Estimation of Emission from Open Burning of Sugarcane Residues before Harvesting

Kanittha Kanokkanjana and Savitri Garivait

Abstract— *This study aims to estimate emission of gases and aerosols from open burning of sugarcane leaves in the field before harvesting. The information of emission factor and amount of biomass is obtained by measurement. Burned area is obtained from combining of national statistic data and sugar factory report. Field experiments were conducted to measure amount of biomass in sugarcane field. Result of biomass load is 1,007±295 g_{dm}/m^2 and residue to product ratio is 0.28±0.05. The measured emission concentrations consisted of $PM_{2.5}$, CO, and CO_2, which were calculated to obtain emission factor. Results of the EF are separated into two categories: flaming and smoldering. During flaming phase, low emission released so the EFs are low. Difference of the EFs in both phases is significant in $EF_{PM2.5}$. Annual open burning of sugarcane leaves released CO 929±341 Gg, CO_2 8,864±1,863 Gg, and $PM_{2.5}$ 152±113 Gg. High standard deviation was presented because the value included flaming and smoldering phase. Flaming phase burning can reduce emission of gases and aerosols, especially $PM_{2.5}$ can be reduced for five times of smoldering phase. Therefore, the control of open burning in sugarcane field represents a significant global warming reduction option.*

Keywords— **Sugarcane residues, open burning, climate change, emission inventory.**

1. INTRODUCTION

Sugarcane is one of major economic crops in Thailand. Thailand is the forth sugarcane exporter of the world with market share 11% [1]. Sugarcane can be planted in nearly all regions of Thailand, except south. Plantation area of sugarcane is increasing because Renewable Energy Development Plan (REDP) of the government promotes renewable energy utilization i.e. gasohol. Gasohol is a renewable energy that can reduce petroleum import and increase agricultural production price. Gasohol (E10, E20, and E85) is made of mixture between benzene and ethanol, which is pure alcohol produced from crops production i.e. sugarcane, cassava, sorghum, rice, and corn [2]. The demand of ethanol has a result in increasing price of the agricultural product so trend of sugarcane cultivation is increasing. Planted area of sugarcane is expanded from 942,468 ha in 2005 to be 1,093,924 ha in 2008 [3]. The sugarcane field was increased so rapidly for 16% in three years. The problem of harvesting sugarcane in a large area was lacking of labor. Consequently, burning of sugarcane before harvesting is more frequent in order to remove sharp foliage and harvest easily. Burning of the agricultural residues in the field is uncontrolled condition so a large amount of gaseous and aerosols is released into the atmosphere. These air pollutants are leading to climate change problem that affect large areas of the world in global level, long-range transport or transboundary problem in region level, and health problem in local level [4]-[5]. Therefore, this study aims to estimate emission of gases and aerosols from open burning of sugarcane leaves in the field before harvesting.

2. METHODOLOGY

Quantification amount of biomass burned

The selected area is main area where sugarcane is planted for input as a raw material to the sugar mill in western and eastern region of Thailand. Field experiments were conducted in sugarcane field planted traditionally by the farmers at Danmakhantia district, Kanchanaburi province in 2008, and Banbueng and Nhongyai district, Chonburi province in 2009-2010 (Fig. 1).

Sampling area was 2 m × 2 m randomly for four replicates in each area. The sampling size covered a part of one row of sugarcane. The above ground biomass of sugarcane was cut at ground level and moved out of the field to separate leaves, stem, and top (Fig. 2). Wet weight of the biomass was measured at the field and brought back to the laboratory to analyze for moisture content.

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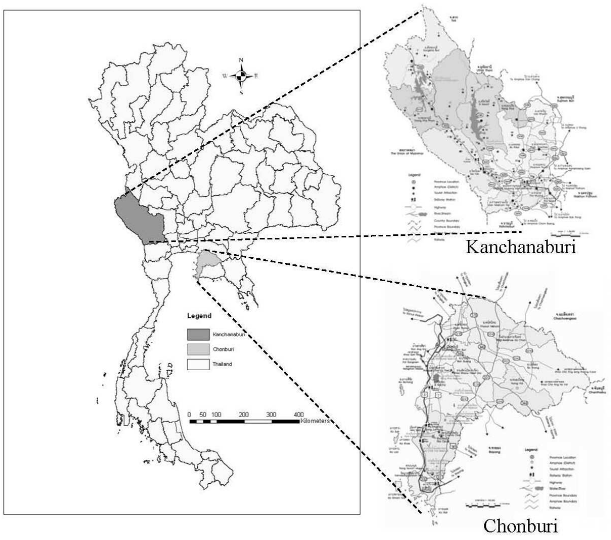

Fig.1. Studied sites in Kanchanaburi and Chonburi province.

