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Research Article

Calculation of methane gas emissions (CH_4) from domestic waste water in Nhue–Day River basin

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Abstract: The process of domestic wastewater treatment has created a large amount of greenhouse gases (GHG). However, the measure for evaluating domestic wastewater treatment is only the treatment efficiency. Meanwhile, the factors to assess the possibility of generating GHG emissions have not been concerned. The Nhue–Day River basin plays an important role on the socio–economic development; therefore, one of the problem needs to be filled with concern is the level of GHG emissions from waste sources, including domestic wastewater. In order to contribute to forecast and evaluate the domestic wastewater impacts on the generation of GHG emissions, the study has been implemented. The main methods taken as synthesis, analysis, and inheritance of research documents and calculations are based upon the guidance of the Intergovernmental Panel on Climate Change, 2006, chapter 5,6 – Wastewater disposal and treatment and other Vietnamese studies on climate change. The study has calculated GHG emissions from wastewater in the Nhue–Day River basin through the use of septic toilets, other toilets and centralized treatment plant by aerobic technologies for the current status (2019) and the scenario in 2030. Thereby, it shows that the CH_4 gas is mainly generated from anaerobic treatment of domestic wastewater with total CH_4 emissions currently at 52,850,201.55 Gg CH_4/year (processed 49,742,761.24 Gg CH_4/year accounting for 94.12%); and for the scenario up to 2030 is 212,764,669.79 Gg CH_4/year (processed 212,700,144.64 Gg CH_4/year at 99.97%).

Keywords: Nhue–Day River basin; Methane gas emissions; Domestic waste.

1. Introduction

The Nhue–Day River basin is a dynamic economic center as well as important economic area of the North and the whole country. Especially, Hanoi under the Nhue–Day River basin is the capital, the economic, cultural and political center of Vietnam. The basin has a total area of 7,665 km^2, accounting for 10% of the entire Red River basin, in the territory of 5 provinces/cities as Hoa Binh, Hanoi, Ha Nam, Nam Dinh and Ninh Binh. Nevertheless, the environment in the Nhue–Day River basin is considered as one of high levels of pollution due to untreated wastewater discharged into the river [1]. According to different studies [1–4], the biggest source of environmental pollution for the Nhue–Day River basin is domestic wastewater, accounting for up to 70% of total wastewater in the basin. In addition to increase the pollution of river, domestic wastewater is also the source of greenhouse gas emissions, thereby leading to negative impacts on environmental quality and hman health. Over the past years, the measures of domestic wastewater treatment

(septic tanks, toilets, centralized wastewater treatment plants, etc.) have achieved certain results that contribute to the improvement of environmental quality. At present, new challenges are being considered and oriented to ensure the sustainability of wastewater treatment measures in terms of economic sustainability as well as limit negative impacts on the environment. Greenhouse gas emissions from the measures of domestic wastewater treatment are one of the main factor related to the sustainability of the approach. The recent studies have identified that domestic wastewater treatment as potential sources of artificial GHG emissions contributes climate change and air pollution [5]. Methane gas (CH_4) is mainly generated by anaerobic decomposition of organic matter (sludge from wastewater treatment systems). Nevertheless, there has not been any specific study on the inventory and evaluation of GHG emission trend from domestic wastewater in the Nhue–Day River basin. Besides, due to rapid economic development, the achievement of green growth targets is currently a big challenge for Vietnam [6]. Therefore, the major objective of the study aims to assess the impact of domestic wastewater on the generation of greenhouse gas emissions and provide the first visual perception of its contribution on reduction emission target of Vietnam.

The calculation of CH_4 emission from domestic wastewater in the Nhue–Day River basin is indicated through the main subjects:

– Untreated domestic wastewater (Discharge 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).

2. Methodology

2.1. Description of study site

The Nhue–Day River basin has geographic coordinates from 20^o to 21^{o}20’ North latitude and 105^o to 106^{o}30’ East longitude, including the administrative territory of 5 provinces/cities (Table 1, Figure 1).

