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Impact of COVID-19 Pandemic on Greenhouse Gas Emissions from Municipal Solid Waste Disposal of Bangkok Metropolitan

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Abstract

The impact of COVID-19 pandemic on greenhouse gas emissions from solid waste disposal in Bangkok was evaluated using statistics of waste quantities disposed by composting, incineration, and landfill methods from the transfer stations during pre-pandemic period (2015-2019) and pandemic period (2020-2022). The potential emissions of greenhouse gases from these activities were evaluated using the 2006 IPCC and 2019 Refinement methodologies. During pre-pandemic period, the emissions was estimated at 1147.98 $GgCO_2$-eq/year in which waste disposal in landfills contributed majority at 1002.58 $GgCO_2$-eq/year. The landfill emissions gradually decreased to 861.23, 809.78, and 754.73 $GgCO_2$-eq in 2020-2022, respectively. Meanwhile, greenhouse gas emissions from composting and incineration of general wastes during the pandemic were maintained at the same levels as the pre-pandemic period. During the pandemic period, greenhouse gas emissions from infectious waste incineration were significantly increasing to 10.79 $GgCO_2$/year from those during pre-pandemic period (5.42-7.25 $GgCO_2$/year). Despite of these increases, total GHG emissions from waste disposal in Bangkok in 2022 was reduced by 22% from those in 2018 due to the decreasing amount of general waste produced during the pandemic period.

Keywords : Greenhouse Gas; COVID-19 pandemic; Infectious waste; Bangkok waste

Introduction

Proper handling of municipal solid waste (MSW) is one of the challenges in urban areas especially those situated in developing countries. An increase in the population and the changing lifestyle of the population generally resulted in an increasing quantity of MSW as well as complexation of MSW composition. The change would require more effective waste management and facilities to cope with. In Thailand, the amount of municipal solid waste generated was approximately 27.35 million tons or about 75,000 tons per day in 2020 [1] and it was forecasted to increase to 84,070-95,728 tons per day in 2030 [2]. Within Thailand, the amount of MSW collected and sent to disposal from Bangkok Metropolitan was 9,058 tons per day in 2020 [3]. During MSW management, greenhouse gases (GHGs) can arise from several management activities such as composting, incineration and solid waste disposal on land using either open dumping or landfill methods. They are one of the major anthropogenic activities contributed to the global climate change problem. In Thailand, GHGs generated from waste sector accounted for about 4.3% of the national total in 2019 [4]. From 2019, the occurrence of COVID-19 pandemic has resulted in a drastic change of people lifestyle affecting the generation of waste such as limited social activities and consumption of food at home. On the other hand, the use of single-use personal protection materials and equipment (PPEs) such as face masks and

antigen test kits (ATK) has become normal practice for people. A survey on the quantity of used masks and wastes collected at 11 communities in Bangkok has revealed an increase of their weight by almost 100% during October to November 2021 [5]. Additionally, the amount of infectious waste (IW) also increased from increased numbers of patients affected from the pandemic. These changing behavior of the people affects the amount and type of waste generated from their activities thus may lead to the change in GHG emissions and its impact from their disposal [6]. There have been previous studies in other countries in attempt to quantify the generation of the waste arising from single use PPEs and medical waste during COVID-19 pandemic [6-9]. Nevertheless, the extent of impact of COVID-19 pandemic on the amount of waste generated and disposal as well as their associated GHG emissions in Thailand especially Bangkok Metropolitan is still unclear.

Therefore, this study aims to evaluate waste quantity and associated GHG emissions from MSW management in Bangkok Metropolitan during pre-COVID-19 pandemic (2015-2019) and during pandemic period (2020-2022). The waste quantity used in this study was acquired from relevant governmental agencies mainly Bangkok Metropolitan Administration (BMA) for MSW and infectious waste while single-use PPEs was estimated based on estimated number of Bangkok population disposed them when having activities outside their houses. The emissions from MSW, infectious waste and single-used PPEs disposal were estimated by IPCC methodology using actual activity data but default emission factors proposed in IPCC guidelines were assumed. Meanwhile, the study did not cover socio-economical aspect to explain consumption and waste disposing behavior of Bangkok people during the pandemic period.

Materials and Methods

Waste quantity determination

The quantities of general and infectious waste generated during pre-COVID-19 pandemic (2015-2019) and during pandemic period (2020-2022) was obtained from Bangkok Metropolitan Administration (BMA) statistics. All general waste collected from 50 districts in Bangkok Metropolitan was transported to 3 transfer stations, namely On-nut, Nongkhaem, and Saimai stations, with the total weight received being recorded daily. The collected waste is then treated in composting units (~1,600 tons/day maximum capacity) located at On-nut station, an incineration plant (1,500 tons/day capacity) located at Nongkhaem station, while majority of the waste is transported from the transfer stations to their final disposal in landfills. The waste composition at each transfer station was determined and recorded annually.

