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Methane Emissions from Municipal Solid Waste - Case Study in Cai Rang District, Can Tho City, Vietnam

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ABSTRACT

This study investigates the current situation and projects CH_4 emissions from municipal solid waste in Cai Rang district, Can Tho city by 2050. Total 60 households at Tan Phu ward (urban area) and Ba Lang ward (countryside area) - Cai Rang district were chosen for daily collected solid waste, then sorted into organic, inorganic, and recyclable categories over a one-week period. Results show that daily household waste generation significantly increased from Friday to Sunday, peaking on weekends. Organic waste constituted the largest fraction, consistently higher in urban areas (0.55 - 0.65 kg/person/day) than countryside (0.45 - 0.60 kg/person/day). Both inorganic and recyclable waste also exhibited an upward trend towards the weekend and were found in higher volumes in urban zones. The waste generation peaks during weekends, with urban households generating more organic and recyclable waste than countryside ones. By 2050, the study area discharge organic waste about 62.880 tons/year, and CH_4 emissions are expected rise to 973.8 tons/year, corresponding. The growth in emissions correlates with increased waste volume, driven by urban expansion and population growth, significantly worsen methane release. The study emphasizes the need for urgent intervention through the implementation of advanced solid waste treatment technologies such as composting, anaerobic digestion, or waste-to-energy incineration. These strategies are vital to reducing greenhouse gas emissions and promoting sustainable development in urbanizing areas like Cai Rang district.

Keywords: landfill, methane emissions, municipal solid waste, organic waste, urbanization.

INTRODUCTION

Climate change stands as one of the most pressing global challenges today, primarily driven by the increasing emission of greenhouse gases (GHGs) resulting from human activities. Among these gases, methane (CH_4) is particularly potent, exhibiting a global warming potential 28 to 34 times greater than carbon dioxide (CO_2) over a 100-year period (IPCC, 2023). Major sources of CH_4 emissions include agricultural practices, fossil fuel extraction, and, significantly, the treatment and disposal of municipal solid waste (MSW) (EPA, 2023).

In Vietnam, rapid urbanization has resulted in a substantial rise in MSW generation. Organic waste forms a major fraction, accounting for approximately 50 - 65% of total household waste (Truong, Nguyen & Le, 2025). The dominant waste treatment method remains landfilling, much of which lacks proper technical and environmental control. These poorly managed landfills create anaerobic conditions that promote the decomposition of organic waste and the consequent release of CH_4 into the atmosphere (MONRE, 2022; ESCAP, 2015).

Cai Rang district, located in Can Tho city, is a fast developing area that includes both urban and rural territory. With the increase in population and economic activities, the volume of MSW has grown significantly. However, waste is still primarily collected without segregation at source, and organic waste is often disposed of directly

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into landfills (Truong, Nguyen & Le, 2025). Despite these trends, there remains a lack of localized studies quantifying CH_4 emissions from the organic fraction of MSW in Cai Rang. This gap limits the ability to formulate data-driven waste management strategies and monitor progress toward greenhouse gas reduction targets.

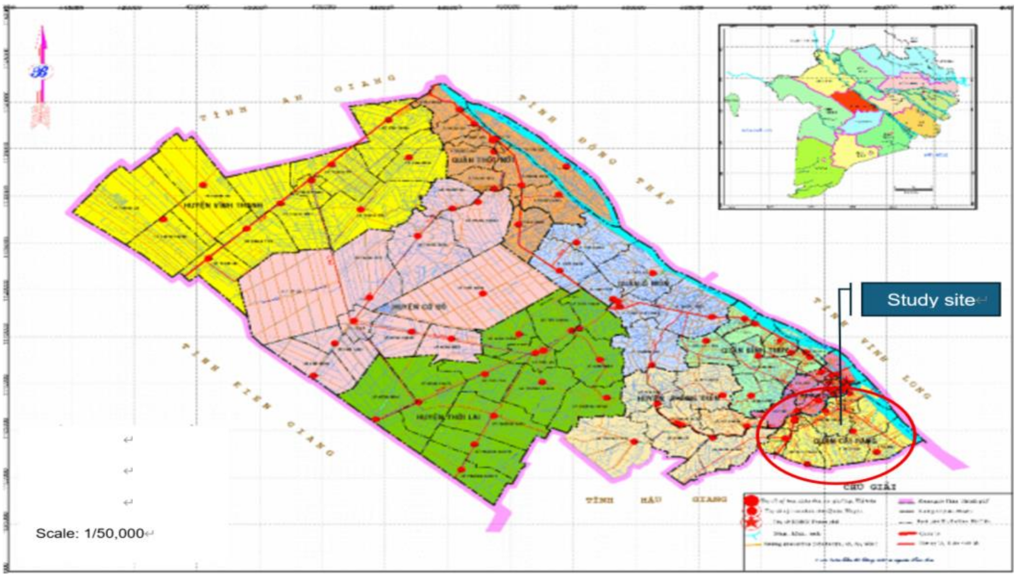

Figure 1. The study site in the map of Can Tho city and the Mekong delta

Conducting a CH_4 emission inventory for this locality is crucial. It not only contributes to national GHG accounting but also supports the development of appropriate mitigation strategies, such as organic waste composting, anaerobic digestion, or CH_4 recovery systems (ESCAP, 2015; Ngan, Vo & Tran, 2004). The findings will also serve as a valuable reference for local policymakers and environmental managers in implementing sustainable waste management and climate adaptation plans.

