In Context of Technology Transfer
Sharing Research Experience on Anaerobic Digestion

Renewable and Sustainable Energy Laboratory, Kathmandu University, Nepal

"Research transforms money into knowledge … technology transfer transforms knowledge into money." Geoffrey Nicholson

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27/09/2020

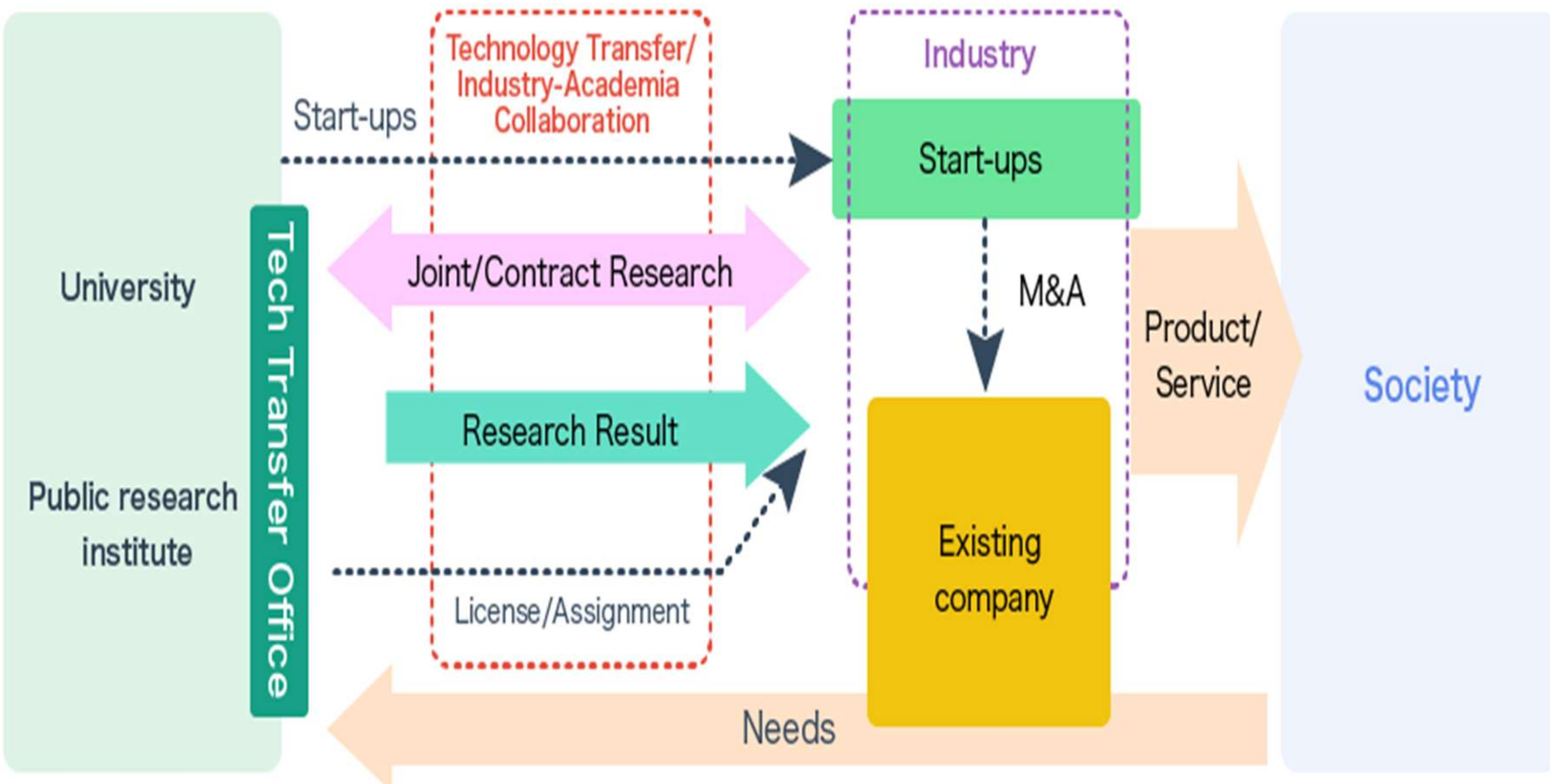
Contents

Technology Transfer

- **Technology transfer (TT)** refers to the process of conveying results stemming from scientific and technological research to the market place and to wider society, along with associated skills and procedures, and is as such an intrinsic part of the technological innovation process.

- Technology transfer covers the complex value chain linking research to its eventual societal deployment.

Technology Transfer from University

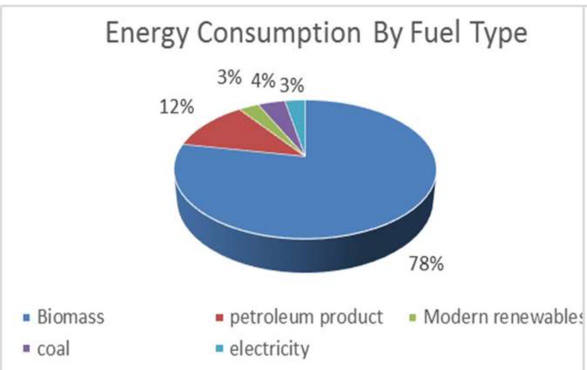


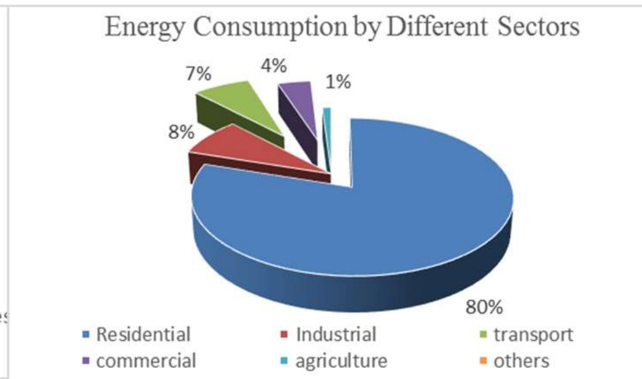
Source: https://unitt.jp/en/tlo/

Sharing Biogas Research Experience at Kathmandu University

Overall Energy Scenario

- **Energy crisis, biomass energy covers around 78% of which 80% of energy consumes in residential sector, mainly cooking**
- **Burning of biomass causes INDOOR air pollution (24,000 death/year), inefficient outdated technology, pressure on forest, workload to women and children**





Source: Economic Survey, *Shekhar Sharma 2018, Kantipur daily, internet image*

Waste Water Management Problem in Nepal

Wastewater generation: >800 MLD

(Dangolet.al.,2017)

