GLOBAL WATER AND CLIMATE ADAPTATION CENTRE
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Water Security and Climate Adaptation Conference (WSCA 2023)

WATER SECURITY AND CLIMATE ADAPTATION
WSCA

ABS051 - Reducing carbon emissions through use of renewable energy in WASH services in cities of Maharashtra, India

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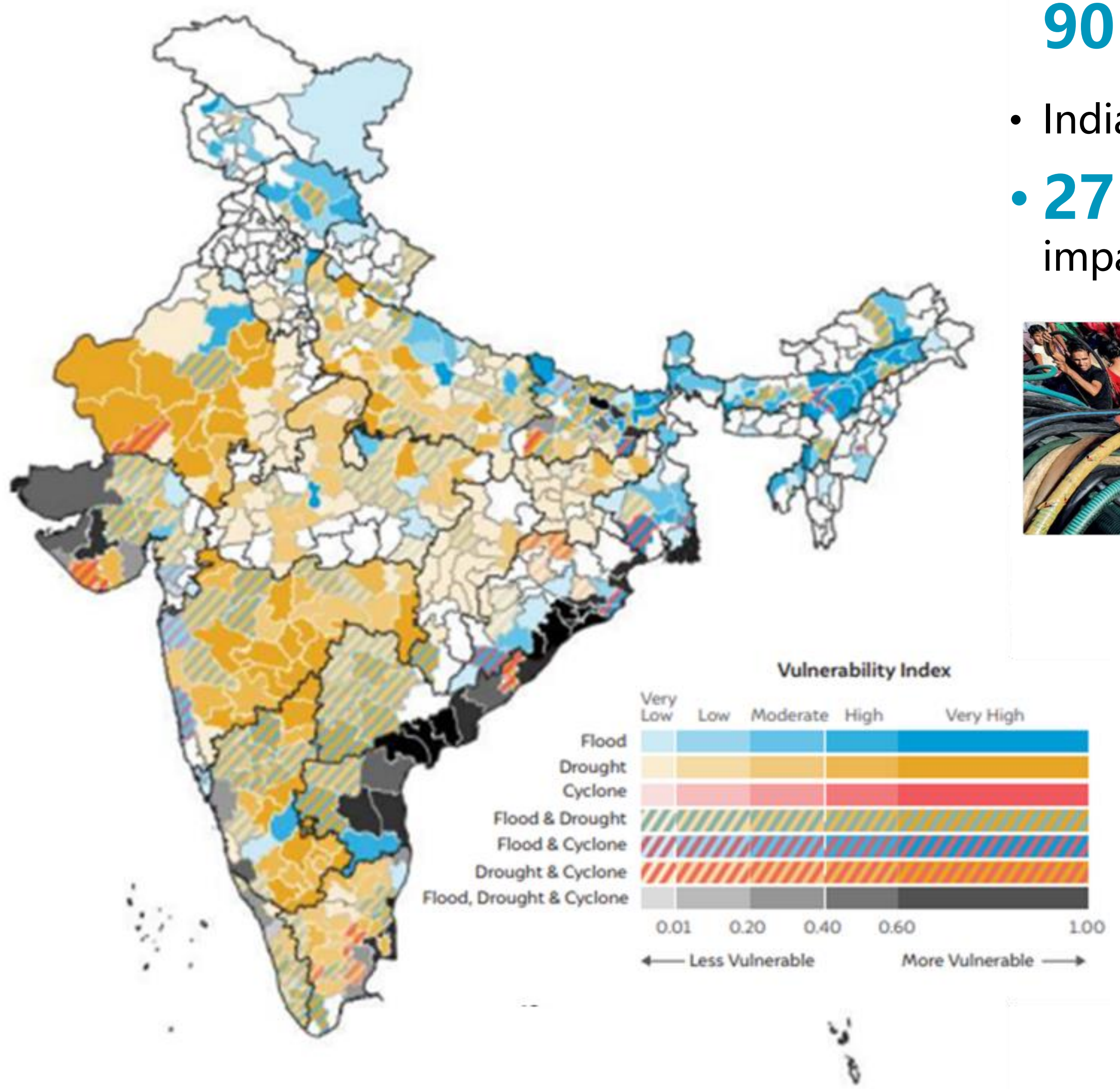
The threat of climate change



- 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

Impact on water services…

- Higher drought frequency will lead to **"load shedding of water supply" or "intermittent water supply".**
- This will further lead to accessing the distant water sources **which means more consumption of energy and finance needs**

Source : Mohanty, Abinash, and Shreya Wadhawan. 2021. Mapping India's Climate Vulnerability – A District Level Assessment. New Delhi: Council on Energy, Environment and Water.

Emissions, mitigation and India’s NDCs

- India is 3rd largest GHG emitter among all the countries.

2,953 Mt CO_2e overall emissions

Energy sector the largest contributor

1 Reduce the emissions intensity of its GDP to **45%** below 2005 levels by 2030.

2 Achieve about **50%** cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030.

3 Create an additional carbon sink of 2.5-3.0 billion tonne of carbon dioxide equivalent through additional forest and tree cover by 2030.

4 Propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation, including through a mass movement for ‘LiFE’– ‘Lifestyle for Environment’ as a key to combating climate change.

Focusing on Carbon capture usage and storage technologies

Sector specific targets for all action and strategies

Focus on research and innovation towards clean fuel technologies

Focus on international cooperations and financial credit flows

Source: https://pib.gov.in/PressReleasePage.aspx?PRID=1876119

Quantification of emissions in WASH sector is essential . . .

Global estimate suggest 5 % emissions are from WASH sector.

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.

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

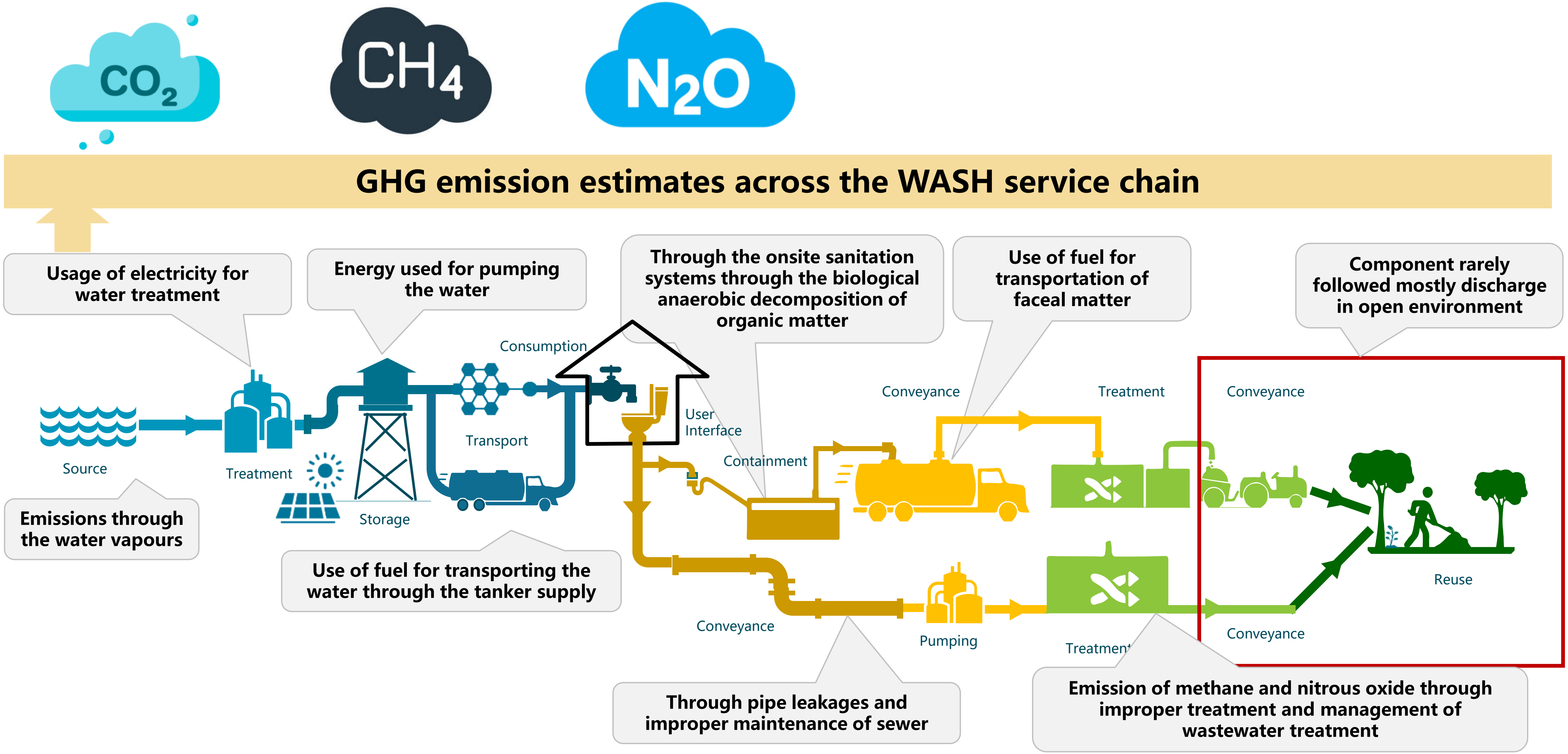
Provides empirical methodology to estimate emissions using country level factors....

However, this requires localization for actions

Types of Emissions

IPCC methodology for emission inventory

Dynamics of Water and sanitation value chain varies…



Need to assess factors and assumptions listed by IPCC and localization 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

Image source: Indian express, Times of India

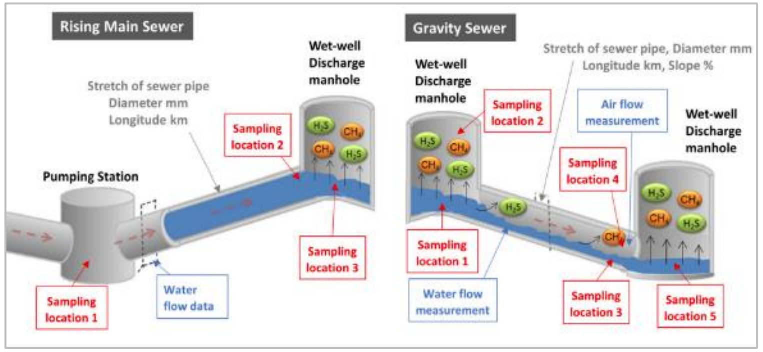


Image source: Ye, L., Porro, J., & Nopens, I. (Eds.). (2022). Quantification and Modelling of Fugitive Greenhouse Gas Emissions from Urban Water Systems. IWA Publishing. doi:10.2166/9781789060461

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,

Greenhouse Gas Emissions from Blackwater Septic Systems

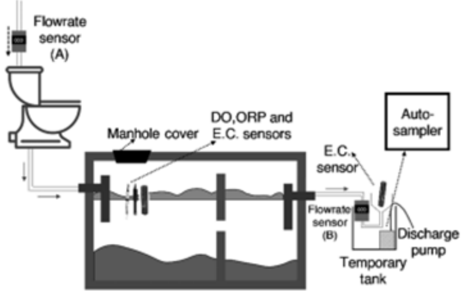
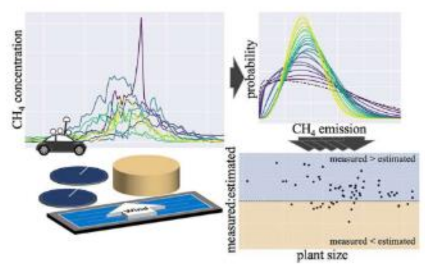


Figure 1. Experimental setup of sensor and autosampler for water and septage monitoring.

