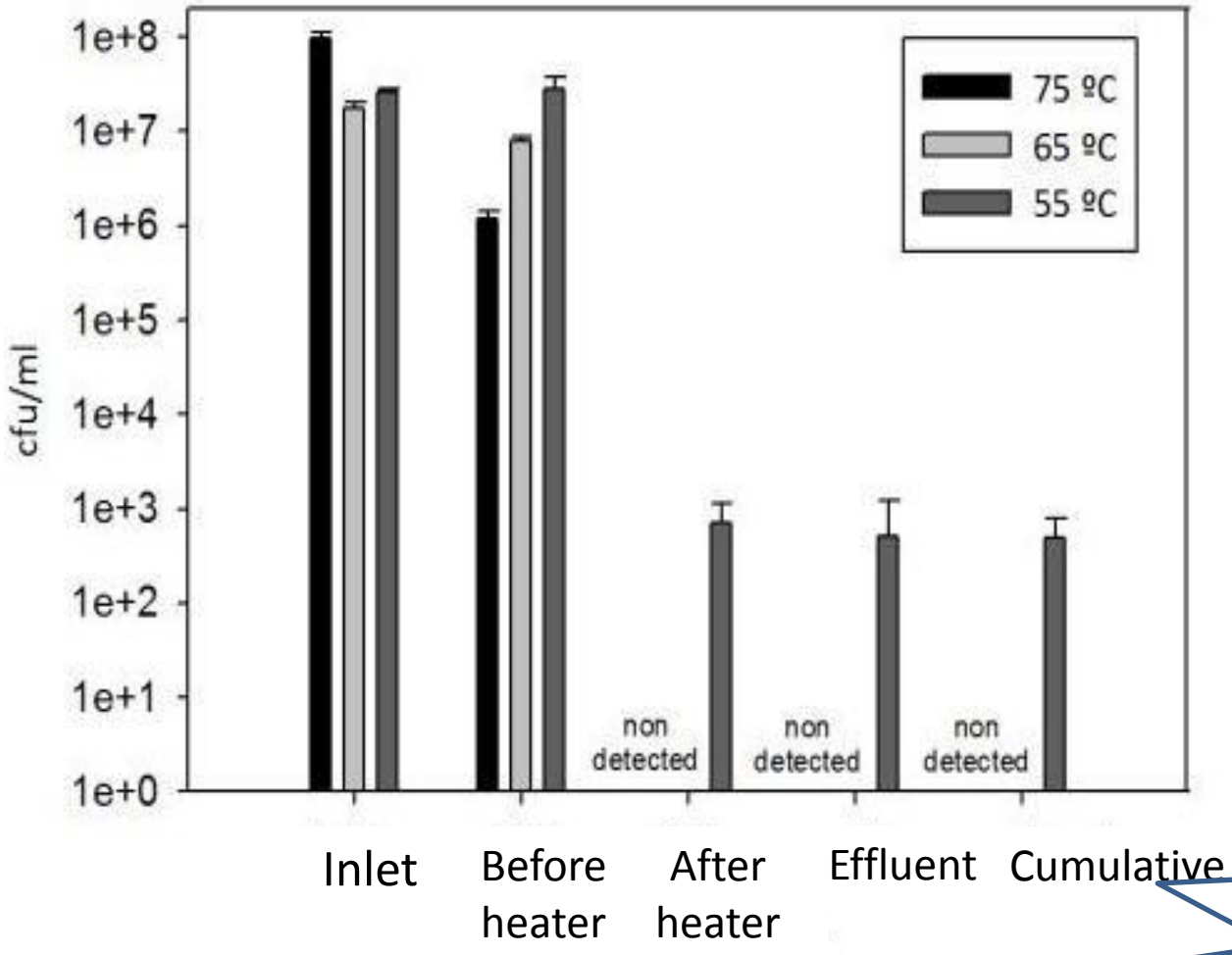


From digester

Treated effluent

Pasteurization Systems Made Locally In Eldoret

Pasteurization Results (Lab)