Fig. 2. Sugarcane biomass collection at the field

Residue of sugarcane considered in this study is sugarcane leaves because leaves are the most burned part of open burning in the field before harvesting. The biomass load was calculated from dry weight of sugarcane leaves in one square meter (g/m^2). The residue to product ratio (RPR) is the ratio of dry leaves and wet weight of cane production.

Total amount of biomass burned was obtained from information of biomass load in this study, planted area from national statistic data (Office of Agricultural Economics, OAE), and fraction of burned production from sugar mill (Office of the Cane and Sugar Board, OCSB). Calculation of burned sugarcane leaves before harvesting was done by

$$M = A \times BL \times FB \times CE \qquad (1)$$

where M is total amount of sugarcane leaves open burned in the field before harvesting obtained from information of total area burned (A, unit m^2) calculated from planted area by national statistic data (Office of Agricultural Economics, OAE) and fraction of burned production from sugar mill (Office of the Cane and Sugar Board, OCSB), biomass load (BL, unit g/m^2) is the amount of sugarcane leaves per area obtained from field experiment results in this study, fraction burned (FB, unit %) is accounted for burning fraction of the leaves remaining in the field after utilization or moving out of the field, and combustion efficiency (CE) is the percentage of burned leaves after burning.

$$CE = \left[\frac{B_{before} - B_{after}}{B_{before}} \right] \times 100 \qquad (2)$$

where B_{before} is amount of biomass (sugarcane leaves) before open burning and B_{after} is amount of biomass (sugarcane leaves) after open burning. Total amount of sugarcane leaves burned was used for estimating total emission load released from open burning in the sugarcane field before harvesting.

Measurement of emission concentration

In order to estimate the total emission from open burning of sugarcane leaves, burning experiments were conducted in the simulated open burning chamber. The real fire at the sugarcane field is quite harmful and difficult to measure the emission concentration in the plume because top of the flame range is higher than 15 m; therefore, burning in the chamber was conducted in this study.

The chamber was designed to simulate open burning in the field, which was observed in the field experiments that meteorological condition was calm wind. The chamber is located at King Mongkut's University of Technology Thonburi Ratchaburi campus. Figure of the chamber is presented in Fig. 3.

Fig. 3. Simulated open burning chamber.

There are two main parts of the chamber: combustion zone and chimney. Total height of the chamber is 3.50 m. The combustion zone is 1m×1m×1m size made of steel plate that can resist fire and high temperature. Three sides of chamber are closed and one side is opened for let air in or out without any control. The position of emission concentration measurement was set in front of the open side of the chamber.

The samples of sugarcane leaves fuel were collected from the sugarcane field at the studied sites. Sugarcane residues samples were dried naturally to prevent fungi. Preparation of biomass was done by weighing the biomass, placing the biomass on the 1m×1m tray, and placing in the chamber. Amount of samples in each experiment were between 100-200 g_{dry}.

Types of the air pollutant that we measured consists of carbon dioxide (CO_2), carbon monoxide (CO), and particulate with diameter less than 2.5 micrometers ($PM_{2.5}$) measured by real-time with 1 s frequency through air quality monitoring equipments consisting of DustTrak (model 8520 TSI Inc., USA, measure $PM_{2.5}$) and Quest Suite IAQ monitor (model AQ5000Pro Quest Technologies, USA, measure CO and CO_2). The air quality monitoring was conducted before the experiment to obtain ambient air concentration and during the open burning to measure emission from open burning of sugarcane leaves, respectively. The measured emission concentration unit of $PM_{2.5}$ was mg/m^3, but unit of CO_2 and CO was ppm so the unit was converted to mg/m^3 by the temperature was taken into account and then calculated to obtain emission factor. Time of burning was recorded to obtain burned rate. After combustion, ash and unburn were collected to analyze for moisture content to obtain dry mass for determining CE.