The infectious waste was collected separately and sent to its disposal in an infectious waste incinerator located at On-nut station. The amount of incinerated waste was recorded daily.

The quantities of PPEs including face masks and antigen test kits (ATK) were estimated assuming the use and disposal of 1 face mask per day and 1-3 ATK every 14 days for Bangkok citizen. This assumption was set following average facemask consumption rate reported in Benson et al [10]. The antigen testing intervals were assumed following the recommendations of international standard for screening of COVID-19 of 1-3 times [11] within the recommended monitoring period of 14 days set by Ministry of Public Health, Thailand. Lyng et al [12] also reported that COVID-19 testing strategies with least frequency of 14 days interval could yield 56.1% and 46.5% reduction in cumulative infections in communities with low and high prevalence, respectively. The waste generation was not considered from whom worked or stayed at home during travel restriction period, estimated at 85% of total population in 2020 as indicated in public transportation records of Ministry of Transport during Dec 2019 (pre-COVID-19 outbreak) - Mar 2020 (after governmental lock-down announcement) [13] but the condition was resumed to normal in 2022. These wastes are generally produced in households and disposed together with general waste excepted those generated in hospitals and clinics which are managed as infectious waste.

Estimation of GHG emissions

The estimation of GHG emissions was performed following guidelines proposed by

Intergovernmental Panel on Climate Change (IPCC). The most updated methodologies include 2006 IPCC Guidelines for National Greenhouse Gas Inventories [14] and 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [15]. According to the IPCC Guidelines, GHGs from following solid waste management activities are considered.

1) Disposal of general waste in landfills

In landfills, methane (CH_4) is generated from anaerobic decomposition of organic waste. To estimate CH_4 emissions from landfills, the activity data used are historical data of waste deposited in landfills, receiving waste amount during the calculation year, degradable waste composition categorized into food waste, paper, textile and yard waste types. The emission factors used in the calculation include degradable organic carbon (DOC), fraction of biodegraded degradable organic carbon (DOC_f), CH_4 generation rate constant (k) for each waste type which are applied specifically to the waste composition of Bangkok. The parameters used in the calculation are shown in Table 1.

For the estimation of GHG arising from disposal of PPE waste in landfills, only paper fraction of those waste was considered to be degradable. The weight of paper in the face masks and ATK materials were estimated based on information provided in their material safety data sheet of a representative commercial product [16].

2) Composting of organic waste mainly food and yard waste. CH_4 and nitrous oxide (N_2O) are considered GHGs in this activity. In the calculation, activity data was the amount of waste (food and yard waste components) treated in compost plant whereas IPCC default CH_4 and N_2O emission factors (4 gCH_4 and 0.3 gN_2O per kg wet waste treated) were used.

3) Incineration of general and infectious waste. containing fossil carbon, mainly plastics, are contributing carbon dioxide (CO_2) emissions. N_2O emissions are also considered in this activity. The estimation of emissions was determined using actual activity data in terms of amount of general and infectious waste incinerated, fossil carbon (plastic) composition (13.33-18.86%) in MSW. The IPCC default emission factors in terms of total (60%) and fossil carbon (40%) content in clinical waste and oxidation factor (100%) for continuous feed stoker type incinerator were applied.

Upon the estimation of GHGs including CO_2, CH_4, and N_2O, overall GHG emissions were determined by converting them into CO_2 equivalent unit (CO_2-eq) using global warming potential of 25 for CH_4 and 298 for N_2O respectively [17].

Results and Discussion

MSW and infectious waste quantity

Table 2 presents the total amount of general waste received at all 3 transfer stations, infectious waste treated in infectious waste incinerator and estimated amount of single-use personal protective materials in Bangkok Metropolitan. The quantities of general waste received were relatively stable between 3.42-3.71 million tons during 2015-2019 (pre-COVID-19 period) while they were reduced to 2.44-2.86 million tons during 2020-2022 (pandemic period) with a decreasing trend observed within this period. On average, the waste amount generated during pandemic period was reduced by 24% from that during pre-COVID19 period. This reduction in waste generation could be mainly due to the effect of pandemic situation on socio-economic activity and the restrictions imposed on society [18]. Moreover, there were relocations of manpower from Bangkok to other provinces due to the shutdown of several commercial activities especially in construction sector in Bangkok. According to statistics from Ministry of Labor, an increase of unemployment rate in April and October 2020 increased by 24% and 181% from the previous year [19]. Fan et al [20] also reported a decrease of waste quantity of 23% in Shanghai, China during the pandemic. Meanwhile, the amount of MSW treated by composting and incineration were varied between 0.25-0.59 and 0.13-0.18 million tons respectively. During COVID-19 pandemic, the amount of waste sent to composting and incineration plants remained relatively constant.