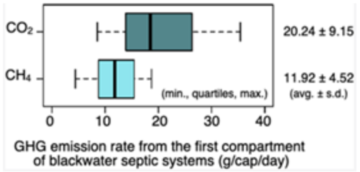
Wastewater sector emits nearly twice as much methane as previously thought

by Princeton University

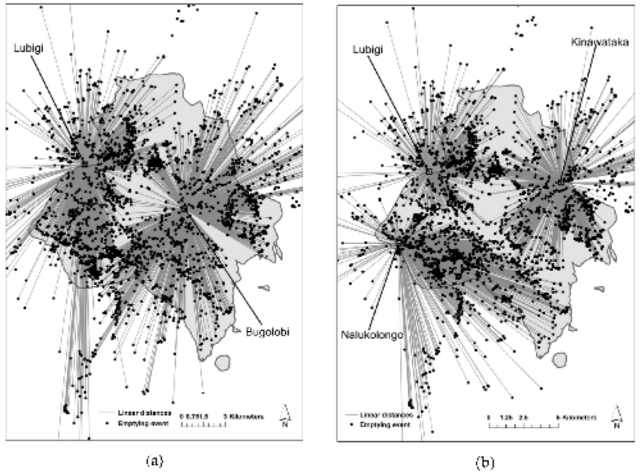


Graphical abstract: Environmental Science & Technology (2023). DOI: 10.1021...

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-wastewater-sectoremits-methane-previously.html



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



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

Comparison of GHG emission from onsite sanitation

Sr. No.	City	Method Adopted	Population	Per capita methane emission from septic tank (kg/ cap/ CO_2 eq./ year)
1	Kampala	Practical prototype + IPCC factors	22,50,000	54
2	IPCC (Ichalkaranji)	Using IPCC factors	3,68,916	101
3	Vietnam	Practical field study	84,35,700	136

Enhancing empirical estimates through field measurements . . . (1/2)

Present Methodology and factors . . .

Estimation of CH4 emissions – IPCC methodology

1. CO2eq = CH4 X 14
2. Sum emissions for each discharge pathway

EQUATION 6.1A (NEW)
TOTAL CH_4 EMISSIONS FROM DOMESTIC WASTEWATER TREATMENT AND DISCHARGE

$$CH_4\ Emissions = \sum_j [CH_4 Emissions_j] \bullet [10^{-6}]$$

3. Calculate emissions for particular discharge pathway (j)

EQUATION 6.1 (UPDATED)
CH_4 EMISSIONS FROM DOMESTIC WASTEWATER FOR EACH TREATMENT/DISCHARGE PATHWAY OR SYSTEM, J

$$CH_4\ Emissions_j = [(TOW_j - S_j) \bullet EF_j - R_j]$$

4. Calculate sludge removed in each treatment pathway

EQUATION 6.3B (NEW)
ORGANIC COMPONENT REMOVED AS SLUDGE FROM AEROBIC TREATMENT PLANTS

$$S_{aerobic} = (S_{mass} \bullet K_{rem} \bullet 1000)$$

EQUATION 6.3C (NEW)
ORGANIC COMPONENT REMOVED AS SLUDGE FROM SEPTIC SYSTEMS

$$S_{septic} = TOW_{septic} \bullet F \bullet 0.5$$

5. Calculate emission factors for each discharge pathway using suggested values of Maximum Methane Producing Capacities (B0 0.6 kg CH4/kg BOD) and Methane Correction Factors (MCF)

EQUATION 6.2
CH_4 EMISSION FACTOR FOR
EACH DOMESTIC WASTEWATER TREATMENT/DISCHARGE PATHWAY OR SYSTEM

$$EF_j = B_o \bullet MCF_j$$

6. Subtract CH4 being recovered – Default value is zero
7. Calculate Total Organically Degraded Material at country level using suggested BOD values of domestic wastewater (34 for India)

EQUATION 6.3 (UPDATED)
TOTAL ORGANICALLY DEGRADABLE MATERIAL IN DOMESTIC WASTEWATER

$$TOW = P \bullet BOD \bullet 0.001 \bullet 365$$

8. Calculate Total Organics in wastewater each discharge pathway and each demographic fraction (rural, urban high, urban low) using listed values for urbanization and degree of utilization of pathway)

EQUATION 6.3A (NEW)
TOTAL ORGANICS IN DOMESTIC WASTEWATER BY TREATMENT/DISCHARGE PATHWAY OR SYSTEM

$$TOW_j = \sum_i [TOW \bullet U_i \bullet T_{ij} \bullet I_j]$$

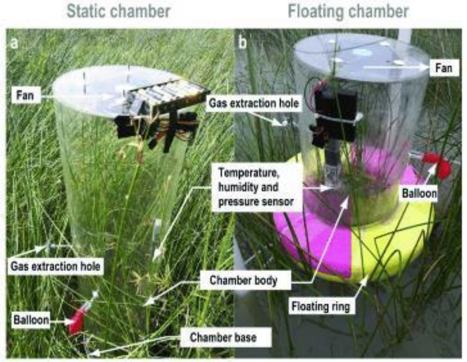
Localization through field measurements

Sensor equipment measurements with discrete and continuous sampling

Carrying out field survey at selected locations across WASH value chain with different typologies to quantify the emissions using the available sensor based instruments

Lab testing approach

Collecting samples using certified labs using standard sampling techniques



Enhancing empirical estimates through field measurements (2/2)

Localizing the estimation factors . . .

Estimation of CH4 emissions – IPCC methodology

1. CO2eq = CH4 X 14
2. Sum emissions for each discharge pathway

Capture all possible (and unreported) discharge pathways observed in cities

EQUATION 6.1A (NEW)

3. Calculate emissions for particular discharge pathway (j)

EQUATION 6.1 (UPDATED)
CH₄ EMISSIONS FROM DOMESTIC WASTEWATER FOR EACH TREATMENT/DISCHARGE PATHWAY OR SYSTEM, J

$$CH_4\ Emissions_j = \left[\left(TOW_j - S_j \right) \bullet EF_j - R_j \right]$$

4. Calculate sludge removed in each treatment pathway

EQUATION 6.3B (NEW)
ORGANIC COMPONENT REMOVED AS SLUDGE FROM AEROBIC TREATMENT PLANTS

Does regular emptying reduce emissions from septic tanks?

ORGANIC COMPONENT REMOVED AS SLUDGE FROM SEPTIC SYSTEMS

$$S_{septic} = TOW_{septic} \bullet F \bullet 0.5$$

5. Calculate emission factors for each discharge pathway using suggested values of Maximum Methane Producing Capacities (B0 0.6 kg CH_4/kg BOD) and Methane Correction Factors (MCF)

EQUATION 6.2
EACH DOMESTIC WASTEWATER TREATMENT/DISCHARGE PATHWAY OR SYSTEM

Ground truthing by measuring B_0 on field using sensor equipment

$$EF_j = B_0 \bullet MCF_j$$

Explore methods to capture CH_4

6. Subtract CH_4 being recovered – Default value is zero
7. Calculate Total Organically Degraded Material at country level using suggested BOD values of domestic wastewater (34 for India)

TOTAL ORGANICALLY DEGRADABLE MATERIAL IN DOMESTIC WASTEWATER

Using BOD values measured through lab tests

8. Calculate Total Organics in wastewater each discharge pathway and each demographic fraction (rural, urban high, urban low) using listed values for urbanization and degree of utilization of pathway)

TOTAL ORGANICS IN DOMESTIC WASTEWATER BY TREATMENT/DISCHARGE PATHWAY OR

Values of population fractions and pathway utilization using city specific data

$$TOW_j = \sum \left[TOW \bullet U_i \bullet T_{ij} \bullet I_j \right]$$

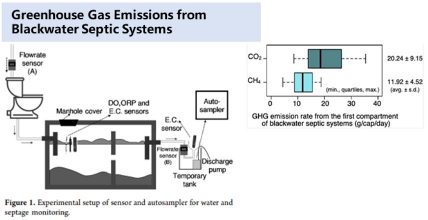
Are there any direct emissions from water supply-production and treatment?

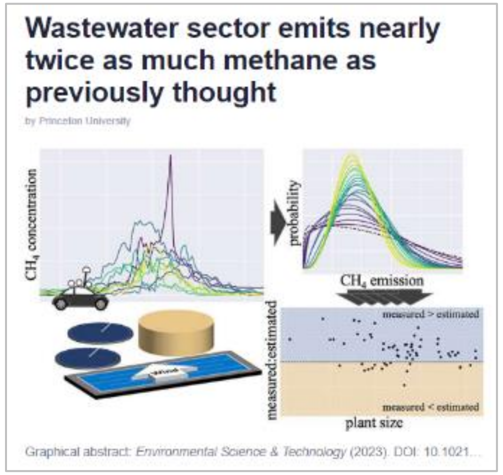
Are the atmospheric conditions fully aerobic in deeply loaded drying beds or nallas?

Are methane correction factors relevant for Indian cities? Re-evaluating by measuring CH_4 using sensors at septic tank vents, sewer inspection chambers, drain outfalls, treatment plant units

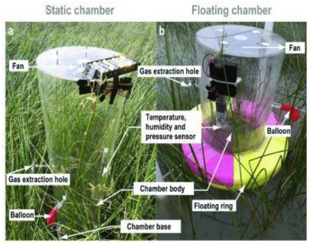
Process methodology adapted for localizing emission factor.....

