GREENHOUSE GAS EMISSIONS FROM MUNICIPAL SOLID WASTE DISPOSAL SITES – A CASE STUDY IN HOI AN CITY

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ABSTRACT

Currently, climate change shows an increasingly high intensity and anthropogenic greenhouse gas emissions are shown as the main drive force of rapid climate change. In 2015, Hoi An City emitted 8,855 tons of $CO_{2\text{-}eq}$ from municipal solid waste disposal sites, which treated 25,000 tons of solid waste from domestic and tourist activities. The flow of solid waste in disposal sites was analyzed and the sources of greenhouse gas emissions were identified by the Life Cycle Assessment (LCA) and Nordtest methods. In addition, IPCC-2006 was a main tool for calculating, estimating and forecasting amount of greenhouse gas. The results of this study shown that some activities in Cam Ha Composting Facility emitted 5,522 tons of $CO_{2\text{-}eq}$, in which activities of using electricity, combusting diesel fuel and composting process were 1.6%, 7.8% and 90.6% of total GHG, respectively. Additionally, 3,344 tons of $CO_{2\text{-}eq}$ was emitted from decomposited of Landfill site. Furthermore, this study was analyzed specifically the composition of GHG whereby three main components were calculated such as CH_4 (67.7% - 6,004 tons of $CO_{2\text{-}eq}$), N_2O (26.6% - 2,357 tons of $CO_{2\text{-}eq}$) and CO_2 (5.7% - 505 tons).

Keywords: *municipal solid waste management, greenhouse gas emissions, composting process, dumping landfill, Hoi An City*

1. INTRODUCTION

In recent years, anthropogenically induced climate change becomes an alarming problem of the whole world. N.T. Viet et al., shown that from 2004 to 2014 the shoreline of Cua Dai Beach in Hoi An City (HAC) had been eroded, slid and engrained 500 m along the coastline. This erosion pulled down many hotels, buildings and threatened the lives of fishermen [1]. The rise of greenhouse gases (GHG) in recent decades is known as one of the main drivers of climate change. According to the 4th report of Intergovernmental Panel on Climate Change (IPCC), amount of GHG emitted from management of solid waste and wastewater was 3% of total amount of GHG from human activities, particularly methane (CH_4) accounted for 90% [2].

HAC is an ancient tourist city so the two main sources of solid waste are domestic and tourism activities. According to the report of "Building a Hoi An Ecological City Project", 80% of total solid waste in HAC was collected and treated. Over 50% of municipal solid waste amount was composted, about 5% of solid waste was recycled and the remainder was treated by dumping on landfills [6]. Composting is a friendly solution with environment. However, it must be admitted that there are considerable amounts of GHG emitted from the composting

process[3]. Additionally, dumping on landfills is known as a main source of GHG emission from solid waste disposal. All of them contribute to increasing the effects of global warming[4].

2. MATERIALS AND METHODS

2.1. Accounting GHG emission from using electricity

The electricity was used for operating equipment in composting facility is considered in this study. The GHG emission from using electricity was determined by the following equation:

$$Emission(kg) = MJ \times \left[CO_2(kg) \times E_{CO_2} + N_2O(kg) \times E_{N_2O} + CH_4(kg) \times E_{CH_4}\right] \quad [7]$$

Where: MJ is electricity consumption (MJ – 1 Kwh = 3.6 MJ); E is equivalency factors.

2.2. Accounting GHG emission from diesel combustion

In this study, one truck (15 tones) was used to transport solid waste from separating point to the landfill and two scooping trucks were used for mixing, scooping and moving solid waste in composting process. Thus, the estimation of GHG emissions bases on vehicle type, distance travelled and working time per day (8 hours). The emissions (CO_2 equivalents) were determined using life cycle inventory data and the formula below:

$$Emission(kg) = S(Km) \times \left[CO_2(kg) \times E_{CO_2} + N_2O(kg) \times E_{N_2O} + CH_4(kg) \times E_{CH_4}\right] \quad [7]$$

Where: S is distance travelled (Km); E is equivalency factors.

