Enhanced energy recovery from co-digestion of toilet and kitchen wastes using water-conserving toilets

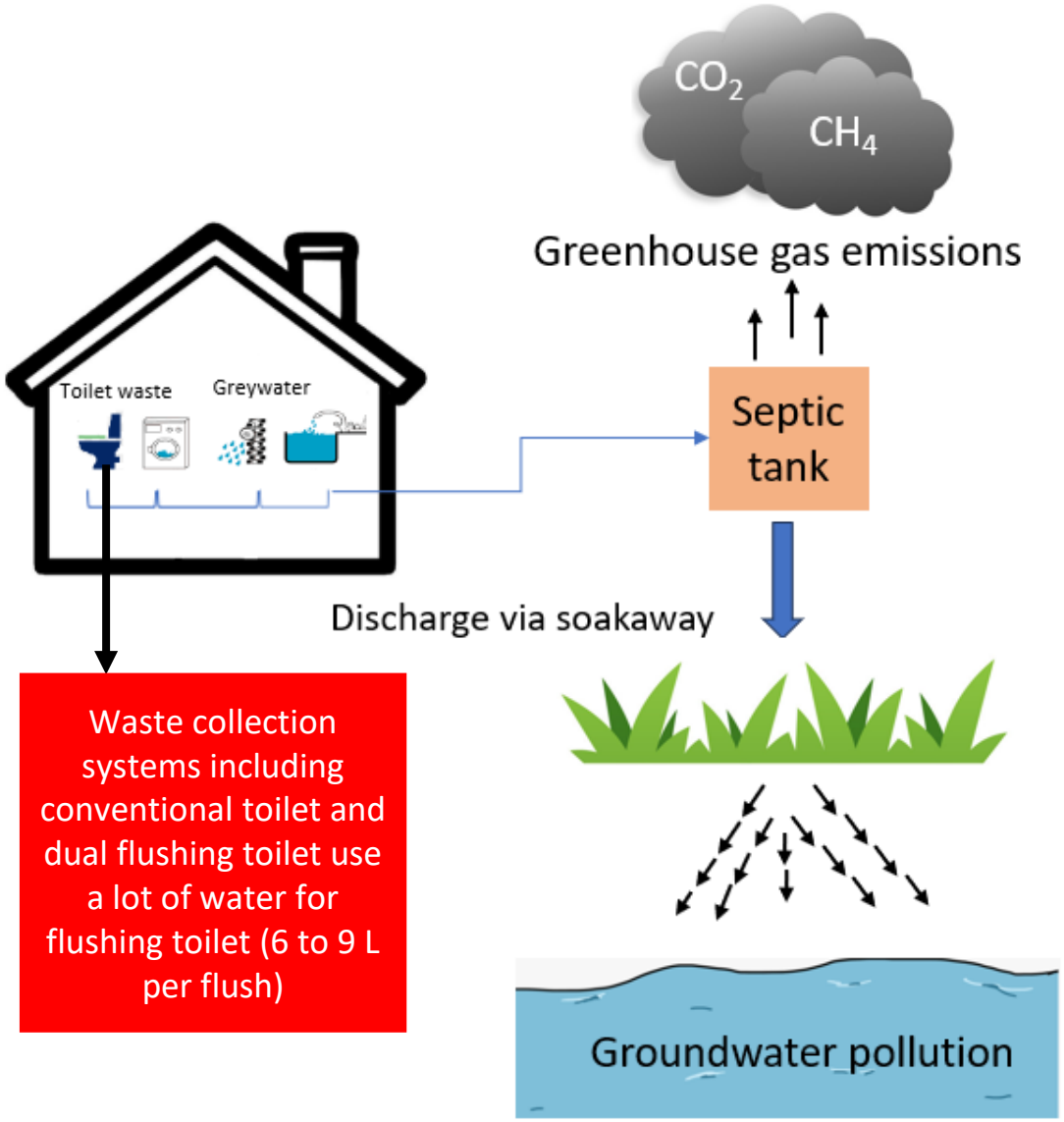
Fara Jamali-Behnam
Ricardo Bello Mendoza (University of Canterbury)
Maria Gutierrez-Gines
Kristin Bohm
Fatemeh Jamali-Behnam