Literature review





Estimation methodology selection



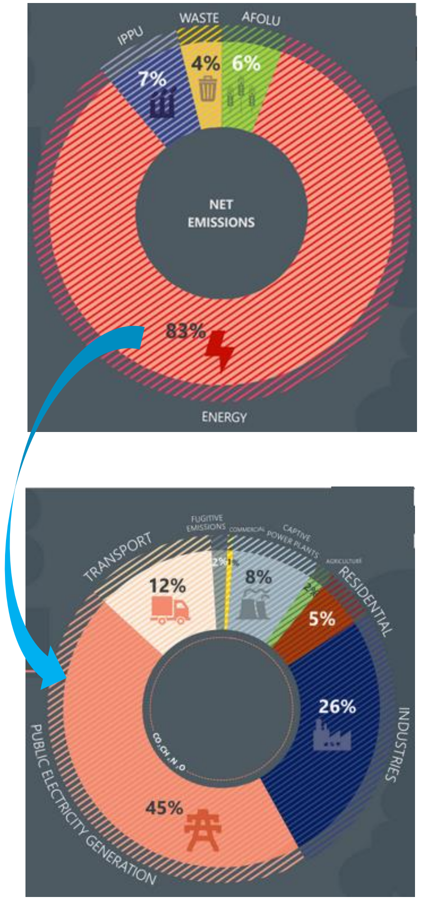
Site selection and Reco survey at sites identified

Final Site selection and survey

Result estimation and deriving local emission factor for each pathway

Mitigation – Electricity consumption plays a big role

Sectoral contribution

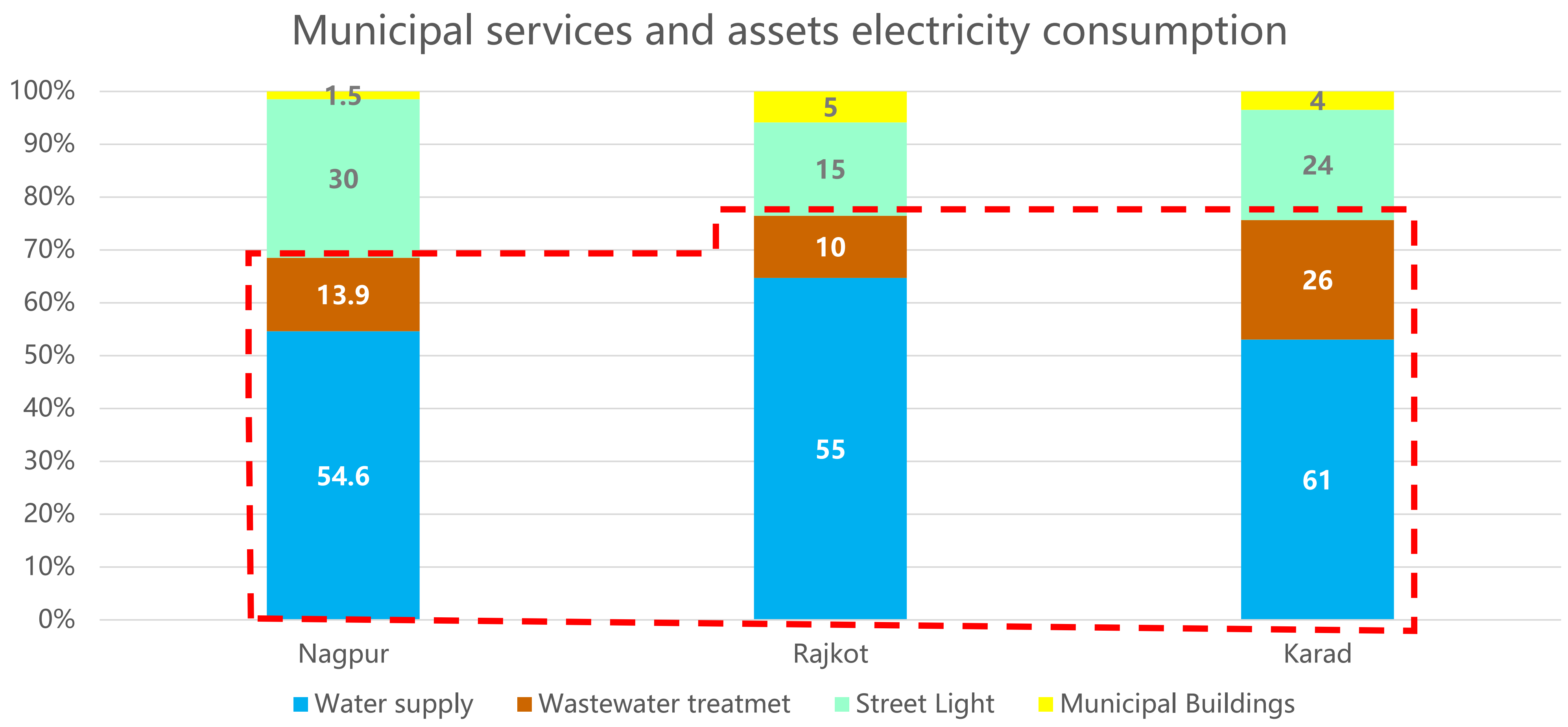


Source : GHG Platform India

2,455 Mt CO_2e

emission from the energy sector

40% to 60% of the electricity bill of municipal corporations goes towards water / sewage pumping



Source : 1. https://southasia.iclei.org/wp-content/uploads/2022/04/6.-Thane-City_GHG-Emission-Inventory-2017-18-Report_v-2.0.pdf; 2. https://southasia.iclei.org/wp-content/uploads/2022/04/2.-Climate-Resilient-City-Action-Plan-Nagpur-Report-Low-Res_compressed.pdf; 3. Karad municipal council, 2023

Energy transition – important for achieving mitigation targets

Multiple benefits of shifting from fossil fuels to renewable energy :

Reduction in energy cost

Reduction in emissions

Low maintenance inputs

Reduction in transmission losses

Exploring options in a few cities of Maharashtra / Interlocking renewable energy with WASH sector yields benefits in terms of emissions and cost saving over long terms

**** The selected pilot cities population ranges between 50k – 400 K***

- **5** pilot cities
- **Solar Installation across WASH service value chain**
- **1** installation at water treatment plant
- **4** installation at wastewater, greywater and faecal sludge treatment facility

Exploring options and feasibility in pilot cities

Process methodology followed:

1 Preliminary assessment

Collecting electricity bills of all the components across WASH services chain, assessment of land availability and creating the profile of each component

2 Electricity consumption and Demand assessment

Calculating the past, present and future electricity consumption based on electricity bills and collecting the details about the plans for expansion of WASH components

3 Calculation of solar requirement and installation

Based on the calculated demand and available land, calculating the capacity of solar plant that can be installed

The requirement calculated using the assessment:


Wai : 30 Kw at FSTP


Sinnar : 15 Kw


Karad : 72 Kw at STP


Satara : 30 Kw


Ichalkaranji : 81 Kw at WTP

Solar and benefits …

Wai

- **Year of installation** : 2021
- **Renewable energy generation** : 46.4 MWH
- **Emission reduction :** 923 tons CO2 eq. (over 25 years)

Satara

- **Year of installation** : 2023
- **Installation capacity** : 30 KW
- **Renewable energy generation** : 18.5 MWH
- **Emission reduction :** 923 tons CO2 eq. (over 25 years)

Sinnar

- **Year of installation** : 2020
- **Installation capacity** : 15 KW
- **Renewable energy generation** : 25.7 MWH
- **Emission reduction :** 461 tons CO2 eq. (over 25 years)

Reducing **16 %** dependency on conventional energy source of municipal services as per current usage.

Clean energy generated till June

126 MWH

Clean energy generation potential over 25 years

8550 MWH

Emission reduction Potential (over 25 years)

7,011 tons CO2

Projected Overall cost saving (25 yrs)

INR 5.9 Cr.

Karad

- **Year of installation** : 2023
- **Installation capacity** : 72 KW
- **Renewable energy generation** : 26 MWH
- **Emission reduction :** 2,214 tons CO2 eq. (over 25 year)

Ichalkaranji

- **Year of installation** : 2023
- **Installation capacity** : 81 KW
- **Renewable energy generation** : 10 MWH
- **Emission reduction :** 2419 tons CO2 eq. (over 25 years)

Can explore the potential of carbon credits based on the energy transition

Developing urban forest using the wastewater treated using the renewable energy at STP and FSTPs

Source : impact estimated using the Nation roof top solar calculator, https://solarrooftop.gov.in/rooftop_calculator

Overcoming challenges

1 High initial CAPEX investment

Benefit and cost recovery requires longer time frame if the entire requirement is transferred to renewable and requires storage space for energy.

2 Land availability at location

Requires vacant land for installations and requirement of transmission infrastructure with availability of the net – metering.

3 Focus on building level solar

Less focus is provided towards setting up solar in municipal infrastructure services and reducing the energy demands of small and medium towns.

Exploring financially sustainable PPP models

- Land supplied by government.
- Initial capital investment by private player.
- Bidding for costs lower than discoms energy supply rates.
- Solar farm model and solar credits.

Online system for monitoring the solar unit generation

Scaling up practice and contributing the national goals

State level initiative

माझी वसुंधरा

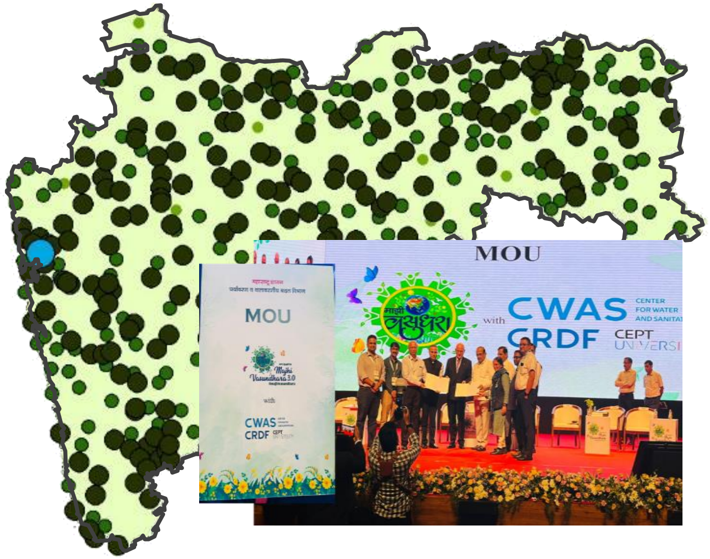
Majhi Vasundhara

A Maharashtra govt initiative for tackling climate change

In 2023, provided funding for **75 MW solar**

Climate mitigation funds

Exploring various financing sources in form of climate funds, mitigation funds and financing from multilaterals



417 cities in Maharashtra

CWAS has recently signed an MoU with Environment and Climate Change Department of Government of Maharashtra for supporting activities related to climate change and WASH under Majhi Vasundhara

Similar practice can be replicated in cities of global south, which can assist in improving the basic service delivery through using the clean sources of energy.

