Evaluating GHG emissions across non-sewered sanitation chain

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Global South Academic Conclave on WASH and Climate linkages

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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

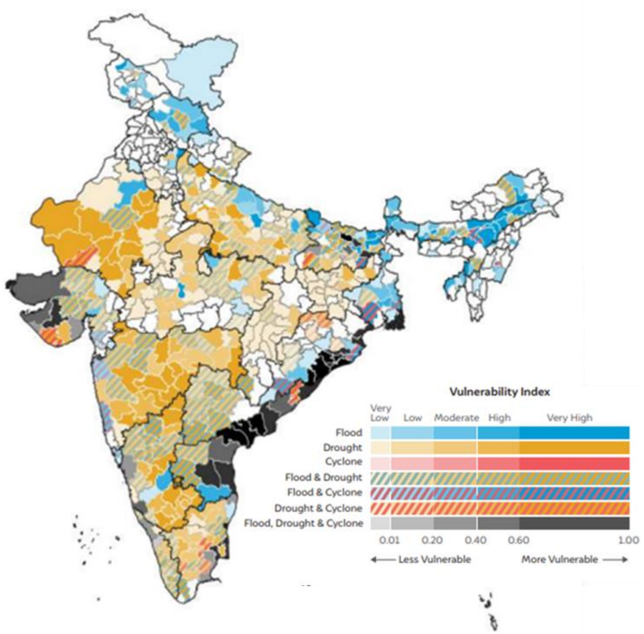
Delhi Floods, 2023 – Water Treatment plants are dysfunctional; sewage mixing with flood water

Uttarakhand, 2023 - Cloud burst destroys city infrastructure and services

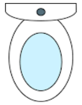
Chennai floods, 2021 and drought, 2019

Kerala floods, 2018 – Access to sanitation facilities

Latur, 2016 - Water delivered through trains during drought



Water sector 

Sanitation sector 

- 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

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 ; ;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

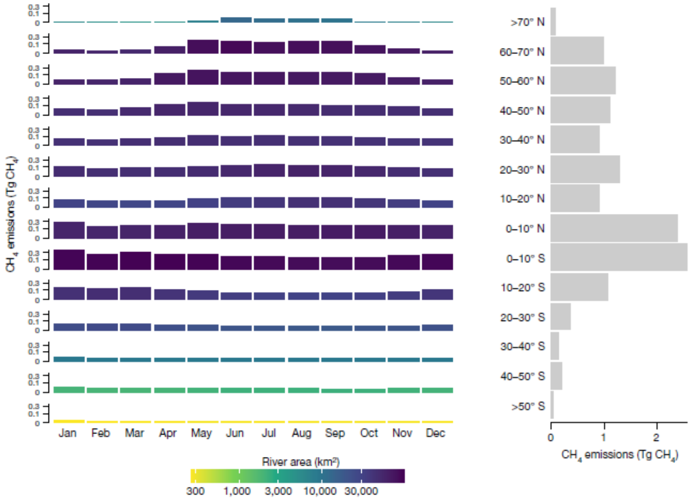
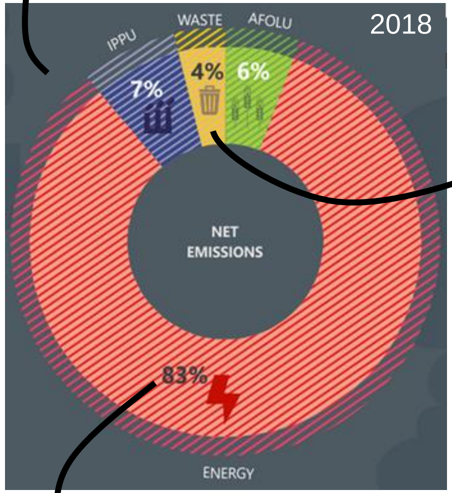


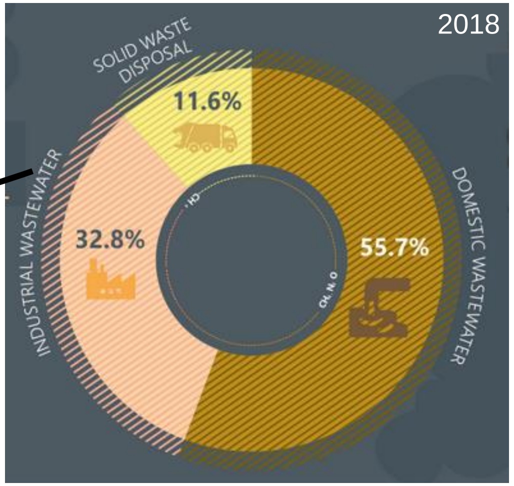
Fig. 3 | Seasonal patterns of CH_4 emissions. Left: total monthly CH_4 emissions for each latitudinal band (10° bins), with the colour representing total river area. Right: total yearly emissions for each latitudinal band. In the left panel, the y axis is square-root transformed, and the colour scale is log transformed.

Source: 1. Our World Data, Hannah Ritchie, Max Roser and Pablo Rosado (2020) - "CO_2 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

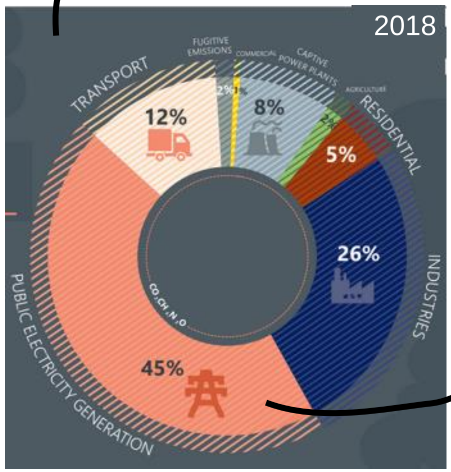
IPCC estimates of WASH sector to GHG emissions considers only direct emissions

4% direct emissions in India due to waste sector



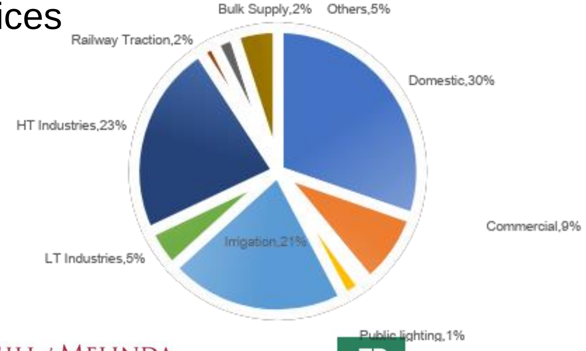


Direct emissions : Wastewater (domestic and industrial) is a high contributor in waste sector in India



Indirect emissions: Significant portion of electricity consumed by WASH services

40% to 60% of the electricity consumed by a municipal corporation is spent towards the operation of water / sewage pumping



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Quantification of emissions is essential

Emissions by sanitation value chain.
Methane CH_4, Nitrous Oxide N_2O

Emission through the fuel and generation of electricity, which is then used in water and wastewater service chain.
Carbon Dioxide CO_2.