Source: Internet image

Solid Waste Problem in Nepal

Average Municipal Solid Waste Generation 0.32 kg per capita

Total Solid Waste Generation in Urban Areas 631,000 tons per year

About 60% Organic Fraction

No Proper Management

Source: Internet Image

Manure Management Problem in Nepal

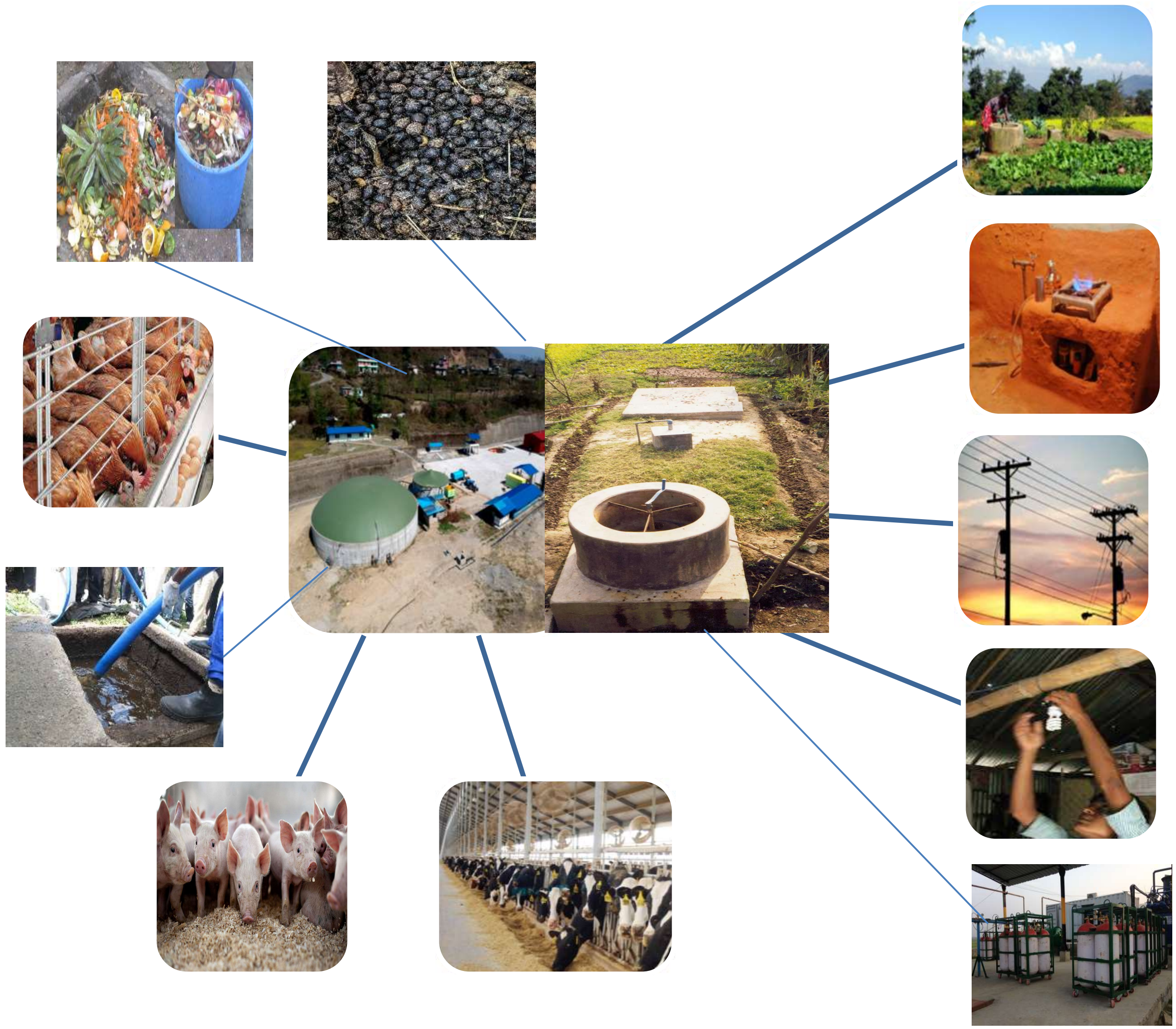
Livestock (cow, buffalo) number is 12.5 million, Manure Generation 164 thousand tons per day

Number of Chickens is about 68 million, Poultry Droppings Generation 8,200 tons per day