Help in moving towards targets of SDG

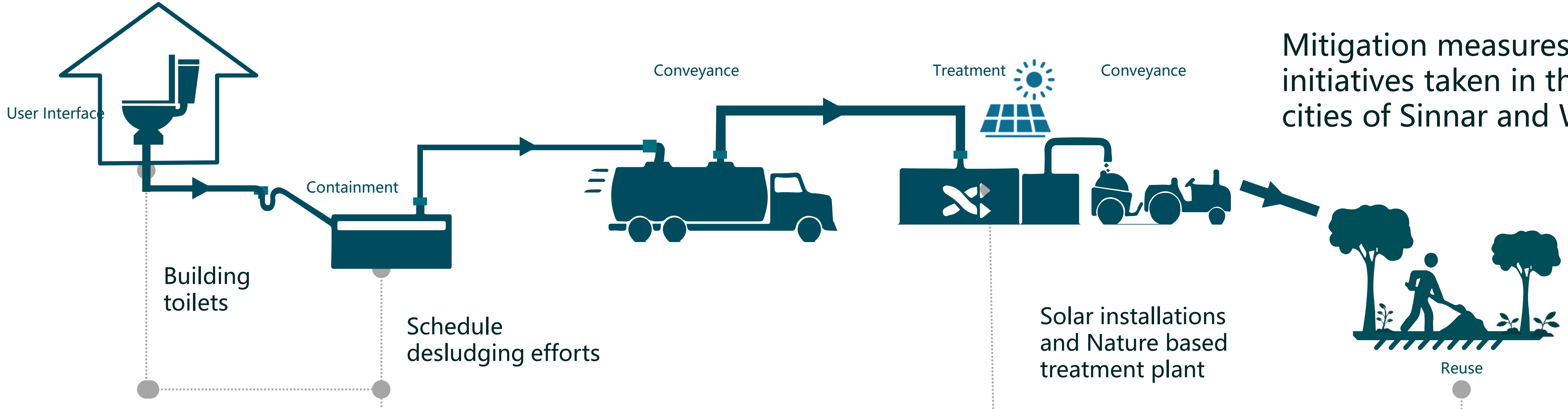
6 CLEAN WATER AND SANITATION

7 AFFORDABLE AND CLEAN ENERGY

13 CLIMATE ACTION

Mitigation measures have made Sanitation infrastructure carbon neutral in Wai and Sinnar . . .

Mitigation measures and initiatives taken in the cities of Sinnar and Wai



Sinnar	**5.3 kt CO2 emissions reduced** Carrying out schedule desludging and improving toilet coverage and treating grey water	**22.7 MT CO2 emissions reduced** Through installation of 7.5 KW solar panel at FSTP treatment facility	**23.8 MT CO2 sequestered** Through developing 8000 sq.mt urban forest with 1400 plants
Wai	**11. 1 kt CO2 emissions reduced** Carrying out schedule desludging and improving toilet coverage, eliminating open defecation	**46.5 MT CO2 emissions reduced** Through installation of 30 KW solar panel at FSTP treatment facility	**8.2 MT CO2 sequestered** Through developing 4000 sqmt urban forest with 1434 plants

** Impact estimated on basis of field assessment numbers, Numbers estimation till 1st July, 2023*

Transition using wastewater and sludge as a resource…

Based on experience of these cities ...
CWAS is working towards Climatic resilient WASH services . . .

Water and Sanitation Climate Resilience Framework

Mitigation | **Adaptation**

Assessments and support measures

GHG emissions

Direct (Scope 1 – CH4, N20, CO2) from

- Septic tanks : regular emptying at 2-3 years
- Trucks : Non-fossil based conveyance of water, septage and solid waste
- Sewers: Maintenance of sewers to avoid stagnation.
- Methane capture units at wastewater treatment plant
- Treated Wastewater reused for carbon sinks

Indirect (Scope 2 – CO2) from

- Electricity : Non-fossil fuel (Solar, Wind, Hydro) Power supplied for water , sanitation and SWM services

Risk and Vulnerability

Water , sanitation and SWM services

- Access to individual household services
- Improved Quality of services achieving service levels
- Robust infrastructure of WS, WW, SW and SWM
- Reduction in ground water dependency
- Ground water recharge – RWH
- Reducing Vulnerability of low lying coastal and dense localities

Climate Hazards

- Reduction of impacts on service delivery during heavy rainfall, heatwaves, drought, storms etc.

Institutional and Financing mechanisms | **Monitoring systems for impacts measurement** | **Community engagement, Inclusivity and gender**

Resilience is the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity of self-organization, and the capacity to adapt to stress and change.

Mitigation means making the impacts of climate change less severe by preventing or reducing the emission of greenhouse gases (GHG) into the atmosphere and enhancing activities that remove these gases from the atmosphere.

Adaptation is the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities.

The designed framework will help to adapt a structured approach to assess the existing WASH infrastructure w.r.t to climate and assist in making the WASH services Climate Resilient and Carbon neutral (or carbon negative services) at city level and further scaling up at the state level.

Note : * For indirect, we are not considering Scope 3 emissions . Scope 3 emissions are the result of activities from assets not owned or controlled by the reporting organization, but that the organization indirectly affects in its value chain

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About us

The Center for Water and Sanitation (CWAS) at CEPT University carries out various activities – action research, training, advocacy to enable state and local governments to improve delivery of services.

Thank you

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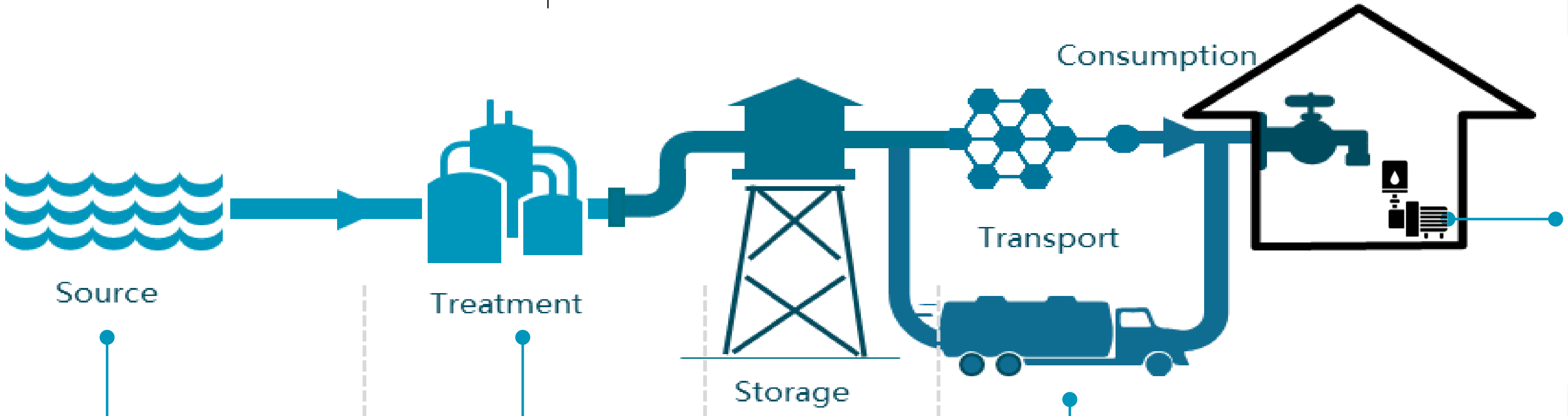
Process for Calculating the Emissions in Water Sector

No direct emissions are emitted from water sector as per IPCC

Water sector contributes to emission through usage of energy and fuel only



Source

a. Unit energy used is **6.9** millions units / year[1]

b. Power source is hydro electricity, and its grid factor is **0.024 CO_2/KWH**

Total emission = 6.9^10^6 * 0.024

Total emission = 166 tons

Treatment

a. Unit energy used is **2.7** millions units / year[1]

Power source is hydro electricity, and its grid factor is **0.024 CO_2/KWH**

Total emission = 2789040 * 0.024

Total emission = 67 tons

Storage

As pumping in not done at the ESR, due to this there are no energy emissions from storage facilities.

Pressure based system is used

Transport

a. If we consider there is 1 tanker and travelling 10 KM daily with average of 3KM. (4 liters of fuel consumption daily)

b. Burning of 1 liter of fuel emit 2.7 kg of CO_2

Total emission will be:
4 * 2.7 = 10.8 kg CO_2 per day

Consumption

Total emission from water sector: 233 tons eq.CO_2

The household is having alternate groundwater supply with install borewell with pump capacity of 5 HP running for 2 hours and consuming 6 KWH of energy.

Receiving power from coal-based power station

Total emission will be : 6 * 0.97 (coal-based energy grid emission)

Total emission = 5.82 kg CO_2 per day

How this data is obtained :

- **Energy database –** through the energy bills of each meter connection.
- **Grid emission factor** – Through the nation level grid emission report.
- **Fuel Consumption –** From the vehicle department and total average kilometer travelled.
- **Borewell and pumps details** – Pumps installed and running time and its unit energy consumption

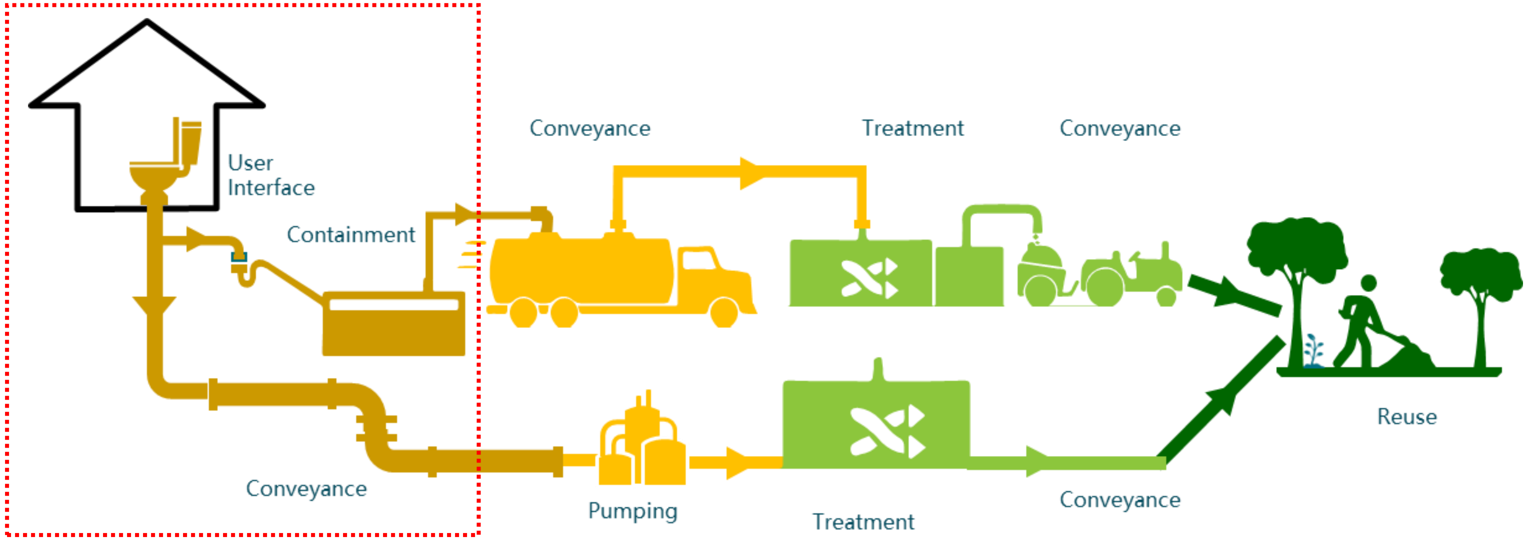
Formula for calculating emission from energy use

GHG emission (kg CO_2eq) = Energy consumption x Emission factor of the grid

Emission from the fuel consumption

GHG emission for Fuel used :
Litres of petrol used x Emission factor of the vehicle