2.3. Accounting GHG emission from composting

In composting process, a large fraction of the degradable organic carbon (DOC) in the waste material is converted into CO_2, CH_4 is formed in anaerobic sections of the compost and N_2O also produced. Poorly working composts are likely to produce more both of CH_4 and N_2O [7]. The CH_4 and N_2O emissions of biological treatment can be estimated using the default method given in follow equations:

$$CH_4 Emission = \sum_i (M_i \times EF_i) \times 10^{-3} - R;$$

$$N_2O\ Emission = \sum_i (M_i \times EF_i) \times 10^{-3} \quad [7]$$

Where: M is mass of organic waste treated by composting (Gg); EF is emission factor for composting (g CH_4 or N_2O/kg waste treated); R is total amount of CH_4 recovered in inventory year (Gg); i is composting.

2.4. Accounting GHG emission from landfill site

The greenhouse gases emissions related to landfilling are mainly due to CH_4 and carbon dioxide CO_2 present in the biogas produced by anaerobic bacteria. The equation is as follows: $\mathrm{CH_4\ Emission} = \mathrm{MSW_T \times MSW_F \times MCF \times DOC \times DOC_F \times F \times \frac{16}{12} - R}$ [8]

Where: MSW_T is total MSW generated (Gg/yr); MSW_F is fraction of MSW disposed to solid waste disposal sites; MCF is methane correction factor (fraction); DOC is degradable organic carbon (fraction) (kg C/kg SW); DOC_F is fraction DOC dissimilated; F is fraction of CH_4 in landfill gas (IPCC default is 0.5); 16/12 is conversion of C to CH_4, R is recovered CH_4 (Gg/yr).

3. RESULTS AND DISCUSSION

1.1 Municipal solid waste management in Hoi An City

On the land of 61.71 km^2, HAC has 9 wards and 4 communes of administration, which form 3 main featured areas such as the ancient town area in the center of the city, the residential area and rural area. According to the statistics from Center of Population and

Family Planning, Center of Management and Tourism Development and Public Works Ltc., in recent years while the population of HAC has been relatively stable, number of tourists has increased significantly and the amount of municipal solid waste also respectively raise as the below Table 1.

Table 1. Statistics of population, tourist and MSW in Hoi An city in recent years

Year	2009	2010	2011	2012	2013	2014	2015
Population (people)	93,806	91,368	94,531	92,389	94,246	94,367	89,755
Tourist (people)	1,474,098	1,504,478	1,753,228	1,679,262	1,911,000	1,756,916	1,899,000
MSW (ton)	19,282	20,147	22,164	23,915	24,548	26,101	25,339

3.2. Flow of solid waste and composition of MSW

Life Cycle Assessment method was used to analyze the flow of solid waste in disposal sites and identify sampling points. Nordtest methods (NT ENVIR 001 & 004) were used for sampling and measuring the composition of municipal solid waste which is showed in the Fig 1. 175 samples were sampled continuously from 5 positions of composting process in 7 days of a week to calculate the average value and assess the stability of data between weekdays [9,10]. The proportions of municipal solid waste components are shown in the Fig. 1 bellows.