Institute of Environmental Science and Research

water NEW ZEALAND
The New Zealand Water & Wastes Association Waiora Aotearoa

water NEW ZEALAND CONFERENCE & EXPO 17–19 OCTOBER 2023
Tākina, Te Whanganui-a-Tara Wellington

Issues in current wastewater management in decentralised areas in Aotearoa



Waste collection systems including conventional toilet and dual flushing toilet use a lot of water for flushing toilet (6 to 9 L per flush)

21 % of New Zealand population live in decentralised areas

Septic tanks are common way to manage wastewater in decentralised areas

Septic tank is not able to generate a high quality effluent

Loss of resources such as nutrients and energy

Is greenhouse gas emissions from non-sewered wastewater treatment systems (NSSS) negligible?

Comparison of GHG emissions between NSSS and WWTPs.

Country	the GHG emissions, Mt CO_2e/year		
	NSSS (this study)[a]	WWTPs (other studies)[b]	
China	45.4	42.9	Ren et al. (2021)
the USA	12.9	13.4	USEPA (2020)
Greece	0.3	0.9	Koutsou et al. (2018)
Canada	1.1	0.7	Sahely et al. (2006)
Argentine	2.2	3.6	Santalla et al. (2013)
Vietnam	10.6	17.1	Hoa and Matsuoka (2015)
Nigeria	11.4	21.3	UNFCCC (2021a)
Poland	2.5	3.6	UNFCCC (2021b)

[a] The GHG from NSSS does not include CO_2 and N_2O, that is, only CH_4 emission is considered.

[b] The GHG from WWTPs includes CH_4 and N_2O, but CO_2.

Year 2020

↓

377 (22–1003) Mt CO_2e/year

↓

4.7% of global anthropogenic methane emissions

↓

Comparable to the GHG emissions from WWTP

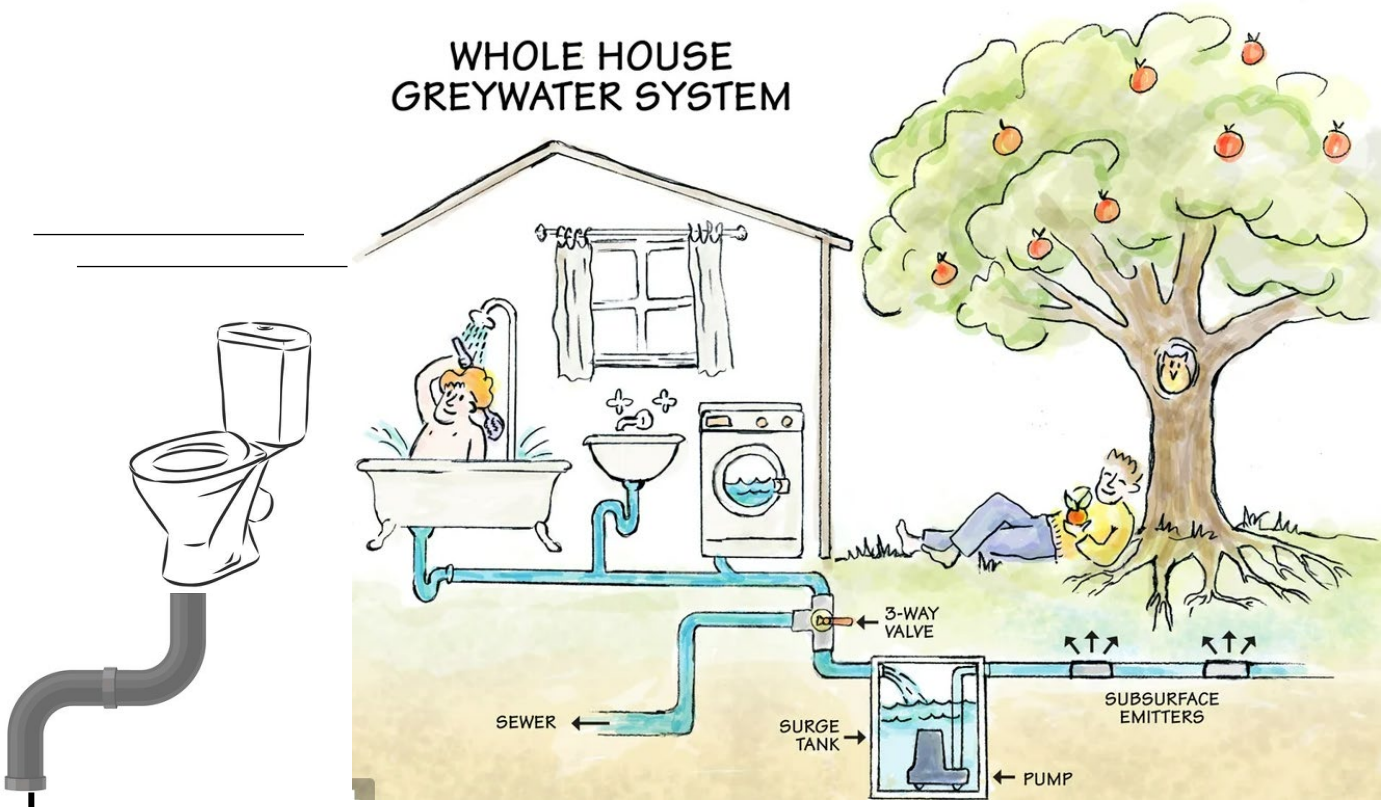
Source: Environmental Research 2022 Vol. 212 Pages 113468