Numbers of Goats is 11 million and droppings 6,600 tons per day

Source: Internet Image

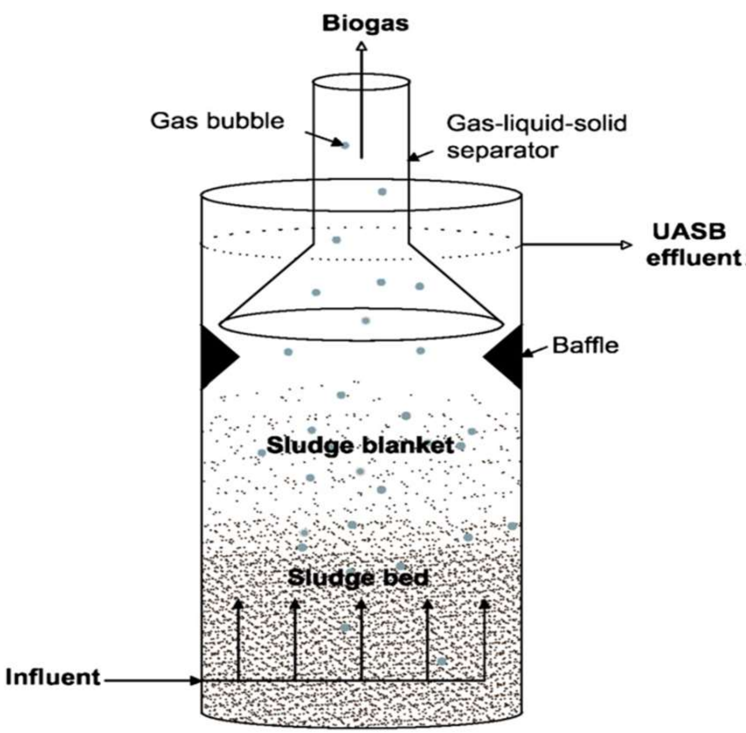
Biogas Feedstock and End Uses



Experience on High Rate Anaerobic Digestion of Wastewater

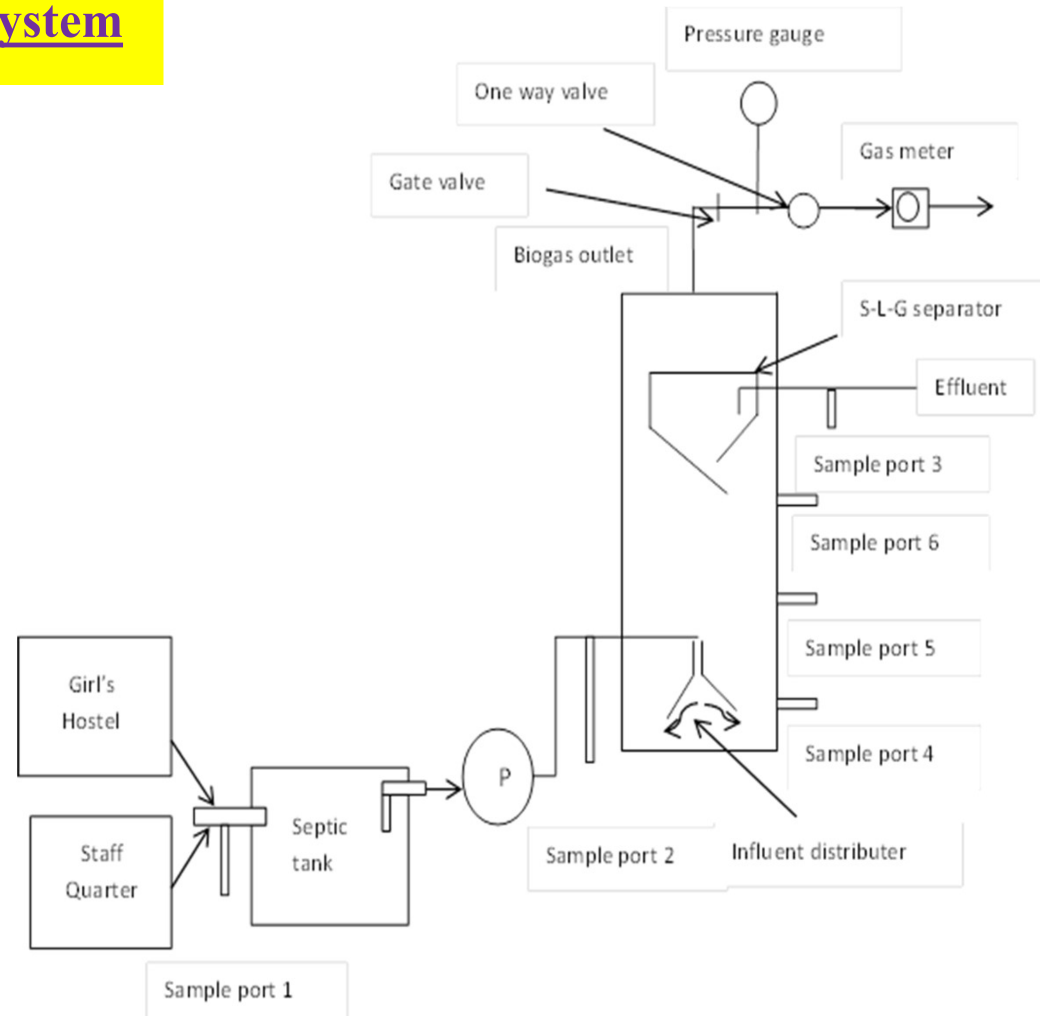
High Rate AD of Domestic Wastewater

Septic Tank –UASB Combined System



Schematic representation of UASB reactor.

(Chong et al., 2012)



Schematics of ST-UASB Pilot Plant

High Rate AD

UASB System

- Septic tank working volume 13.5 m^3
- 18 h HRT
- Generate feed solution for UASB

- UASB reactors 250 L (height 1 m and diameter 0.56 m)
- 550 L (height 1.7 m and diameter 0.64 m)

High Rate AD - UASB operational parameters

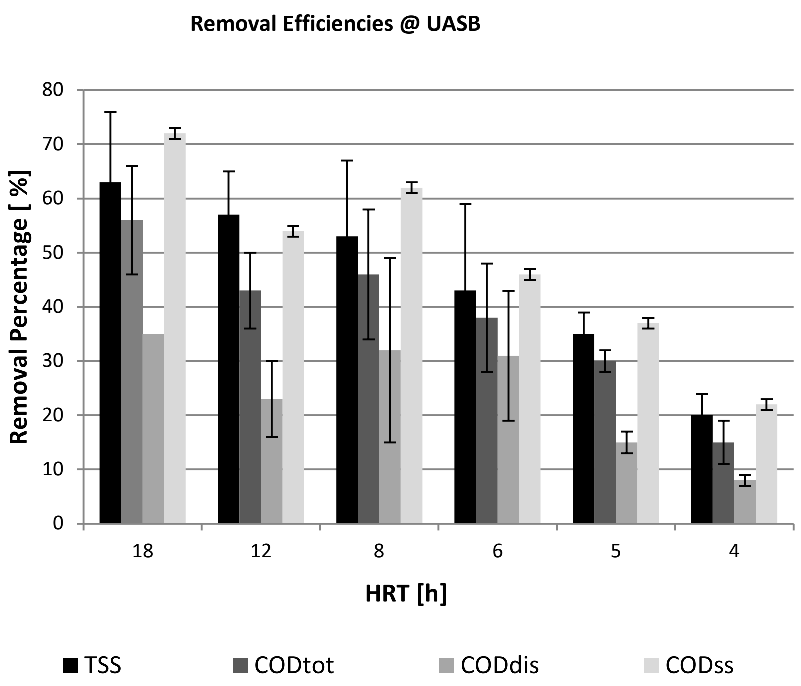
Reactor	HRT	Vup, m/h	Q, m3/d	CODinf, mg/L	OLR, kgCOD/(m^3.d)	Operation time (Month)
250 L	10 d	~ 1.25	0.02	610 (212)	0.06	~ 1.5
	4 d	~ 1.25	0.05	513 (226)	0.128	~ 3
	1 d	~ 1.25	0.2	524 (290)	0.524	~ 2
	18 h	~ 1.25	0.267	750 (499)	1	~ 1.5
	12 h	~ 1.25	0.4	863 (117)	1.72	~ 1
	8 h	~ 1.25	0.6	742 (204)	2.23	~ 1.5
	6 h	~ 1.25	0.8	803 (159)	3.21	~ 2
	5 h	~ 1.25	0.96	618 (107)	2.96	~ 1
	4 h	~ 1.25	1.2	686 (59)	4.11	~ 1
550 L	4 d	~ 1.25	0.12	456 (210)	0.113	~ 3
	1 d	~ 1.25	0.47	496 (169)	0.496	~ 2

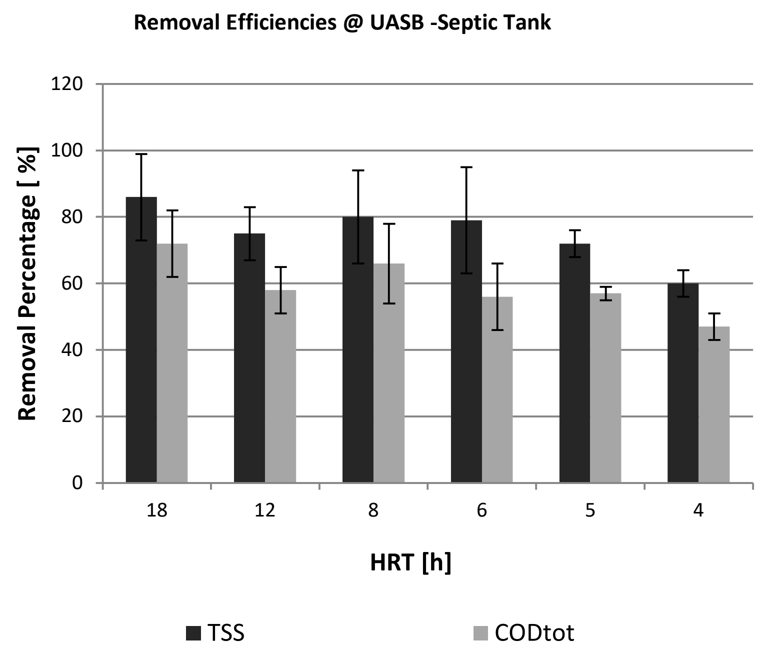
High Rate AD– Results Overview

- **Influence of Height of Reactor and Start-up History – Not much!**

Load Limit of UASB Reactor:

