ESTIMATION OF METHANE EMISSIONS FROM DOMESTIC WASTEWATER IN CAU RIVER BASIN BY 2030

Cai Anh Tu(1), Le Van Quy(2), Nguyen Duc Toan(3)

(1)VNU University of Science, Viet Nam National University, Hanoi

(2)Viet Nam Institute of Meteorology, Hydrology and Climate Change

(3)Institute of Natural Resources and Environment Training

Received: 8 August 2022; Accepted: 30 August 2022

Abstract: *The Cau River basin has recently raised significant concerns about associated pollution issues and their critical role in socio-economic development. This study aims at assessing and forecasting the impacts of domestic wastewater on the generation of greenhouse gas emissions in Cau River basin in 2030. The main methods have been applied in this study including data collection and analysis, synthesization and inheritance method of research documents. Moreover, the study has calculated the amount of greenhouse gases from wastewater in the Cau River basin basin from the use of septic toilets, other toilets and centralized wastewater treatment plant based upon the guidance of the IPCC (2006). The results show that the CH_4 gas is mainly generated from the anaerobic treatment of domestic wastewater with total CH_4 emissions for the scenario up to 2030 at 234,337.91 Gg CH_4/year (accounting for 95.3%) of the total amount (corresponding to 245,818.59 Gg CH_4/total kg of BOD) emitted when applying treatment measures.*

Keywords: *Methane gas, Domestic waste, Cau River basin.*

1. Introduction

Cau River basin is one of the five longest rivers in Northern Viet Nam and also one of the major river basins in Viet Nam, with a special geographical position, diverse and rich in resources as well as in the history of socio-economic development among provinces located in its basin. The Cau River basin is receiving wastewater from six provinces, namely Bac Can, Thai Nguyen, Bac Giang, Vinh Phuc, Bac Ninh, Hai Duong and part of Hanoi. According to the analysis of research projects, domestic wastewater is the main cause of water pollution in Cau River basin [1, 2]. Domestic wastewater at 6 provinces within Cau River basin is only partially processed, the remaining part is directly discharged into the Cau River. Moreover, domestic wastewater is also one of the sources of greenhouse gas (GHG) emissions, which brings negative impacts on environmental quality and human health.

Recent studies have identified that domestic wastewater treatment as potential sources of artificial GHG emissions contributes climate change and air pollution [1]. Methane gas (CH_4) is mainly generated by anaerobic decomposition of organic matter (sludge from wastewater treatment systems). However, there has not yet had any specific research to comduct the inventory and assessment of current status of GHG emissions from domestic wastewater in Cau River basin.

2. Methodology and research subjects

Methodology

The study was implemented using the following main methods:

- *Collection, analysis, synthesization and inheritance method of research documents*

The method is used to collect, synthesize and analyze relevant data as: Calculation formulas, basic parameters for the calculation (population,

Corresponding author: Cai Anh Tu

E-mail: caianhtu1984@gmail.com

percentage of people applying septic tanks; percentage of people not applying any domestic wastewater treatment system, proportion of people using other types of toilets, current capacity of wastewater treatment plants (by aerobic technology), etc.

- GHG emission calculation

The calculation formulas for GHG emissions from domestic wastewater are based upon Viet Namese and international guidances on GHG inventory of waste and wastewater [3, 7, 15]. The main formulas are applied in this research as follows:

- Identification of total organic content in wastewater

The total organic content in wastewater is calculated by the formula [4, 6, 7]:

$$T0Wi = p \times BOD \times I \times 365 \quad (1)$$

In which:

$T0W_i$: Total organic content in wastewater (kg BOD/year)

P: Population in inventory year (person)

BOD: Amount of BOD generated per capita (g BOD/person/day)

I: Correction factor

i: Population group

The amount of BOD generated per capita in domestic wastewater is the prescribed value at 35 g/person/day [2, 4].

Identification of emission factor

Emission factor is calculated for each treatment method according to the formula as [4, 6, 7]:

$$EF_j = Bo \times MCF_j \times Ui \times T_{ij} \quad (2)$$

In which:

Bo: Maximum CH_4 emissions (kg CH_4/kg BOD): 0.6

EF_i: Emission factor (kg CH_4/kg BOD)

MCF_j: Methane correction factor (fraction)

T_{ij}: Degree of utilisation of treatment/discharge system j, for each population group fraction i in inventory year

i: Population group (e.g. urban/rural)

j: Each treatment/discharge system (such as septic tanks, types of latrines, with/without drainage systems)

Identification of total CH_4 emission

Total CH_4 emissions are determined according to the following formula [6, 7]:

$$CH_4 \text{ emissions} = (T0W_i - S_i) \times (EF_i - R_i) \times 10^{-3} \quad (3)$$

In which:

CH_4: Total CH_4 emissions (ton/year)

$T0W_i$: Total organic content in wastewater (kg BOD/year)

S_i: Organic components removed as sludge (kg BOD /year)

EF_i: Emission factor (kg CH_4/kg BOD)

R_i: Amount of CH_4 recovered (kg CH_4/year)

i: Population group (e.g. urban/rural) for wastewater treatment system (such as septic tanks, types of latrines, with/without drainage systems).