Table 1. The scope of Nhue–Day River basin [7].

No	Province/City	Cities, counties, districts, towns
1	Hoa Binh	Districts: Ky Son, Luong Son, Kim Boi, Yen Thuy và Lac Thuy.
2	Hanoi	Districts: Ba Dinh, Bac Tu Lirm, Cau Giay, Dong Da, Ha Dong, Hai Ba Trung, Hoan Kiem, Hoang Mai, Nam Tu Liem, Tay Ho, Thanh Xuan. Ba Vi, Chuong My, Dan Phuong, Hoai Duc, My Duc, Phu Xuyen, Phuc Tho, Quoc Oai, Soc Son, Thanh Oai, Thanh Tri, Thach That, Thuong Tin, Ung Hoa, Son Tay city.
3	Ha Nam	Phu Ly city; districts: Kim Bang, Ly Nhan, Thanh Liem, Binh Luc, Duy Tien.
4	Ninh Binh	Ninh Binh city, Tam Diep town, districts: Nho Quan, Gia Vien, Hoa Lu, Kim Son, Yen Khanh, Yen Mo.
5	Nam Dinh	Nam Dinh city, districts: Vu Ban, Y Yen, My Loc, Nam Truc, Truc Ninh, Xuan Truong, Giao Thuy, Hai Hau và Nghia Hung.

The study focuses upon domestic wastewater discharging from various households within the river basin.

2.2. Research methods

2.2.1. Methods on synthesization, analysis and inheritance of research documents

The method is used to collect, synthesize and analyze relevant data such as calculation formulas and necessary parameters. In which, the parameters include as population, percentage of people applying septic tanks and not applying domestic wastewater

treatment, proportion of people using other types of toilets, capacity of wastewater treatment plants (by aerobic technology), etc. The statistic calculates for the year of 2019 based upon the Preliminary census results in 2019 from General Statistics Office. The data predicts for 2030 according to the Decision 681/QD–TTg on the Planning of drainage and wastewater treatment systems for residential and industrial areas in the Nhue–Day River basin to 2030.

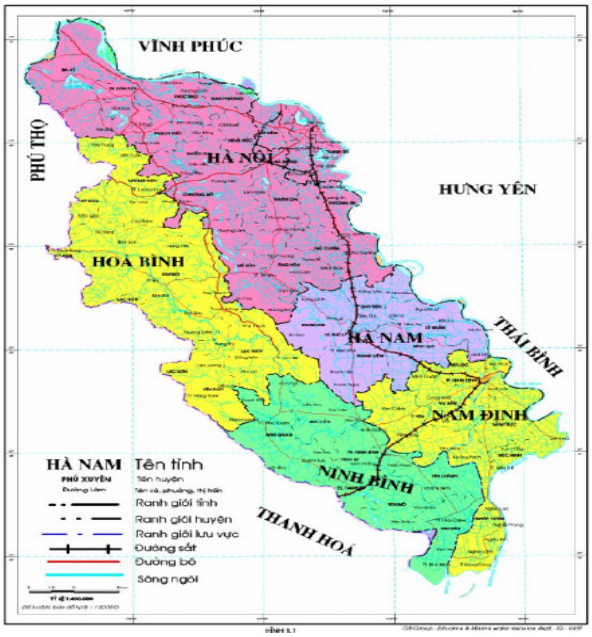

Figure 1. Location of Nhue–Day River basin.

2.2.2. Calculation methods

The calculation formulas for GHG emissions from domestic wastewater are based upon Vietnamese and international documents on GHG inventory of waste and wastewater [8,9,10]. The main formulas are applied in this study as:

Determine the total organic content in wastewater

The total organic content in waste water is determined by the formula:

$$T0W_i = P \times BOD \times I \times 365 \quad (1)$$

where $T0W_i$ is the total organic content in the wastewater (kg BOD/year); P is Population in inventory year (person); BOD is the BOD city–specific per capita BOD in inventory year (g BOD/person/day); I is the correction factor; i is the population group.