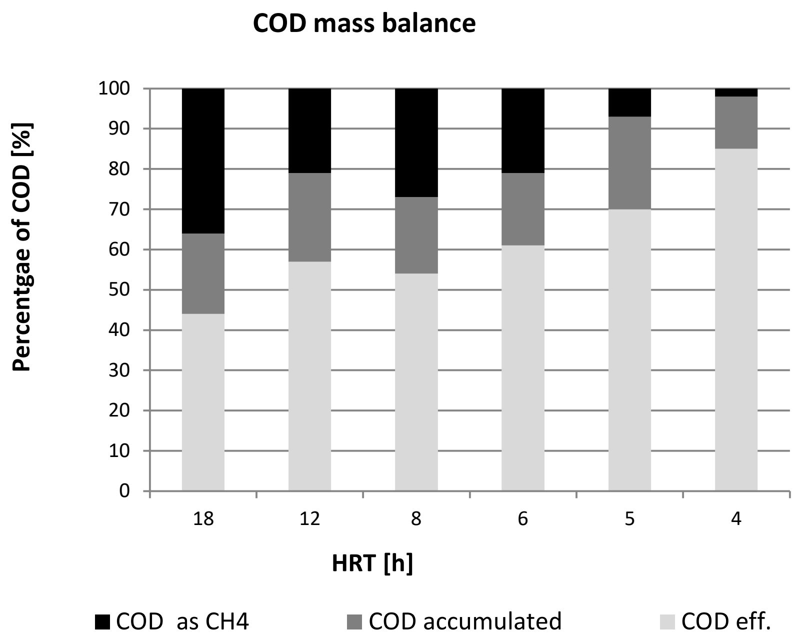
- **UASB Removal efficiencies: TSS: 44-63%, COD_T : 39 -56% at HRT ≤ 6 h.**
- **ST-UASB Combined System: TSS: 75-86%, COD_T: 56-72% at HRT ≥ 6 h.**
- **ST-UASB combined system: TSS: 79% , COD_T: 55% at 6h HRT at an average ambient air temperature of 20 °C.**

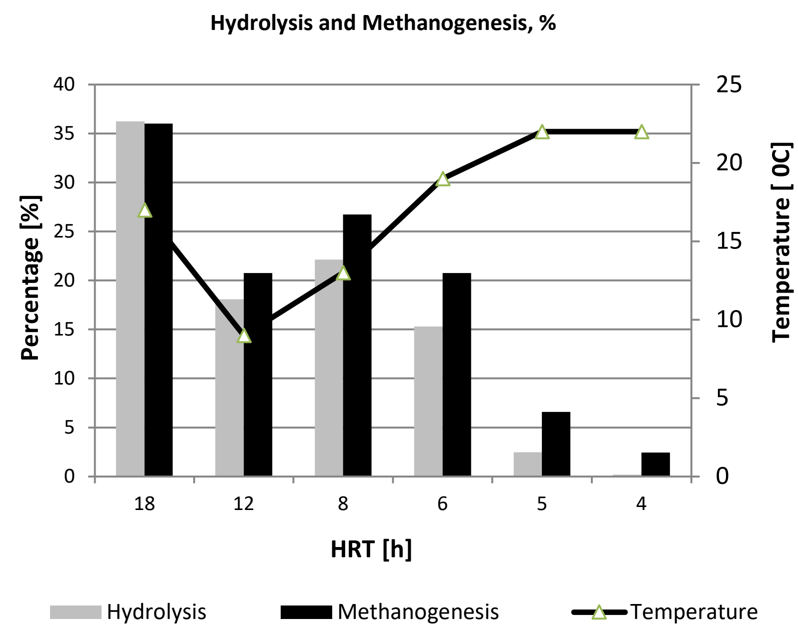




Lohani et al., 2015

High Rate AD –Methane Recovery





- **15% of influent COD accumulated**
- **25-35% was recovered as methane and the rest was released with the effluent.**
- **UASB performance dropped at HRT< 6 h (3 kgCOD/m3.d) even at high temperature,**
- **Relatively stable performance was established ≥ 6 h HRT and was a lower limit for this pilot test study.**
- **250 L UASB Reactor seems sufficient for wastewater treatment for a single Nepali family (5/6 members).**

Lohani et al., 2015

Anaerobic Digestion Modelling (ADM 1) on UASB

ADM 1

- **The International Water Association (IWA) task force has developed the Anaerobic Digestion Model Number 1 (ADM1) to serve as a general platform for anaerobic digestion modelling**

- **ADM1 is implemented at AQUASIM 2.1 to model and simulate UASB and ST-UASB reactor at mesophilic and low temperature condition.**

(Batstone et al., 2002)

Biochemical Processes in ADM1

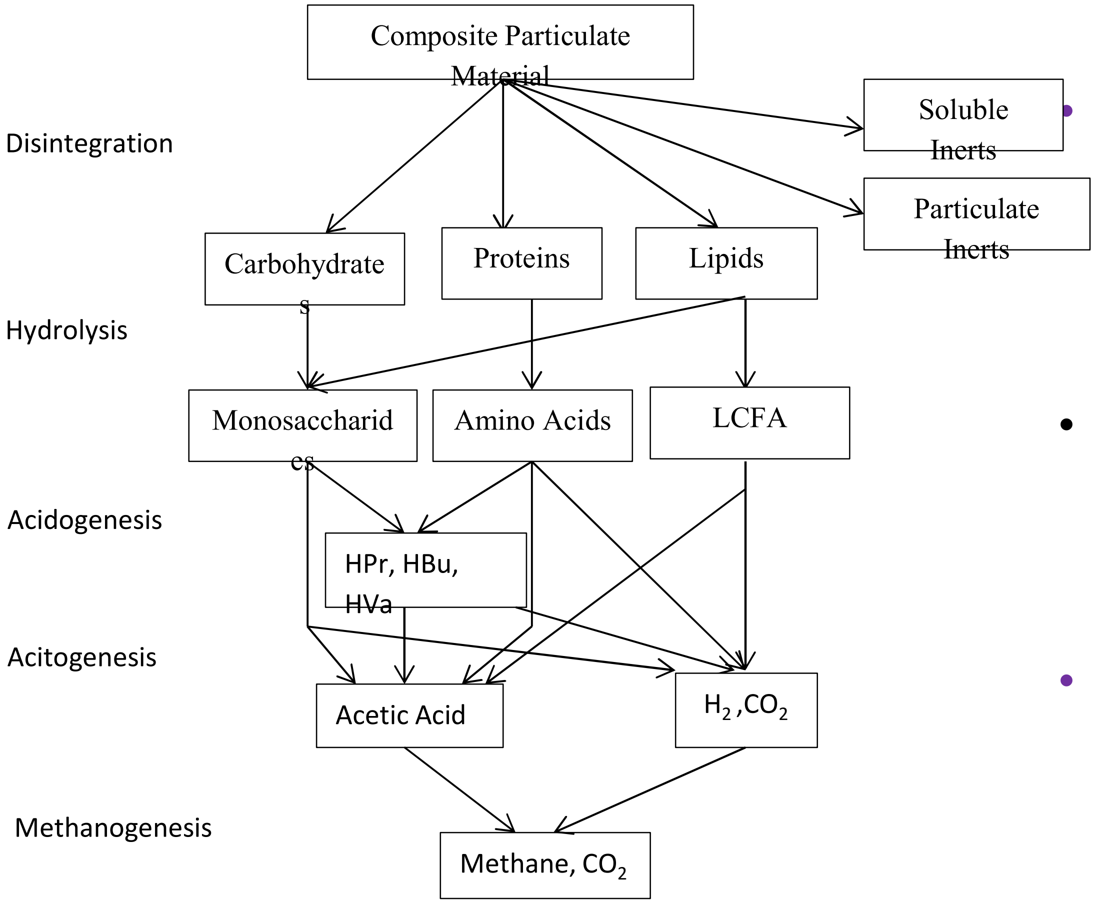


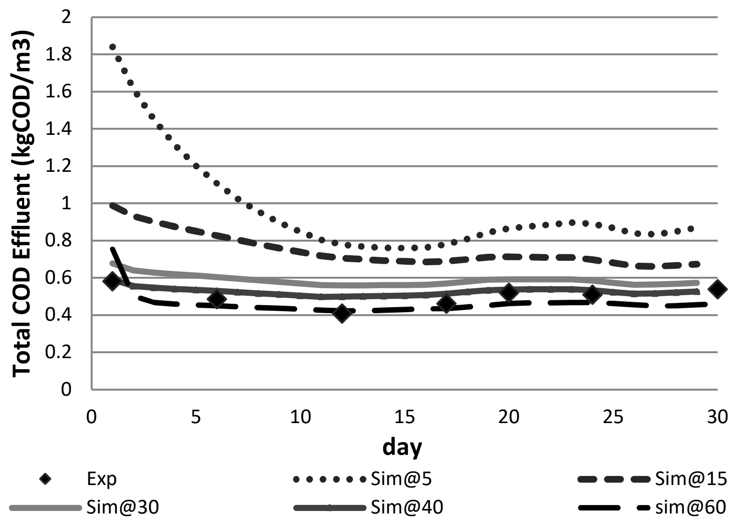
Figure 3: COD mass flow for a particulate composite in ADM1. Propionic acid (HPr), Butyric acid (HBu) and Valeric acid (HVa) are grouped for simplicity (Adapted from Batstone et al, 2002)