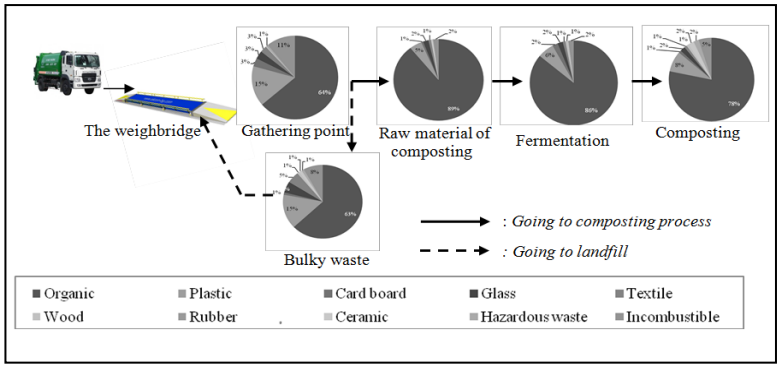

Figure 1. *Flow of solid waste in disposals and composition of MSW*

The municipal solid waste is aggregated into the gathering point at the Cam Ha Composting Facility, where solid waste is classified for the next treatment stages. The composition of solid waste in HAC was identified including 64% of organic, 15% of plastic, 11% of incombustible waste, 9% of glass, textile and card board and 1% of hazardous waste. While the recycled waste is moved to the recycle companies in Da Nang City (DNC), small organic waste (89%) is collected for being the raw material of composting process, which has 11% of small size impurities such as plastic (4%), glass (2%), incombustible waste (2%), textile (1%) and card board (1%). However, the biodegradable process from the fermenting and composting process is reduced due to the significant impurities in the final product. In addition, the bulky waste, which is transported to the landfill has 63% of organic (bulky bough, garden waste), 15% of plastic, 8% of incombustible waste, 10% of textile and glass and the remainders of card board, wood and ceramic. Comparing to the characteristic of the municipal solid waste in DNC - a famous tourist city, which is one of the biggest cities in the central of Vietnam receives about 720 tons of solid waste every day with the component was identified by 66.71% organic waste 14% plastic, 9.7% incombustible waste and 9.59% of others [5]. Although HAC is smaller than DNC (about urban scale and amount of solid waste generation), the composition of the municipal is relatively homologous.

3.3. Activities of MSW disposals and sources of GHG emissions

The municipal solid waste of HAC is collected and transported to Cam Ha Solid Waste Facility by trucks and is classified for the next treatment stages. Composting and dumping landfill are two main disposal methods. Several activities in Composting Facility and Landfill Site are shown and sources of GHG emissions from disposal sites are identified in the Fig. 2. In Composting Facility, GHG can emitted from three main activities such as burning diesel fuel from transportation by trucks and mixing waste by scooping trucks, using electricity for operating equipment and official activities and composting process. Furthermore, using compost in agriculture is known as a way of saving carbon and nitrogen in soil that is the potential and long term emission. In addition, at the dumping landfill, transportation and decomposition is two main processes can emit GHG [4].