Process for Calculating the Emissions in Sanitation Sector



Step 1: Calculate the total organics in wastewater generated – (i.e., TOW)

Formula used : TOW = P * 0.001 * 365 * BOD — **1**

TOW for Ichalkaranji = 54,53,501 kg BOD/ year

P = population of city

BOD value – Use of value five-day BOD (country specific and state specific value are provided

0.001 - is used for conversion of BOD from gm to kg

365 – Number of days in inventory year

Value used for Ichalkaranji

Population – 3,68,916

BOD value – 40.5 (standard selected for Maharashtra state)

Formula for calculating overall sanitation chain direct emissions:

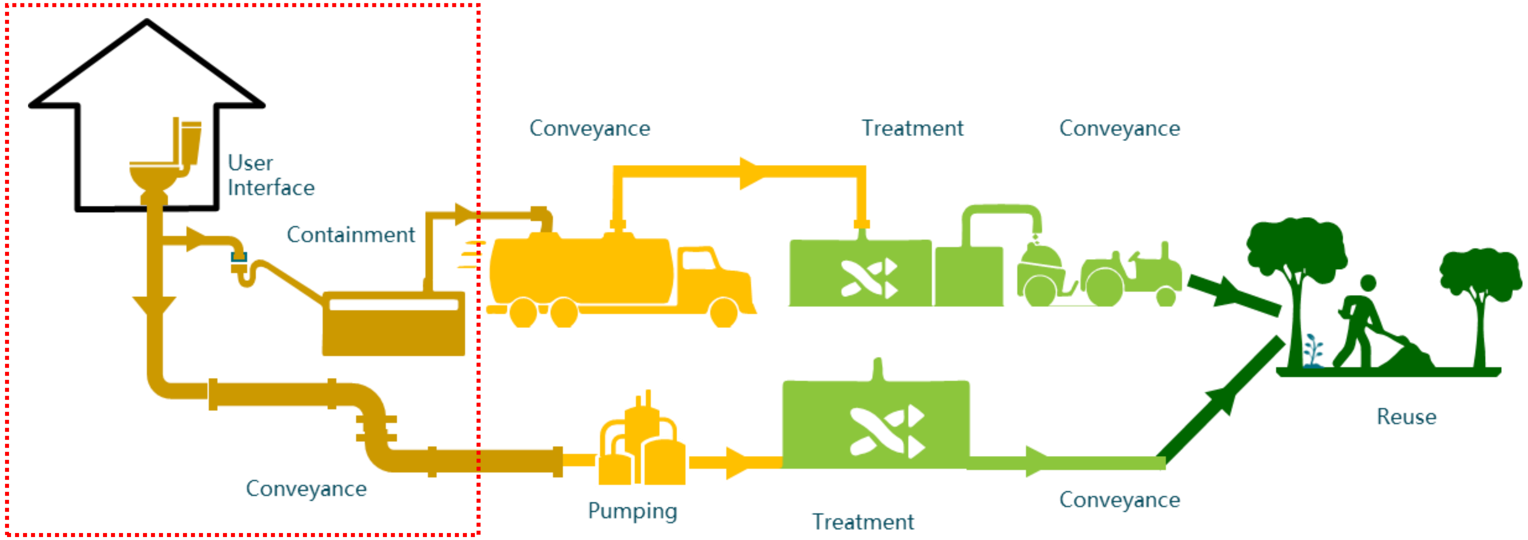
Sanitation emission calculation :

(U x T x EF) x (TOW-S)-R

1. **TOW (total organics in wastewater) = 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**

Source : Deborah, B., Michael, D. S., Yoshitaka, E., Juraj, F., Céline, G., Gregory M, P., . . . M, K. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Wastewater treatment and discharge . IPCC, pg – 6.21 – 6.22

Process for Calculating the Emissions in Sanitation Sector



Step 2 : Calculate the total organics in wastewater generated for different pathways

Formula used : $TOW_j = TOW * U_i * T_{ij} * I_J$ — **2**

a. TOW_J **–** Total organics in WW for different income groups and treatment pathways

b. TOW – Total organics in WW

c. U_i **–** fraction of population in income group i in inventory year

d. T_{ij} **–** degree of utilization of treatment facility for each group

e. I_j **–** addition of industrial BOD to Domestic WW standard is consider 1.25 for collected and 1 for uncollected as per IPCC

TOW for Septic tank system = 26,17,680 kg BOD/ year

This process will be repeated for different pathways and income groups as per their availability in the city

Formula for calculating overall sanitation chain direct emissions:

Sanitation emission calculation :

(U x T x EF) x (TOW-S)-R

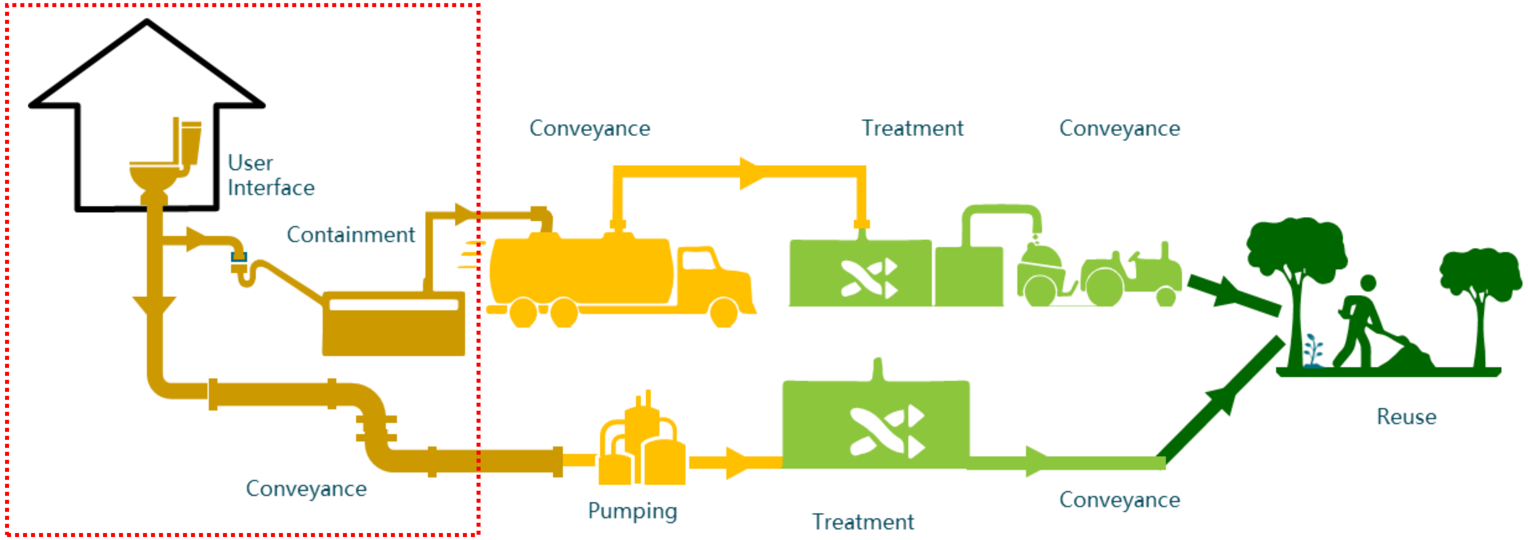
1 **TOW (total organics in wastewater) = Volume of wastewater generated x BOD**
2 **BOD wastewater, sludge**
3 **B0 – Maximum Methane Producing factor**
4 **MCF – Methane Correction factor**
5 **Emission Factor = (B0 x MCF)**
6 **S = Sludge Removed**
7 **U = Population fraction**
8 **T = Degree of utilisation**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

Value used for Ichalkaranji

b. TOW - 54,53,501 kg BOD/ year	**Derived using the equation 1**
c. U_i **–** 100 %	**Consider 100 % population is urban and all are strata of high-income group**
d. T_{ij} **–** 48 %	**As 48 % of population is dependent on on-site system**

Source : Deborah, B., Michael, D. S., Yoshitaka, E., Juraj, F., Céline, G., Gregory M, P., . . . M, K. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Wastewater treatment and discharge . IPCC, pg – 6.22 – 6.26

Process for Calculating the Emissions in Sanitation Sector



Step 3 : Calculating the Emission factor for the containment facility

Formula used : EF = B0 * MCF — 3

a. EF – Emission Factor
Varies as per technology and pathway

b. B0 – Maximum Methane producing factor
Remains fix and is provided by IPCC which is 0.6 kg CH4/kg BOD

c. MCF – Methane Correction factor
Changes as per the technologies and pathways adopted, is also provided by IPCC for different treatment types and pathways

EF for Septic tank system = 0.6 * 0.5
0.3 kg CH4/ kg BOD

This process will be repeated for different pathways and treatment options available in the city

Formula for calculating overall sanitation chain direct emissions:

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

1. **TOW (total organics in wastewater) = 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**

Value used for Ichalkaranji

b. B0 – 0.6 kg CH4 / kg BOD	**Standards provided by IPCC**
c. MCF – 0.5 (ranges from 0.4 – 0.72) for septic tank	**Average value is considered**

Similar process need to followed based for calculating emission factor for other systems

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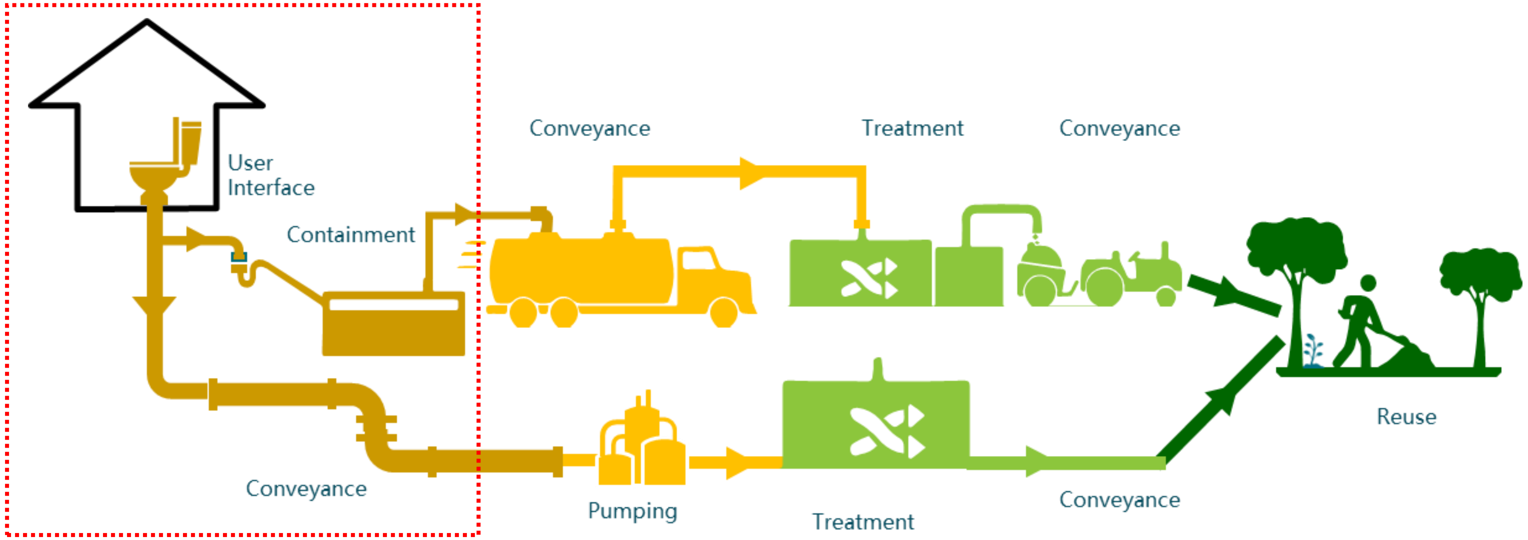
Source : Deborah, B., Michael, D. S., Yoshitaka, E., Juraj, F., Céline, G., Gregory M, P., . . . M, K. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Wastewater treatment and discharge . IPCC, pg – 6.18 – 6.21