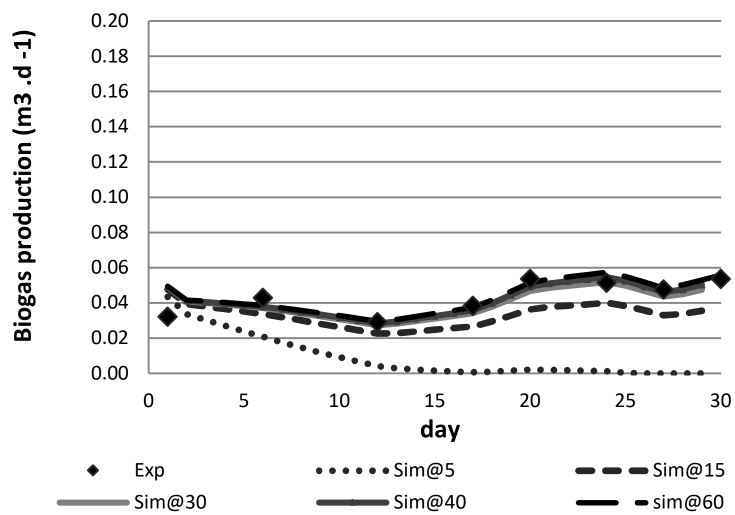
- **ADM1 involves biochemical processes for substrate disintegration, hydrolysis, acidogenesis, acetogenesis and methanogenesis[20].**
- **Disintegration and hydrolysis processes are extracellular solubilization steps and are described by first order kinetics.**
- **The acidogenesis, acetogenesis and methanogenesis processes are intracellular biochemical reactions and are described by substrate-based uptake Monod-type kinetics.**

(Batstone et al., 2002)

ADM1 with Standard Kinetics

Model Calibration (12h HRT)



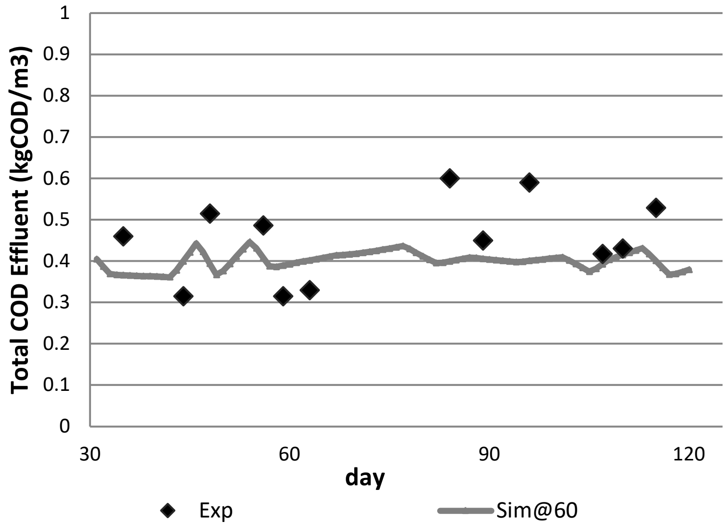


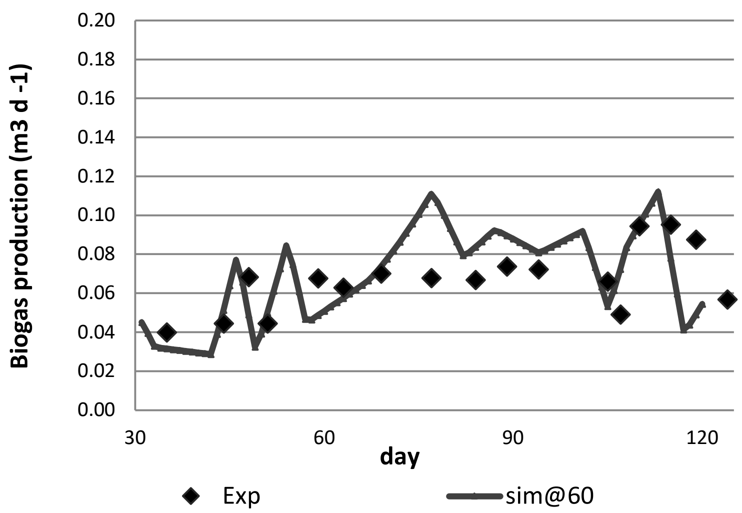
SRT strongly affects AD process simulations.

Quite reasonable fit of data at given influent characteristics and 60 d SRT during calibration of this model.

Lohani et al., 2016

Model Verification (8 & 6 h HRT)





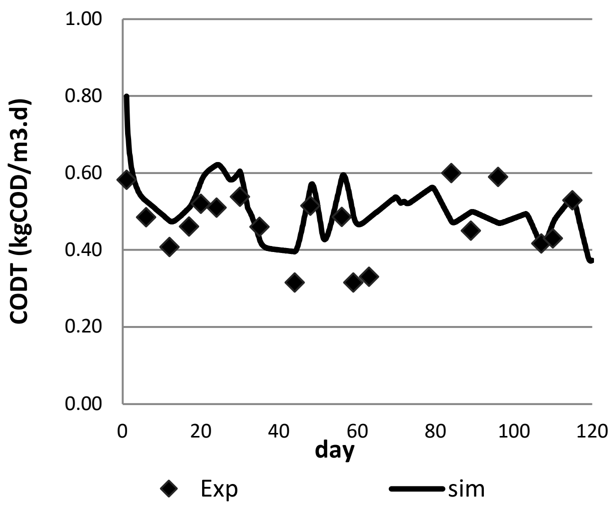
Average experimental results were within 10-15% of the simulated ones. implying that the model could simulate reality reasonably well

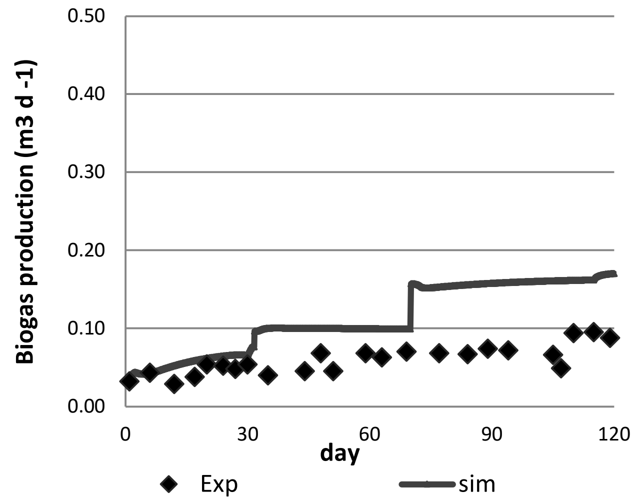
Calibrated model applied to higher load conditions also show reasonable fit of the model to the pilot test data.