10 person model
Intermittent load:
0.6 L each hr (14 L/d)
E. Coli feed

Thermal Efficiency:
55-70%

Heat exchange:
14 °C

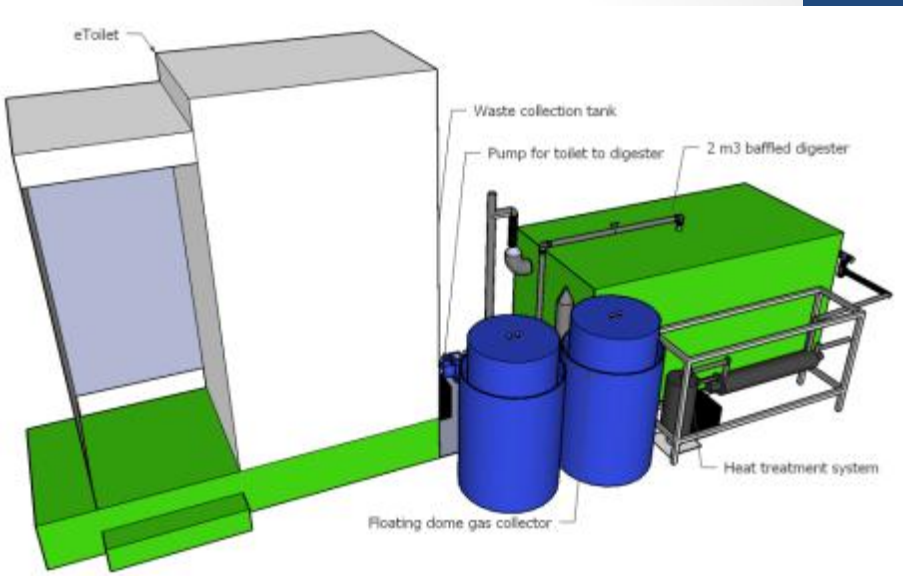
Biogas required:
230-280 L_{biogas}/d

65-75% of biogas produced required

Field Studies

3 systems each with 3 toilets, ~80 users total

1 system, 1 toilet, 10 users



With ERAM's eToilet, IITM campus 30-60 users

Kenya **Philippines** **India**

2013 | 2014