Process for Calculating the Emissions in Sanitation Sector



Formula for calculating overall sanitation chain direct emissions:

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

1 **TOW (total organics in wastewater) = 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**

Step 4 : Calculating the Sludge component removed from the containment

Formula used : $S_{septic} = TOW_{septic} * F * 0.5$ — 4

a. TOW $_{septic}$ **–** TOW of septic tank

b. F – % of population cleaning their septic tank as per the compliance

c. 0.5 – fraction of organics removed as sludge from the WW in septic tank

EF for Septic tank system = 26,17,680 * 0.2 * 0.01

4964 kg BOD / Year

Value used for Ichalkaranji

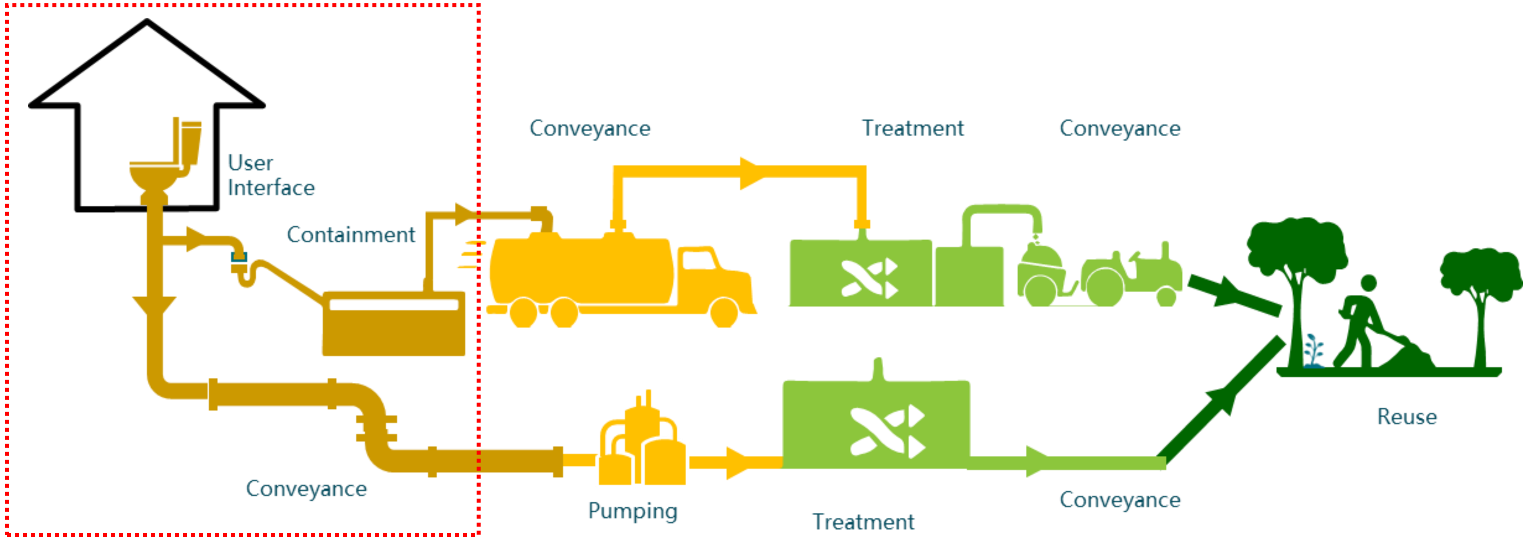
a. TOW $_{septic}$ **–** 26,17,680 kg BOD/ year — **From equation 2**

b. F – 1 % of population emptying septic tank as per compliance

c. 0.5 – 0.2 (as septic tanks in Indian context doesn't remove half of organic content — **As the efficiency of septic tank is expected to reduce by 30 to 40 %**

Source : Deborah, B., Michael, D. S., Yoshitaka, E., Juraj, F., Céline, G., Gregory M, P., . . . M, K. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Wastewater treatment and discharge . IPCC, pg – 6.28

Process for Calculating the Emissions in Sanitation Sector



Step 5 : Calculation of emission from the containment facility

Formula used : Emission $_{containment}$ =

(TOW_j – S) * EF - R — **5**

a. TOW_j – TOW for particular pathway

b. EF – Emission factor for particular pathway

c. S – Sludge component removed from the TOW

d. R – Amount of Methane recovered from the TOW in WW

EF for Septic tank system =
0.3 * (26,17,680 - 4964) - 0
7,33,414 kg CH4/ year

This process will be repeated for different pathways and treatment options available in the city

Formula for calculating overall sanitation chain direct emissions:

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

1. **TOW (total organics in wastewater) = 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**

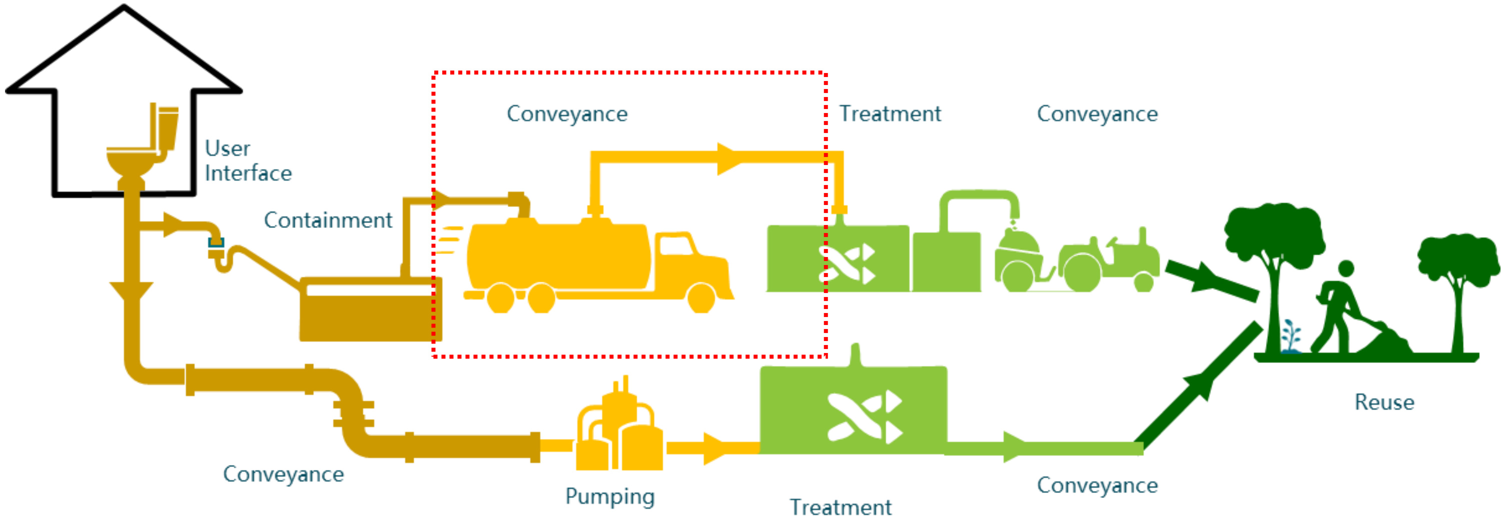
Value used for Ichalkaranji

a. TOW_j – 26,17,680 kg BOD/ year	**Derived using equation 2**
b. EF – 0.3	**Derived using equation 4**
c. S - 4964 kg BOD / Year	**Derived using equation 4**
d. R - 0	**As methane captured process is not available at Ichalkaranji**

Similar process need to followed based for calculating emission factor for other systems

Source : Deborah, B., Michael, D. S., Yoshitaka, E., Juraj, F., Céline, G., Gregory M, P., . . . M, K. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Wastewater treatment and discharge . IPCC, pg – 6.17

Process for Calculating the Emissions in Sanitation Sector



Step 6 : Calculation of emission from the conveyance

Formula used : Fuel consumed * Emission factor[1] — **6**

a. **Fuel Consumed :**

Derived using following considerations

1. **Trip performed by vehicle (A)**
   a. working days (288) * b. Avg. trip length (2.5) * c. Avg. septic tank cleaned daily (1.5)* d. number of vehicles (2)
2. **Average of the desludging vehicle (B)**
3. **Total fuel consumed (C)**

b. EF – Emission factor for fuel used

EF for Septic tank system =
1. (288 * 2 * 2.5 * 1.5)
2. 2160 * 2.5
3. 5400 * 2.7

14.58 Tons CO2/Year

Formula for calculating overall sanitation chain direct emissions:

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

1 **TOW (total organics in wastewater) = 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**