Estimation of emission load

The emission load of gases and aerosols released from open burning of sugarcane field before harvesting was estimated by using emission factors (*EF*) that have been developed in this study and total amount of biomass burned (*M*) in Thailand.

$$E_i = M \times EF_i \tag{3}$$

The emission factors (EF_i) are the emission factor of each pollutant i, consisting of EF_{CO2}, EF_{CO}, and $EF_{PM2.5}$, with unit g of pollutant per kg of dry sugarcane leaves; and amount of biomass burned (*M*) is obtained from Eq. (1). This calculation is the same as IPCC, 2006 [6].

3. RESULTS

Amount of biomass burned in sugarcane field

Results of the field biomass samplings consisted of biomass load (BL) and residue to product ratio (RPR). From four experiments with three replicate in each sampling site, result of sugarcane leaves biomass load is 1,007±295 g_{dm}/m^2. The highest BL was found in the sample that collected from Kanchanaburi province. Although, type of sugarcane planted in Kanchanaburi was the same as in Chonburi but the BL was higher for nearly twice because of soil type. The soil type in Kanchanaburi province is Kamphaengsan brown soil, the most suitable soil for sugarcane plantation, whereas in Chonburi is Banbueng grey soil, the second suitable soil for sugarcane plantation. The result of sugarcane leaves to product ratio (RPR) is 0.28±0.05. This value is in the same magnitude as other research 0.17-0.30 [7]-[9]. However, most studies considered top and trash; whereas, this study focused only on leaves because this part was burned in the field but the top was not burned because of high moisture content.

From the statistic of Office of the Cane and Sugar Board in Thailand, season of operating sugar mill was during November to July. Therefore, sugarcane harvesting was in the same period because the production could not be stored so long before selling. The report of Sugarcane Statistics year 2008/2009 presented total area of sugarcane planted for selling product to the sugar mill 1.03 million ha [3]. Total cane input to the factory was 66.46 million ton, which composed of burned cane 42.25 million ton so percentage of burned product was 63.57% [10]. Therefore, total burned area of sugarcane field was 653,542 ha.

Field survey results showed the farm that burned before harvesting not utilize or move the sugarcane leaves out of the farm. It means all sugarcane leaves were burned in those burned areas. Therefore, fraction of sugarcane leaves burned (FB) was 100%. The main reason of burning before harvesting was to be convenient for harvesting, which was decided by the harvesting labors. Due to lacking of labor, the farmers could not decide the way of harvesting. The farmers did not satisfy with burning before harvesting because they lost some weight of production, and the burned production could not be stored so they needed to sell to the sugar factory as soon as possible. The lower of production weight and unable to store caused lower income to the farmers. However, they still prefer harvesting by labor rather than machine because they believed that harvesting by the machine lost more juice than harvesting by labors.

Emission concentration from open burning of sugarcane leaves

The simulating open burning in the chamber was conducted for seven experiments to measure concentration of CO_2, CO, and $PM_{2.5}$ releasing from open burning of sugarcane leaves. The ambient air concentration of CO and $PM_{2.5}$ were not significant; whereas, the concentration of CO_2 was significantly high in the atmosphere. Therefore, only the ambient air CO_2 concentration was removed from the emission concentration when we considered the emission concentration results and the emission factor. The obstacle of the measurement was occurred when the maximum concentration is over the maximum detection limit so the peak concentration could not be detected. The average maximum concentration of CO_2, CO, and $PM_{2.5}$ was calculated from average of the concentration above ambient air level. Results of the average max concentrations were presented in Table 1.

Table 1. Emission Concentration from Open burning of Sugarcane Leaves

Sampling sites	Value	Emission concentration (mg/m^3)		
		CO_2	CO	$PM_{2.5}$
KB	Max	6,664	325	77
	Avg	1,385±64	111±18	9±2
BB	Max	6,746	494	187
	Avg	1,321± 39	163± 22	25± 3
NY	Max	7,956	951	187
	Avg	1,320±245	184±23	44±16

Note: KB = Kanchanaburi province, BB = Amphoe Banbueng in Chonburi province, and NY = Amphoe Nhongyai in Chonburi province

From Table 1, average values of CO_2 and CO concentrations are the same magnitude among three samples; whereas, $PM_{2.5}$ concentrations are varied by combustion phase. Flaming phase is more dominant in experiment of KB samples burning, noticed from lower CO concentration than BB and NY experiments. The results of $PM_{2.5}$ concentration depends mainly on combustion phase. Lower $PM_{2.5}$ concentration was found in flaming dominant in KB experiment and higher $PM_{2.5}$ was found in smoldering dominant in BB and NY experiments. The maximum value of $PM_{2.5}$ concentration reached maximum detection limit so the results were the same in BB and NY experiments.