RESEARCH METHODOLOGY

Data Collection

This study conducted a survey to assess the generation of MSW at two wards in Cai Rang district, Can Tho city, in which Tan Phu ward located at urban area and Ba Lang located at countryside area. Due to the extensive area and high population density of the study site, efficient data collection required optimization in terms of time and cost. Therefore, the study selected 60 households in total to ensure an optimum sample size for descriptive statistics and subsequent analysis.

Each participating household was provided with a waste bag of 55 cm × 65 cm to collect all waste generated daily. The collection period lasted seven consecutive days, from Monday to Sunday (May 5 - 11, 2024).

Each waste bag was labeled with the household's identification details. Each day, the waste bags were gathered and transported to a meeting point for sorting and weighing. At the meeting point, the waste from each bag was separated into three categories: organic waste, recyclable materials, and non - recyclable waste. Each waste category was weighed using a 5 kg table - scale, then data were recorded to a logbook.

Forecasting Methodology

Municipal Waste Generation Forecast

First, the population of Cai Rang district by 2050 was estimated using the compound growth formula, assuming a constant annual growth rate (General Statistics Office, 2020).

$$P_{2050} = P_{2025} \times (1 + r)^n \quad [1]$$

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in which:

P_{2050}: projected population in 2050 (persons)

P_{2025}: Projected population in 2025 (persons)

r: annual population growth rate (assumed at 0.015)

n: number of years from 2025 to 2050

Then, the amount of MSW generated in Cai Rang district by 2050 was estimate based on the projected population, the per capita waste generation rate, the timeline, etc. following the equation proposed by Kaza et al. (2018):

$$Q = P \times R \times T \quad [2]$$

in which

Q: total projected solid waste quantity (kg or tons)

P: projected population (persons)

R: average daily waste generation rate per capita (kg/person/day)

T: time period in days (commonly 365 days per year)

Methane Emissions Projection

Methane emissions from MSW were calculated using following equation (IPCC, 2006):

$$CH_4 = (WT \times WF \times DOC \times DOCF \times F \times \frac{16}{12} - R) \times (1 - OX) \quad [3]$$

in which

WT: total annual solid waste generated (tons/year)

WF: ratio of waste disposed in landfills

MCF: methane correction factor (default value of 0.6)

DOC: degradable organic carbon rate in the waste

DOCF: ratio of DOC that degraded actually (default value of 0.7)

F: ratio of methane in landfill gas (default value: 0.5)

R: amount of methane recovered (tons/year)

OX: oxidation factor (ratio of CH_4 oxidized before release)

Data Processing and Analysis

The collected data were processed and analyzed using Microsoft Excel to assess of status of MSW generation in the two studied wards. At each participant household, the number of current members was recorded so that the present data is count for each person, not for household.

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T-test was conducted to determine whether there was a statistically significant difference in waste generation, in waste components, in weekday and weekend, etc. within and between Tan Phu ward and Ba Lang ward.

RESULTS AND DISCUSSION

Solid Waste Status

Solid Waste Generation

Table 1 shows the average daily household waste generation across the days of the week. From Monday to Thursday, waste volumes remained relatively low and stable, with Tuesday recording the lowest average at 0.79 ± 0.03 kg/person/day, and the Wednesday reach the highest weight at 0.84 ± 0.01 kg/person/day. However, a marked increase in waste generation was observed from Friday onwards. On Friday, the average waste reached 0.95 ± 0.05 kg/person/day, exceeded 1.01 ± 0.06 kg/person/day on Saturday and 1.02 ± 0.05 kg/person/day on Sunday. The weekend period showed the highest levels of household waste generation. This flow can be attributed to lifestyle patterns such as social gatherings, family meals, increased consumption of processed foods, and recreational activities. These behaviors indicate a statistically significant difference in waste generation between weekdays and weekends ($p<0.02$).