Value used for Ichalkaranji

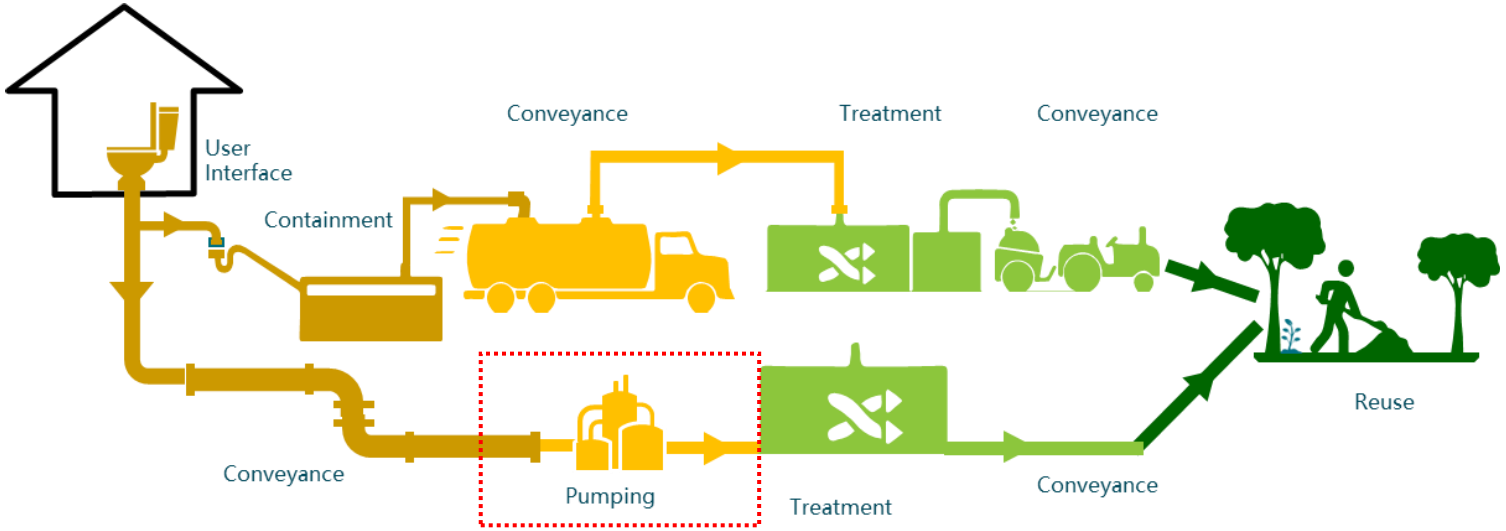
a. A.a = 288, A.b = 2.5, A.c = 1.5, A.d = 2, B = 8 Km/l, — **Database for desludging as received from city**

b. EF – 2.7 — **Standard emission after using 1 liter of fuel**

Similar process need to followed based for calculating emission from the vehicles used in sanitation service provision

Source: 1. https://connectedfleet.michelin.com/blog/calculate-co2-emissions/#:~:text=One%20litre%20of%20diesel%20creates,has%20emitted%20in%20a%20month.; 2. Drainage and health dept, Ichalkaranji Municipal Corp., 2022

Process for Calculating the Emissions in Sanitation Sector



Step 7 : Calculation of indirect emission from the pumping activities

Formula used : Energy consumption[1] x Emission factor of the grid[2] — 7

Indirect emission from energy used for pumping wastewater =
2.2 * 10 ^5 * 0.024

5.4 Tons CO2/Year

a. **Energy consumption in units**

b. **EF –** Grid Emission factor for energy source

No direct emission measured as IPCC suggests flowing sewer emission factor is 0[3]

Formula for calculating overall sanitation chain direct emissions:

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

1 **TOW (total organics in wastewater) = 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**

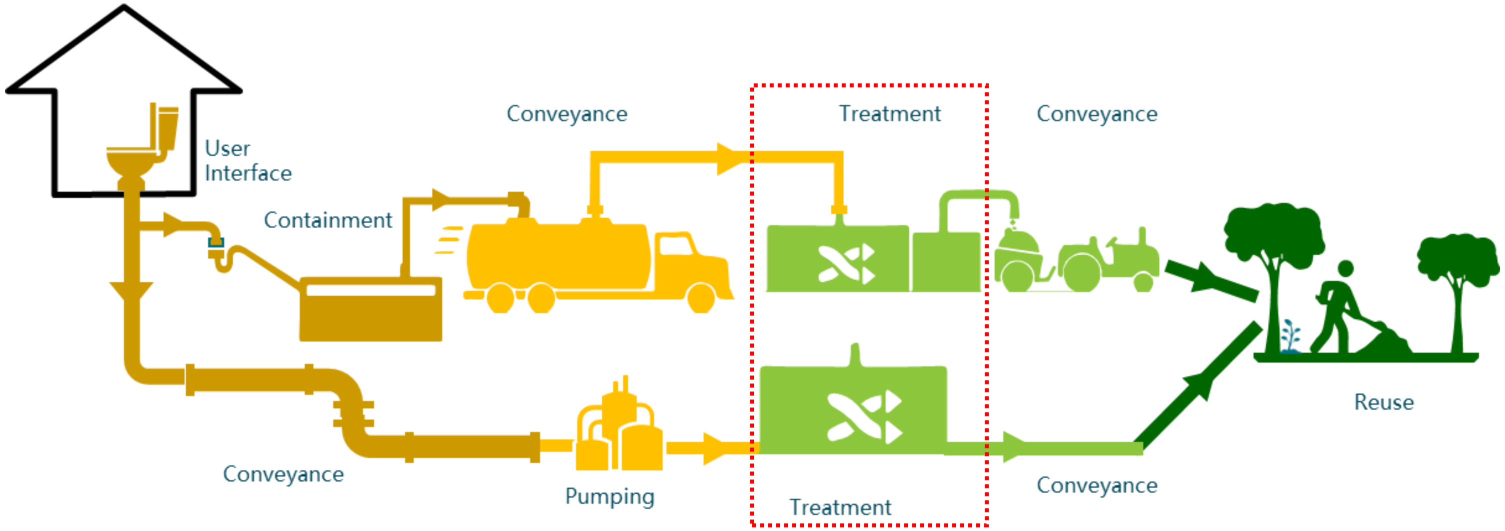
Value used for Ichalkaranji

a. Units – 2.2 * 10^5 KWH	**Database for desludging as received from city**
b. EF – 0.024 CO2/KWH	**Standard grid emission factor for Hydro based energy generation**

In process of generating evidences for showing that conveyance through closed flowing sewer and pumping contribute to direct emissions

Source: 1. Drainage dept. and Electricity dept, Ichalkaranji Municipal Corp., 2022; 2. https://www.waterpowermagazine.com/opinion/opinionan-important-role-to-play-10564801/; 3. Deborah, B., Michael, D. S., Yoshitaka, E., Juraj, F., Céline, G., Gregory M, P., . . . M, K. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Wastewater treatment and discharge . IPCC, pg – 6.20

Process for Calculating the Emissions in Sanitation Sector



Step 8 : Calculation of Sludge remove from aerobic treatment facility

Formula used :

$S_{mass} * K_{rem} * 1000$ — **8**

a. S_{mass} **–** Amount of Sludge removed as dry mass

b. K_{mass} **–** Sludge factor provided by IPCC based on treatment type

Sludge aerobic :
6200[1] * 0.8[2]

4964 Kg BOD/Year

Formula for calculating overall sanitation chain direct emissions:

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

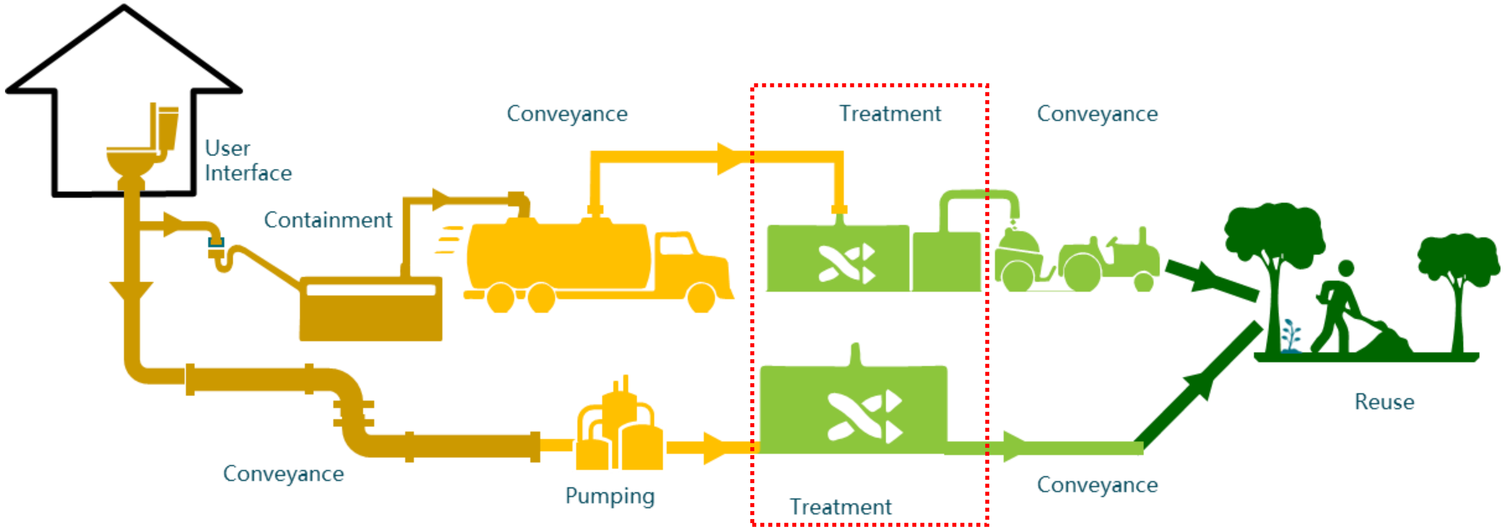
1 **TOW (total organics in wastewater) = Volume of wastewater generated x BOD**
2 **BOD wastewater, sludge**
3 **B0 – Maximum Methane Producing factor**
4 **MCF – Methane Correction factor**
5 **Emission Factor = (B0 x MCF)**
6 **S = Sludge Removed**
7 **U = Population fraction**
8 **T = Degree of utilisation**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

Value used for Ichalkaranji

a. S_{mass} – 6200 Kg / year	**Database from STP of IMC**
b. K_{rem} – 0.8	**Standard value for the Aerobic treatment plants with primary treatment provided by IPCC**

Source: 1. Drainage dept. and Electricity dept, Ichalkaranji Municipal Corp., 2022; 2. Deborah, B., Michael, D. S., Yoshitaka, E., Juraj, F., Céline, G., Gregory M, P., . . . M, K. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Wastewater treatment and discharge . IPCC, pg – 6.27

Process for Calculating the Emissions in Sanitation Sector



Step 9 : Calculation of emissions from the treatment facility

Formula used :
U * EF * T * (TOW $_{collected}$ – S) — **9**

a. EF – Emission factor for particular pathway :
B0 * MCF = EF

b. U – Fraction of population dependent on sewer network

c. T – Degree of utilization of type of treatment facility

d. TOW$_{collected}$ – Volume of WW collected by sewer network * inlet BOD of STP[1]

e. S[1] – Sludge component removed from the WW

Indirect emission from energy used for pumping wastewater =
0.33 * 0.18 * 0.165 * (22,49,569 – 4964)

66.7 Tons CH4/Year

Formula for calculating overall sanitation chain direct emissions:

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

1 **TOW (total organics in wastewater) = 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**

Value used for Ichalkaranji

a. U – 0.33	**Database from IMC related to % of population dependent on sewer**
b. EF – 0.18, B0 – 0.6; MCF – 0.3	**Standards provided by IPCC from different treatment facilities**
c. T – 0.165; (0.33 * 0.5)	**% Population dependent on sewer * % of WW treated**
d. S[1] – 4964	**From eq. 8**