Source separated household wastewater

Efficient way of recovery of water, nutrients and energy

>90% of water is recovered by greywater collection system without polluting with pathogenic microorganisms

Recover resources from toilet wastewater containing 50% organic matter and 80-95% nutrients



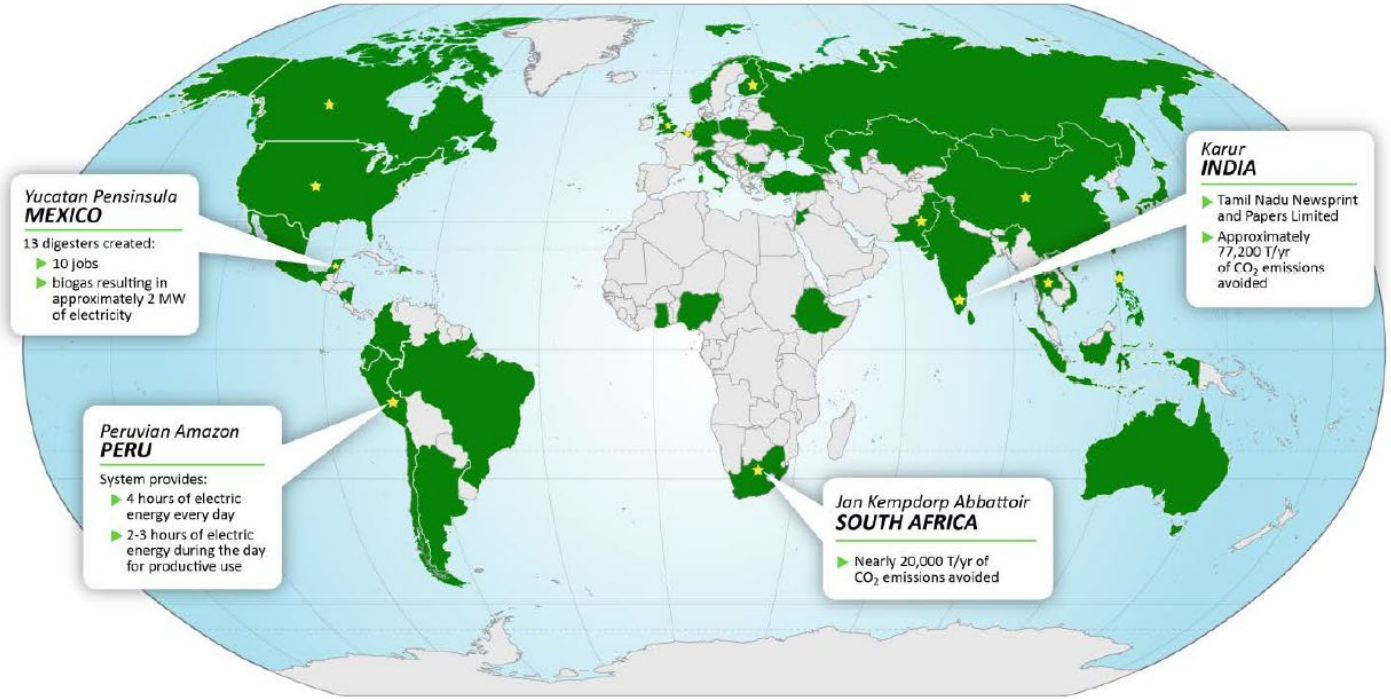
Greywater treatment system

Source: https://www.instructables.com/Grey-Water-Guide-Simple-System/

Toilet wastewater treatment system

Anaerobic digestion: a technology to treat wastewater on-site

Successful applications of anaerobic digestion around the world



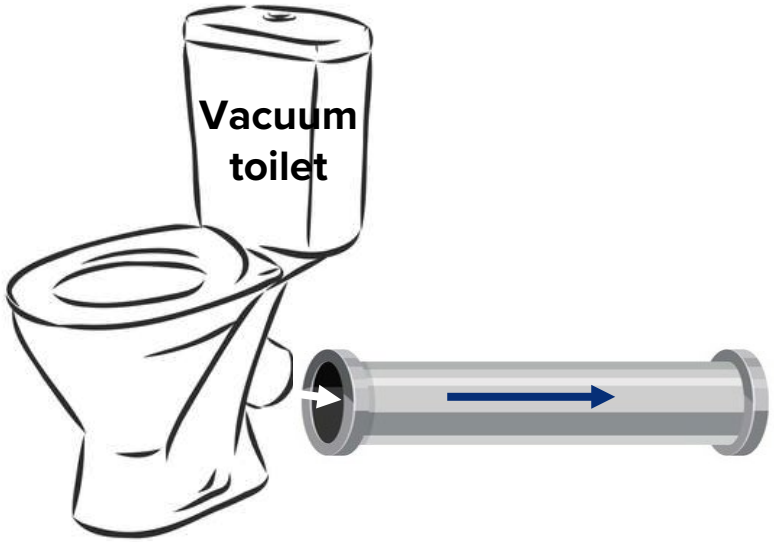
The four highlighted projects alone will reduce more than 150,000 Tons of CO_2 per year