Table 1. Daily household waste generation in countryside and urban area

Week-day	**Generated waste in countryside**		**Generated waste in urban area**	
	Weight (kg/person/day)	***Ratio (%)***	***Weight (kg/person/day)***	***Ratio (%)***
Monday	0.83 ± 0.22	12.95	0.81 ± 0.35	12.94
Tuesday	0.75 ± 0.25	11.70	0.83 ± 0.34	13.26
Wednesday	0.84 ± 0.23	13.10	0.84 ± 0.33	13.42
Thursday	0.90 ± 0.24	14.04	0.91 ± 0.33	14.45
Friday	0.99 ± 0.25	15.44	0.91 ± 0.34	14.45
Saturday	1.05 ± 0.28	16.38	0.97 ± 0.34	15.50
Sunday	1.05 ± 0.26	16.38	0.99 ± 0.34	15.81

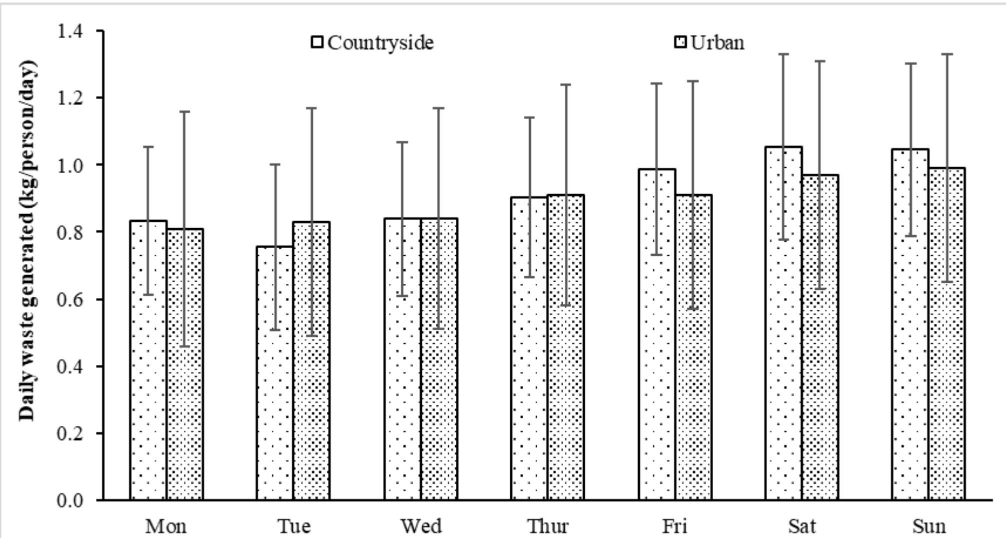

Figure 2. Daily household waste generation over a week

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Figure 2 aligns with findings from previous studies conducted in Vietnam. For example, Tran, Le and Nguyen (2021) reported that weekend waste volumes were 12 - 18% higher than weekday averages in Can Tho city. Pham (2019) observed a substantial increase in waste output on Saturdays and Sundays in Ho Chi Minh city, which was linked to fresh food consumption and the use of packaged products as families spent more time at home. Similarly, Nguyen, Hoang and Pham (2020) found a comparable trend in Ha Noi city where waste quantities rose sharply during weekends, particularly in middle to high income residential areas.

Based on the findings, the design of waste collection strategies should consider daily variations in waste release, particularly the significant increase recorded on weekends. In additional, communication and awareness raising campaigns should be strengthened to promote waste classification and reduction during peak days, thereby enhancing the overall efficiency of the MSW management system.

Composition of Generated MSW

a) Organic Waste Component

The weekly generation of organic waste showed notable differences between countryside and urban areas, with a slight upward trend observed from the beginning to the end of the week in both zones (Table 2). Specifically, organic waste generation in urban households was consistently higher on most days, ranging from 0.55 to 0.65 kg/person/day, while countryside households produced slightly less, approximately 0.45 to 0.60 kg/person/day. Although differences in organic waste volumes were recorded, no statistically significant difference was found in household consumption behavior and waste generation within the same area ($p>0.2$).

Table 2. Daily household organic waste generation in countryside and urban area

Week-day	**Organic waste in countryside**		**Organic waste in urban area**	
	Weight (kg/person/day)	***Ratio (%)***	***Weight (kg/person/day)***	***Ratio (%)***
Monday	0.57 ± 0.18	13.64	0.59 ± 0.31	14.00
Tuesday	0.55 ± 0.20	13.15	0.57 ± 0.31	13.65
Wednesday	0.55 ± 0.19	13.15	0.57 ± 0.30	13.48
Thursday	0.58 ± 0.21	14.01	0.61 ± 0.30	14.50
Friday	0.62 ± 0.22	14.67	0.59 ± 0.30	14.09
Saturday	0.65 ± 0.23	15.76	0.63 ± 0.30	14.99
Sunday	0.63 ± 0.22	15.31	0.64 ± 0.30	15.30