The amount of BOD generated per capita in domestic wastewater is taken according to the prescribed value of 35 g/person/day [11].

Determine the emission factor

The emission factor is calculated for each treatment method according to the formula:

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

where EF_i is the mission factor (kg CH_4/kg BOD); B_o is the maximum CH_4 producing capacity (kg CH_4/kg BOD): 0.6; MCF_j is the CH_4 correction factor (fraction); U_i is the fraction of population group i in inventory year; T_{ij} is the degree of utilization (ratio) of treatment/discharge pathway or system, j, for each population group fraction i in inventory year; i is the population group; j is each treatment/discharge system.

Determine the total CH_4 emissions

The total CH_4 emissions are determined by the following formula [8]:

$$CH_4 = \sum i [(T0W_i - S_i) \times EF_i - R_i] \times 10^{-3} \quad (3)$$

where CH_4 is total CH_4 emissions (ton/year); $T0W_i$ is total CH_4 emissions (ton/year); S_i is the organic component removed as sludge (kg BOD /year); EF_i is the emission factor (kg

CH_4/kg BOD); R_i is the amount of CH_4 recovered (kg CH_4/year); i is the population groups are urban and rural. The wastewater treatment and handling system is classified as septic tanks, toilets, with/without drainage systems).

2.2. Research subjects

Basic parameters for calculation

The calculation parameters to determine CH_4 generated from domestic wastewater collected from the published papers verified by the Scientific Councils.

Table 2. Urban and rural population of provinces in Nhue–Day River basin in 2019 [7].

Province	Population (people)	Urban	Rural
		Number of people	Number of people
Hoa Binh	854,131	134,081	720,050
Hanoi	8,053,663	3,962,310	4,091,353
Ha Nam	811,126	68,466	742,660
Ninh Binh	1,780,393	339,019	1,514,093
Nam Dinh	982,487	206,524	775,963
Total	*12,481,800*	*4,710,400*	*6,527,680*

Based upon the average fertility rates according to the 2019 Local Statistical Yearbook, the urban and rural populations in the Nhue–Day River basin are determined for the year of 2030.

Table 3. Urban and rural population of provinces in Nhue–Day River basin in 2030 [7].

Province	Population (people)	Urban	Rural
		Number of people	Number of people
Hoa Binh	915,222	143,671	771,551
Hanoi	10,309,183	5,072,000	5,237,183
Ha Nam	892,217	75,311	816,906
Ninh Binh	1,483,079	332,000	1,482,747
Nam Dinh	1,097,324	230,663	866,661
Total	*14,697,025*	*5,521,977*	*9,175,048*

3. Results and discussions

3.1. Calculation on current level of methane greenhouse gas emissions from domestic wastewater

3.1.1. Results of total organic content in domestic wastewater

a) Basic parameters for calculation

The calculation parameter of total organic content in domestic wastewater is based on the guidance document 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 Nhue–Day River basin.

Table 4. Basic parameters for emission calculation [8].

Parameter	Value
I – Correction factor	= 1,25: For industrial and domestic wastewater. = 1: For domestic wastewater.
BOD g/peson/day (assumption of moderate emissions)	35
Level of wastewater treatment Tkj (%)	
– Septic tank	20
– Drainage drainage (Discharge into rivers, lakes and	10

Parameter	Value
surrounding area)	
– Centralized wastewater treatment plants (by aerobic technology)	50
– Other treatment methods (Other types of toilet)	20

The average percentage of people using a septic toilet in the Nhue–Day River basin accounts for 82% of the total population at 7,779,136 people [7]. Besides, the average rate of people using other types of toilets accounts for 10%, corresponding to 1,450,192 people. The average percentage of the population not applying any domestic wastewater treatment system is 8% at 2,008,752 people.