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

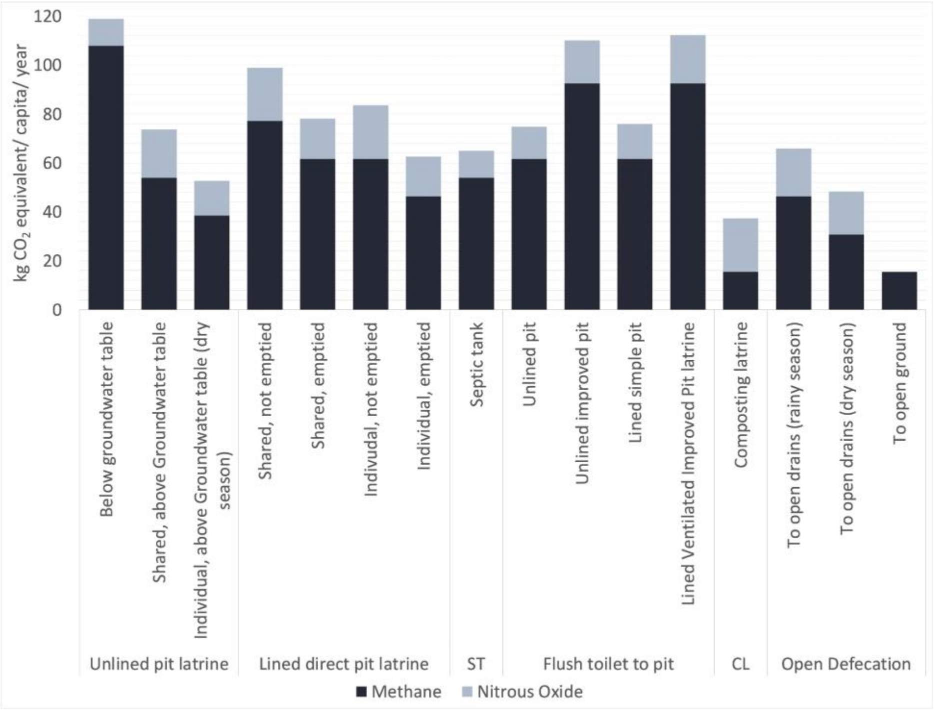
Ireland Case : Two septic tanks were analyzed through **continuous and discrete measurement for 446 days**

- 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, https://doi.org/10.1021/acs.est.0c03418, 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, https://doi.org/10.5194/bg-19-1067-2022, 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:

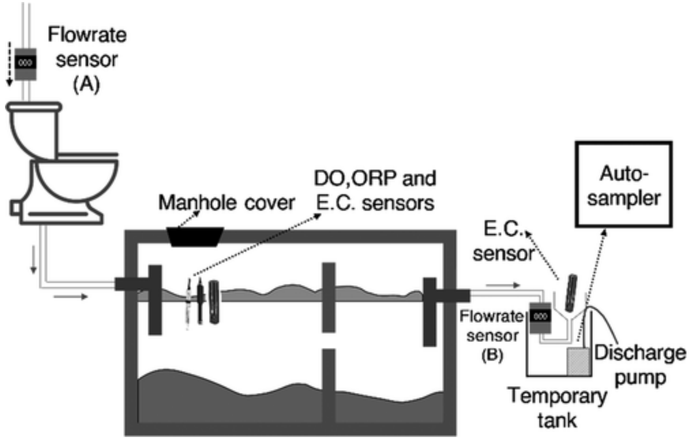
CH4 emission rate is

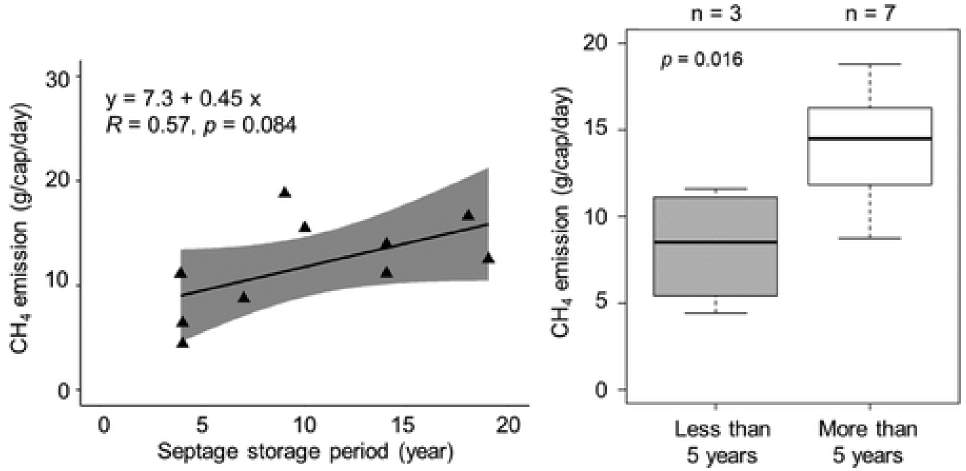
1. **directly correlated to following parameters : -**

- Septage oxidation–reduction potential
- COD mass
- BOD mass

2. **Not correlated to following parameters :**

- Water temperature
- Dissolved Oxygen





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, https://doi.org/10.1021/acs.est.0c03418, 2021

Case 4 – Different treatment technologies contribute to emissions differently . . .

No.	Biological treatment technology	IPCC 2019		This study		
		CH_4	N_2O	CH_4	N_2O	CO_2
		g CH_4/kg COD	g N_2O /kg TN influent	g CH_4/kg COD removed (No. 1–11); g CH_4/kg COD (No, 12–27)	g N_2O /kg TN influent	g CO_2/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	A²O	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.

Source:

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

?

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

?

Re-evaluating emission factors from onsite systems like septic tanks in India with infrequent emptying and drain connections

?

Localizing factors for demography and sanitation technologies

?