Emission factor of sugarcane leaves burning

Results of emission factors are presented in Table 2.

Table 2. Emission Factors from Open Burning of Sugarcane Leaves

Sampling sites	Biomass type	Emission Factors (g/kg)		
		CO_2	CO	$PM_{2.5}$
KB	Sugar leaves	1,449.85 ±198.53	117.25 ±29.79	9.59 ±2.69
BB	Sugar leaves	1,111.84 ±26.22	137.13 ±18.98	20.96 ±2.54
NY	Sugar leaves	1,157.99 ±184.88	161.80 ±16.24	38.77 ±13.36
[4]	Agricultural residues	1,515 ±177	92 ±84	3.9
[11]	Rice straw	1,147 ±169	97 ±8	8.3 ±2.7

From Table 2, the EFs of open burning of sugarcane leaves are in the same magnitude as open burning of other agricultural residues [4] and [11], except higher $EF_{PM2.5}$ result in this study. However, $EF_{PM2.5}$ in flaming dominant phase is similar to the $EF_{PM2.5}$ of other studies.

Average EFs of open burning of sugarcane leaves in the field in this study are 1,181±248 g_{CO2}/kg, 124±45 g_{CO}/kg, and 20±15 $g_{PM2.5}$/kg, respectively. Results of the EF contain high variation because they are separated into 2 categories: flaming and smoldering. During flaming phase dominant, EF_{CO2} is 1,037.92±213.40 g/kg, EF_{CO} is 60.70±26.75 g/kg, and $EF_{PM2.5}$ is 5.21±1.70 g/kg; whereas, during smoldering phase EF_{CO2} is 1,237.61±237.82 g/kg, EF_{CO} is 148.98±19.30 g/kg, and $EF_{PM2.5}$ is 26.35±13.67 g/kg, respectively. When flaming phase dominant, low emission was released; consequently, the EFs are low. Difference of the EFs in both phases is significant in $EF_{PM2.5}$. Lower $PM_{2.5}$ was emitted in flaming phase than smoldering phase for five times.

The results of average EFs in this study are used to estimate emission load from open burning of sugarcane leaves in Thailand.

Emission load of open burning in sugarcane field, Thailand

Annual open burning of sugarcane leaves in the field released CO 929±341 Gg, CO_2 8,864±1,863 Gg, and $PM_{2.5}$ 152±113 Gg. High standard deviation was presented because the value included flaming and smoldering phase. From the literature review, biomass burning released 4,213 Gg CO and 514 Gg PM_{10} [12]. Fraction of emission from open burning of sugarcane compare with biomass burning was 22% CO and 30% PM. Larger fraction of PM should be presented because we considered $PM_{2.5}$, a fraction of PM_{10}. There is no reference for CO_2 released from biomass burning because it is supposed to be nutral by sinking through photosynthesis process of crops in the next cultivation.

4. CONCLUSION

Sugarcane is one of the major economic crops of Thailand. The harvesting of sugarcane is still manual, and hence open burnings of sugarcane fields are generally conducted before harvesting to reduce injury to workers from sharp foliage. Open burning of cropland is an uncontrolled combustion, and leads to a large amount of reduced or incompletely burned gases and aerosols released into the atmosphere. This study aims at estimating the emission of gases and aerosols from open burning of sugarcane fields before harvesting. Total burned area of sugarcane field was 0.75 million ha, which contained 7.5 million ton sugarcane leaves. Emission factors were 1,181±248 g_{CO2}/kg, 124±45 g_{CO}/kg, and 20±15 $g_{PM2.5}$/kg. Therefore, annual open burning of sugarcane leaves in the field released 929±341 Gg of CO, 8,864±1,863 Gg of CO_2, and 152±113 Gg of $PM_{2.5}$. Fraction of the emission from open burning of sugarcane before harvesting covered 22% CO and 30% PM released from biomass burning. High standard deviation was observed because the value included both flaming and smoldering phase emissions. Flaming phase burning produced lower emissions of gases and aerosols compared to smoldering. Flaming phase burning can reduce emission of gases and aerosols, especially $PM_{2.5}$ can be reduced for five times of smoldering phase. Therefore, the control of open burning in sugarcane field represents a significant global warming reduction option.

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