Accordingly, the centralized wastewater treatment plant (CWTP) using aerobic technology in the Nhue–Day River basin currently handle about 7.73% (875.7x10^3 m^3/day) of the total amount of domestic wastewater (1,333.4x10^3 m^3/day) [5,7]. Thus, it is estimated that the CWTP using aerobic technology for approximately 964,843 people and the amount of wastewater at about 11,516,957 people in the basin is not discharged into the wastewater treatment system (Table 5).

Table 5. Population rate according to the current treatment plan [7].

Type of treatment method	Urban			Rural			Total of people
	Rate (%)		Number of people	Rate (%)		Number of people	
	Value range	Average value		Value range	Average value		
Hygienic toilets in provinces	78–95	92	4,333,568	68–78	75	4,895,760	9,229,328
Average septic tanks in the provinces of the river basin (%)	75–85	82	3,862,528	55–62	60	3,916,608	7,779,136
Population using other toilets	7–12	10	471,040	10–17	15	979,152	1,450,192
Population does not apply any treatment methods for domestic wastewater	5–9	8	376,832	21–28	25	1,631,920	2,008,752
Estimated population has domestic wastewater treated in centralized wastewater treatment plants (CWTP) by aerobic technology		7.73	964,843				964,843
Estimated population has untreated domestic wastewater in CWTP							11,516,957

b) Calculation results

The calculation results in the Nhue–Day River basin show that:

– Total organic content generated in case of no domestic wastewater treatment system is 25,661,806,8 kg BOD/year.

– The total organic content generated in case of domestic wastewater treatment is 130,230,534,2 kg BOD/year as:

+ Derived from the concentrated wastewater treatment plant (CWTP) is 12,325,869 kg BOD/year.

+ Derived from the septic tank system (ST) is 99,378,462.4 kg BOD/year

+ Derived from other types of toilet (T): 18,526,202,8 kg BOD/year.

– The total organic content generated in both cases without and with wastewater treatment system in the Nhue–Day River basin is 155,892,341 kg BOD/year.

T0Wi (no treatment) = 2,008,752 people x 35 g/person/day x 1 x 365 days
= 25,661,806.8 kg BOD/year

T0Wi (CWTP) = 964,843 people x 35 g/person/day x 1 x 365 days
= 12,325,869 kg BOD/year

T0Wi (ST) = 7,779,136 people x 35 g/person/day x 1 x 365 days
= 99,378,462.4 kg BOD/year
T0Wi (T) = 1,450,192 people x 35 g/person/day x 1 x 365 days
= 18,526,202.8 kg BOD/year

3.1.2. Calculation results of emission factors

a) Basic parameters for calculation

The CH_4 emission factor is calculated based upon specific treatment cases in the Day–Nhue River basin (Tables 6 and 7).

Table 6. Correction coefficient of CH_4 (MCF_j) for domestic wastewater [9].

Case	CH_4 value	
No treatment method		
– No treatment for domestic wastewater	0.1	0–0.2
Treatment method		
Centralized wastewater treatment plants by aerobic technology – Good management	0	0–0.1
Centralized wastewater treatment plants by aerobic technology – Mismanagement	0.3	0.2–0.4
Septic tanks	0.5	0.5
Other types of toilets	0.7	0.7–1.0

Table 7. Basic parameters for emission calculation [11].

Parameter	
Amount of CH_4 recovered (kg CH_4/year)	Since the sludge treatment is currently only carried out in wastewater treatment plants at a very low rate, this value thereby could be ignored.
Ri–Amount of CH_4 recovered (kg CH_4/year)	Since there is no mandatory regulation to recover CH_4 gas during the sludge treatment, this value is 0.

b) Calculation results

The results indicate that the CH_4 emission factor in case of not applying any measures for domestic wastewater treatment is 12,052.51 kg CH_4/kg total BOD.

The CH_4 emission factor for domestic wastewater treatment system at a concentrated wastewater treatment plant (by aerobic technology) is 86,835.87 kg CH_4/kg total BOD.

