Evaluating GHG emissions across non-sewered sanitation chain

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WASH sector is most impacted by Climate change...

•Climate change impacts seen more on developing countries - **90** % human losses reported from developing countries

- •India is **7th** most vulnerable country to the climate hazard
- •27 out of 36 states are highly vulnerable to climate change impact



Delhi Floods, 2023 – Water Treatment plants are dysfunctional; sewage mixing with flood water

Chennai floods, 2021 and drought, 2019



Latur, 2016 - Water delivered through trains during drought





Uttarakhand, 2023 - Cloud burst destroys

city infrastructure and services

Kerala floods, 2018 – Access to sanitation facilities







- Water scarcity due to inadequate rainfall and drought
- Increased water demand during heatwave
- Inequitable access to WASH services
- Slum dwellers and vulnerable population have hindered access to public sanitation facilities during extreme weather events
- Breakdown of service infrastructure in flood situation – treatment plants, sewers, septic tanks
- Aquifer degradation due to overexploitation / contamination due to flood

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Source: IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Core Writing Team, H. Lee and J. Romero (eds.)). IPCC, Geneva, Switzerland, 36 pages. (in press) <u>https://www.ipcc.ct//report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.ddf</u>; Mohanty, Abinash, and Shreya Wadhawan. 2021. Mapping India's Climate Vulnerability – A District Level Assessment. New Delhi: Council on Energy. Environment and Water.





It is also a contributor to GHG emissions...

Table 1: Estimated methane emissions from the waste sector in India in 2016

Source	Emissions (Gg)
Industrial wastewater treatment and discharge	979
Domestic and commercial wastewater treatment and discharge	1,087
Solid waste disposal on land	754
Total	2,820
Source: India's third BUR. MoEFCC. 2016	

It is evident that the sanitation sector contribute higher to GHG emissions as compare to SWM emissions, despite of having underestimating quantification methodologies.

In addition, sanitation system also lead to generation of emissions from disposal of methane from freshwater ecosystems



Fig. 3 | Seasonal patterns of CH₄ emissions. Left: total monthly CH₄ emissions for each latitudinal band (10° bins), with the colour representing total river area. Right: total yearly emissions for each latitudinal band. In the left panel, the y axis is square-root transformed, and the colour scale is log transformed.

Source: 1. Our World Data, Hannah Ritchie, Max Roser and Pablo Rosado (2020) - "CO₂ and Greenhouse Gas Emissions". Published online at OurWorldInData.org. Retrieved from: "https://ourworldindata.org/co2-and-greenhouse-gas-emissions"; Sharma K V, 2012, Energy conservation opportunities in municipal water supply systems: a case study, TERI ; 3. Rohilla S., Kumar P., Matto M., and Sharda C., 2017, Mainstreaming Energy Efficiency In Urban Water And Wastewater Management In The Wake Of Climate Change, CSE 4. Report on twentieth electric power survey of India, CEA, Goi, Rocher-Ros, G., Stanley E.H., Loken, L.C. *et al.* Global methane emissions from rivers and streams. *Nature* 621, 530–535 (2023). https://doi.org/10.1038/s41586-023-06344-6

IPCC estimates of WASH sector to GHG emissions considers only direct emissions

4% direct emissions in India due to waste sector



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Quantification of emissions is essential





Emissions by sanitation value chain. Methane CH4, Nitrous Oxide N2O

Emission through the fuel and generation of electricity, which is then used in water and wastewater service chain. Carbon Dioxide CO2.

IPCC provides methodology for emission inventory

2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Provides empirical methodology to estimate emissions using country level factors....

However, this requires localization for action at city level

Various studies are carried out to understand the emissions from sewered and non-sewered sanitation facilities

Case 1 - Emissions from septic tanks, USA

Study carried out on the containment part of sanitation value chain showcasing the low field based emissions as compared to the IPCC emissions.

Field studies showcase the methane and nitrous emissions were 11 and 0.005 grams per capita per day.