Lohani et al., 2016

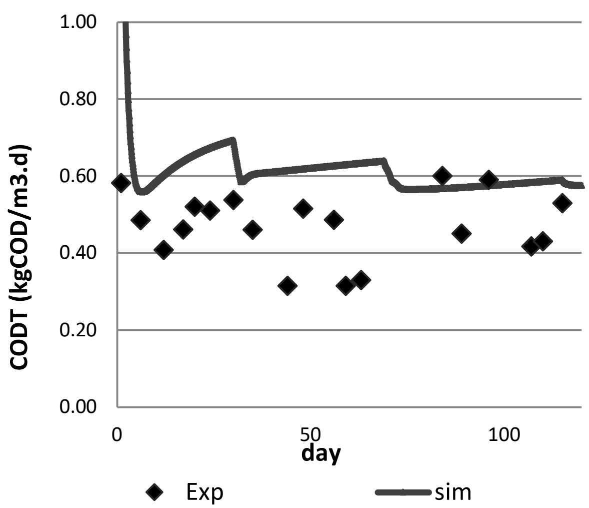
Modelling Temperature Effects

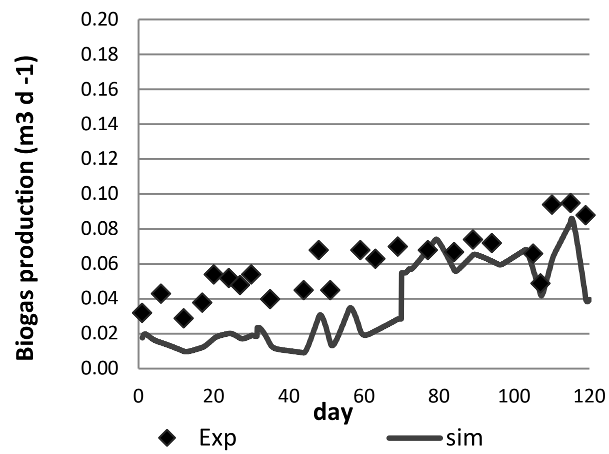
UASB Reactor





ST-UASB Reactor



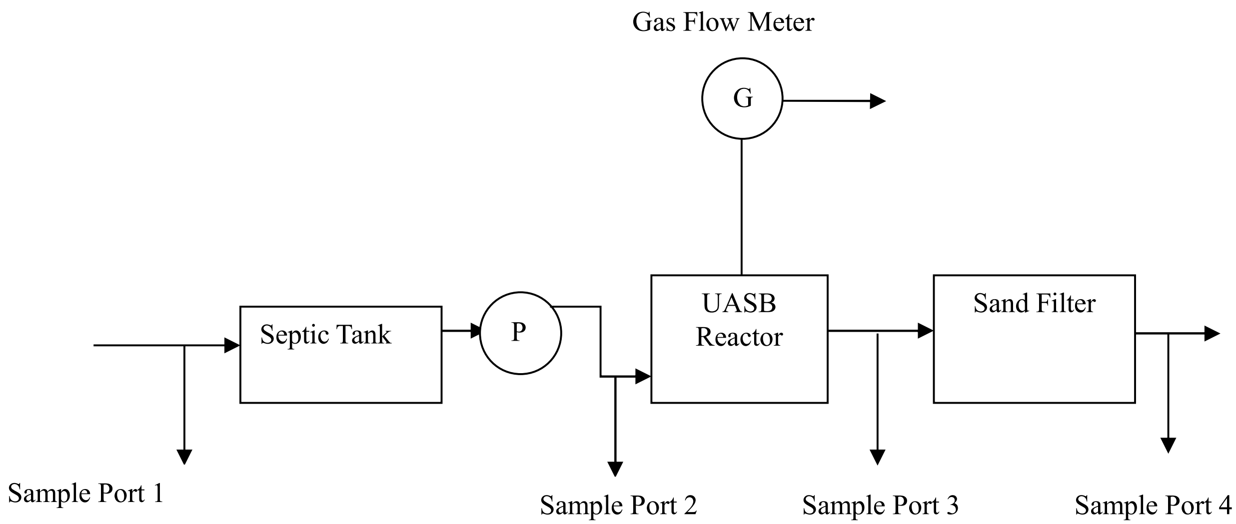


COD removal is reasonably simulated by the UASB model but biogas production is about 5 to 15% overestimated.

COD removal and biogas production both are under-estimated by the ST-UASB model but the simulation can be adequate for preliminary design purposes.

Visual Observation

ST-USB and Filtration Combined System

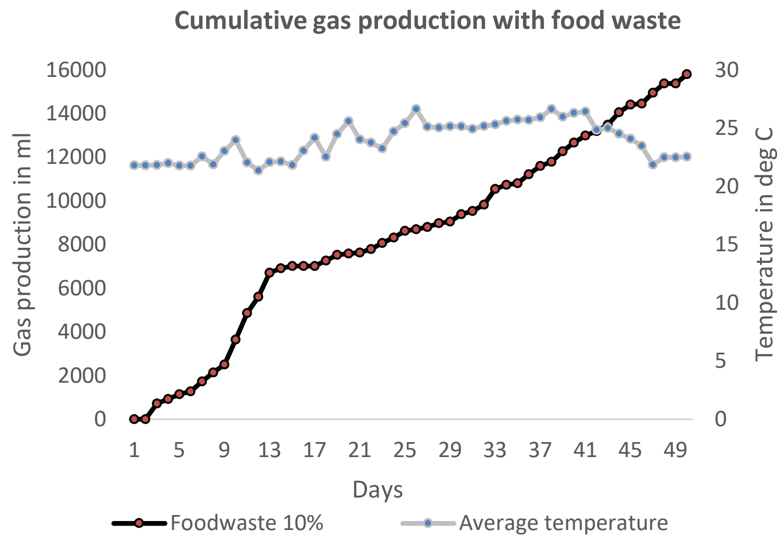


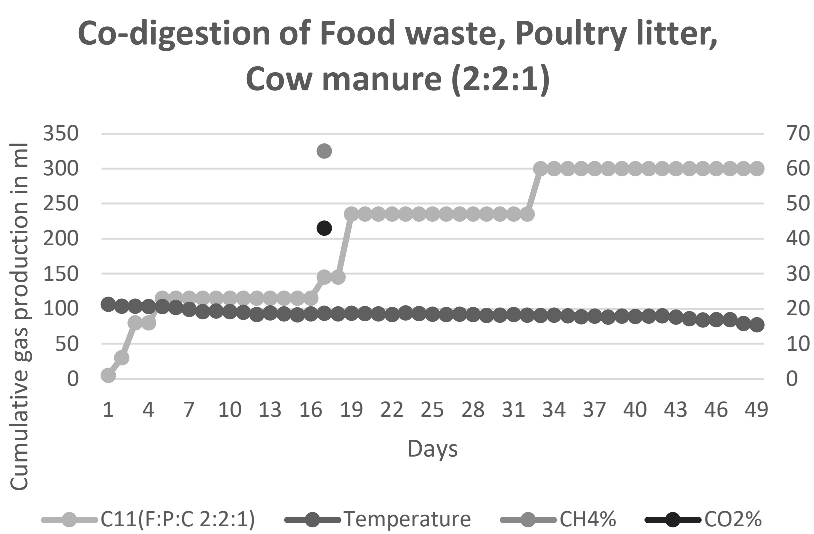
Parameters	Septic tank Removal Efficiency, %	UASB Removal Efficiency, %	Septic tank - UASB Removal Efficiency, %	Sand filter Removal Efficiency, %	UASB-Sand filter Removal Efficiency, %	Septic tank-UASB-Sand Rev.Removal Efficiency, %
TSS	62 (17)	45(13)	79 (14)	69 (11)	83 (8)	93 (10)
COD	31 (14)	38 (18)	56 (8)	71 (13)	82 (10)	87 (8)
FC	31	78	85	55	84	93