The CH_4 emission factor in case of using a septic tank is 466,748.16 kg CH_4/kg total BOD, and is 121,816.13 kg CH_4/kg total BOD for other toilets.

Thus, the total CH_4 emission factor for all cases with and without treatment measures is 687,452.67 kg CH_4/kg total BOD.

EF_j (no treatment) = 0.6 kg CH_4/kg BOD x 0.1 x 2,008,752 people x 10%
= 12,052.51 kg CH_4/kg total BOD
EF_j (CWTP) = 0.6 kg CH_4/kg BOD x 0.3 x 964,843 people x 50%
= 86,835.87 kg CH_4/kg total BOD
EF_j (ST) = 0.6 kg CH_4/kg BOD x 0.5 x 7,779,136 people x 20%
= 466,748.16 kg CH_4/kg total BOD
EF_j (T) = 0.6 kg CH_4/kg BOD x 0.7 x 1,450,192 people x 20%
= 121,816.13 kg CH_4/kg total BOD

3.1.3. Calculation results of total CH4 emission

a) Basic parameters for calculation

The basic parameter for the identification of total CH_4 emission is based upon the calculation from:

– Total organic content in domestic wastewater;

– Emission factors.

b) Calculation results

CH_4 (no treatment) = 25,661,806.8 kg BOD/year x 1,205.251 kg CH_4/kg total BOD x 10^{-3}
= 30,928,918 tons CH_4/year

CH_4 (CWTP) = 12,325,869 kg BOD/year x 86,835.87 kg CH_4/kg total BOD x 10^{-3}
= 1,070,327,558 tons CH_4/year

CH_4 (ST) = 99,378,462.4 kg BOD/year x 466,748.16 kg CH_4/kg total BOD x 10^{-3}
= 46,384,714,469 tons CH_4/year

CH_4 (T) = 18,526,202.8 kg BOD/year x 121,816.128 kg CH_4/kg total BOD x 10^{-3}
= 2,256,790,292 tons CH_4/year

Therefore, the total CH_4 emission from domestic wastewater in the Nhue–Day River basin is 49,742,761,237 tons CH_4/year corresponding to 49,742,761.24 Gg CH_4/year.

Table 8. Results of total organic value, correction coefficient and total CH_4 emission in domestic wastewater in the Nhue–Day River basin in 2019.

Treatment method		Symbol	Total organic content (kg BOD/year)	Correction coefficient CH_4 (kg CH_4/ kg total BOD)	Total CH_4 emission (ton CH_4/year)
No treament method	Discharge wastewater into the surrounding area (river, lake, etc.)	No treatment	25,661,806.8	1,205.251	30,928,918
	Centralized wastewater treatment plants (by aerobic technology)	CWTP	12,325,869	86,835.87	1,070,327,558
	Septic tank system	ST	99,378,462.4	466,748.16	46,384,714,469
Treament method	Other treatment methods (Other types of toilets)	T	18,526,202.8	121,816.128	2,256,790,292
	Total treatment measures		130,230,534.2	675,400.16	49,711,832,319
	Total		155,892,341	676.605.41	49,742,761,237

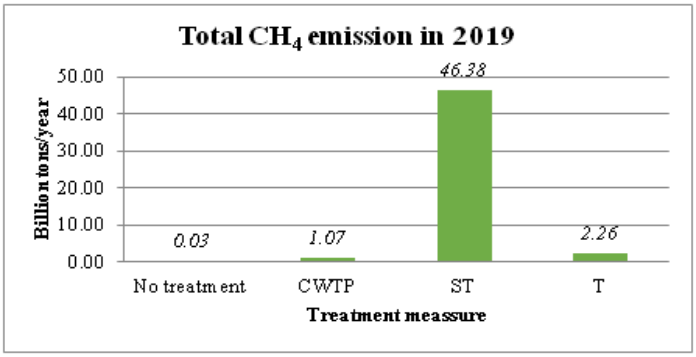

Figure 2. Total CH_4 emission in the Nhue–Day River basin in 2019.