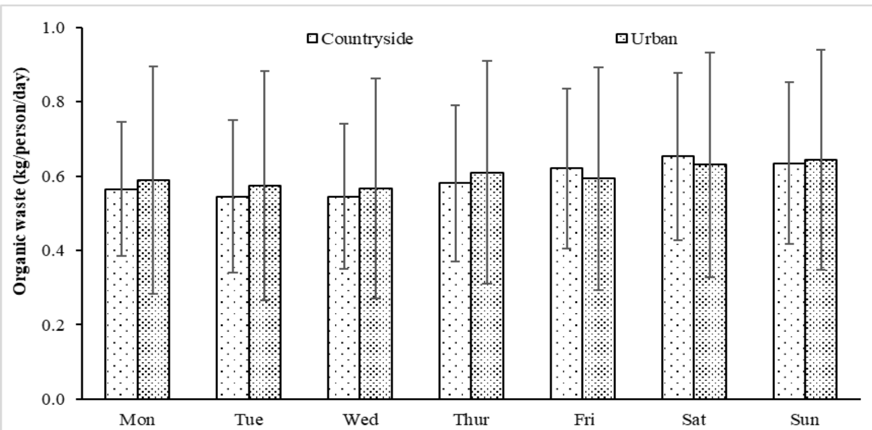

Figure 3. Daily organic waste generation over a week

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The observed urban-countryside variation can be attributed to differences in consumption patterns and daily routines (Figure 3). In urban side, higher consumption of processed food, packaged vegetables, and other pre-packed items tends to result in increased organic waste, primarily from household cooking and food preparation activities. These findings are consistent with the study by Tran, Hoang and Pham (2019) in Can Tho city, which reported that organic waste generation in urban area was 15 - 20% higher than in countryside region. Similarly, Le and Nguyen (2020) found that organic waste accounted for a significant proportion of MSW in the central districts of Ho Chi Minh city, especially during weekends.

Furthermore, organic waste in both countryside and urban areas showed a slight increase on Saturday and Sunday, suggesting a link to lifestyle patterns such as home cooking, family gatherings, and higher consumption of fresh food during weekends. These results contribute to a better understanding of the relationship between socioeconomic characteristics and household waste behavior, underline the importance of waste classification at source and organic waste treatment in practice, especially in urban area where organic waste volumes are significant high.

b) Inorganic Waste Component

The daily generation of inorganic waste in both countryside and urban areas revealed a gradual upward trend from the beginning to the end of the week (Table 3), with a statistically significant difference between the two areas ($p<0.01$). Throughout a week survey, urban households consistently produced higher volumes of inorganic waste, ranging from 0.08 to 0.18 kg/person/day, while countryside households generated slightly less, fluctuating between 0.06 and 0.15 kg/person/day. Notably, during the weekend time, inorganic waste generation rose sharply in both areas, peaking on Saturday and Sunday. This trend reflects increased consumption behaviors typically associated with weekends, particularly the use of packaged goods, plastic containers, and disposable items contributors to inorganic waste. The gap in inorganic waste volume between urban and countryside areas can be explained by differences in living standards, consumption habits, and urbanization levels. In urban area, residents tend to consume more packaged products and rely more heavily on plastics, non-biodegradable materials, and disposable goods, thereby leading to higher quantities of inorganic waste. The findings are consistent with report of Pham, Tran and Le (2020) that inorganic waste accounts for 30 - 40% of total MSW, while in countryside areas they range from 15 to 20% in Ha Noi and Ho Chi Minh cities. Similarly, Nguyen (2018) emphasized that urban commercial and consumer activities significantly contribute to the rise in inorganic waste, particularly during weekends and holidays.

Table 3. Daily household inorganic waste generation in countryside and urban area

Week-day	**Inorganic waste in countryside**		**Inorganic waste in urban area**	
	Weight (kg/person/day)	***Ratio (%)***	***Weight (kg/person/day)***	***Ratio (%)***
Monday	0.06 ± 0.09	7.31	0.08 ± 0.09	10.28
Tuesday	0.08 ± 0.09	7.98	0.10 ± 0.08	12.89
Wednesday	0.11 ± 0.11	13.41	0.10 ± 0.08	12.89
Thursday	0.12 ± 0.09	14.63	0.12 ± 0.11	15.22
Friday	0.14 ± 0.09	17.07	0.12 ± 0.08	15.22
Saturday	0.16 ± 0.09	19.51	0.13 ± 0.06	16.75
Sunday	0.16 ± 0.07	19.51	0.13 ± 0.06	16.75

Daily fluctuations volume (Figure 4) also show that the quantity of inorganic waste is not only dependent on geographical areas but also closely related to local communities' lifestyle and consumption behavior over time.

This requires flexible inorganic waste management policies in both spatially and temporally, including promoting at source separation, effective collection and increasing the recycling solutions of potential materials such as plastics, metals, and packaging.