Further, based on the study conversion factor was revised to 0.5 (IPCC factor) to 0.22 (field based factor)



Studies arguing that IPCC may be underestimating or overestimating sanitation emissions

Source: Diaz-Valbuena LR, Leverenz HL, Cappa CD, Tchobanoglous G, Horwath WR, Darby JL. Methane, carbon dioxide, and nitrous oxide emissions from septic tank systems. Environ Sci Technol. 2011 Apr 1;45(7):2741-7. doi: 10.1021/es1036095. Epub 2011 Mar 7. PMID: 21381675.





Studies in Ireland, Vietnam and Kampala

Practical approach

Ireland Case : Two septic tanks were analyzed through continuous and discrete measurement for 446 days

- Assessing the dissolved concentration sample (100 ml) has been taken in bubbler bottle and connected to gas analyser (headspace method for CH4 and CO2)
- Samples taken from septic tank were analysed at the lab with 72 hours using gas chromatograph.
- Model used to analyse the CH4 concentration is UGGA 915-0011..

Vietnam Case : 10 septic tanks were analyzed through floating chamber method

- Toilet need not to be used during this process, after sampling the GHG gases were also analysed using portable gas analyzer (PG300, HORIBA)
- 12 ml samples were taken till 1 L volume was not collected. The collected samples were tested in lab using the
- Only carried out for single compartment, need to replicate it for second compartment also.

Kampala Case : Direct emissions from pits and tanks vary a lot depending on operating conditions



Environmental drivers impacts on GHG emission – 1. rainfall, 2. wind, 3. air, 4. soil temperature, 5. variation as per the season – a. higher in warmer summer, b. lower in cold winters

Source : Huynh, L. T., Harada, H., Fujii, S., Nguyen, L. P. H., Hoang, T.-H. T., and Huynh, H. T.: Greenhouse gas emissions from blackwater septic systems, Environ. Sci. Technol., 55, 1209–1217, <u>https://doi.org/10.1021/acs.est.0c03418</u>, 2021., Knappe, J., Somlai, C., and Gill, L. W.: Assessing the spatial and temporal variability of greenhouse gas emissions from different configurations of on-site wastewater treatment system using discrete and continuous gas flux measurement, Biogeosciences, 19, 1067–1085, <u>https://doi.org/10.5194/bg-19-1067-2022</u>, 2022.

The Vietnam study's observation is that the methane emission rates from septic tanks accumulating septage for >5 years were significantly higher than those at 0–5 years.

Details:

CH4 emission rate is

- 1. directly correlated to following parameters : -
- Septage oxidation-reduction potential
- COD mass
- BOD mass
- 2. Not correlated to following parameters :
- Water temperature
- Dissolved Oxygen



Case 4 – Different treatment technologies contribute to emissions differently

		IPCC 2019		This study			
		CH4	N ₂ O	CH4	N ₂ O	CO ₂	
No.	Biological treatment technology	g CH₄/kg COD	g N ₂ O /kg TN influent	g CH4/kg COD removed (No. 1-11); g CH4/kg COD (No, 12-27)	g N2O /kg TN influent	g CO₂/kg COD removed	
1	Aerobic Biological Treatment	7.50	25.00	0.70	1.20	560.00	
2	Activated sludge	7.50	25.00	0.70	1.20	560.00	
3	AO	7.50	25.00	0.74	13.94	365.75	
4	A ² O	7.50	25.00	2.66	6.19	375.53	
5	OD	7.50	25.00	4.27	2.18	510.65	
6	SBR	7.50	25.00	1.76	43.60	531.80	
7	AB	7.50	25.00	0.70	1.20	560.00	
8	Biofilm	0.00	25.00	0.00	11.67	436.20	
9	Biofilter	0.00	25.00	0.00	11.67	436.20	
10	Rotating Biological Contactor	0.00	25.00	0.00	11.67	436.20	
11	Biological Contact Oxidation	0.00	25.00	0.00	11.67	436.20	
12	Anaerobic Biological Treatment	200.00	0.00	200.00	0.00	380.50	
13	Anaerobic Hydrolysis	200.00	0.00	200.00	0.00	380.50	
14	Typical Anaerobic Reactors	200.00	0.00	200.00	0.00	380.50	
15	Anaerobic Biofilter	200.00	0.00	200.00	0.00	380.50	
16	Other Anaerobic Biological Treatment	200.00	0.00	200.00	0.00	380.50	
17	Stabilization Pond, Constructed Wetland and Land Treatment	68.06	11.98	68.06	11.98	502.91	
18	Stabilization Lagoon	66.25	18.75	66.25	18.75	515.13	
19	Oxidation Lagoon	7.50	25.00	7.50	25.00	560.00	
20	Anaerobic Lagoon	200.00	0.00	200.00	0.00	380.50	
21	Facultative Lagoon	50.00	25.00	50.00	25.00	560.00	
22	Aerated Lagoon	7.50	25.00	7.50	25.00	560.00	
23	Constructed Wetland	42.50	4.94	42.50	4.94	482.54	
24	Subsurface Flow Constructed Wetland	13.75	6.39	13.75	6.39	482.54	
25	Surface Flow Constructed Wetland	100.00	2.04	100.00	2.04	482.54	
26	Land Infiltration	125.00	0.70	125.00	0.70	502.91	
27	Biological Treatment	7.50	25.00	7.50	25.00	560.00	