Research subjects

Research subjects

The calculation of CH_4 emissions from domestic wastewater in Cau River basin is indicated through the key subjects:

- Untreated domestic wastewater (Discharging wastewater into neighboring areas as rivers, lakes, etc)

- Treated domestic wastewater: (i) Centralized wastewater treatment plants (CWTP), (ii) Septic tanks (ST), (iii) Other types of toilets (T).

Research scope

Cau River has a basin area of about 6,030 km², with a length of about 290 km, the average height of the basin is 190 m, the average slope of 16.1%, and the average width of the basin is 31 km.

Table 1. Wastewater flow (liter/person/day and night) [2]

No.	Drainage area	Wastewater flow (liter/person/day and night)
1	Urban	100 - 200
2	Rural	80
3	Industrial park	20 - 40 m^3/ ha/day and night

Table 2. Expected wastewater treatment plants for urban areas within the Cau River basin until 2030 [2]

No.	Wastewater treatment plant	Capacity (m^3/day and night)
I	*Bac Kan Town*	
1	Duc Quan Factory	6,000
2	Xuat Hoa Factory	3,000
II	*Thai Nguyen City*	
1	Tuc Duyen Factory	28,000
2	Tan Lap Factory	20,000
3	Dong Bam Factory	10,000
4	Huong Son Factory	30,000
III	*Vinh Phuc City*	
1	West Vinh Yen factory	49,000
2	Vinh Yen Central Factory	46,000
3	South Vinh Yen Factory	44,000
4	North East Vinh Yen Factory	25,000
5	Phuc Yen Factory	46,000
IV	*Bac Giang city*	
1	Factory No. 1 (already available)	25,000
2	My Do Factory	15,000
3	Da Mai Factory	5,000
V	*Bac Ninh City*	
1	Kim Chan Factory	28,000
2	Van An Factory	8000
VI	*Hai Duong City*	
1	Ngoc Chau Factory	40,000
2	Lo Cuong Factory	40,000
3	South Sat River Factory	10,000
VII	*Hanoi City (Me Linh, Dong Anh, Soc Son)*	
1	Dai Thinh factory	19,000
2	Tien Phong Factory	48,000
3	North Thang Long Factory (already available)	116,000
4	Son Du Factory	104,000
5	Co Loa Factory	61,000
6	Soc Son Factory	37,000

No.	Wastewater treatment plant	Capacity (m^3/day and night)
7	Dong Xuan Factory 1	41,000
8	Dong Xuan 2 Factory 2	38,000
9	Duc Tu Factory	29,000
	Total	*971,000*

Basic parameters for calculation

The calculation parameters to determine CH_4 emissions generated from domestic wastewater at Cau River basin in 2030 are collected on the basis of data and information in planning related to the Cau River basin at national and provincial levels.

3. Research results

3.1. Results of total organic content in domestic wastewater

Basic parameters for calculation

The basic calculation parameters of total organic content in domestic wastewater is based on the guidance documents on GHG inventory issued by the Intergovernmental Panel on Climate Change (IPCC) in 2006 along with a number of recent studies on environmental issues in the Cau River basin, namely in Table 3.

According to the master plan, the proportion of people using septic tanks will account for 70% to 97% with an average of 92%, and the estimation of 7,918,650 people in the urban areas of the Cau River basin by 2030. Meanwhile, in rural areas, the proportion of people using septic tanks accounts for 55% to 75%, an average of 67% and corresponding to 7,682,185 people.

Table 3. Basic parameters for calculation [1, 3, 6]

Parameter
I - Correction factor: For industrial and domestic wastewater discharged together: I = 1.25 For domestic wastewater separately discharged: I = 1.
BOD g/person/day (assumption of average emissions): BOD = 35 g/person/day Degree of wastewater treatment Tij (%): - Septic tank: Tij = 20% - Discharge sewer (Discharging into rivers, lakes and surrounding areas): Tij = 10% - Centralized wastewater treatment plants (by aerobic technology) Tij = 50% - Other treatment methods (Other types of toilet) Tij = 20%

Table 4. Forecasted amount of wastewater generated in urban areas and rural areas within the Cau River basin in 2030 V