Table 8 and Figure 1 show the calculation results of total organic content, the correction coefficient and total CH_4 emission in domestic wastewater in the Nhue–Day River basin such as:

– Total organic content: 155,892,341 kg BOD/year.

– Correction coefficient: 676,605.41 kg CH_4/kg total BOD.

– The total emissions are 49,742,761,237 tons CH_4/year corresponding to 49,742,761.24 Gg CH_4/year. CH_4 greenhouse gas mainly comes from the anaerobic decomposition of domestic wastewater in septic tanks and other types of toilets. Specifically, CH_4 gas generated from anaerobic decomposition (septic tank systems and other toilets) accounts for 97.85% (equivalent to 48,641,504,761 kg CH_4/kg total BOD)

compared to total amount of emissions in case of applying treatment measures (corresponding to 49,711,832,319 kg CH_4/kg total BOD).

3.2. Calculation on the level of methane greenhouse gas emissions from domestic wastewater in 2030

3.2.1. Results of total organic content in domestic wastewater

Pursuant to the Decision 681/QD–TTg on the Planning of drainage and wastewater treatment systems for residential and industrial areas in the Nhue–Day River basin to 2030 and the plan of the Hanoi People's Committee on environmental protection in Nhue–Day River basin until 2020, the CWTP by aerobic technology in the Nhue–Day River basin will be able to handle about 43% by 2030 (from 875.7 x 10^3 m^3/day at present to 1,182.5 x 10^3 m^3/day according to Decision 681/QD–TTg) [12]. Therefore, it is estimated that the CWTP with aerobic technology for about 6,319,721 people in the basin and the amount of wastewater is not discharged into the wastewater treatment system at approximately 8,377,304 people. Additionally, the average proportion of people using a septic toilet account for 92% of total population in the Nhue–Day River basin at 13,521,263 people. The average rate of people using other types of toilets accounts for 8% corresponding to 1,175,762 people. Besides, there are no households that do not apply any measures of domestic wastewater treatment by 2030.

Table 9. Population rate according to the treatment plan in 2030.

Type of treatment method	Urban		Rural		Total of people
	Average value (%)	Number of people	Average value (%)	Number of people	
Hygienic toilets in provinces	100	5,521,977	90	8,257,543	13,779,520
Average septic tanks in the provinces of the river basin (%)	92	8,080,219	70	6,422,534	14,502,753
Population using other toilets	8	441,758	20	1,835,010	2,276,768
Population does not apply any treatment methods for domestic wastewater	0	0	10	917,505	917,505
Estimated population has domestic wastewater treated in centralized wastewater treatment plants (CWTP) by aerobic technology	43				6,319,721
Estimated population has untreated domestic wastewater in CWTP					8,377,304

Calculation results

T0Wi (no treatment) = 917,505 people x 35 g/person/day x 1 x 365 days
= 11,721,126.38 kg BOD/year

T0Wi (CWTP) = 6,319,721 people x 35 g/person/day x 1 x 365 days
= 80,734,435.78 kg BOD/ year

T0Wi (ST) = 14,502,753 people x 35 g/person/day x 1 x 365 days
= 185,272,669.58 kg BOD/year

T0Wi (T) = 2,276,768 people x 35 g/person/day x 1 x 365 days
= 29,085,711.2 kg BOD/year

– Total organic content generated in case of no domestic wastewater treatment system is 11,721,126.38 kg BOD/year.

– Total organic content generated in case of domestic wastewater treatment system is 295,092,816.56 kg BOD/year as:

+ Derived from the concentrated wastewater treatment plant (CWTP) is 80,734,435.78 kg BOD/year.

+ Derived from the septic tank system (ST) is 185,272,669.58 kg BOD/year.

+ Derived from other types of toilet (T) is 29,085,711.2 kg BOD/year.