Different technologies contribute differently to the emissions depending on the functionality and context of technology.

A study carried out in china showcase variation in actual field estimates and theoretical estimates

System functionality and efficiency determines the emission rate which varies context to context.

The need of on-field study arises to understand the actual emissions

Need for evidence

- Evidence are available based on lab based (prototype) study
- Majority studies on field are available from developed country
- Field reality needs to be assessed
- Localization and understanding of emissions across the non-sewered sanitation chain is needed

Access to Climate Finance

- Climate finance
- Carbon Credits
- Localization is needed to access them





Need for cross examining of factors and assumptions at local level to localize for Indian cities

Not treated: 642

Treated: 2909

Not treated: 0

Not treated 0

Treated: 3

Accounting for fugitive emissions from sewer networks – IPCC suggests no emissions from fast flowing closed networks

Ludhiana gas leak: Amid disaster, fingers pointed at pollution board, civic body

It is being suspected that some chemical was discharged into the se methane and other same to produce Dydromes Subbide.



 308 died while cleaning sewers, septic tanks in last five years across India
 Cressic Laura (TRI/Updeed Arr 2.003, 100 st)

Image source: Indian express, Times of India



Image source: Ye, L., Porro, J., & Nopens, I. (Eds.). (2022). Quantification and Modelling of Fugitive Greenhouse Gas Emissions from Urban Water Systems. IWA Publishing. doi:10.2166/9781789060461 Re-evaluating emission factors from onsite systems like septic tanks in India with infrequent emptying and drain connections

Whole-system analysis reveals high greenhouse-gas emissions from citywide sanitation in Kampala, Uganda

Table 5 Principal sources of greenhouse gas emissions from whole-chain sanitation systems (a) onsite systems, (b) offsite tems in Kampala. Total emissions by category (tCO2e) (2) Emptying/ emptying and transport (3) Treatment (1) Containment otic tanks and contains ed tran Contained: 87,950 Delivered: 0 Treated: 26.650 Not contained 8.036 Not delivered: 2573 Not treated: 642 operational (C Contained: 0 Delivered: 556 Not delivered: All treatment: 0 mbedded carbon (E) All trucks: 0 Treated: 59 All systems: 4,262 Not treated: 0 b) Offsite systems (with see ased transport) irect (D) Contained: 0 Delivered: 0 Treated: 29,629

Johson J. Zakaria F. Nkuru

Not contained: 0

Not contained: 0

Contained: 0

Ul systems: 0

perational (O)

mbedded carbon (E)

Johson J., Zakaria F., Nkurunziza a., Way C., Camargo-Valero M., Evans B., April 2022, Whole system analysis reveals high greenhouse gas emissions from citywide sanitation in Kampala, Uganda, https://doi.org/10.1038/s43247-022-00413-w.