Eldoret, Kenya – 2013 - Present

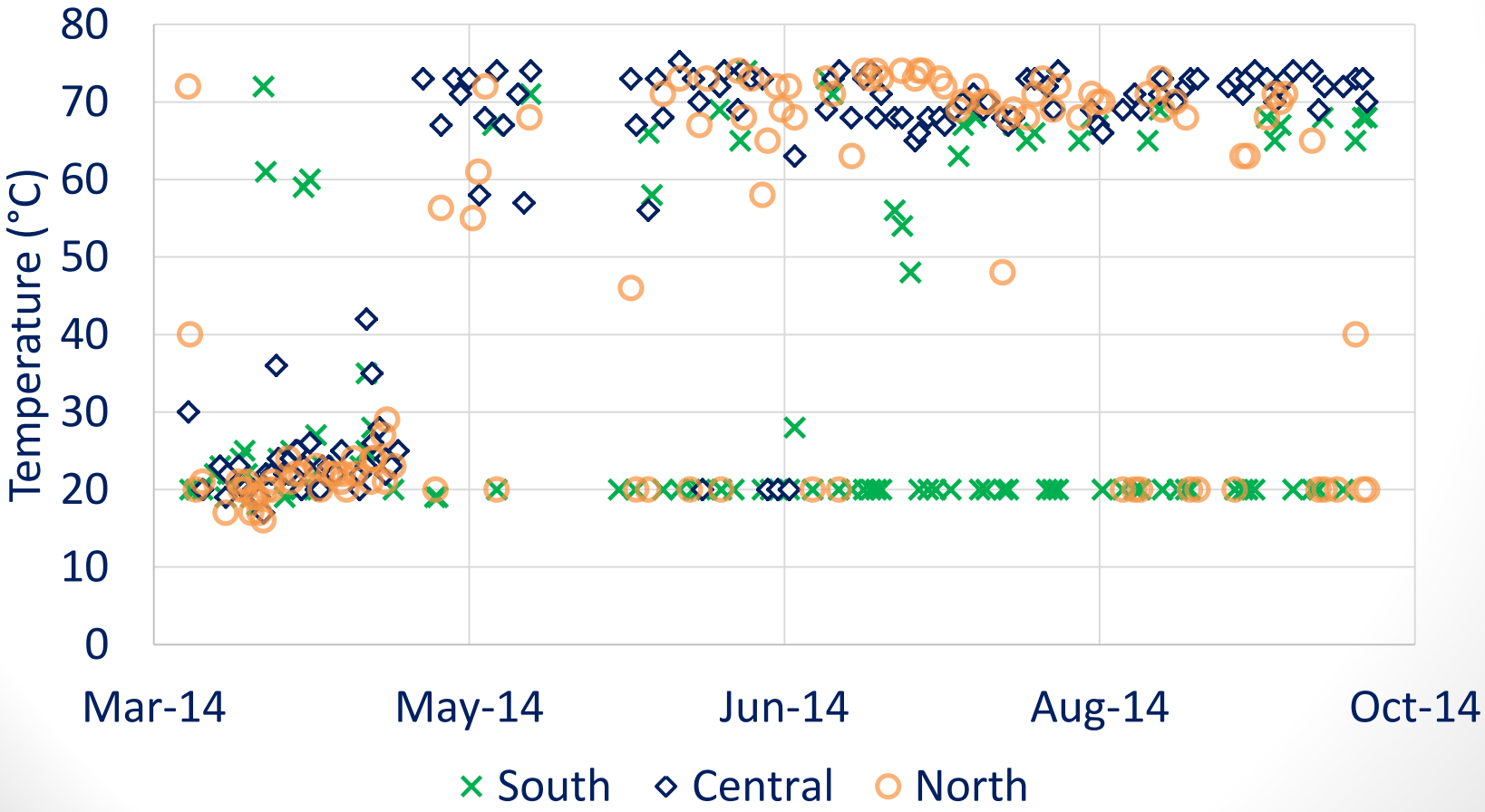
- 3 sites (17, 35, 24 residents)
- Squat-style latrines, wipers, 1 L pour flush
- Fully enclosed treatment system, 3x3 meter footprint
- SimGas 2m^3 floating dome digester
- Locally fabricated heating system
  - 16 g galvanized steel
  - 7.7 L heating tank
  - 9.4 L heat exchanger
- All gravity flow, no moving or externally powered parts