– The total organic content generated in both cases without and with wastewater treatment system in the Nhue–Day River basin is 306,813,942.94 kg BOD/year.

3.2.2. Calculation results of emission factors

Calculation results

The results indicate that the CH_4 emission factor in case of not applying any measures for domestic wastewater treatment is 5,505.03 kg CH_4/kg total BOD.

The CH_4 emission factor for domestic wastewater treatment system at a CWTP (by aerobic technology) is 568,774.89 kg CH_4/kg total BOD.

The CH_4 emission factor in case of using a septic tank is 870,165.18 kg CH_4/kg total BOD, and is 191,248.51 kg CH_4/kg total BOD for other toilets.

Thus, the total CH_4 emission factor for all cases with and without treatment measures is: 1,635,639.61 kg CH_4/kg total BOD.

$$E_j \text{ (no treatment)} = 0.6 \text{ kg } CH_4\text{/kg BOD} \times 0.1 \times 917{,}505 \text{ people} \times 10\%$$
$$= 5{,}505.03 \text{ kg } CH_4\text{/kg total BOD}$$
$$E_j \text{ (CWTP)} = 0.6 \text{ kg } CH_4\text{/kg BOD} \times 0.3 \times 6{,}319{,}721 \text{ people} \times 50\%$$
$$= 568{,}774.89 \text{ kg } CH_4\text{/kg total BOD}$$
$$E_j \text{ (ST)} = 0.6 \text{ kg } CH_4\text{/ kg BOD} \times 0.5 \times 14{,}502{,}753 \text{ people} \times 20\%$$
$$= 870{,}165.18 \text{ kg } CH_4\text{/kg total BOD}$$
$$EF_j \text{ (T)} = 0.6 \text{ kg } CH_4\text{/kg BOD} \times 0.7 \times 2{,}276{,}768 \text{ people} \times 20\%$$
$$= 191{,}248.51 \text{ kg } CH_4\text{/kg total BOD}$$

3.2.3. Calculation results of total CH_4 emission

a) Basic parameters for calculation

The basic parameter for the identification of total CH_4 emission is based upon the calculation from:

– Total organic content in domestic wastewater;

– Emission factors.

b) Calculation results

$$CH_4 \text{ (no treatment)} = 11{,}721{,}126.38 \text{ kg BOD/year} \times 5{,}505.03 \text{ kg } CH_4\text{/kg total BOD} \times 10^{-3}$$
$$= 64{,}525{,}152 \text{ tons } CH_4\text{/year}$$
$$CH_4 \text{ (CWTP)} = 80{,}734{,}435.78 \text{ kg BOD/year} \times 568{,}774.89 \text{ kg } CH_4\text{/kg total BOD} \times 10^{-3}$$
$$= 45{,}919{,}719{,}830 \text{ tons } CH_4\text{/year}$$
$$CH_4 \text{ (ST)} = 185{,}272{,}669.58 \text{ kg BOD/year} \times 870{,}165.18 \text{ kg } CH_4\text{/kg total BOD} \times 10^{-3}$$
$$= 161{,}217{,}825{,}874 \text{ tons } CH_4\text{/year}$$
$$\text{(T)} = 29{,}085{,}711.2 \text{ kg BOD/year} \times 191{,}248.51 \text{ kg } CH_4\text{/kg total BOD} \times 10^{-3}$$
$$= 5{,}562{,}598{,}930 \text{ tons } CH_4\text{/year}$$

Therefore, the total CH_4 emission from domestic wastewater in the Nhue–Day River basin is 212,764,669,786 tons CH_4/year corresponding to 212,764,669.79 Gg CH_4/year.

Table 10. Results of total organic value, correction coefficient and total CH_4 emission in domestic wastewater in the Nhue–Day River basin in 2030.