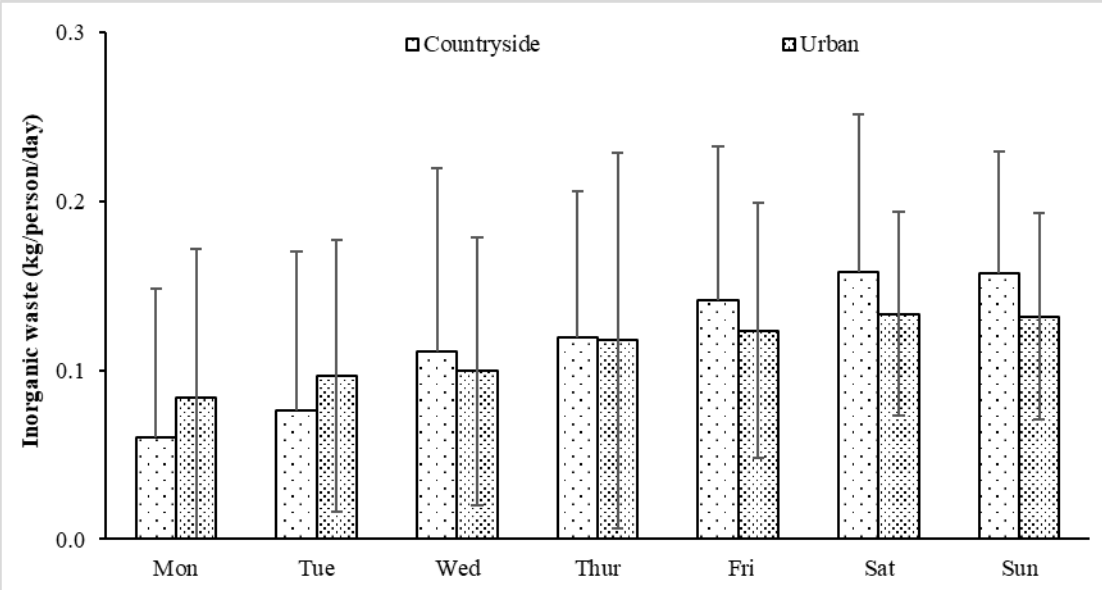

Figure 4. Daily inorganic waste generation per capita

c) Recyclable Waste Fraction

Table 4 indicate the quantity of recyclable waste in urban area tended to be higher than in countryside through the 7-day monitoring period. During the first three days (Monday to Wednesday), the difference in recyclable waste between the two areas was relatively small, fluctuating between 0.01 and 0.03 kg/person/day. However, a statistically significant difference ($p<0.02$) appeared from Thursday onward with urban households generating increasingly higher volumes, peaking on Saturday and Sunday at approximately 0.24 kg/person/day. In contrast, countryside areas maintained a lower volume, remaining below 0.20 kg/person/day. This inequality highlights differences in consumption habits, access to recyclable-packaged products, and the effectiveness of source classification practices between the two areas. The findings align with the study by Nguyen, Le and Do (2020) reported recyclable waste volumes in urban areas were 25 - 30% higher than in countryside, mainly due to higher levels of urbanization and living standards. Similarly, Tran, Hoang and Pham (2021) observed urban households tend to consume more packaged goods, leading to greater quantities of recyclable materials such as plastics, paper, and metals. In addition, the upward trend in recyclable waste generation during the weekend - particularly in urban area - may be linked to shopping behaviors and the increased consumption of processed foods on non - working days. Pham, Nguyen and Vo (2022) reported that household waste volumes rose by an average of 12% on weekends, with recyclable materials accounting for a significant proportion of the total waste generated.

Table 4. Daily household recyclable waste generation in countryside and urban area

Week-day	**Recyclable waste in countryside**		**Recyclable waste in urban area**	
	Weight (kg/person/day)	***Ratio (%)***	***Weight (kg/person/day)***	***Ratio (%)***
Monday	0.21 ± 0.19	14.19	0.14 ± 0.13	10.69
Tuesday	0.16 ± 0.15	10.81	0.17 ± 0.13	12.98
Wednesday	0.19 ± 0.13	12.84	0.20 ± 0.11	12.98
Thursday	0.20 ± 0.12	13.51	0.20 ± 0.12	15.27

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Friday	0.22 ± 0.12	14.86	0.20 ± 0.12	15.27
Saturday	0.25 ± 0.14	16.89	0.21 ± 0.10	16.03
Sunday	0.25 ± 0.11	16.89	0.22 ± 0.10	16.79