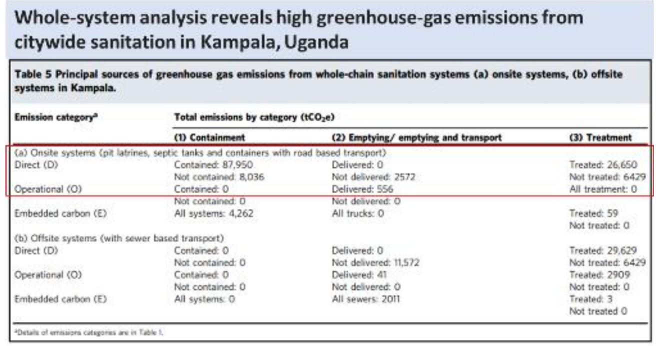
Estimating quantum of indirect emissions contributed by WASH to give a holistic picture of emissions from service delivery

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

It is being suspected that some chemical was discharged into the sewer where it got mixed with methane and other gases to produce Hydrogen Sulphide.

308 died while cleaning sewers, septic tanks in last five years across India

Image source: Indian express, Times of India



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 systems in Kampala.

Emission category[a]	Total emissions by category (tCO_2e) (1) Containment	(2) Emptying/ emptying and transport	(3) Treatment
(a) Onsite systems (pit latrines, septic tanks and containers with road based transport)			
Direct (D)	Contained: 87,950 Not contained: 8,036	Delivered: 0 Not delivered: 2572	Treated: 26,650 Not treated: 6429
Operational (O)	Contained: 0 Not contained: 0	Delivered: 556 Not delivered: 0	All treatment: 0
Embedded carbon (E)	All systems: 4,262	All trucks: 0	Treated: 59 Not treated: 0
(b) Offsite systems (with sewer based transport)			
Direct (D)	Contained: 0 Not contained: 0	Delivered: 0 Not delivered: 11,572	Treated: 29,629 Not treated: 6429
Operational (O)	Contained: 0 Not contained: 0	Delivered: 41 Not delivered: 0	Treated: 2909 Not treated: 0
Embedded carbon (E)	All systems: 0	All sewers: 2011	Treated: 3 Not treated 0

[a]Details of emissions categories are in Table 1.

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,

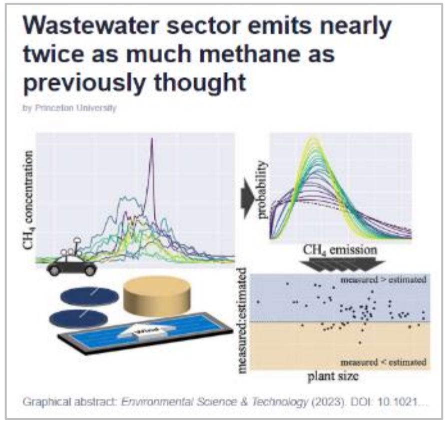


Image source: Wastewater sector emits nearly twice as much methane as previously thought (2023, February 28) retrieved 18 July 2023 from https://phys.org/news/2023-02-wastewater-sectoremits-methane-previously.html

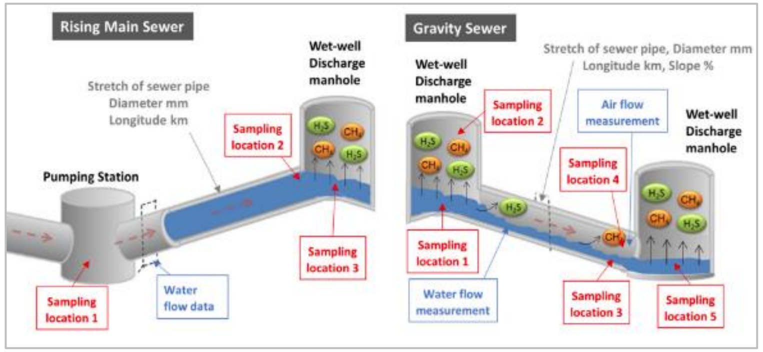


Image source: Ye, L., Porro, J., & Nopens, I. (Eds.). (2022). Quantification and Modelling of Fugitive Greenhouse Gas Emissions from Urban Water Systems. IWA Publishing. doi:10.2166/9781789060461

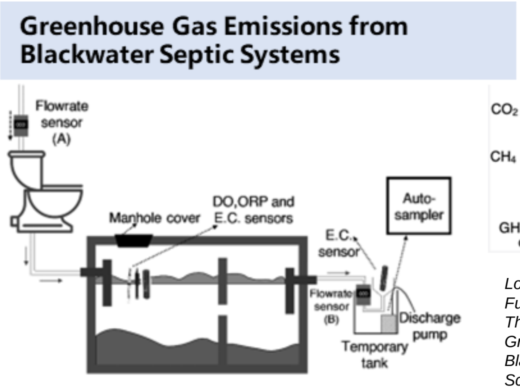
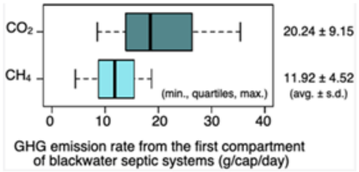
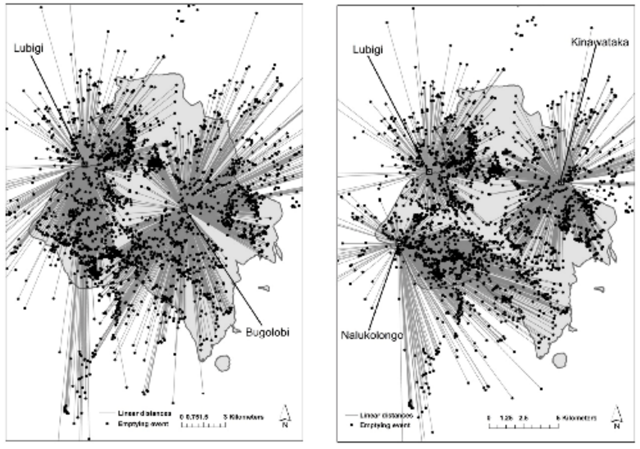


Figure 1. Experimental setup of sensor and autosampler for water and septage monitoring.