Not delivered: 11.572

Delivered: 41

Not delivered: O

All sewers: 201

Greenhouse Gas Emissions from Blackwater Septic Systems



Figure 1. Experimental setup of sensor and autosampler for water and septage monitoring.

Localizing factors for demography and sanitation technologies

Wastewater sector emits nearly twice as much methane as previously thought



Graphical abstract: Environmental Science & Technology (2023). DOI: 10.1021.

Image source: Wastewater sector emits nearly twice as much methane as previously thought (2023, February 28) retrieved 18 July 2023 from https://phys.org/news/2023-02-wastewatersectoremits-methane-previously.html



GHG emission rate from the first compartme of blackwater septic systems (g/cap/day)

Loi Tan Huynh, Hidenori Harada, Shigeo Fujii, Lien Pham Hong Nguyen, Thu-Huong Thi Hoang, and Hai Trung Huynh, Greenhouse Gas Emissions from Blackwater Septic Systems, Environmental Science & Technology 2021 55 (2), 1209-1217, DOI: https://doi.org/10.1021/acs.est.0c03418 Estimating quantum of indirect emissions contributed by WASH to give a holistic picture of emissions from service delivery





Schoebitz L, Bischoff F, Lohri CR, Niwagaba CB, Siber R, Strande L. GIS Analysis and Optimisation of Faecal Sludge Logistics at City-Wide Scale in Kampala, Uganda. Sustainability. 2017; 9(2):194. https://doi.org/10.3390/su9020194

Methodology adopted for quantification of emissions

Understanding of IPCC estimation methodology for wastewater and water sector

Assessment for the WASH service chain in these cities to map out different water pathways for quantification of emissions

Assessment for the WASH service chain in these cities to map out energy requirements

Developing initial empirical estimates for emissions from WASH service chains using country level factors and city level WASH information

Field measurements with gas sensors and lab testing of sludge to compare with empirical estimates

Localization of estimation

Methodology adapted for quantification of emissions

Initial GHG estimates using IPCC empirical quantification . . .



Formula for calculation:

Direct emissions (Scope 1) :

Sanitation emission calculation : (U x T x EF) x (TOW-S)-R

- TOW = Volume of wastewater generated x BOD
 BOD wastewater, sludge
- **3 B0 Maximum Methane Producing factor**
- 4 MCF Methane Correction factor
- 5 Emission Factor = (B0 x MCF)
- 6 S = Sludge Removed
 - 7 U = Population fraction
 - 8 T = Degree of utilisation
 - 9 R = Methane Recovered or captured

Indirect emissions (Scope 2) :

GHG emission (kg CO2eq) = Energy consumption x Emission factor of the grid

GHG emission for Fuel used : Litres of petrol used x EF

Source: empirical estimate through the IPCC methodology; Wastewater Treatment and Discharge, 2019 IPCC Guidelines for National Greenhouse Gas Inventories Annex 1 : Sample calculation for one city ...

Enhancing empirical estimates through field measurements in three cities

Three cities are selected

- 1. Different Sanitation Systems
- 2. Diverse Sanitation Technology
- 3. Presence of Slum Settlements

		Vita	Karad	Ichalkaranji	
1	Population	57k	89k	368k	K
2	Household	12.5k	13.9k	67.8k	
3	Area (Sq.Km.)	55.5	29.9	10.55	
4	IHHT coverage	90 %	92 %	70 %	
5	Wastewater generated	6.1 MLD	9.5 MLD	36 MLD	
4	Sanitation system	On – site system	Sewer system	Partially sewered with partial aquatic discharge	
5	Sanitation treatment facility type	Well managed FSTP : SDB + PGF + ABR	Well managed STP: MMBR (Multi Media Bio Reactor) (Aerobic)	Not well managed STP: SBR (Sequential batch reactor) (Aerobic)	
6	Reuse of used water	100 %	100 %	No reuse	