Kenya – Operation

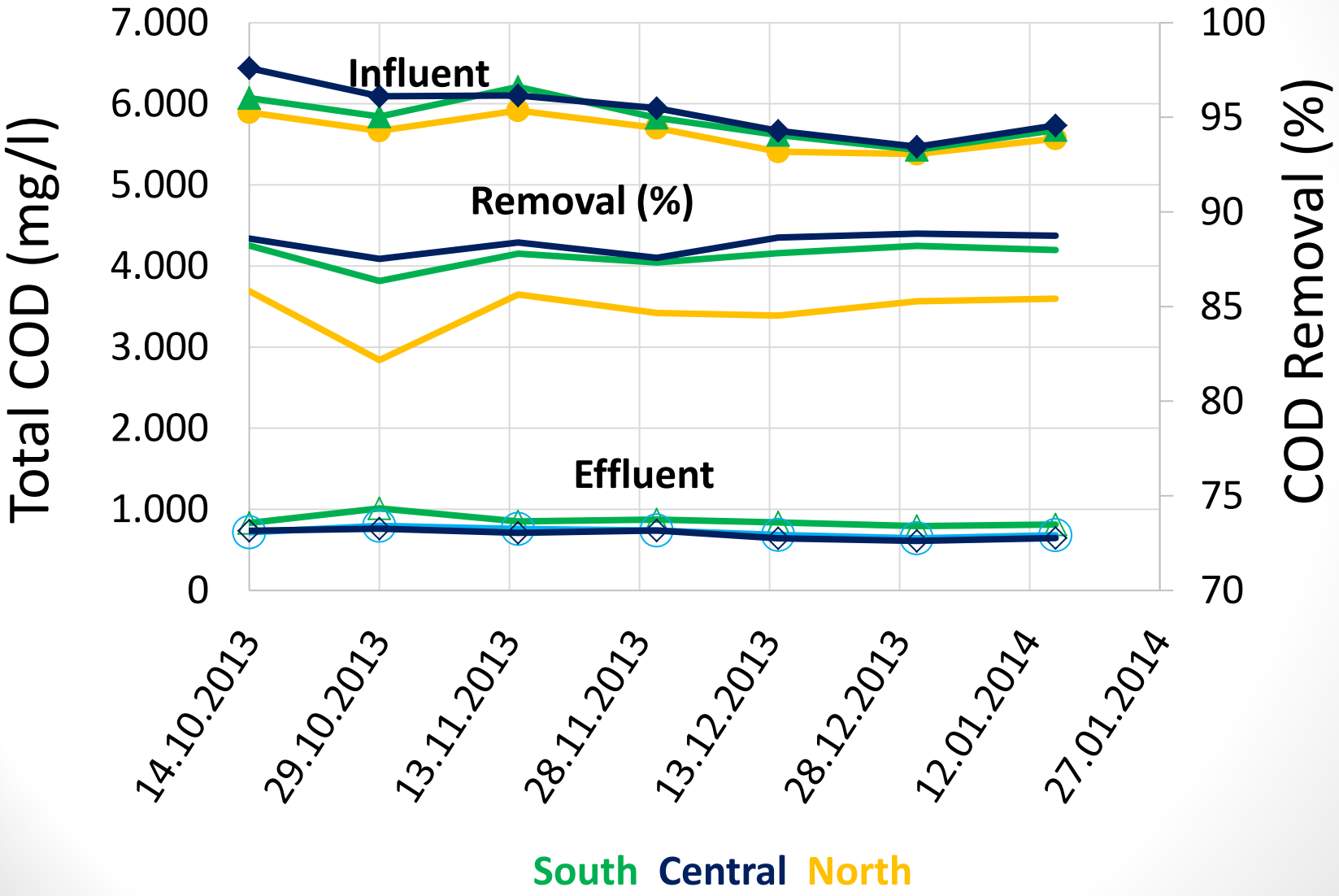
- Seeded with AD sludge from dairy farm
- Gradual acclimation period with manure and urea
- Semi-autonomous – daily checks for burner operation, clogs, and leaks
- User advantages – Less odor & flies, well-lit, resources
- User disadvantages – Height inconvenience, no solid waste disposal, pour flush
- Regular usage at Central results in consistent operation and rarely requires adjustments
- Irregular usage at South yields inconsistent gas production

Kenya – Results

- Avg. biogas production:
  325 L/d (South), 791 L/d (Central), 453 L/d (North)
- Cost: $1500 ($800 digester, $200 heat system, $500 toilet structure)