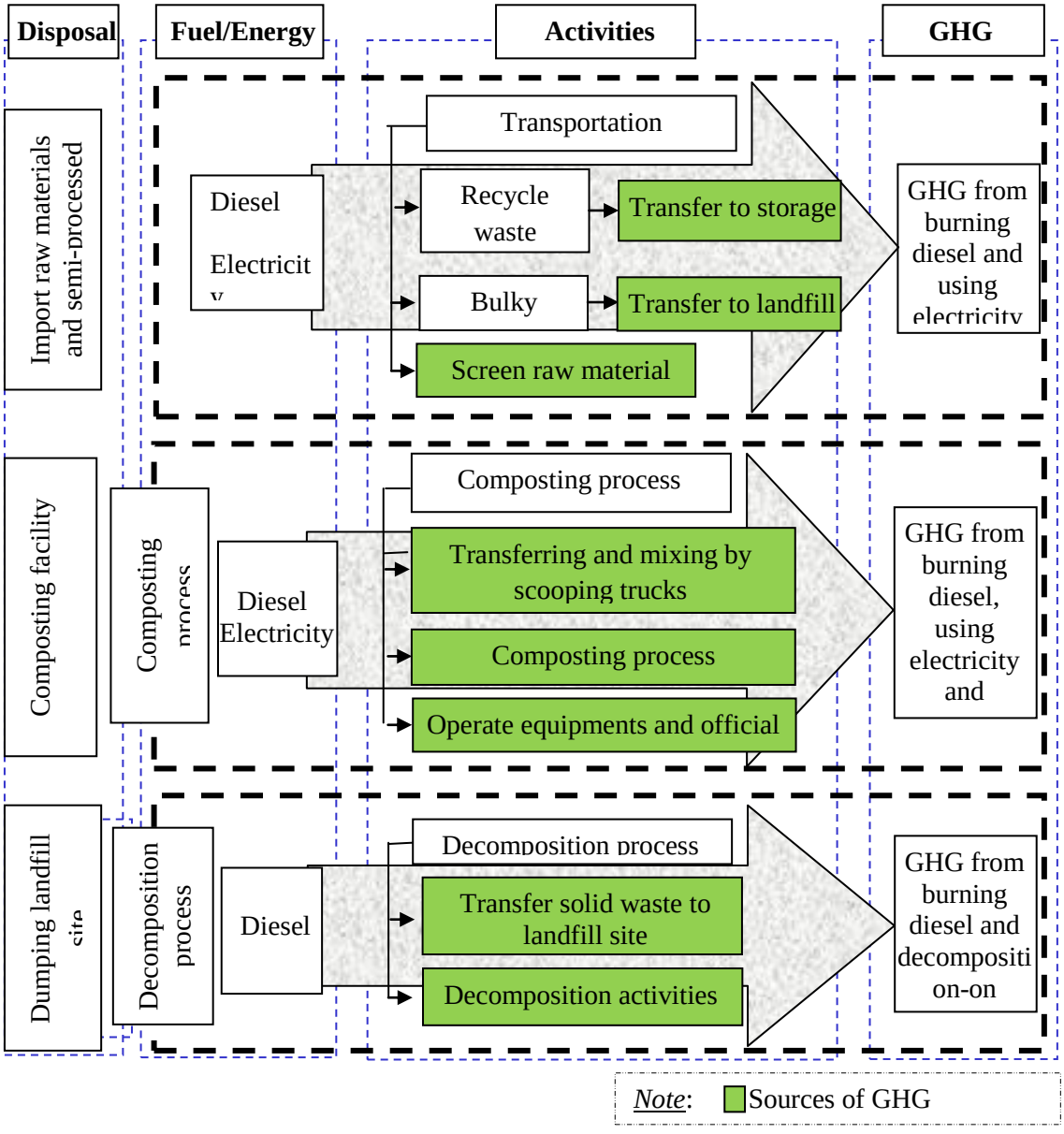

Figure 2. *Sources of GHG emissions from activities of municipal solid waste disposals*

3.4. GHG volume from disposal activities

This bar chart in Fig.3 shows the amount of GHG emitted from four activities in both of disposals in HAC in 2015. In particular, the volume of GHG from composting process was the highest proportion with 5,017 tons of $CO_{2\text{-eq}}$ (equivalent to 56.6%), while decomposition activity from the landfill emitted about 3,343 tons of $CO_{2\text{-eq}}$ (equivalent to 37.7%). On the other hand, combusting diesel and using electricity activities emitted 429 tons and 76 tons $CO_{2\text{-eq}}$ (equivalent to 4.8% and 0.9%), respectively. Comparing to GHG emission in DNC, 160,000 tons $CO_{2\text{-eq}}$ (equivalent to 7,573 tons CH_4), which were emitted from Khanh Son Landfill site in Danang City were more than HAC's 10 times of solid waste volume and 18 times of GHG emission volume [5]. These data illustrate that aerobic and anaerobic decompositions is the main generation sources of GHG by 94.4%. Thus, well controlling the processes of composting and landfilling, the amount of GHG emission will be reduced. Particularly, oxygen should be supplied enough to restrict anaerobic space in composting piles. The operating parameters such as moisture, temperature, the C/N ratio have to frequently check and control to reach optimum values. Additionally, the recovery and reuse of CH_4 should be improved to increase R coefficient and simultaneously reduce the amount of GHG from landfill.