Treatment method		**Symbol**	**Total organic content (kg BOD/year)**	**Correction coefficient CH_4 (kg CH_4/kg total BOD)**	**Total CH_4 emission (ton CH_4/year)**
No treament method	Discharge wastewater into the surrounding area (river, lake, etc.)	No treatment	11,721,126.38	5,505.03	64,525,152

	Treatment method	Symbol	Total organic content (kg BOD/year)	Correction coefficient CH_4 (kg CH_4/kg total BOD)	Total CH_4 emission (ton CH_4/year)
Treamen t method	Centralized wastewater treatment plants (by aerobic technology)	CWTP	80,734,435.78	568,774.89	45,919,719,830
	Septic tank system	ST	185,272,669.58	870,165.18	161,217,825,874
	Other treatment methods (Other types of toilets)	T	29,085,711.2	191,248.51	5,562,598,930
	Total treatment measures		295,092,816.56	1,630,188.58	212,700,144,634
	Total			1,635,693.61	212,764,669,786

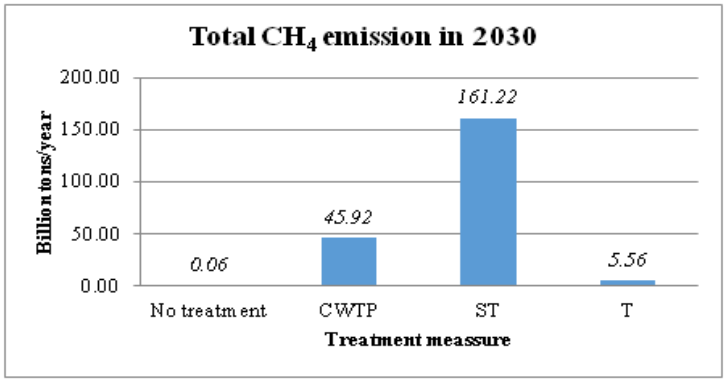

Figure 3. Total CH_4 emission in the Nhue–Day River basin in 2030.

Table 10 and Figure 2 describe that the calculation results of total organic content, the correction coefficient and total CH_4 emission in domestic wastewater in the Nhue–Day River basin by 2030 as:

– Total organic content: 306,813,942.94 kg BOD/year.

– Correction coefficient: 1,635,693.61 kg CH_4/kg total BOD.

– The total emissions are 212,764,669,786 tons CH_4/year corresponding to 212,764,669.79 Gg CH_4/year. CH_4 greenhouse gas mainly comes from the anaerobic decomposition of domestic wastewater in septic tanks and other types of toilets. Specifically, CH_4 gas generated from anaerobic decomposition (septic tank systems and other toilets) accounts for 78.41% (equivalent to 166,780,424,804 kg CH_4/kg total BOD) compared to total amount of emissions in case of applying treatment measures (corresponding to 212,700,144,634 kg CH_4/kg total BOD).

4. Conclusion

The study has indicated that the total amount of gas emissions from domestic wastewater reach at 52,850,201.55 Gg CH_4/year in 2019 and 212,764,669.79 Gg CH_4/year by 2030. CH_4 greenhouse gas mainly comes from the application of anaerobic treatment measures for domestic wastewater. In 2019, the total emissions are 49,742,761.24 Gg CH_4/year. Specifically, CH_4 gas generated from anaerobic digestion (septic tank systems and other types of toilets) accounts for 97.85% of the total emissions in case of applying treatment measures. In 2030, CH_4 gas from anaerobic decomposition only remains at 78.41% of the total emissions when applying the measures; meanwhile aerobic treatment efficiency in plants has increased from 7.73% in 2019 to 43% by 2030.

Accordingly, among with the requirement on waste management to limit the GHG generation through anaerobic measures, it is necessary to encourage the use of environmentally friendly technologies in centralized wastewater treatment plants [13]. The

study proposes that, when the operational efficiency of waste treatment technologies is considered, it should take into account the level of GHG generation besides the factors of wastewater treatment efficiency [14]. Moreover, it is necessary to have further specific studies on other GHG emissions in the Nhue–Day River basin.

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