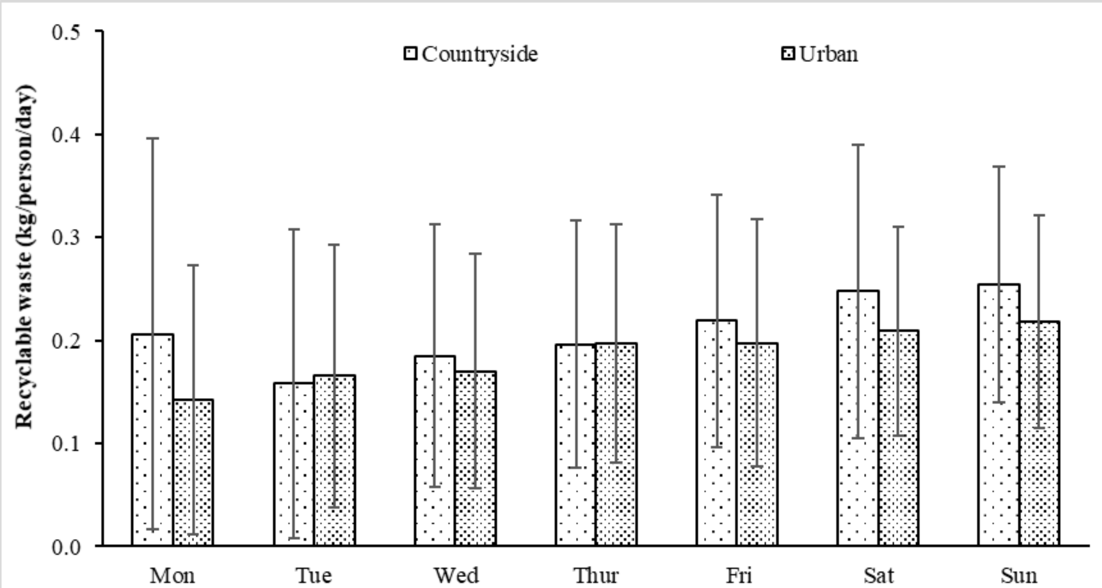

Figure 5. Daily recycle waste generation per capita

Methane Emission from Organic Waste

Projected Organic Waste Generation

The annual generation of organic waste in Cai Rang district was estimated using the average population growth rate for each projected year between 2025 and 2050, and a baseline per capita organic waste generation rate. The annual population growth rate in Cai Rang district is estimated to be 1.23% (2025 - 2030), 1.24% (2030 - 2035), and then stabilize at around 1.238% until 2050. This increase is consistent with the general trend of Vietnamese urban areas and is within the range of 1.0 - 1.5%/year (General Statistics Office, 2022). The selected population growth rates is within the overall socio-economic development orientation of Can Tho city until 2050 (Prime Minister, 2023) and is consistent with a satellite district in the process of shaping and developing urban services. The current organic waste generation rate in study area is 0.60 kg/day. To reflect lifestyle changes and increasing consumption, the organic waste generation rate was assumed to increase by 0.10 kg/person/day every five years. Applying this method, the quantity of organic waste generated is projected to rise sharply - from approximately 25.37 tons/year in 2025 to nearly 62.88 tons/year in 2050 (Table 5).

Table 5. Forecasting the rate of household organic waste generation in Cai Rang district by 2050

Year	**Population (person)**	**Waste generation rate (kg/person/day)**	**Generated waste weight**	
			(ton/day)	**(ton/year)**
2025	115,885	0.62	25,37	24,487.85
2030	123,061	0.62	31,44	25,155.80
2035	130,686	0.62	38,16	25,531.75
2040	138,778	0.62	45,58	25,947.85

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2045	147,366	0.62	53,78	26,305.55
2050	156,480	0.62	62,82	26,699.75

The growth trend in the Figure 6 is driven by both demographic expansion and a gradual increase in individual waste generation behavior which align with global trends. According to Kaza et al. (2018), waste generation is expected to grow significantly in developing countries due to increasing population density, changes in consumption habits, and economic development. Similarly, Hoornweg et al. (2012) reported that organic waste comprises the largest fraction of MSW in low- and middle-income countries up to 56% which is comparable to the situation in Cai Rang district. These evaluations suggest that the district may face similar challenges in waste management if proactive strategies are not implemented. Given the projected increase, local authorities should consider adopting sustainable management approaches such as source separation of organics, community-based composting systems, and awareness programs to reduce food waste. These measures not only minimize the volume of waste sent to landfills but also contribute to reducing CH_4 emissions, a potent GHG resulting from the decomposition of organic matter in anaerobic conditions. Therefore, improving organic waste management in Cai Rang district is not only an environmental necessity but also a critical component of climate change mitigation.

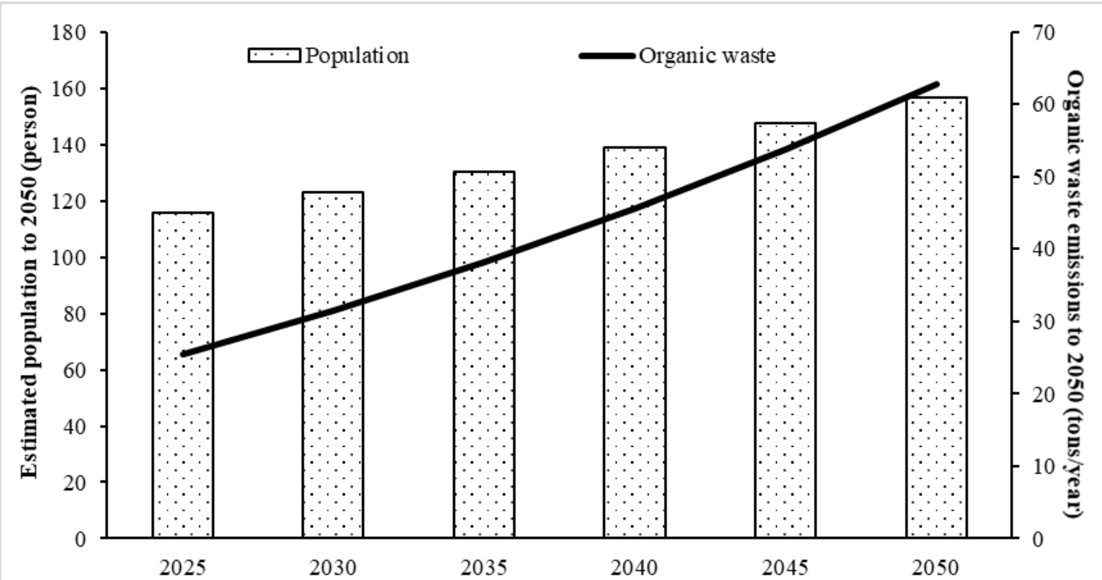

Figure 6. Projected organic waste generation in Cai Rang district households to 2050