Table 1 Parameters used for calculation of GHG emission from landfill disposal of Bangkok waste

Parameters	Food waste	Paper	Textile	Yard
Composition in Bangkok waste (%)	43.35-52.96	7.11-11.31	2.33-5.61	4.79-6.13
DOC	0.15	0.4	0.24	0.43
DOC_f	0.7	0.5	0.5	0.1
k (1/year)	0.4	0.07	0.07	0.035
Half-life time ($t_{1/2}$, year)	1.733	9.902	9.902	19.804
Lag time in deposit year (M, months)	7	7	7	7
Methane fraction in landfill gas (F)	0.5	0.5	0.5	0.5
Methane correction factor (MCF)	1.0	1.0	1.0	1.0

Table 2 Amount of waste disposed during 2015-2022

Year	Total MSW (tons)	Composting (tons)	Incineration (tons)	Infectious waste incinerated (tons)	Estimated PPE waste* (tons)
2015	3,710,841	397,310	-	12,369	-
2016	3,347,999	591,665	129,249	13,586	-
2017	3,535,543	584,000	169,717	14,176	-
2018	3,676,533	246,141	176,188	14,917	-
2019	3,422,933	424,022	161,318	15,729	-
2020	2,856,431	559,663	168,730	16,329	496
2021	2,736,299	490.329	164,052	23,509	3,664
2022	2,444,475	553,086	161,454	23,411	6,784

* The face mask/ATK waste was collected and disposed together with general waste

For infectious waste, the waste amount sent to infectious waste incinerator was slightly increasing during 2015-2019 from 12.4-15.7 thousand tons but rising to more than 23 thousand tons in 2021-2022 or 65% increase from those during pre-COVID-19 period. This observation is corresponding to significant numbers of COVID-19 patients hospitalized in Bangkok as reported by Ministry of Public Health at 466,380 in 2021 and 515,987 in 2022 respectively [21]. The disposal of PPE waste started in 2020 at limited quantity due to governmental travel restriction regulation enforced in March. As a results, majority (85%) of Bangkok people stayed at home. Their estimated amount increased to 3.6 tons in 2021 and 6.8 tons in 2022 as the situation resumed back to normal assuming a linear trend. An increase in PPE waste between 2021 and 2022 was also resulted from more frequent uses of ATK from once to 3 times every 14 days. It should be noted that these wastes were generally disposal together with general waste therefore their quantities were already included in total MSW amount presented in Table 2.

GHG emissions from waste management

Table 3 shows estimated GHG emissions from waste disposal of Bangkok during 2015-2022. The GHG emissions of came from 3 distinct methods: landfill, incineration, and composting. The emissions were varied depending on total amount of waste disposed, material composition of waste disposed and percentages of solid waste by each method. During pre-COVID-19 period, there was a gradual increase in GHG emissions during 2015-2018 followed by its slight drop in 2019 due to decrease of waste disposal quantity. Average emission was estimated at 1147.98 $GgCO_2$-eq/year during this pre-COVID19 pandemic period. During 2020-2022, the emissions were gradually decreasing following reducing solid waste amount disposed with an average of 996.68 $GgCO_2$-eq/year or 13% reduction.

Table 3 GHG emissions from waste management in Bangkok during 2015-2022

Year	Composting		Incineration*			Landfill	Total
	CH_4	N_2O	CO_2	CH_4	N_2O	CH_4	($GgCO_{2eq}$)
2015	39.73	35.51	-	-	-	933.68	1068.93
2016	59.16	52.89	67.35	0.00055	1.61	936.79	1117.8
2017	58.40	52.21	65.87	0.00077	2.18	982.56	1161.22
2018	24.61	22.01	74.29	0.00080	2.27	1094.39	1217.57
2019	42.40	37.91	86.40	0.00071	2.14	1005.54	1174.39
2020	55.97	50.03	79.05	0.00073	2.16	861.23	1048.45
2021	49.03	43.84	90.44	0.00076	2.17	809.79	995.27
2022	55.31	49.45	84.66	0.00075	2.16	754.73	946.31

* Incinerator started its operation in March 2016

Among the emissions from different methods, CH_4 emissions from landfills represent the most predominant contributing activities. Generally, it accounted for more than 80% in the total emissions. The CH_4 emissions from landfills averaged at 990.59 $GgCO_2$-eq/year during pre-COVID-19 period and gradually decreased to 861.23, 809.78, and 754.73 $GgCO_2$-eq in 2020-2022, respectively. Meanwhile, GHG emissions from composting and incineration of general wastes were maintained relatively constant between the pre-COVID-19 and pandemic period. Among them, CO_2 emissions from fossil carbon incineration, CH_4 and N_2O emissions from waste composting were the following GHGs contributing activities in that order.