Source: Global methane initiative

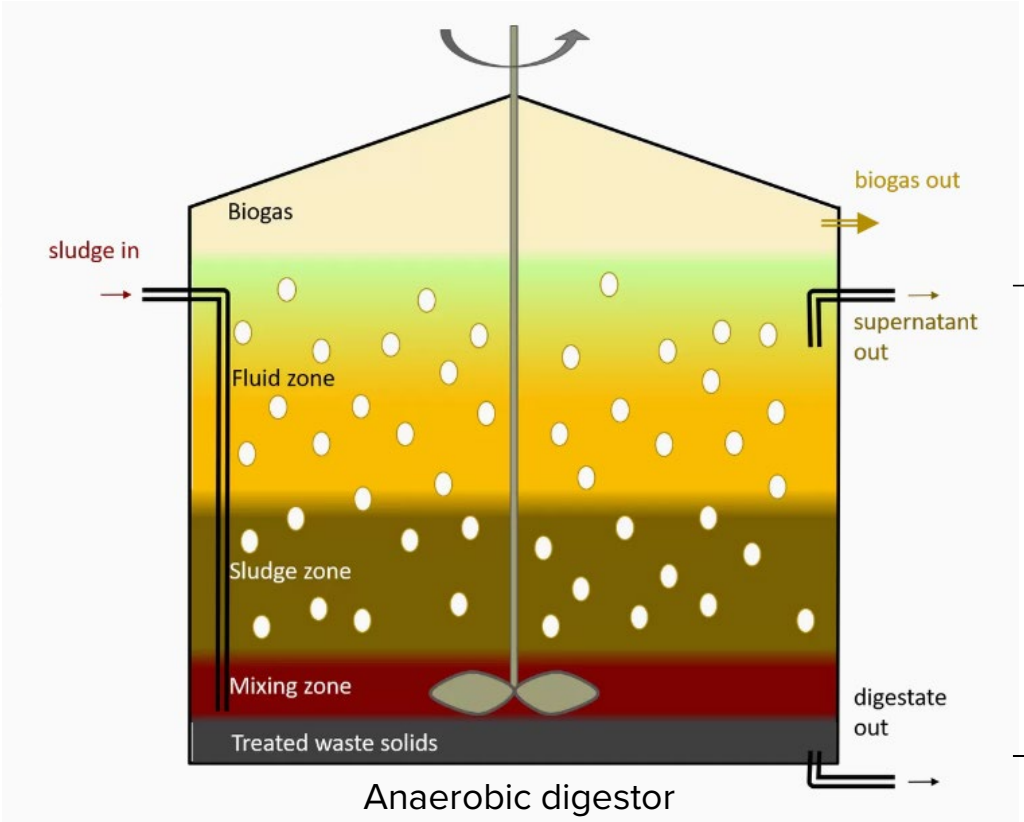
Energy production for rural communities in Parana, Brazil

- **Year installed:** 2009
- **Site type:** 33 small Dairy farm
- **Waste type:** Cow manure
- **CO_2 per year avoided:** 2650 T/y
- **Electricity generation:** 438 MW
- **Biofertilizer production from digestate**

Anaerobic digestion of toilet waste



(using 0.5-1 L water per flush)