Anaerobic Digestion/Co-digestion of Food Waste

Research Experience on Co-digestion of Food Waste - Ongoing

Mono and Co-digestion of Food Waste

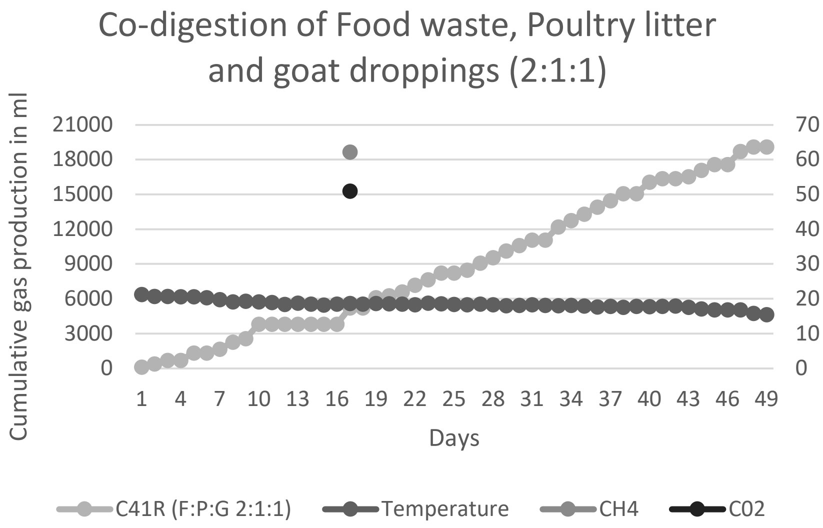


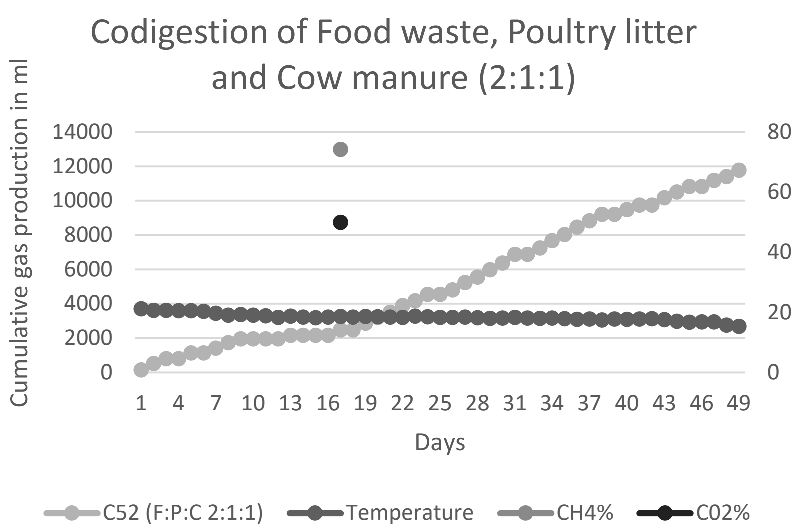


Food Waste: OLR 1 gVS/L.d, 50d HRT and gas yield 135 L/gVS, Methane content maximum 15%. Acidic and no stable methanogenic process.

OLR 1 gVS/L.d, 60d HRT, average temperature range 15-20 °C, Biogas yield 33 L/gVS, Methane content >50%, high share of poultry litter and low temperature might cause ammonium inhibition

Co-digestion of Food Waste



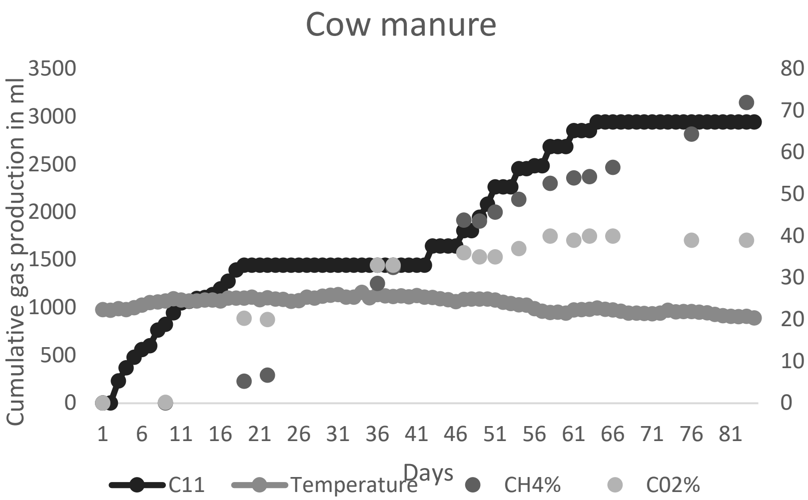


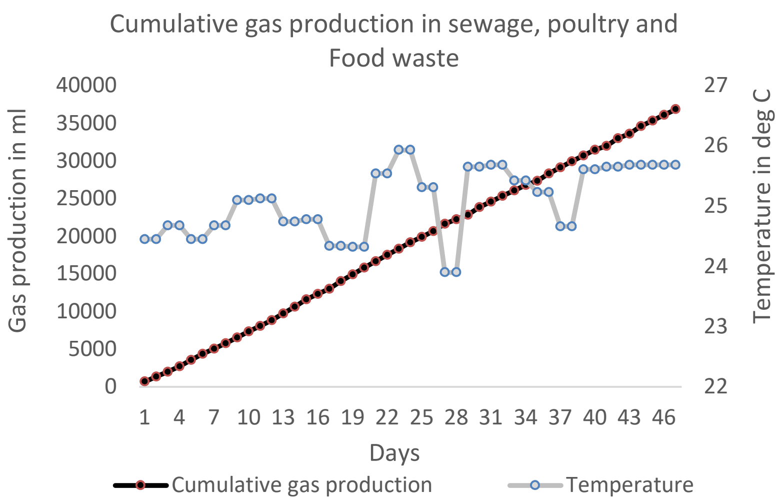
OLR 1.2 gVS/L.d, 60d HRT and Biogas yield 285 L/gVS, Methane content >60%, average temperature range 15-21 ºC, seems stable methanogenic process.

OLR 1.2 gVS/L.d, 60d HRT and Biogas yield 210 L/gVS, Methane content >60%, average temperature range 15-21 ºC seems stable methanogenic process.

Even at low ambient temperature stable AD process and biogas yield. Could be a suitable approach for sustainable energy production and waste management.

Co-digestion of Food Waste





Ratio:2:1:1

Cow manure digestion, only after 50 days methane content in the gas was >50%, cow manure as inoculum need longer time for a stable methanogenic process.

Food waste with Sewage and poultry litter at OLR 1 gVS/L.d, 50 d HRT, average temperature range of 23 to 26 ^{o}C, biogas yield 600 L/gVS, stable AD process.

Could be a suitable approach for sustainable energy production and waste management as part of circular economy of waste.

Digestion/Co-digestion of FW-Conclusion

AD of food Waste alone is not stable and methane content in the gas is negligible.