No.	Area	Amount of wastewater generated (m^3/ day and night)	Level of water supply given according to the planning (liters/person-day)	Average amount of water supplied according to the planning	Number of people
1	Urban	1,118,940	100 - 200	130 liters/person-day	8,607,230
2	Rural	687,957	80	80	11,465,950
3	Industrial park	930,216			
	Total	2,737,158			20,073,180

Table 5. Population rate according to the treatment plans [6]

Treatment plan	Urban			Rural			Total number of people
	Rate (%)		Number of people	Rate (%)		Number of people	
	Value range	Average value		Value range	Average value		
Average septic tanks of the provinces within the river	70 - 97	92	7,918,650	35 - 57	67	7,682,185	15,600,835
Population using other toilets (flush latrines)	2 - 21	14	1,205,012	22 - 27	23	2,637,168	3,842,180
Population does not apply any domestic wastewater treatment methods	1 - 9	5	4,303,615	21 - 38	30	3,439,785	3,870,147
Estimated population has domestic wastewater treated in centralized wastewater treatment plants (CWTP) with aerobic technology		86.8	5,270,756				5,270,756
Estimated population has untreated domestic wastewater in CWTP (aerobic technology)		13.2	3,336,474				3,336,474

The calculation results in Cau River basin in 2030 show that:

- Total organic content generated without domestic wastewater treatment system is 49,441,122 kg BOD/year.

- The total organic content generated with domestic wastewater treatment system is 315,718,433 kg BOD/year as:

+ Derived from the concentrated wastewater treatment plant (CWTP): 67,333,908 kg BOD/year.

+ Derived from the septic tank system (ST): 199,300,667 kg BOD/year

+ Derived from other types of toilet (T): 49,083,858 kg BOD/year.

- The total organic content generated without/with wastewater treatment system in Cau River basin is 365,159,555 kg BOD/year.

T0Wi (no treatment) = 3,870,146 people x 1 x 35 g/person/day x 365 days = 49,441,122 kg BOD/year

T0Wi (CWTP) = 5,270,756 people x 1 x 35 g/person/day x 365 days = 67,333,908 kg BOD/year

T0Wi (ST) = 15,600,835 people x 1 x 35 g/person/day x 365 days = 199,300,667 kg BOD/year

T0Wi (T) = 3,842,180 people x 1 x 35 g/person/day x 365 days = 49,083,858 kg BOD/year.

3.2. Calculation results of emission factors

Basic parameters for calculation

The CH_4 emission factor is calculated based upon specific treatment cases in the Cau River basin (Table 6 and 7).

Table 6. Correction coefficient of CH_4 (MCF_j) for domestic wastewater [1, 4, 5, 6, 7]

Type of treatment	MCF_j of CH_4	
No treatment		
- No treatment for domestic wastewater	0.1	0 - 0.2
Treatment method		
Centralized wastewater treatment plants with aerobic technology - Good management	0	0 - 0.1
Centralized wastewater treatment plants with aerobic technology - Mismanagement	0.3	0.2 - 0.4
Septic tanks	0.5	0.5
Other types of toilets (flush latrines, etc)	0.7	0.7 - 1.0

Table 7. Basic parameters for calculation

Parameter	
S - Organic component removed as sludge (kg CH_4 /year)	Since the sludge treatment is currently only carried out in waste-water treatment plants at a very low rate, this value thereby could be ignored [1].
Ri - Amount of CH4 recovered (kg CH_4/year)	Since there is no mandatory regulation to recover CH_4 gas during the sludge treatment, this value is 0 [1].

The results indicate that the CH_4 emission factor in case of not applying any measures for domestic wastewater treatment is 232,209 kg CH_4/kg total BOD.

The CH_4 emission factor for domestic wastewater treatment system at a concentrated wastewater treatment plant (with aerobic technology) is 474,368 kg CH_4/kg total BOD.

The CH_4 emission factor for using a septic tank is 936,050kg CH_4/kg total BOD, and for other toilets 322,743,2 kg CH_4/kg total BOD (flush latrines, etc).

Therefore, total CH_4 emission factor with and without treatment measures is 1,965,370.2 kg CH_4/kg total BOD.

EF_j (no treatment) = 0.6 kg CH_4/kg BOD x 0.1 x 3,870,147 people x 10% = 232,209 kg CH_4/kg total BOD.

EF_j (CWTP) = 0.6 kg CH_4/kg BOD x 0.3 x 5,270,756 people x 50% = 474,368 kg CH_4/kg total BOD.

EF_j (ST) = 0.6 kg CH_4/kg BOD x 0.5 x 15,600,835 people x 20% = 936,050 kg CH_4/kg total BOD.

EF_j (T) = 0.6 kg CH_4/kg BOD x 0.7 x 3,842,180 people x 20% = 322,743.2 kg CH_4/kg total BOD.

3.3. Calculation results of total CH_4 emission

Basic parameters for calculation

The basic parameters for total CH_4 emission calculation is based upon:

- Total organic content in domestic wastewater.
- Emission factor.