Ongoing field research- methodology adopted

Identified samples

- 1.1. location (slum and non-slum) household.
- 1.2. year of build
- 1.3. emptying frequency
- 1.4. septic tank size
- 1.5. Property sub type (Bungalow, Row house, Apartment, chawl and other)
- 1.6 Family size
- 1.7 Number of households connected to the septic tank

Arrangement for taking samples

Need to make plumbing arrangement at the vent to take the emission readings





Ongoing field research- methodology adopted

Sampling frequency and timings

- Daily frequency
- Taking measurements every hour from 7 am to 7 pm for initial 15 days
- Based on the pattern of values, identify peak emissions time and measure at an interval of every 30 minutes
- Based on these results, plot values and derive the CO2 equivalent

Measuring instrument/ approach

Sensor equipment measurements with discrete and continuous sampling



Also exploring: Lab testing approach

Collecting samples using certified labs using standard sampling techniques

Way Forward

- We aim to quantify methane emissions and identify the potential areas where emissions can be converted into resources
- Identify areas and methods to capture these emissions
- Exploring and scaling up the estimating activities across the sanitation value chain, i.e. for treatment
- Scale-up the activity across other cities in India for localization

Thank You

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Climate Change a global issue !!!

- Climate related disaster contributes about 50 % of total disasters occurred in last 50 years.
- Climate related disaster frequency has increased
 5 times as compared to 50 years ago disaster frequency.
- The economic loss has increased 7 times due to the climate related disaster in last 50 year.

• All disaster having wider impact on developing and underdeveloped nations.



Source: IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 36 pages. (in press) https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf





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Increase in frequency of climate hazards increases risk to countries

- Over past 119 years the climate hazards frequency has been increased at rapid causing loss of human and economic activities.
- 90 % human losses are reported from the developing countries
- India is 7th most vulnerable country to the climate hazard (in 2019)
- 200 % climate hazards have increased in India since 2005 causing over \$87 billions in year 2019





Source : Mohanty, Abinash and Shreya Wadhawan. 2021. Mapping India's Climate Vulnerability: A District-Level Assessment. New Delhi: Council on Energy, Environment and Water; <u>https://economictimes.indiatimes.com/news/india/india-lost-over-1-3-lakh-lives-in-disasters-linked-to-extreme-weather-climate-change-in-50-years-un-agency/articleshow/100424018.cms?from=mdr</u>

Impact of Climate change on the sanitation services

System Diagram Example: Flooding



Impact of Climate change on the sanitation services

System Diagram Example: Drought



Source : Climate Resilient Urban Sanitation (2021)

Impact of climate change on the water supply...

	Climate hazard	Impact on co	nsumption	Impact on in	nfrastructure	Impact on service quality		
1	Rising sea levels, saltwater intrusion	Consumption will be halted : Water is no longer suitable for drinking.		Infrastructure corrosion (steel, iron, etc.).		Services halted due to high salt levels, which cannot be reduced through treatment.		
2	Rise in temperatures, drought and heatwaves	Increase in water needs and in volumes withdrawn for all uses (domestic, agricultural, industrial, etc.), Leading to rapid ground water depletion		Weakened facilities: breakdown of facilities and dry pumping leading pump damage		Interrupted reduced services due to lack of available water resources. Poor quality of water distributed		
3	Variability of seasonal rainfall patterns	-		Breakdown of facilities: Bursting of pipe network, functional disruption to treatment facilities		Contamination of clean water, inaccessible areas due to network breakdown and inaccessible water points		
4	Increased frequency of unpredicted weather patterns	Higher water demand for nonresidential to sustain the sectors, impacting on food and water security		Facilities will become less efficient : pumping, electrical equipment, frequent replace of infrastructure. Impact on seasonal storage facilities		Frequent service interruptions, Poor quality of water supply, Low water supply,		
Health, social and economic impacts								
Increase in Increase in diarrheal diseases conflicts of us		Increase in conflicts of use	More diffic drawing	culty in Greater water migration		Leading to reduction in GDP		
Source: https://www.pseau.org/outils/ouvrages/ps eau wash services climate change impacts and responses 2018.pdf								
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