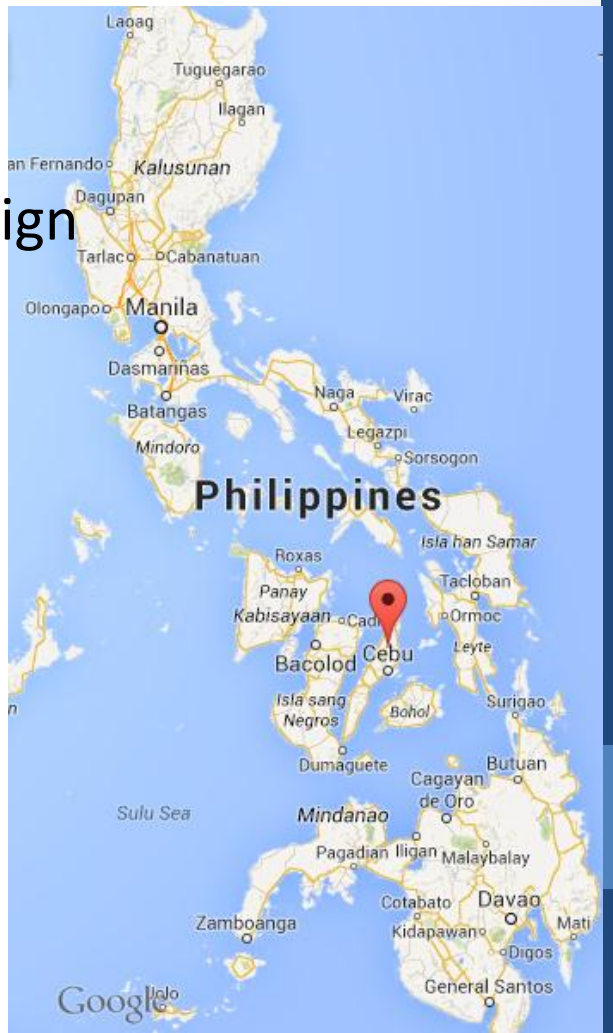


Kenya – Results



Philippines - June 2014

- **Toledo City, Cebu Island**
- Tesari Foundation – Project lead
  - We provide only technical advising
- Part of comprehensive sanitation campaign
- Rural community (barangay) without improved sanitation



Philippines – System

- Prototype for sanitation campaign
- Pour-flush (4 L) pedestal toilet
- Fully enclosed treatment system, 2x1.5 meter footprint
- 250 L drum digester with separate floating dome gas collector (100 L)
- Locally fabricated heating system
  - 10.8 L heating tank
  - 12 L heat exchanger
- All gravity flow, no moving or externally powered parts

Philippines – Operation & Results

- Seeded with septic tank sludge
- Users: 2-7 users per day
- Average biogas production: 18 L/d
- Heating operation: 3-4 hr/d
- pH: 7.9
- Cost: total $837 ($455 for treatment only)

- Usage rate too low to produce sufficient biogas
  - Only foundation employees have access
- Digester will be supplemented with swine manure

India – July 2014: ADPL v2

- With Eram Scientific – eToilet, construction & maintenance
- IIT-Madras – operation & monitoring
- IIT-Madras Campus, Chennai, India (Prof. L. Philip)
  - Women's dormitory