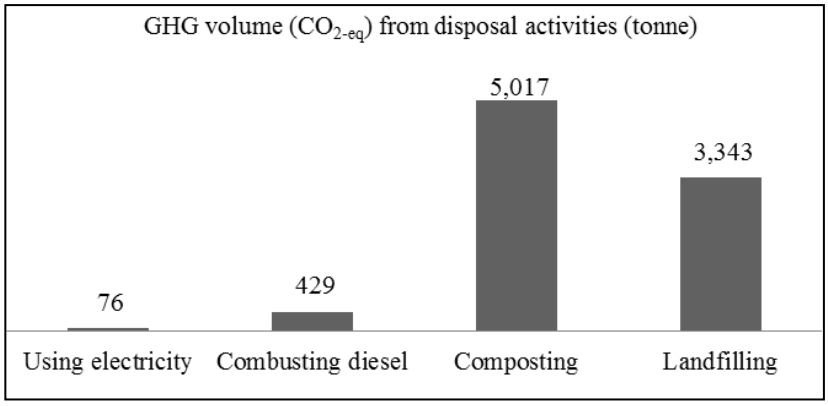

Figure 3. *GHG volume from disposal activities in 2015*

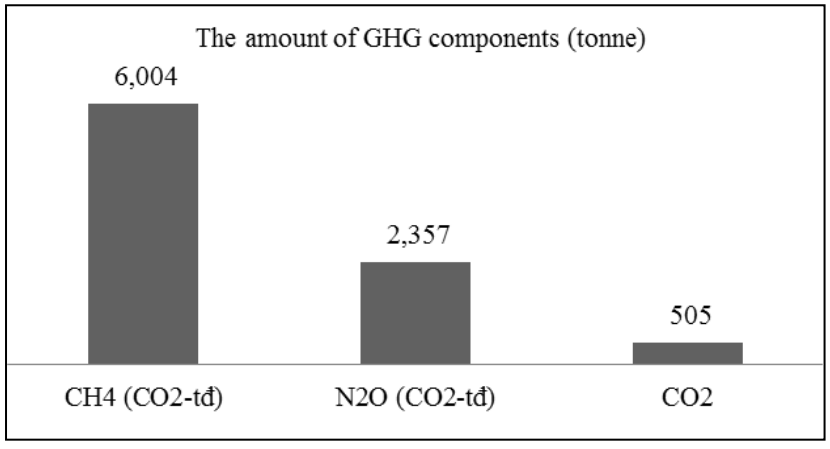

Figure 4. *The amount of GHG components in 2015*

The second chart in Fig.4 illustrates the emission of GHG components from disposal sites. CH_4 has always been a key component of GHG generation. Total amount of CH_4 which was emitted from disposal sites in 2015 was 286 tons (equivalent to 6,004 tons $CO_{2\text{-eq}}$), while there were 7.6 tons N_2O (equivalent to 2,357 tons $CO_{2\text{-eq}}$) and 505 tons CO_2 were emitted, respectively. Thereby, the municipal solid waste disposals in HAC emitted approximately 8,866 tons of $CO_{2\text{-eq}}$ into the atmosphere in 2015. Being born from the anaerobic digestion process, CH_4 accounted for 67.72 % of total amount of $CO_{2\text{-eq}}$. This means that anaerobic decomposition was a significant part in composting process and the considerable leakage of CH_4 from landfill site.

3.5. Estimation of GHG emission from MSW disposal in HAC for the future

According to the "Building an Ecological City Plan" of HAC, there are two scenarios for treating solid waste. All of the municipal solid waste will be treated by composting and incinerator (S1) or will be burned by incineration (S2). However, to improve the effect of sustainable integrated MSWM, the 3rd scenario is proposed which integrates anaerobic digestion, recycling, composting and incineration methods. The estimation of GHG generation in three scenarios from 2015 to 2030 is showed in figure 5.