Fig.1 presents estimated GHG emission from infectious waste incineration. During pre-COVID-19 period, the emissions gradually increased from 5.42 $GgCO_2eq$ in 2015 to 7.25 $GgCO_2eq$ in 2019. The increasing trend continued during COVID-19 pandemic period during which significant increase observed in 2021. The emissions from infectious waste incineration accounted for about 5-7% of the emissions from municipal solid waste disposal during pre-pandemic period and increased to about 10% during pandemic period.

The estimated GHG emissions from land disposal of PPE waste suggested its increase from 0.0003 $GgCO_2eq$ in 2020 to 0.043 and 0.0171 $GgCO_2eq$ in 2021 and 2022, respectively. At most, the emissions from this waste category accounted for only 0.002% of the total emission from MSW disposal in 2022. The main reason was comparatively very small quantity of PPE wastes were generated comparing to MSW. Moreover, only paper component in face masks and ATK waste was considered biodegradable in landfills. Major fraction of the mass in those wastes was composed of plastic component which is not biodegraded in landfills.

Considering total GHG emissions from MSW and infectious waste disposal in Bangkok Metropolitan, there was an increasing trend of GHG emissions from waste disposal from 1,074.36 $GgCO_2$-eq in 2015 to 1,224.11 $GgCO_2$-eq in 2018 However, the emission was slightly dropped to 1,181.64 $GgCO_2$-eq in 2019. During the pandemic period (2020-2022), there was a continuous decreasing trend in total GHG emissions. In 2022, total emission was 957.12 $GgCO_2$-eq, reduced by 22% from that in 2018.

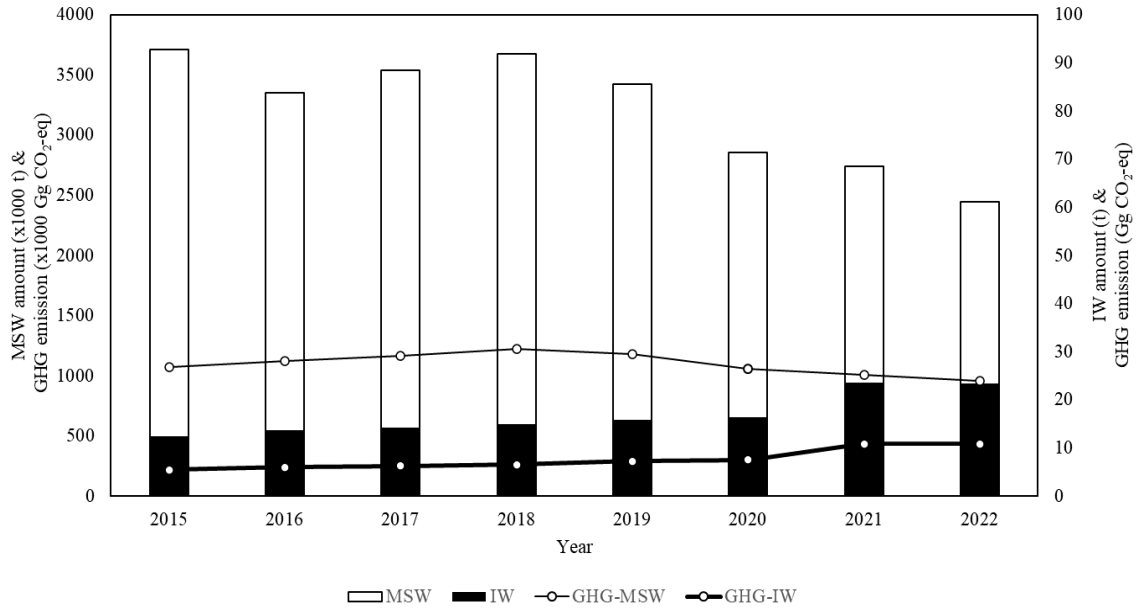

Fig. 1 Variation of amount and GHG from MSW and infectious waste in Bangkok

Conclusions

This study provides a better understanding on the effect of COVID-19 pandemic to waste generation and GHG emissions from waste management in Bangkok Metropolitan. During pre-COVID-19 period (2015-2019), total emissions from general waste management ranged from 1,068.93 to 1,217.57 $GgCO_2$-eq. The emissions gradually declined to 957.12 $GgCO_2$-eq in 2022 mainly due to decreasing amount of waste generated from the effect of changing waste producing behavior of people during the pandemic period. Despite having 35% increase from infectious waste incineration and production of single-use personal protective waste during the pandemic period, total GHG emissions from waste management was reduced up to 22% from the pre-COVID-19 period.

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