Anaerobic digestor

Source: https://www.sludgeprocessing.com/

- Fuel
- Electricity
- Heat

- Feritiliser
- Livestock bedding
- Soil Amendments

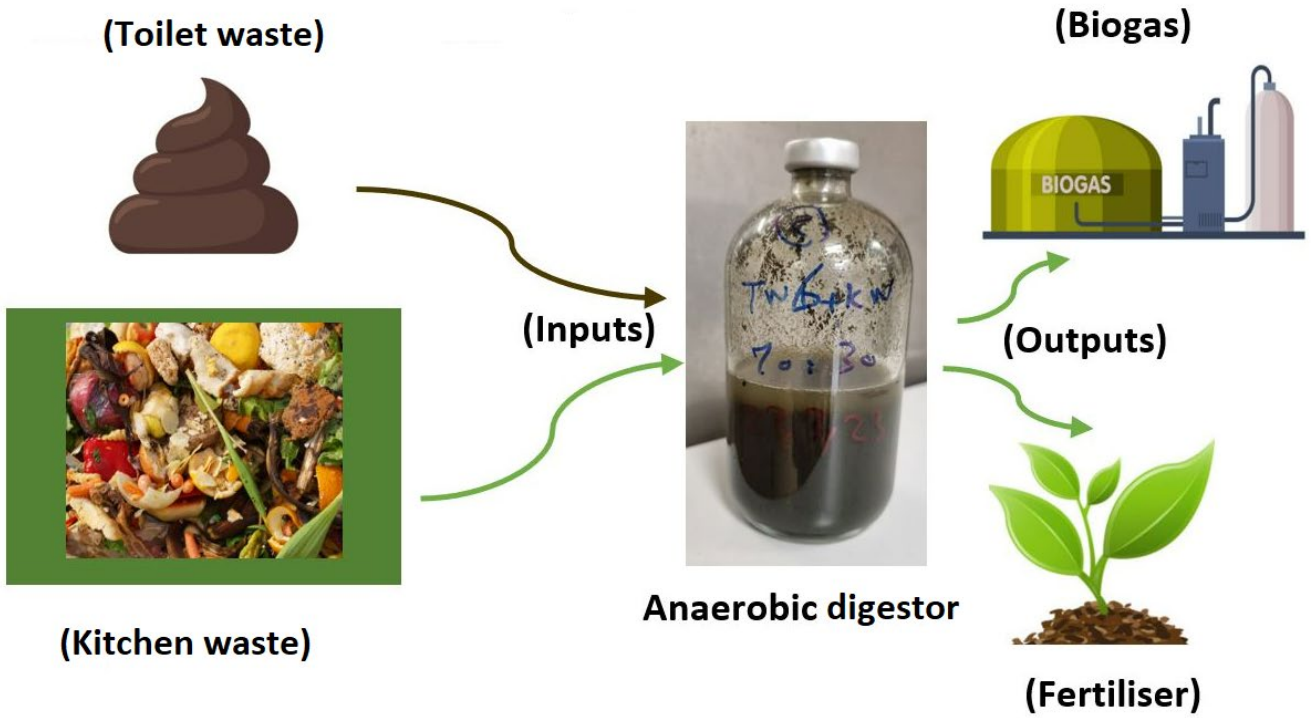
Advantageous

- Minimise water usage
- Less liquid effluent will be generated
- Higher recovery of resources

Disadvantageous

Methane inhibition due to high organic solid and free ammonia concentration (>200mg FA-N/L)

Co-digestion of toilet waste with Kitchen waste - objectives of the Pioneer project



Co-digestion is simultaneous anaerobic digestion of multiple organic waste products in one digestor

optimal moisture and nutrient concentrations

the digestion of different materials, increased cost-efficiency

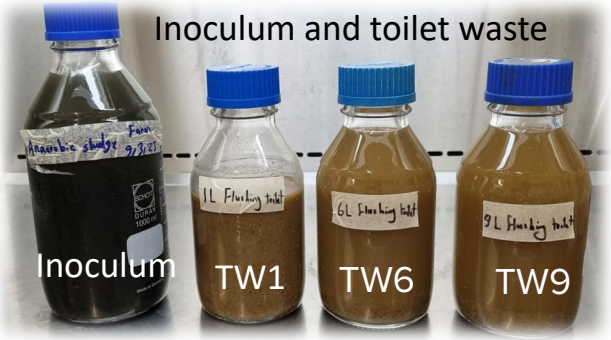
synergistic degradation of treated materials

➢ Research question

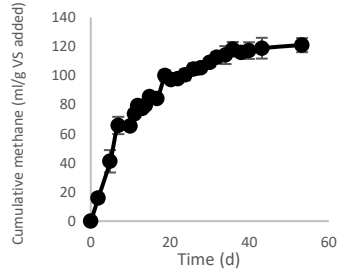
- Does toilet waste collected from various collection systems affect the methane yield in the co-digestion of toilet and kitchen waste?

➢ Materials and methods

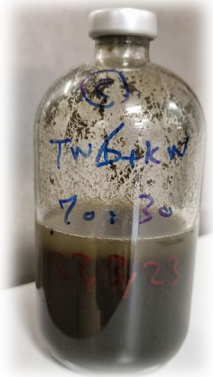
(Biochemical Methane Potential (BMP) Assay)



Mixing ratio (VS basis)
TW:KW, 70:30



Kitchen waste



162 mL serum bottle

1- Collection and preparation of substrates and inoculum
2-Analysis of inoculum and substrates to determine TS and VS

Add components, flush, seal and store bottles

Biogas Sampling with glass Syringe over 55 days

Injection of gas samples to GC machine, completion of BMP test, analysis of samples to determine TS and VS