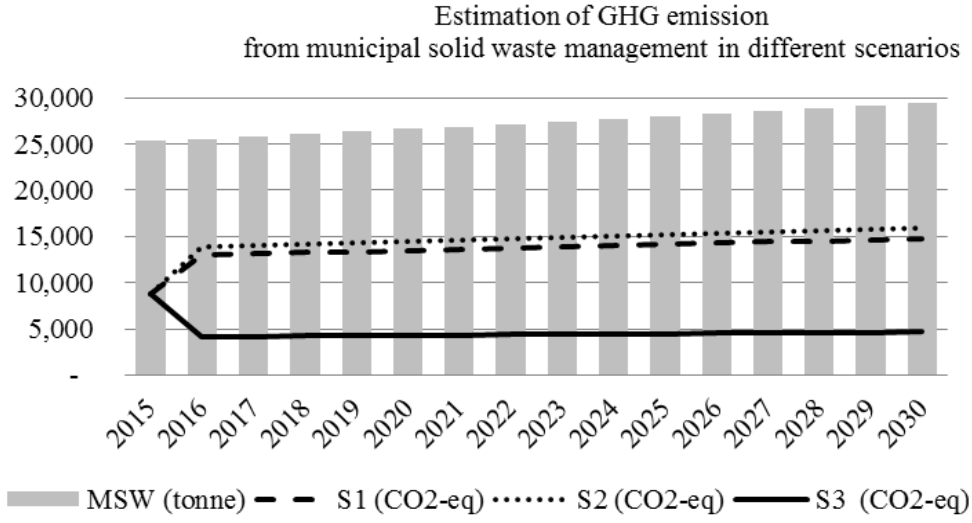

Figure 5. *Estimation of GHG emission from municipal solid waste disposals in the future*

This chart shows clearly that the GHG emission from disposals in scenario 1 (S1) and scenario 2 (S2) will be higher than from scenario 3 (S3) and go up slightly follow the growth of amount of municipal solid waste. This is explained by plastic, flame retardants and wet materials have high CO_2 emission factors from burning. Thus, burning all of solid waste in S2 or a half without separation in S1 will emit more GHG. Whereas, the municipal solid waste will be classified well in scenario 3. Therefore, the recycle waste (plastic, paper, card board, metal, glass,...) will be reused, recycled; the organic waste with high moisture (chicken waste, market waste, sewage sludge, human waste,...) will be decomposed by anaerobic digestion method (AD) which is has low greenhouse gas emissions, produce liquid fertilizer and recover CH_4 for cooking and power generation. The bulky waste (garden waste) will be composted and the remaining fraction (household items) will be

burned. The ash from incinerator will be landfilled. Therefore, the municipal solid waste management (MSWM) in HAC should be integrated and handled according to scenario 3 to reduce total GHG emissions from disposals and get more benefits from energy saving and fertilizer products as well.

4. CONCLUSIONS

HAC generates about 2,000 tons of municipal solid waste every month which is separated by citizen and collected with distinct schedules. However, all of solid waste is gathered to the same point and mixed together. Thus, this makes the separation at the source lose the meaning and cause serious obstacles to the next treatment stage as well. Composting and dumping landfill methods are used for treating all of municipal solid waste in HAC. Cam Ha Composting Facility receives about 50% of total solid waste and the other half is dumped into Cam Ha dumping landfill site. The composition of municipal solid waste was identified including 64% of organic, 15% of plastic, 11% of incombustible, 9% of glass, textile and card board and 1% of hazardous.

In 2015, 8,855 tons of $CO_{2\text{-eq}}$ was emitted from both of disposal sites in HAC, in which 5,522 tons of $CO_{2\text{-eq}}$ were generated from Cam Ha Composting Facility and 3,344 tons $CO_{2\text{-eq}}$ were generated from Cam Ha dumping landfill site, respectively. In total GHG emitted, CH_4 is a key component by 67.7% of total amount of $CO_{2\text{-eq}}$ (equivalent to 6,004 tons $CO_{2\text{-eq}}$), while N_2O and CO2 were 26.6% (equivalent to 2,357 tons $CO_{2\text{-eq}}$) and 5.7% (equivalent to 505 tons CO_2). This showed that these solid waste treatment disposals did not effectively operate. Particularly, there were significantly anaerobic process in composting and considerably leakage of CH_4 from landfill site. The estimation of GHG generation for 3 scenarios of MSWM proved that an integrated MSWM, which includes effect of separation and collection and integration of recycling, composting, anaerobic digestion, incineration and landfilling will emit fewer GHG. This scenario will be the sustainable integrated MSWM model for HAC to build a Hoi An Low-Carbon City and bring numerous benefits for life.

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