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



(a) (b)

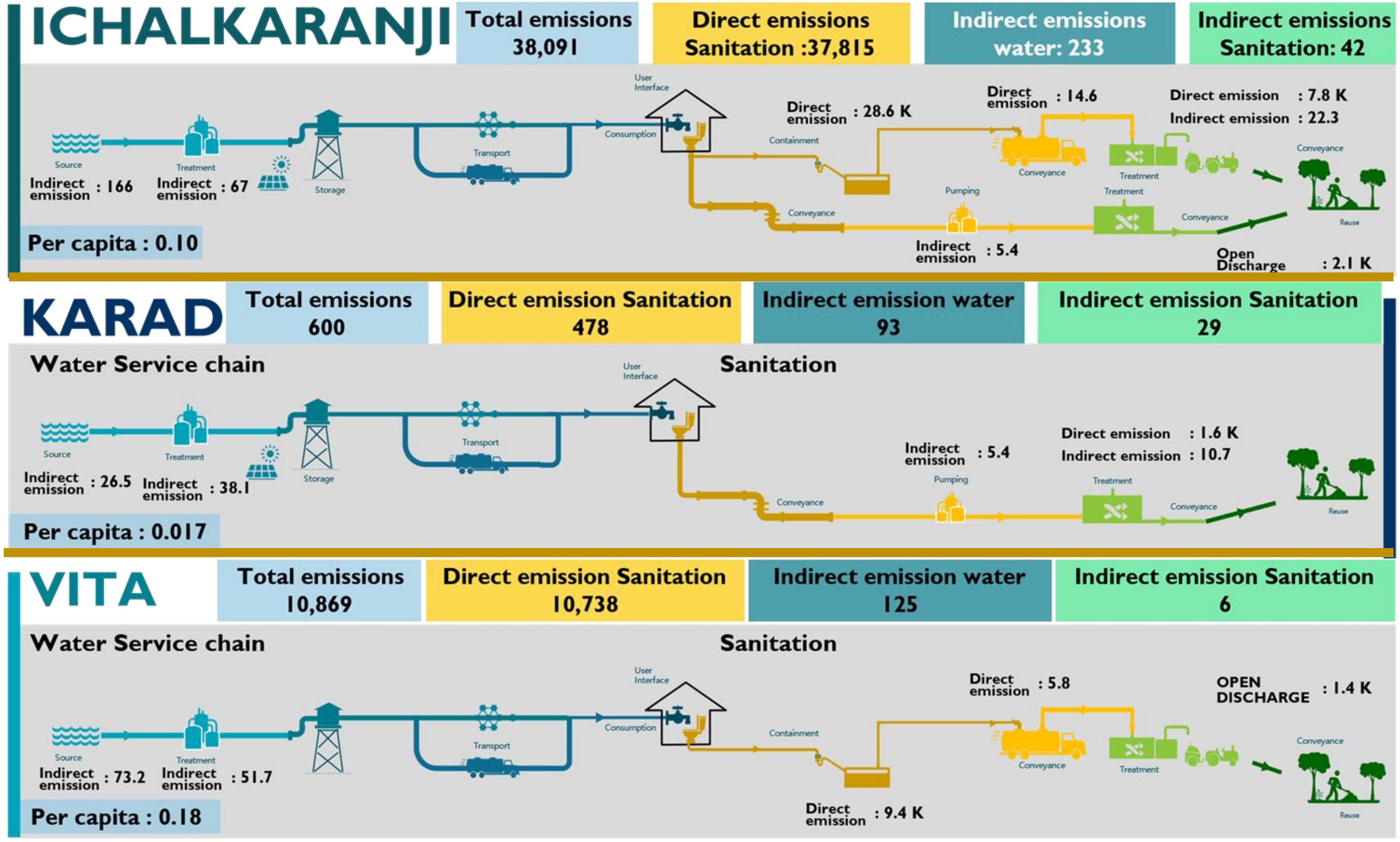
Schoebitz L, Bischoff F, Lohri CR, Niwagaba CB, Siber R, Strande L. GIS Analysis and Optimisation of Faecal Sludge Logistics at City-Wide Scale in Kampala, Uganda. Sustainability. 2017; 9(2):194. https://doi.org/10.3390/su9020194

Methodology adopted for quantification of emissions

Methodology adapted for quantification of emissions

1. Understanding of IPCC estimation methodology for wastewater and water sector
2. Assessment for the WASH service chain in these cities to map out different water pathways for quantification of emissions
3. Assessment for the WASH service chain in these cities to map out energy requirements
4. Developing initial empirical estimates for emissions from WASH service chains using country level factors and city level WASH information
5. Field measurements with gas sensors and lab testing of sludge to compare with empirical estimates
6. Localization of estimation

Initial GHG estimates using IPCC empirical quantification . . .



All emissions are in tons.

Formula for calculation:

Direct emissions (Scope 1) :

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

1. TOW = Volume of wastewater generated x BOD
2. 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

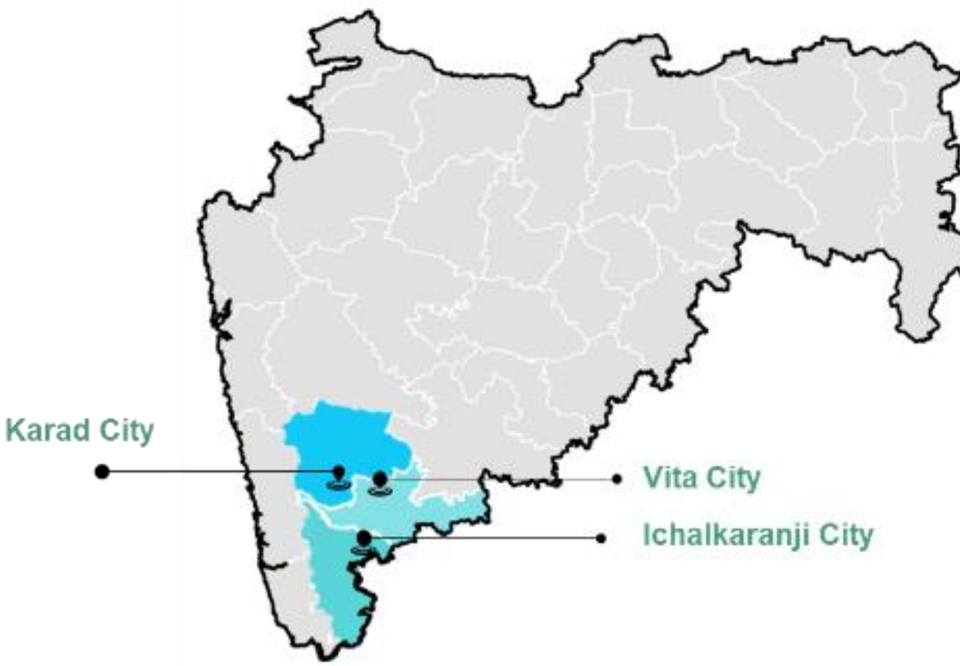
Annex 1 : Sample calculation for one city . . .