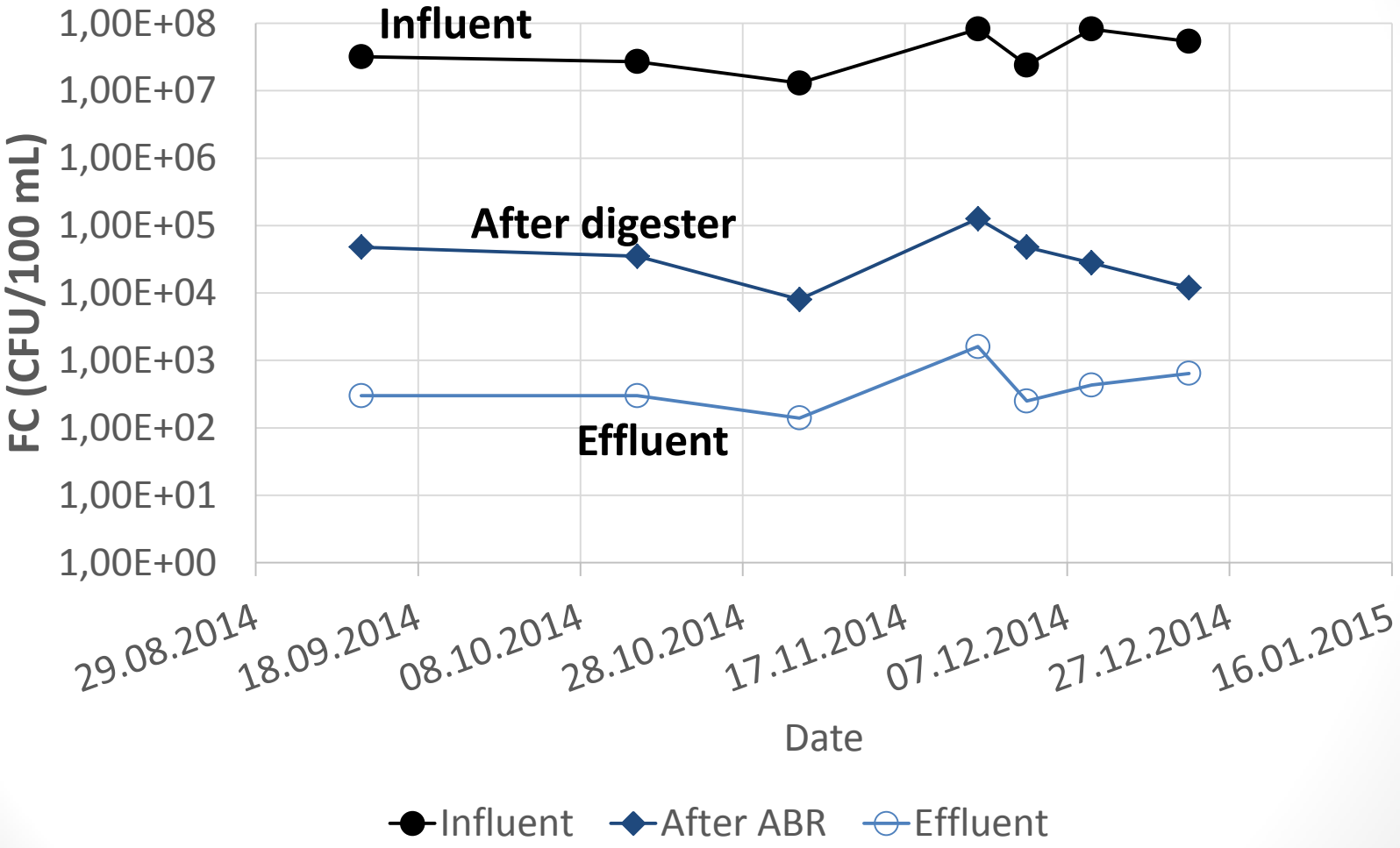
India – System

- Feed via 12 VDC macerator pump (same power supply as eToilet)
- ALFA 2m^3 baffled anaerobic digester
- 150 L floating dome gas collectors (2x)
- US-made heating system
  - Stainless steel 304
  - 10.8 L heating tank
  - 12 L heat exchanger
- Arduino controlled automation for pump and heating operation

India – Operation & Results

- Seeded with AD sludge from municipal WWTP
- Gradual acclimation with campus sewage
- Usage: 50-75 p/d
  - Unexpected barriers to usage by residents
- Average COD removal: 87.5%
- Average TSS removal: 95.4%
- pH: 6.9
- Cost: $4,100*
  - *Heating system came from previous project in the US, accounted for $1,500
  - Controls system: $120

India – Operation & Results Pathogen Control



Conclusions & Future Work

- The ADPL works, it is a simple and economical system
- With proper usage, ADPLs can run autonomously, consistently maintaining temperatures between 65-75 °C and producing more biogas than required
- The concept is scalable and replicable
- We are learning from ADPL deployment in 3 countries

Current and future focus:

- Optimize biogas production and effluent quality
- Optimized design
- Demonstration at greater scale
- Explore sanitation as a business, partnerships with sanitation service organizations

Backup slides/images

System Cost Kenya

Description	Quantity	Total Cost	Cost/System
Gesi2000 Biodigester	3	$2421*	$807
Digester connections	3	$283	$94
Heating system	3	$289	$97
Latrine	3	$1474	$491
Total		**$4632**	**$1544†**