As the population grows alongside urbanization and the expansion of commercial and service activities, organic waste generation is expected to increase proportionally. According to Pham, Le and Tran (2021), organic waste accounts for over 70% of total MSW, mostly consisting of food scraps, vegetables, and other biodegradable materials in rapidly expanding urban areas of Can Tho city. Consequently, the active management of organic waste has become a pressing issue, especially in the context of climate change and the need to reduce GHGs emissions from landfills. Nguyen (2020) reported the average household organic waste issue in Can Tho urban areas ranges from 0.55 to 0.62 kg/person/day, depending on living conditions and consumption levels. However, in the absence of proper source classification strategies and inappropriate organic waste treatment technologies, the sharp rise in organic waste may overwhelm the MSW management system. In this context, models of promoting waste classification at source, of environmentally friendly treatment technologies, of community education, of integrated waste management, etc. are considered optimal solutions that support sustainable urban development. Moreover, accurate forecasting of future MSW generation is essential for infrastructure investment planning and improve solid waste treatment systems in alignment with each phase of urban development.

However, as Vietnam moves towards becoming an upper-middle-income country by 2045 and continues to modernize its urban system, consumer behavior will gradually change to produce less organic waste. The trend of using processed foods, fast foods, canned foods, as well as the popularity of supermarket chains replacing

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traditional markets will reduce the amount of vegetables prepared at home - the main source of organic waste. In addition, with the development of public awareness programs, the “Zero Waste” movement, and policies to reduce food waste, many households will proactively limit food waste disposal and learn how to compost at home. This can significantly change the rate of organic waste in the future.

Besides to behavioral factors, policies and technology also play an important role in reducing the amount of organic waste generated or removing organic waste from the landfill chain. Specifically, Decision 491/QD-TTg has set out the National Strategy on Solid Waste Management to 2025, with a vision to 2050, which requires 100% of urban solid waste to be classified at source, treated with appropriate technology, and encourages the use of compost or energy recovery from organic waste (Prime Minister, 2018). This means that if policies are effectively implemented, while the total amount of household waste may continue to increase with population and economic development, the amount of untreated organic waste sent to landfills may gradually decrease, thanks to treatment at the source or reuse. International trends also support this argument. According to Wilson et al. (2015), as waste sorting systems and treatment technologies advance in developed countries, the proportion of organic waste in total household waste often falls below 40%, giving way to plastic waste, electronic waste and industrial waste. If Vietnam continues to modernize and improve its waste management system, it is likely that the organic waste component of the household waste structure will gradually decrease after 2040. Therefore, the assumption that the amount of organic waste will continue to increase strongly until 2050 needs to be re-evaluated, and forecasting models should incorporate factors such as changing consumer behavior, policy impacts, and the effectiveness of new waste management programs. Updating forecasting models based on different development scenarios will help local authorities make appropriate plans for infrastructure investment and waste treatment, optimize resources, and improve the effectiveness of urban environmental management in the future.

Methane Emissions from Organic Waste

CH_4 emissions from biodegradable organic waste in Cai Rang district are forecast to increase steadily during the period 2025 - 2050, from approximately 720.30 tons/year to 973.80 tons/year (Table 6, Figure 7). This increase is mainly due to population growth, resulting in a larger volume of domestic solid waste, while the organic component remains high (~60%). This trend reflects the close relationship between urban population growth, waste load, and greenhouse gas emissions, similar to the results recorded in the study by Nguyen et al. (2020). According to their study, the total CH_4 emissions of the entire inner-city area (including Ninh Kieu, Binh Thuy, Cai Rang and part of O Mon) are estimated at about 3,900 tons/year, of which Cai Rang is one of the districts with high emission rates due to rapid urbanization and high organic waste ratio. This shows that emissions in Cai Rang contribute significantly to the total greenhouse gas emissions of the city and need to be closely monitored.