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
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

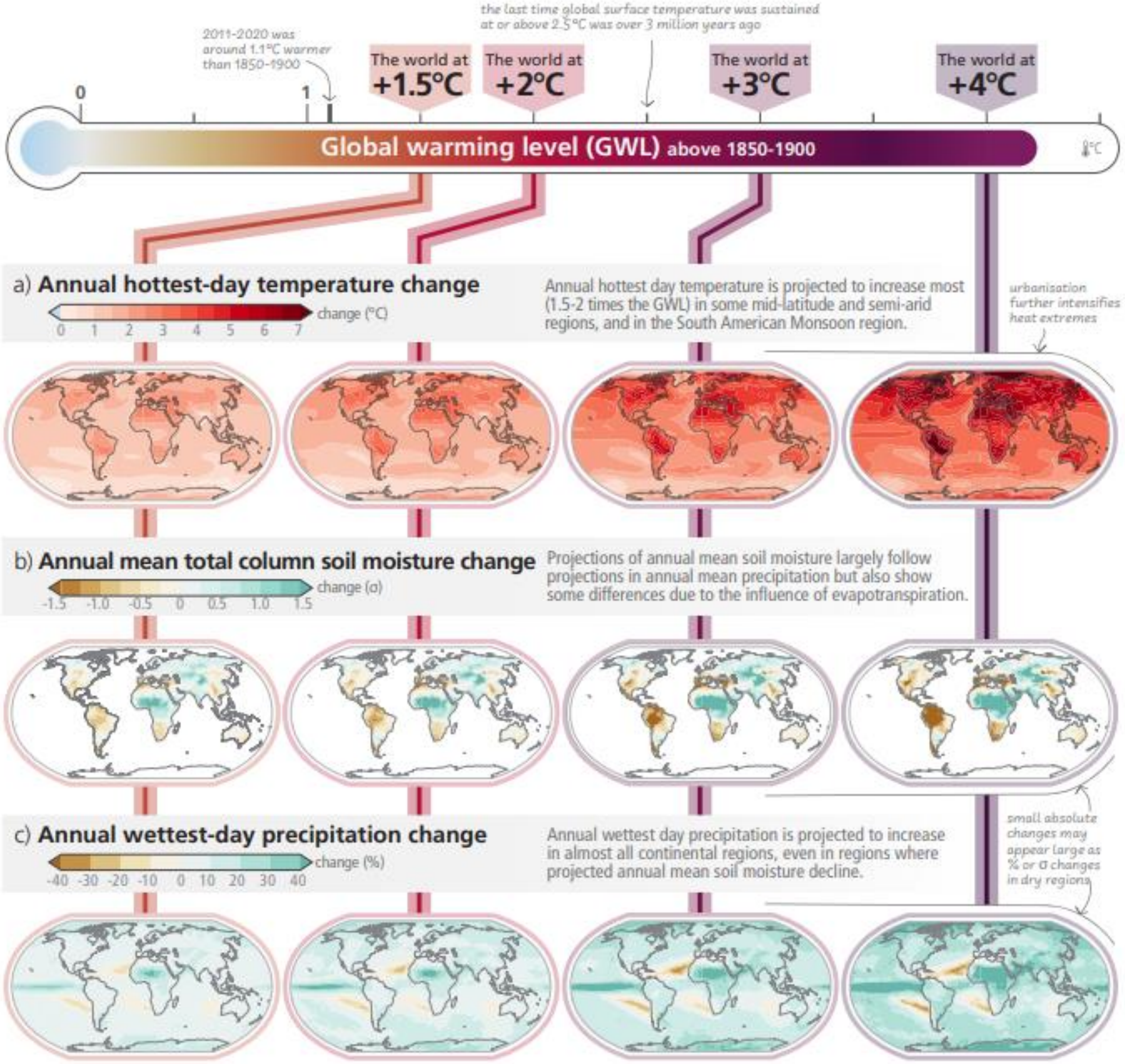
- We aim to quantify methane emissions and identify the potential areas where emissions can be converted into resources
- Identify areas and methods to capture these emissions
- Exploring and scaling up the estimating activities across the sanitation value chain, i.e. for treatment
- Scale-up the activity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

Thank You

Global South Academic Conclave on WASH and Climate Linkages

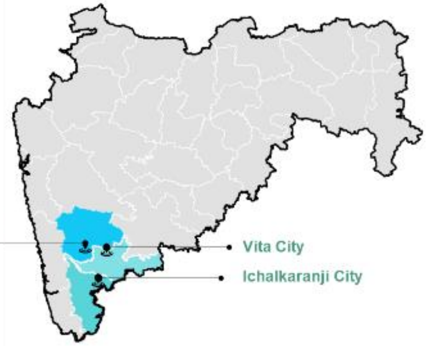
Climate Change a global issue !!!

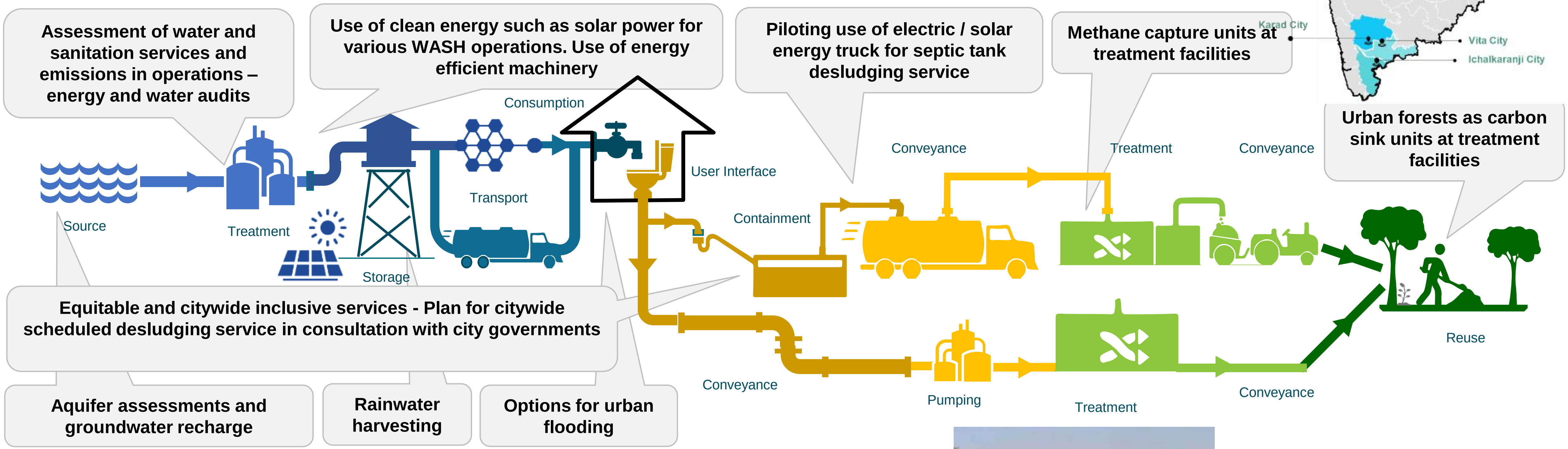
- Climate related disaster contributes about **50 % of total disasters** occurred in last 50 years.
- Climate related disaster frequency has **increased 5 times** as compared to 50 years ago disaster frequency.
- The economic loss has **increased 7 times** due to the climate related disaster in last 50 year.
- All disaster having **wider impact on developing and underdeveloped nations.**