With good culture as inoculum food waste AD process can be stable still long term stability and biogas production is difficult to sustain.

Co-digestion of food waste with sewage, poultry litter, cow manure, goat droppings etc. seems suitable and AD process becomes stable.

Optimization of co-digestion substrate ratio, loading rate and pH gives stable process and highest methane production.

Insulation to the reactor - winter season for stable biogas production (low temperature).

Field Experience/Research on Household Biogas

Biogas - in Community

Nearly 350 household surveyed and two biogas plant monitored for biogas generation/consumption.

- **~55% of plants had non-functional feedstock mixing component, which improves biogas production.**
- **About 30% of plants had faulty valves, of which 3% had leakages.**
- **Most of the biogas owners (>80%) were not satisfied with the performance of biogas plants, especially in winter due to reduced yield.**
- **It causes increases use of firewood for cooking, resulting in increased health risks, and deforestation**
- **On average C:N ratio is very low 10.**
- **Biogas yield is in the range of 150 L/kgVS to 190 L/kg VS.**

Urban Bio-digesters in Nepal

- Sahari Gharelu Biogas Plant (ARTI Model)
- Introduced in Nepal by AEPC, Nepal in 2012/13 for piloting in Kathmandu valley
- Plant size 1 cubic meter ,plastic made similar to water storage
- Didn't function in Kathmandu

100 L plastic tank converted into fixed dome bio-digester

Experimented : Winter (average temperature 10 ºC) and in summer (average temperature 23 ºC)

70 days HRT in winter and 55 days HRT in summer

biogas yield of 90 L/kgVS, methane content 55-58% in summer

No gas production in winter start up

Bio-energy laboratory is working to develop appropriate model of urban bio-digester in Nepalese context.

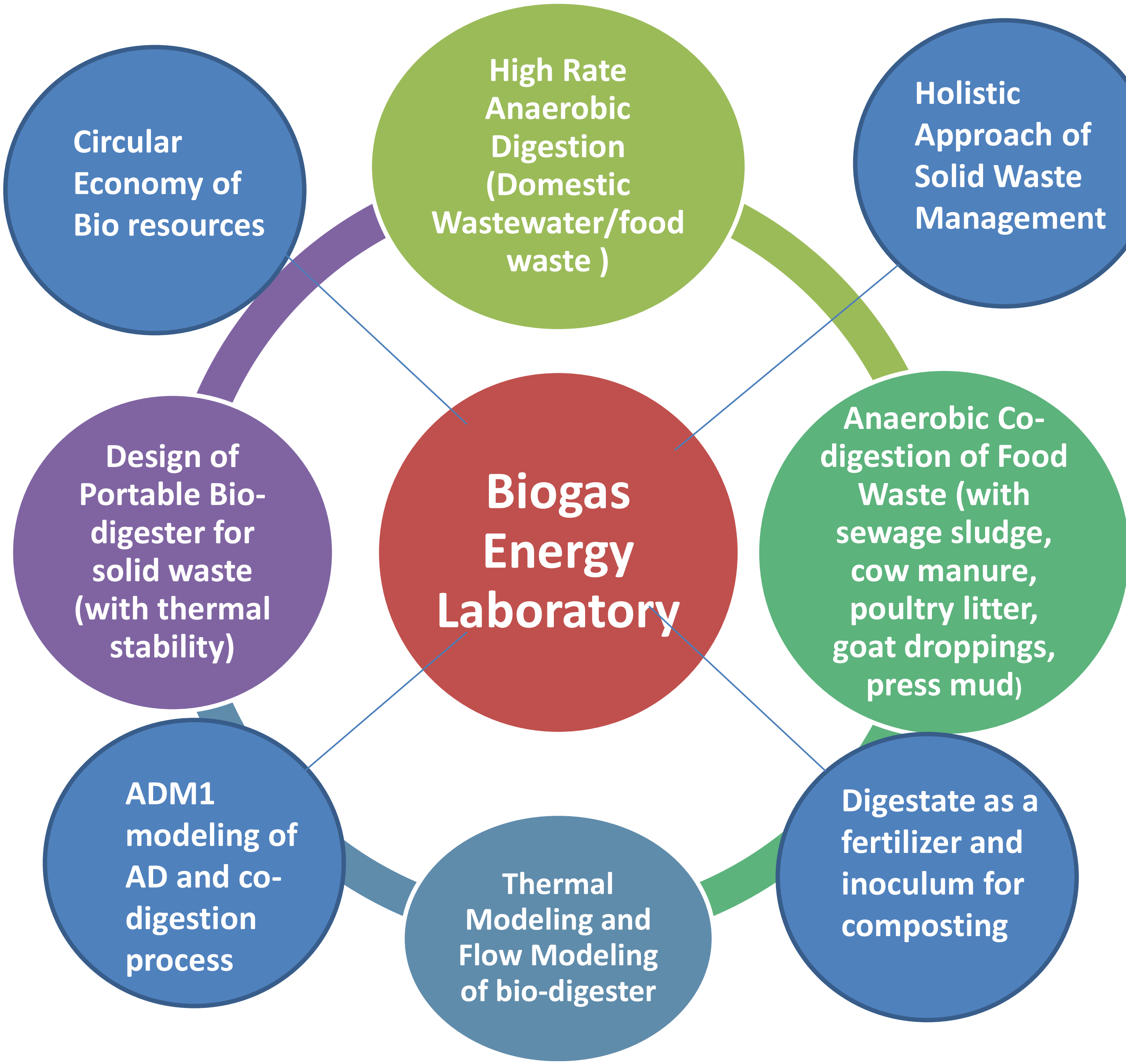
Ongoing Activities

- **Thermal Analysis of GGC Model (fixed dome) biogas plant and urban biogas plant with insulation and greenhouse.**
- **Flow analysis of GGC Model biogas plant and urban biogas plant.**
- **Co-digestion of food waste with different substrate at varying ratio is ongoing to optimize the substrate composition and ratio.**
- **Experiment is going on at 100 L bioreactor with insulation and greenhouse.**
- **Testing of UASB reactor for food waste AD.**

Bioenergy Research Group

Bioenergy Research Group@ Dept. of Mechanical Engineering

since 2012



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ADM1 modeling of UASB treating domestic wastewater in Nepal

Sunil Prasad Lohani [a, c], Shuai Wang [b], Susanne Lackner [c], Harald Horn [c], Sanjay Nath Khanal [a], Rune Bakke [b]

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ANAEROBIC DIGESTION OF FOOD WASTE AT VARYING OPERATING CONDITIONS

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Load limit of a UASB fed septic tank-treated domestic wastewater FREE

Sunil Prasad Lohani; Rune Bakke; Sanjay N. Khanal

Water Sci Technol (2015) 72 (8): 1455-1461.
https://doi.org/10.2166/wst.2015.358   Article history

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Sunil P. Lohani, Rune Bakke, Sanjay N. Khanal

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Modeling temperature effects in anaerobic digestion of domestic wastewater

Sunil Prasad Lohani [a], Shuai Wang [b], Wenche H. Bergland [b], Sanjay Nath Khanal [c], Rune Bakke [b]

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method
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Design, installation, operation and experimentation of septic tank – UASB wastewater treatment system

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Anaerobic Digestion: Factors Affecting Anaerobic Digestion Process

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Sunil P. Lohani, Jouni Havukainen

A simple anaerobic system for onsite treatment of domestic wastewater

Lohani S. P. Chhetri A. Khanal S. N.

Article Number - E561F0651580 | Vol.9(4), pp. 292-300, April 2015 | https://doi.org/10.5897/AJEST2014.1848

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