➢ Results

Methane yield

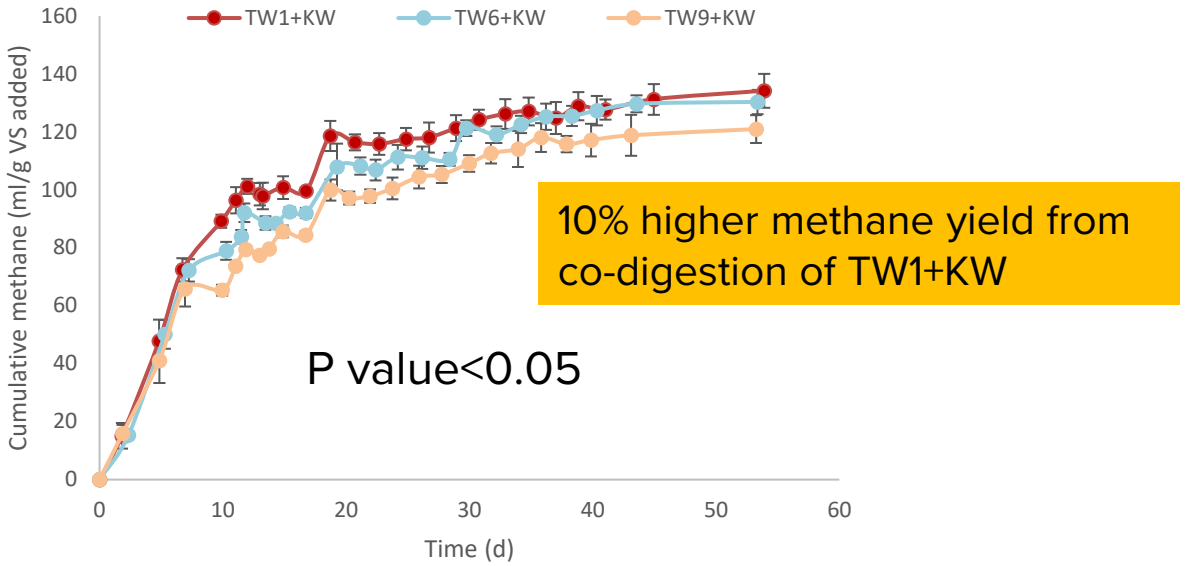


Fig1 Cumulative methane production during co-digestion of different types of toilet wastes with kitchen waste

Table 1 Biochemical methane potential (BMP) of toilet waste and kitchen waste with different levels of dilution and estimate potential methane production per household.

Substrate	BMP ($L\ CH_4\ kg\ VS^{-1}$)	Methane yield ($m^3\ CH_4\ a^{-1}\ household^{-1}$)	Quantity available of TW ($Kg\ a^{-1}\ household^{-1}$)	Required amount of KW ($Kg\ a^{-1}\ household^{-1}$)
TW1+KW	443±5.5	32.4	725	169.2
TW6+KW	433±3.4	31.6	725	169.2
TW9+KW	400±5.8	29.2	725	169.2

Electricity generation of 324 kW per household per year

Case study of co-digestion of toilet waste with animal manure in Cambodia

Input

- Toilet waste
- Animal manure

(like cow, buffalo, or pig waste)

Output

- Gas to fulfil all cooking requirement of the household

Source: Bukauskas etal., Water New Zealand Conference 2017

➢ Conclusions

- Amount of water in the toilet waste was a limiting factor affecting the methane yield
- Co-digestion of water conserving toilet waste and kitchen waste can potentially generate electricity about 324 kW a^{-1} $household^{-1}$
- Toilet waste generated from water conserving toilet can be a good substrate to be applied in anaerobic co-digestion systems for obtaining higher energy recovery

Thank you!

Questions

Fara.behnam@esr.cri.nz

Ricardo.bellomendoza@canterbury.ac.nz

Maria.gutierrez-gines@esr.cri.nz

Kristin.bohm@esr.cri.nz

fbehnam20@gmail.com