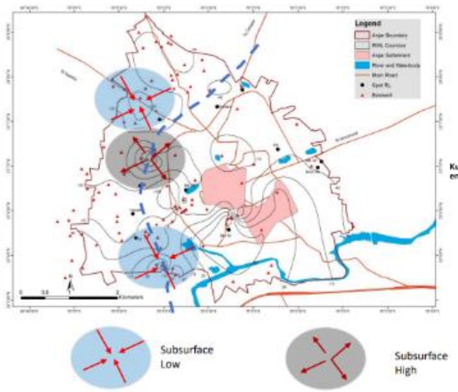


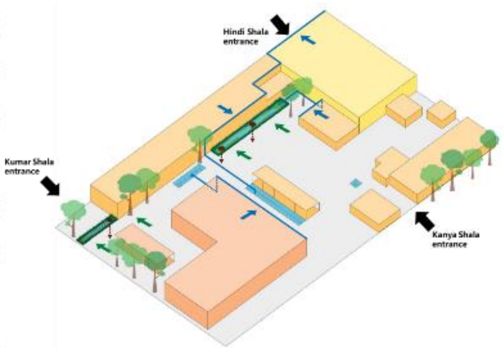
- Source: IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee 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 ; https://news.un.org/en/story/2021/09/1098662

Exploring mitigation measures through energy transition in water provisioning and wastewater management









Exploring adaptation measures through water security plans

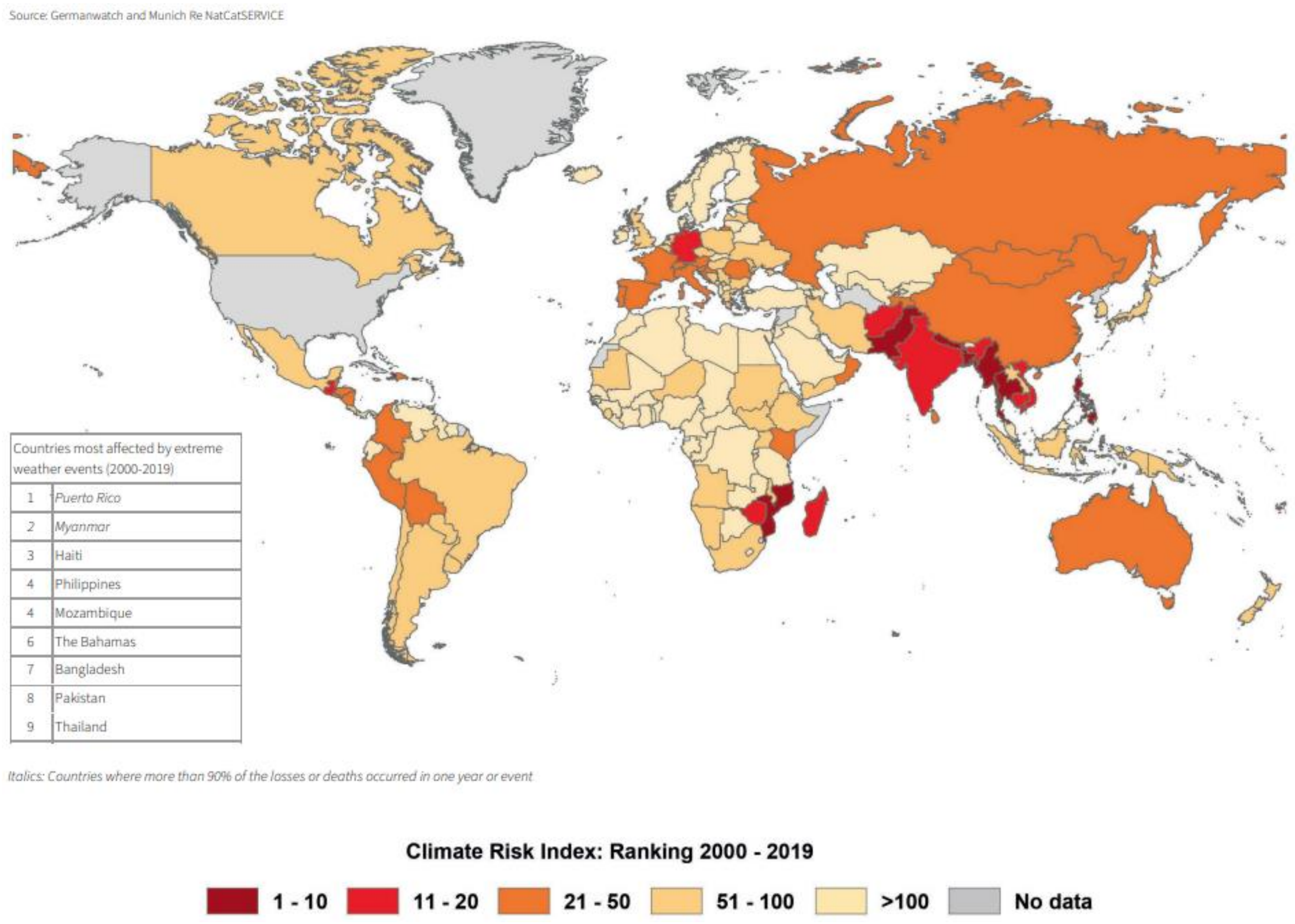
Increase in frequency of climate hazards increases risk to countries