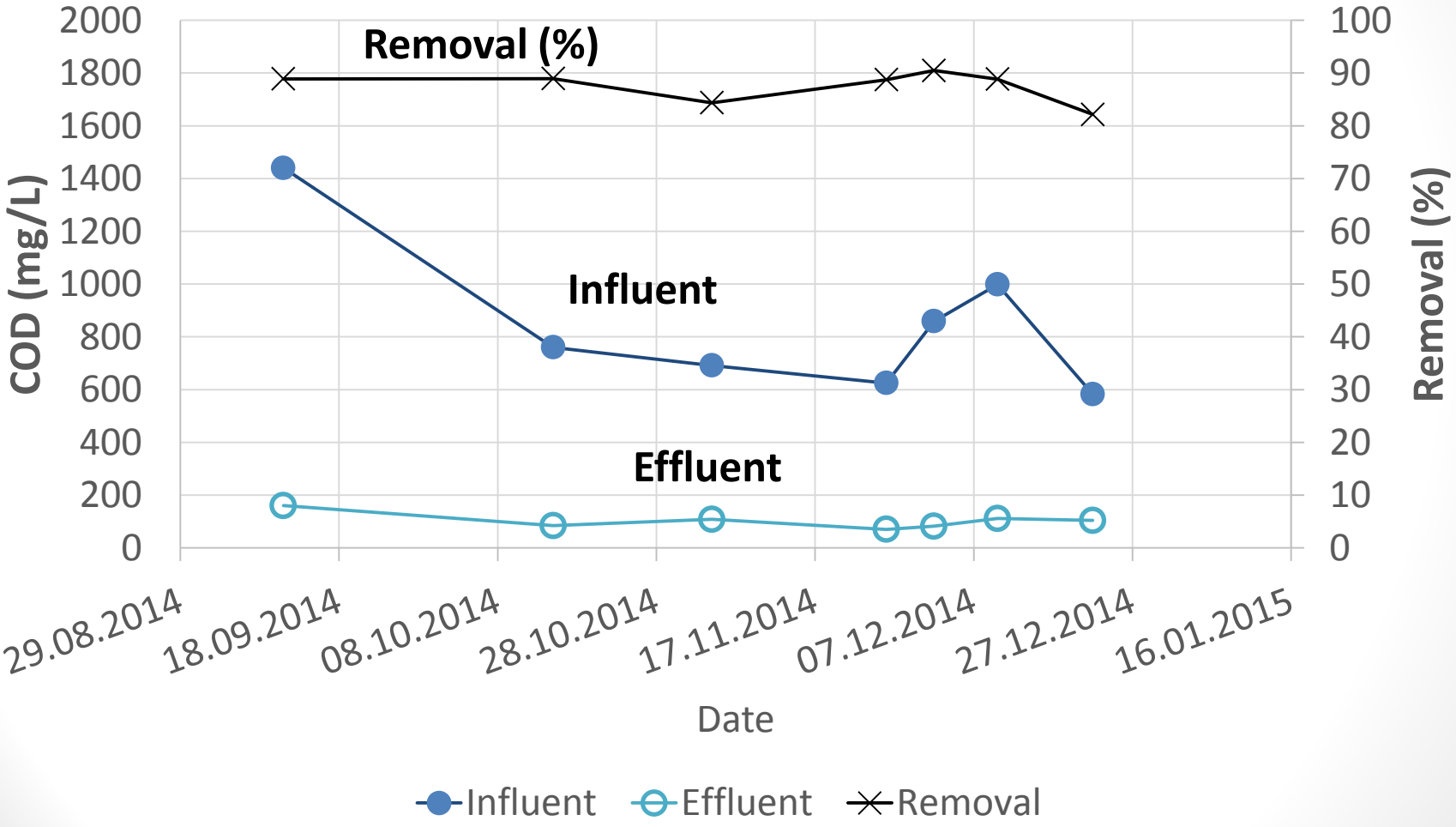
†With a conservative estimate of 5 year lifespan and average of 25 users per system, system cost = **$0.03/p/d**

*Gesi2000 Biodigester was donated by SimGas.