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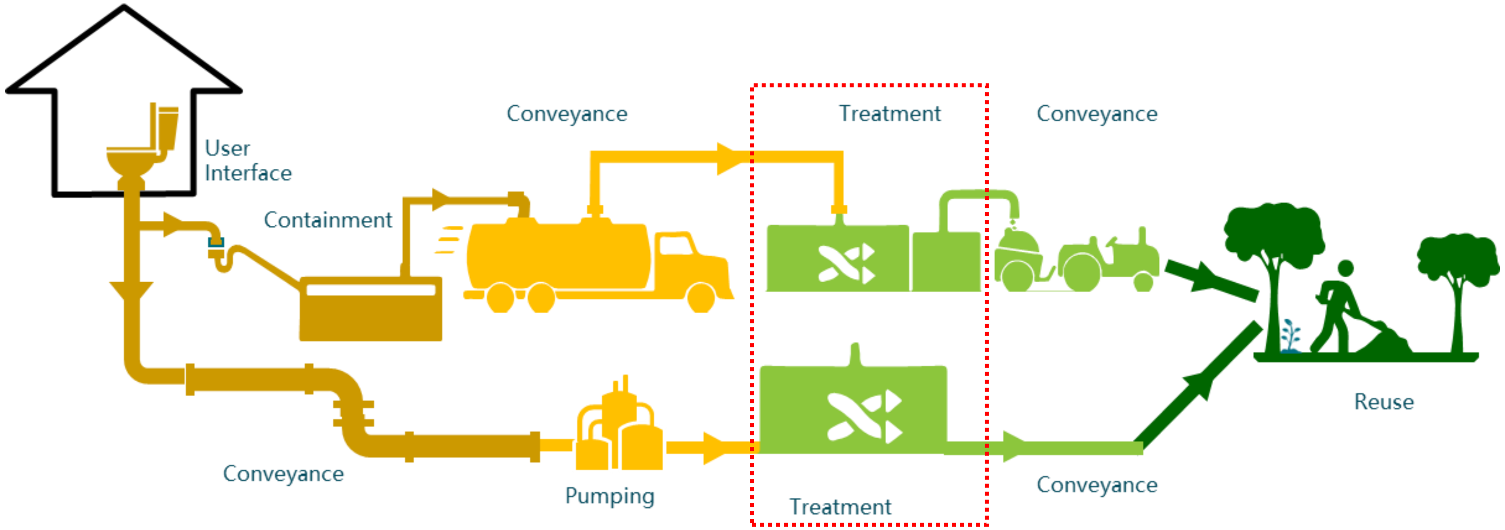
Source: 1. Drainage dept., Ichalkaranji Municipal Corp., 2022; 2. Deborah, B., Michael, D. S., Yoshitaka, E., Juraj, F., Céline, G., Gregory M, P., . . . M, K. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Wastewater treatment and discharge . IPCC, pg – 6.20

Process for Calculating the Emissions in Sanitation Sector



Formula for calculating overall sanitation chain direct emissions:

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

1. **TOW (total organics in wastewater) = 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**

Step 10 : Calculation of indirect emissions from the treatment facility

Formula used : Energy consumption x Emission factor of the grid — **10**

a. **Energy consumption in units**

b. EF[2] – Grid Emission factor for energy source

Indirect emission from energy used for pumping wastewater = 9.2 * 10 ^5 * 0.024

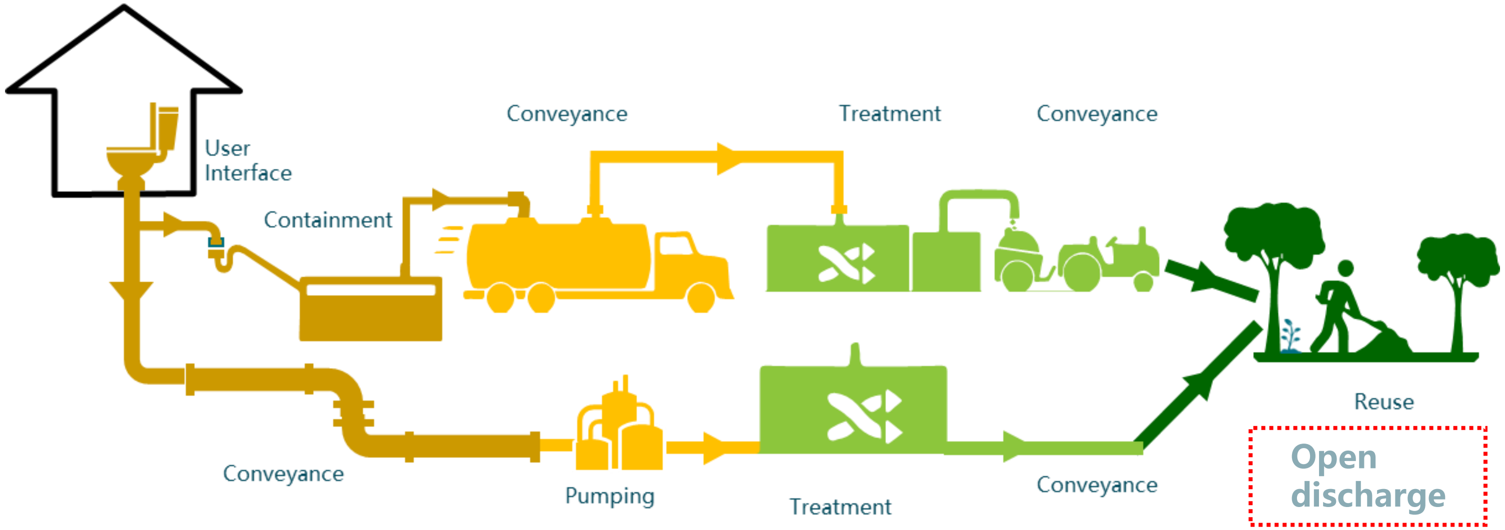
22.25 Tons CO2 /Year

Value used for Ichalkaranji

a. Units – 9.2 * 10^5 KWH	**Database received from electricity dept. of IMC**
b. EF – 0.024 CO2/KWH	**Standard grid emission factor for Hydro based energy generation**

Source: 1. Drainage dept. and Electricity dept, Ichalkaranji Municipal Corp., 2022; 2. https://www.waterpowermagazine.com/opinion/opinionan-important-role-to-play-10564801/;

Process for Calculating the Emissions in Sanitation Sector



Step 11 : Calculation of emissions from open discharge

Formula used :
EF* U * T * ($TOW_{uncollected}$ – S) — **11**

a. EF – Emission factor for particular pathway :
BO * MCF = EF

b. U – Fraction of population doing open discharge

c. T – Degree of utilization

d. $TOW_{uncollected}$ – TOW for open discharge

e. S – Sludge component removed from the TOW

Open discharge emission =
0.06 * 0.23 * 0.5 * (867346 – 0)

59.8 Tons CH4/Year

Formula for calculating overall sanitation chain direct emissions:

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

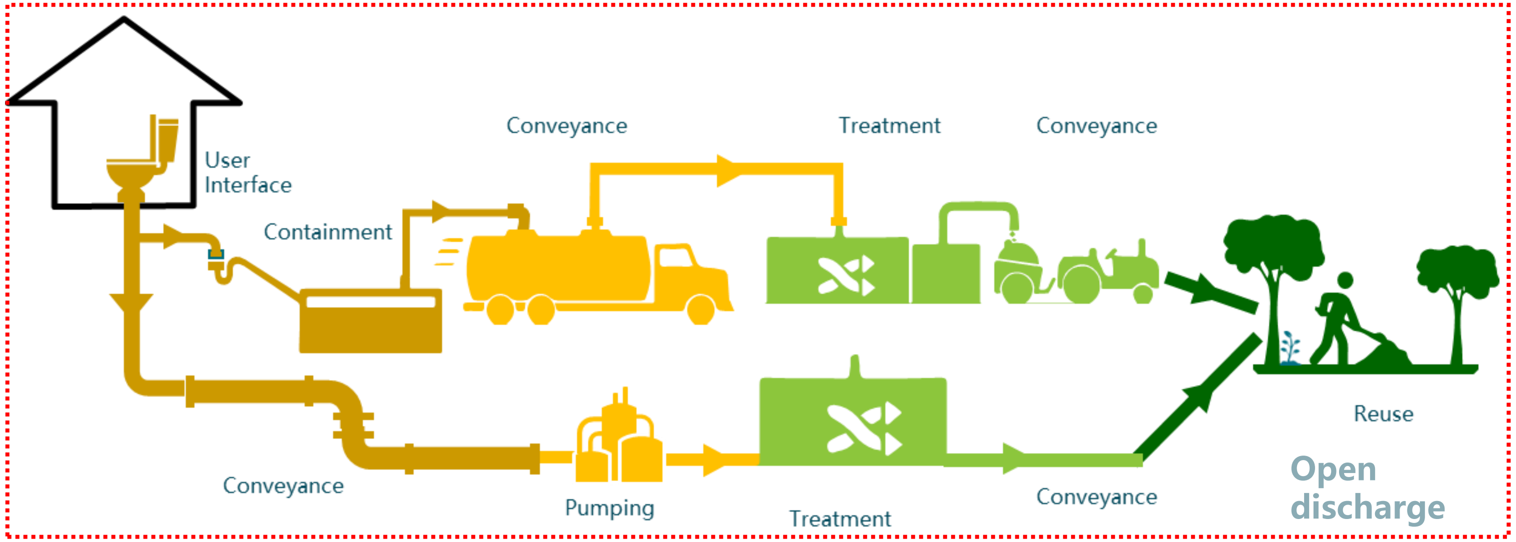
1. **TOW (total organics in wastewater) = Volume of wastewater generated x BOD**
2. **BOD wastewater, sludge**
3. **B0 – Maximum Methane Producing factor**
4. **MCF – Methane Correction factor**
5. **Emission Factor = (B0 x MCF)**
6. **S = Sludge Removed**
7. **U = Population fraction**
8. **T = Degree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

Value used for Ichalkaranji

a. U – 23 %	**percentage estimated using the database provided by IMC**
b. EF – 0.06, **B0** – 0.6, **MCF** – 0.01	**IPCC Factors provided**
c. $TOW_{uncollected}$ – BOD of open discharge WW (118)[2] * Total TOW	**IMC STP quality reports and estimate values based on IMC water and WW data**

Source : Deborah, B., Michael, D. S., Yoshitaka, E., Juraj, F., Céline, G., Gregory M, P., . . . M, K. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Wastewater treatment and discharge . IPCC, pg – 6.20; 2. Drainage dept. IMC, 2022

Process for Calculating the Emissions in Sanitation Sector



Step 12 : Calculating overall direct methane emissions from sanitation sector

Formula used : **addition of all pathways** — **12**

Onsite emissions – 733.4 tons CH4 / year

Sewer emissions – 177.8 tons CH4/ year

Open discharge emissions – 59.8 tons CH4/ Year

Total CH4 emissions – 971 tons CH4/ Year

Step 13 : Calculating overall indirect emissions from sanitation sector

Formula used : **addition of all emission related to the energy and fuel use** — **13**

Indirect emission at pumping – 5.4 tons CO2 / year

Indirect emission at WW treatment – 22.3 tons CO2 / year

Total indirect emissions – 27.7 tons CO2/ Year