CH_4 emissions (no treatment) (ton/year) = 49,441,122 kg BOD/year x 232,209 kg CH_4/kg total BOD x 10^{-3} = 11,480,630 ton CH_4/year

CH_4 emissions (CWTP) (ton/year) = 67,333,908 kg BOD/year x 474,368 kg CH_4/kg total BOD x 10^{-3} = 31,941,051 ton CH_4/year

CH_4 emissions (ST) (ton/year) = 199,300,667 kg BOD/year x 936,050 kg CH_4/kg BOD x 10^{-3} = 186,555,389 ton CH_4/year

CH_4 emissions (T) (ton/year) = 49,083,858 kg BOD/year x 322,743.2 kg CH_4/kg BOD x 10^{-3} = 15,841,472 on CH_4/year

Therefore, the total CH_4 emission from domestic wastewater in Cau River basin is 11,869,938,527,000 ton CH_4/year corresponding to 11,869,938,527 Gg CH_4/year.

Table 8. Calculation results of total organic value, correction factor and total CH_4 emission in domestic wastewater at Cau River basin

Treatment method		Symbol	Total CH_4 emission (ton CH_4/year)
No treatment method	Discharging wastewater into the surrounding area (river, lake, etc)	No treatment	11,480,630
Treatment method	Centralized wastewater treatment plants (aerobic technology)	CWTP	31,941,051
	Septic tank system	ST	186,555,389
	Other treatment methods (Other types of toilets)	T	15,841,472
	Total of treatment measures		234,337,912
Total			***245,818,586***

Table 8 has indicated the calculation results of total organic content, correction coefficient and total CH_4 emission from domestic wastewater in Cau River basin.

- Total organic content: 365,159,555 kg BOD/year.

- Correction coefficient: 1,965,370.2 CH_4/kg total BOD.

- The total emissions are 245,818,586 ton CH_4/year equivalent to 245,818.59 Gg CH_4/year. CH_4 emission mainly comes from anaerobic decomposition of domestic wastewater in septic tanks and other types of toilets. Specifically, CH_4 emission is generated from anaerobic decomposition (septic tank systems and other toilets) accounting for 95.3% (corresponding to 234,337,912 kg CH_4/kg total BOD) compared to the total amount of emissions (equivalent to 245,818,586 kg CH_4/kg total BOD) when applying treatment measures.

4. Conclusion

The study has calculated the total amount of GHG emissions from domestic wastewater and shown that total CH_4 emissions in 2030 are estimated at 245,818.59 Gg CH_4/year. The CH_4 gas generated mainly from the application of anaerobic treatment of domestic wastewater (septic tank systems and other types of toilets) is 234,337.91 Gg CH_4/year accounting for 95.3% of total emissions when the treatment measures are applied.

Accordingly, it is necessary to encourage the usage of environmentally friendly technologies at centralized wastewater treatment plants along with the requirement of waste management to limit GHG generation through anaerobic measures. The study proposes that it should take into account the level of GHG generation with wastewater treatment efficiency when considering the operational effectiveness of waste treatment technologies. Besides, it is essential to have further research on other GHG emissions in Cau River basin.

References

1. Nguyen Lan Huong and Fukushi Kensuke (2018), *Calculation of greenhouse gas from domestic wastewater*. Sustainable Science Integrated Research Institute.
2. Government (2013), *Decision No. 228/QD-TTg dated 25 January 2013 on Approval of planning of water drainage and wastewater treatment system in residential areas and industrial parks within Cau River by 2030.*
3. Cai Anh Tu, Nguyen Thi Kim Anh, Le Van Quy, Pham Thi Quynh and Nguyen Thu Trang (2021), *"Calculation of methane gas emissions (CH_4) from domestic waste water in Nhue - Day river basin", Environment Magazine,* 3 February, 2021.

4. Campos, J. L., Pedrouso, V. (2016), *"Greenhouse Gases Emissions from Wastewater Treatment Plants: Minimization, Treatment, and Prevention, Hindawi Publishing Corporation", Journal of Chemistry,* Volume 2016, Article ID 3796352, 12 pages.
5. Gupta, D., Singh, S. K. (2012), *"Greenhouse Gas Emissions from Wastewater Treatment Plants: A Case Study of Noida", Journal of Water Sustainability*, Volume 2, Issue 2, June 2012, 131–139.
6. IPCC (2006), *Guidelines for National Greenhouse Gas Inventories*. Volume 5, Chapter 6: Wastewater treatment and discharge.
7. JICA (Japan International Cooperation Agency) (2017), *Guidance Document on City-Level Greenhouse Gas Inventory*. Project on Support the Planning and Implementation of NAMAs in a MRV Manner.