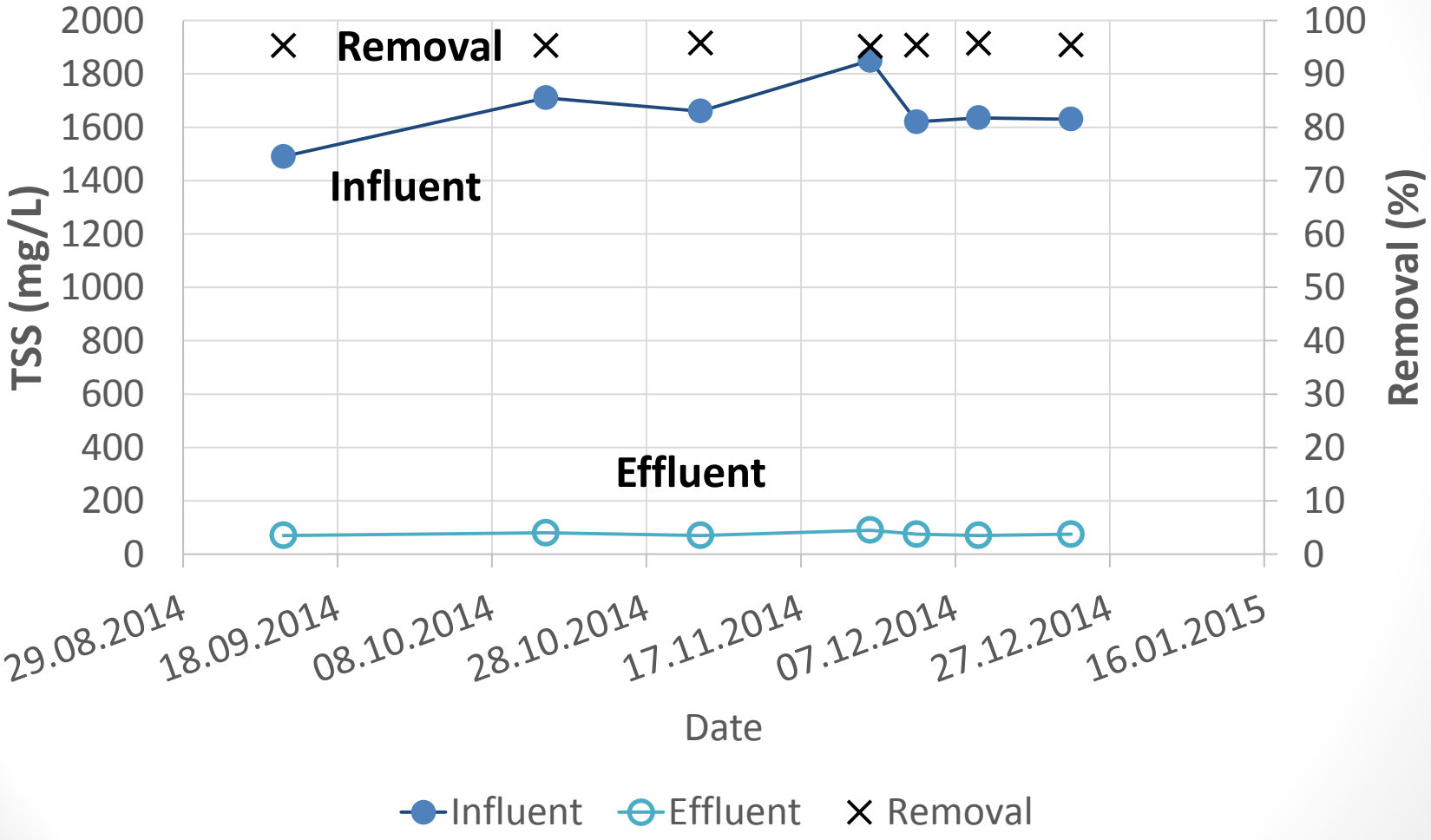
Kenya (June 2013)

- University of Eldoret – Operation & Monitoring
- Wataalamu Repair & Mechanics – Construction & Maintenance
- Sogomo Estate, Eldoret, Kenya
  - Plots are 1/8 acre, municipal water tap, borehole well, shared pit latrines
- 3 sites (17, 35, 24 residents)
- Squat-style latrines, wipers

India – Operation & Results



India – Operation & Results



Toilet & Digester

- Prefabricated plastic latrine labs
  - 2 sites with standard slabs
  - 1 site with urine diversion
- SimGas Gesi2000 floating dome digester
- <1L pour flush

Heating system

- Fabricated in local labor market
  - 16 gage galvanized steel and welded seams
- Heating tank – Left
  - 7.7 L
- Heat exchanger – Right
  - 9.4 L

Complete System

- Acclimated seed sludge and gradual loading
- In use – plots with 17, 24, and 35 residents
- Fully enclosed treatment system, 3x3 meter footprint
- User advantages – Less odor & flies, well-lit, resources
- Disadvantages – Height inconvenience, solid waste, pour flush

Philippines – with Tesari Foundation

Location on Cebu Island

Current “toilet” used

India – with ERAM and IIT Madras

eToilet

ADPL treatment system