- 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

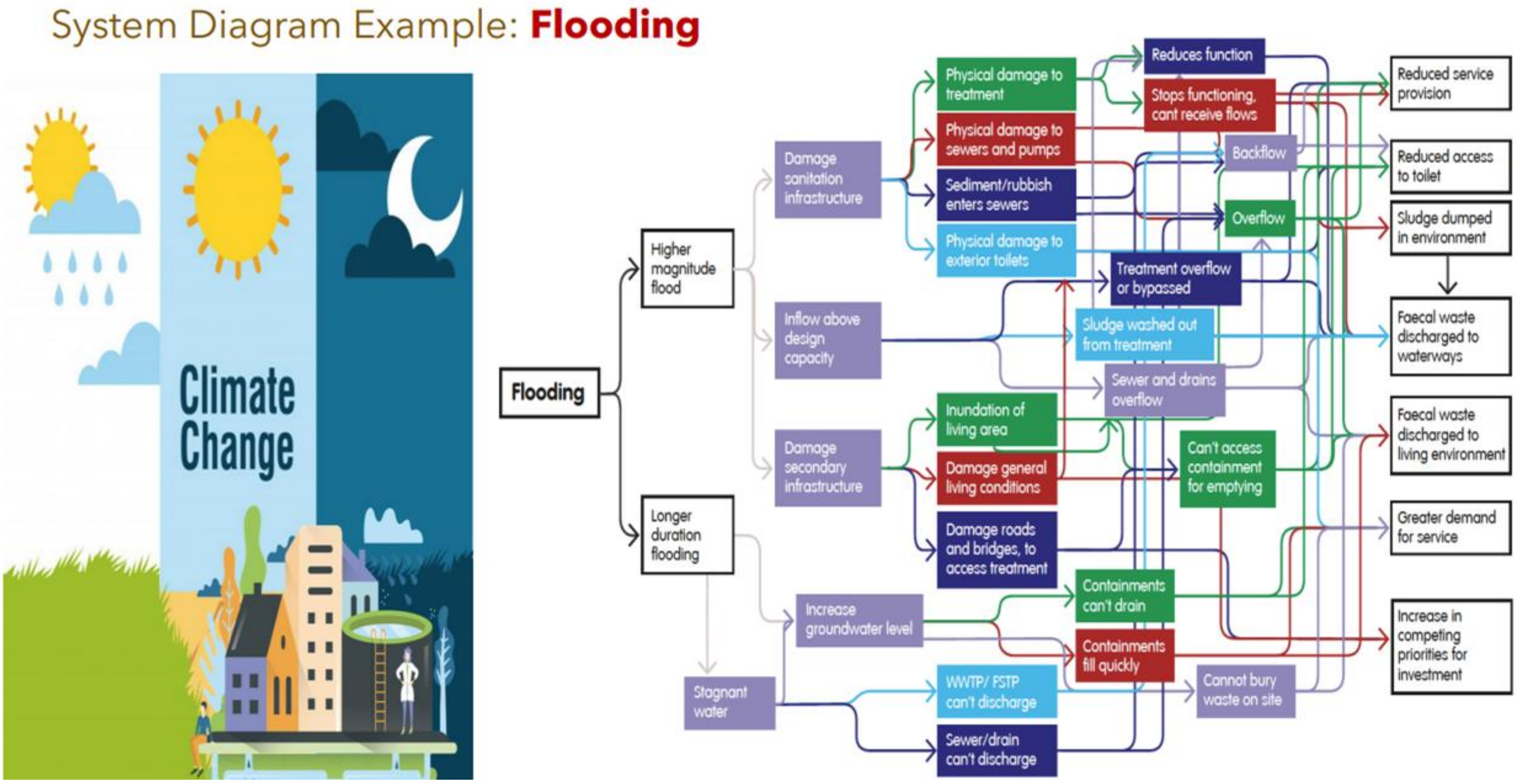
- India is 7th most vulnerable country to the climate hazard (in 2019)

- 200 % climate hazards have increased in India since 2005 causing over $87 billions in year 2019



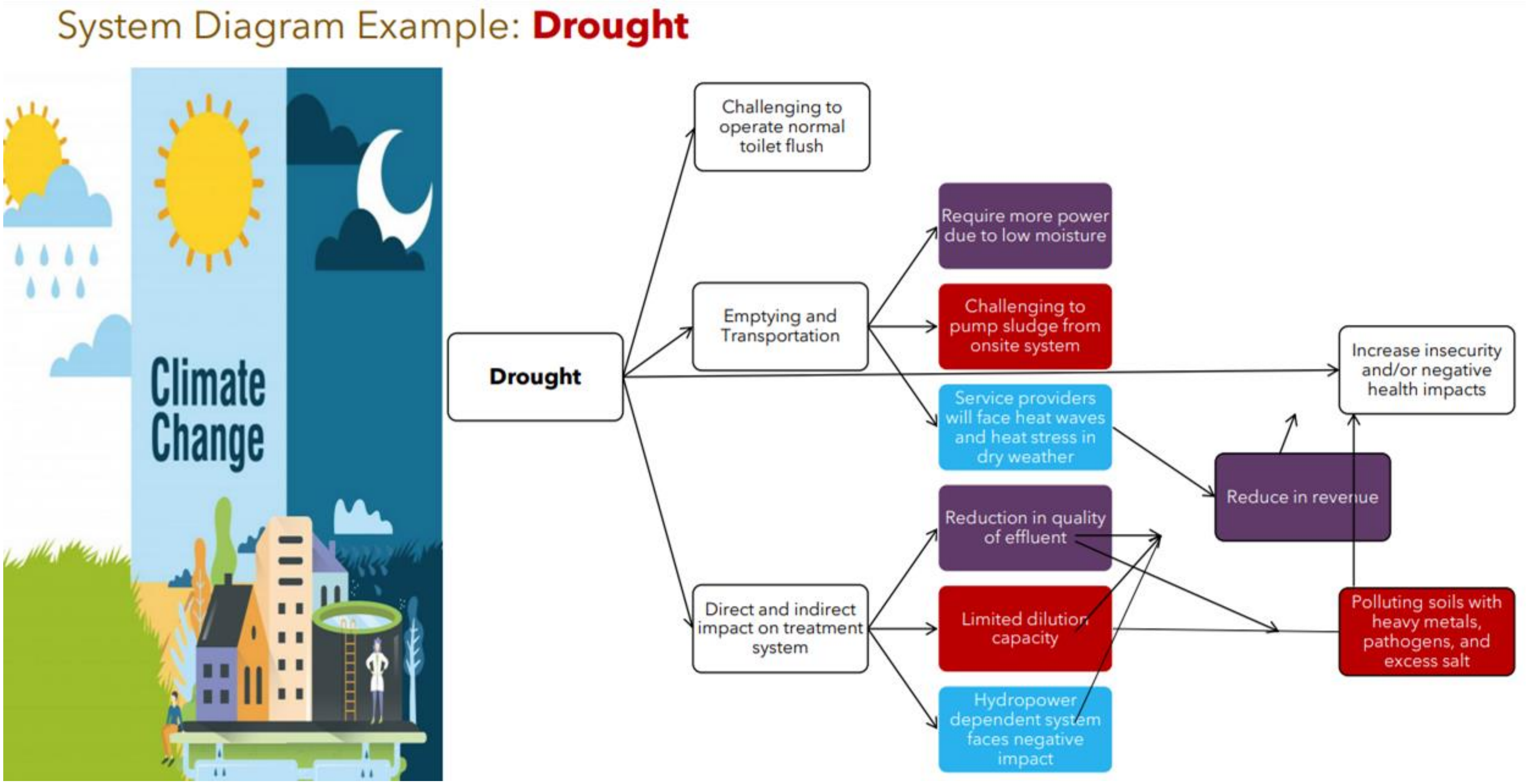
Source : Mohanty, Abinash and Shreya Wadhawan. 2021. Mapping India's Climate Vulnerability: A District-Level Assessment. New Delhi: Council on Energy, Environment and Water; https://economictimes.indiatimes.com/news/india/india-lost-over-1-3-lakh-lives-in-disasters-linked-to-extreme-weather-climate-change-in-50-years-un-agency/articleshow/100424018.cms?from=mdr