Table 6. CH4 emission from organic waste in Cai Rang district

Year	Population (person)	Generated organic waste (ton/year)	CH_4 emission (ton/year)
2025	115,885	24.11	720.30
2030	123,061	25.60	764.90
2035	130,686	27.19	812.50
2040	138,778	28.86	862.90
2045	147,366	30.66	916.80
2050	156,480	32.56	973.80

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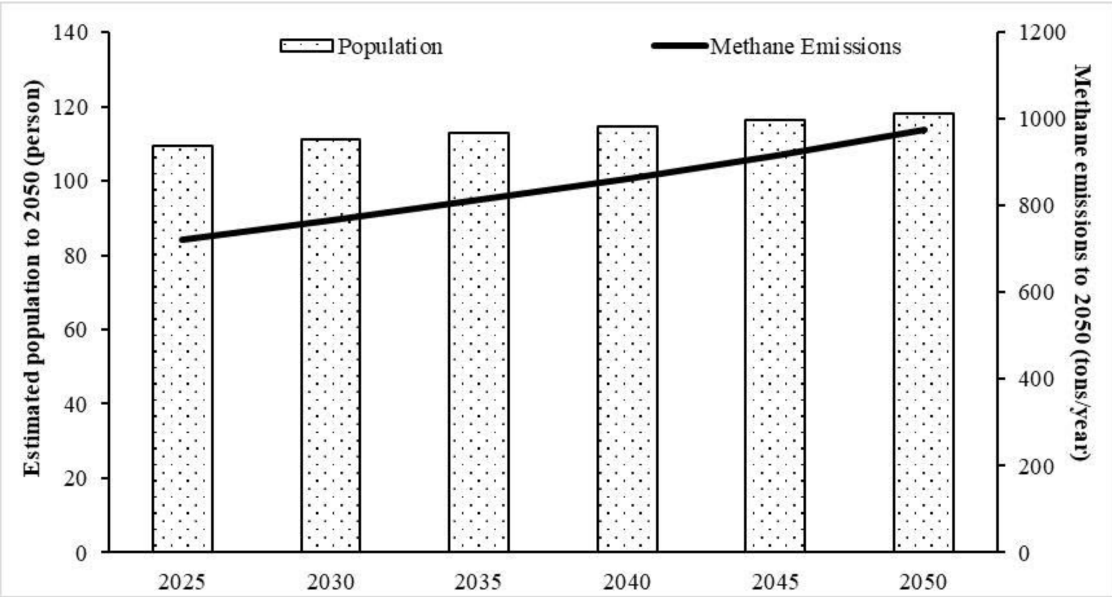

Figure 7. Estimated CH_4 emissions to 2050

Compared to other countries in the Southeast Asian region, the level of CH_4 emissions from organic waste in Can Tho in particular and Vietnam in general is still lower than that of large cities such as Jakarta (Indonesia), Manila (Philippines) or Bangkok (Thailand), where the amount of waste generated daily is up to tens of thousands of tons. However, the trend and nature of the problem are similar: high organic waste rate, outdated treatment infrastructure, and lack of gas recovery systems at landfills. According to the Climate and Clean Air Coalition (2022), Southeast Asia is one of the regions with the fastest growing CH_4 emissions from solid waste in the world, and if treatment technology is not improved, greenhouse gas emissions from waste will continue to increase sharply in the coming decades.

In Can Tho city, the majority of MSW is currently managed through sanitary landfilling. However, the existing landfill facilities lack CH_4 gas capture and treatment systems, resulting in the uncontrolled release of GHGs into the atmosphere. This situation underscores the urgent need to enhance organic waste management technologies, such as community-based composting, anaerobic digestion, and the installation of CH_4 capture systems at landfill sites. Implementing these solutions is crucial not only for mitigating CH_4 emissions but also for promoting a more climate-resilient and sustainable waste management system.

These findings are consistent with the conclusions of IPCC (2006), which identified landfilling as the primary source of CH_4 emissions within the solid waste management sector, particularly in developing nations where gases monitoring systems remain inadequate. Study by Nguyen, Tran and Le (2018) on CH_4 release from Go Cat landfill in Ho Chi Minh city reported up to 50% of landfill gas may consist of CH_4, highlighting the crucial importance of effective GHG recovery strategies. Similarly, Pham (2020) emphasized the need for urban areas in the Mekong delta to gradually transition away from traditional land disposal toward modern treatment alternatives such as composting or waste-to-energy incineration. These advanced methods are essential for limitation CH_4 discharges into the environment and fostering sustainable waste practices.

CONCLUSION

This study focused on assessing the MSW status and CH_4 emissions from organic waste in Cai Rang district, Can Tho city. Onsite surveys conducted in Tan Phu and Ba Lang wards revealed daily fluctuations in household waste generation, with a noticeable increase toward the weekend. Organic materials constitute most waste, and urban area tend to generate more waste than countryside region. The volumes of inorganic and recyclable waste also increase from early to late in the week and are higher in urban zone, reflecting patterns of consumer behavior in cities.

The volume of organic waste is projected to increase steadily-from approximately 25.37 tons/year in 2025 to 62.88 tons/year by 2050. The estimated future CH_4 emissions from organic waste steadily growth from about

720.30 tons/year in 2025 to 973.80 tons/year by 2050. This rise is mainly attributed to population growth and the corresponding increase in waste volume, while landfilling - the dominant treatment approach - contributes significantly to CH_4 releases. The accelerating pace of urbanization and demographic expansion in Cai Rang district is placing growing pressure on the existing waste management system. Strategic interventions, including the adoption of advanced waste treatment technologies, are urgently needed to control GHG emissions and support sustainable urban development.

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