Impact of Climate change on the sanitation services



Source: ISF-UTS and SNV (2019)

Impact of Climate change on the sanitation services



Source : Climate Resilient Urban Sanitation (2021)

Impact of climate change on the water supply…

	Climate hazard	Impact on consumption	Impact on infrastructure	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 diarrheal diseases

Increase in conflicts of use

More difficulty in drawing water

Greater migration

Leading to reduction in GDP

Source: https://www.pseau.org/outils/ouvrages/ps_eau_wash_services_climate_change_impacts_and_responses_2018.pdf

Wide variations in estimates across various studies . . .

Niua Cities
Comparison

Water is a source through which we feel climate change significantly...

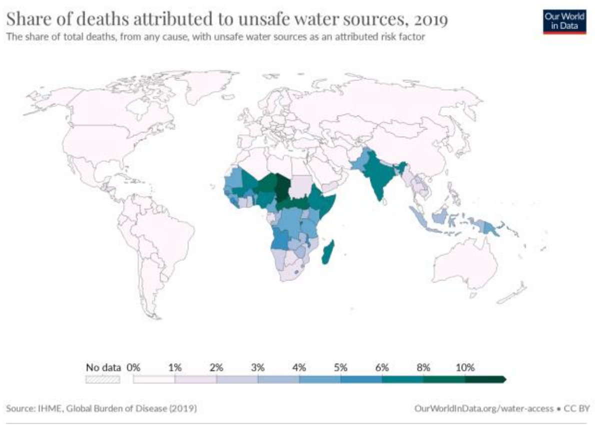


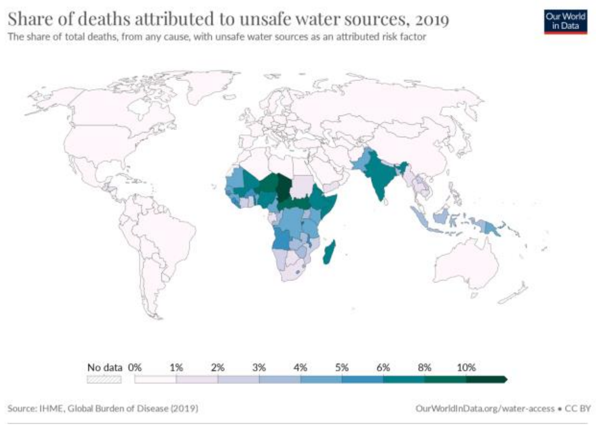

- Climate change has a tremendous negative impact on water, sanitation and hygiene (WASH) services.
- But at the same time, the WASH sector presents a huge opportunity to contribute to global adaptation and mitigation goals, through the building of a climate-resilient, low-carbon WASH sector.

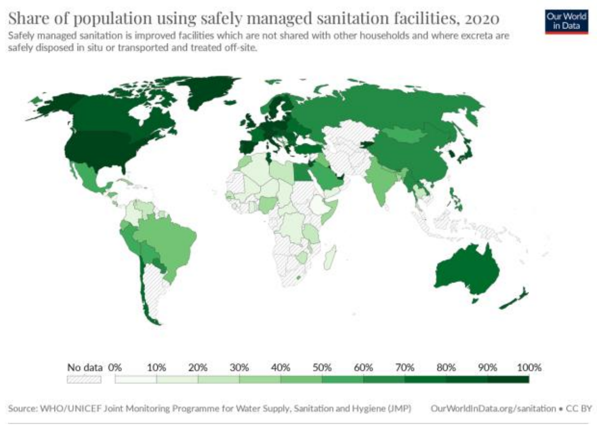
Source: UN-Water: https://www.unwater.org/news/why-wash-must-be-top-climate-agenda

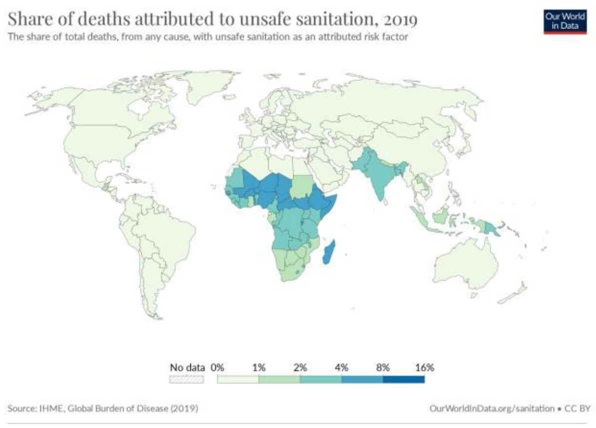
Strengthening basic services in developing countries leading to better tomorrow…

- Better access and quality of basic services i.e., water and sanitation will positively impact on the women, child, aged population and low-income group.
- Women spend eleven times more time than men in management of water and sanitation at household level in Asia and Pacific region[1].









Water services	Sanitation services
Through improving the water services net benefit of **$37 billions** can be achieved in **next 20 years**	Through achieving the safely managed sanitation services net benefit of **$86 billions** can be achieved in **next 20 years**

Source: https://journalism.csis.org/women-and-water-in-the-developing-world-linking-water-insecurity-and-gender-disparities/ ; https://www.sanitationandwaterforall.org/sites/default/files/2021-04/SWA%20Briefing%20Paper%20-%20WASH%20and%20gender_FINAL.pdf ; https://washmatters.wateraid.org/sites/g/files/jkxoof256/files/misin-crtica-invertir-en-agua-saneamiento-e-higiene-para-una-recuperacin-econmica-saludable-y-ecolgica.pdf