METHANE EMISSIONS FROM BAGASSE BURNING IN SUGAR MILLS

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ABSTRACT

In reporting the national greenhouse gas (GHG) emissions from the energy sector, the Intergovernmental Panel on Climate Change (IPCC) methodology requires that net CO₂ emissions from combustion of biomass be treated as zero, on a net basis, as CO₂ produced gets recycled for its growth. Sugarcane, like other biomass, uses atmospheric carbon dioxide for its growth and converts it to sugar and cellulose materials. The carbon in sugar is decomposed through biological processes and is finally released to the atmosphere; whereas the decomposition of cane agricultural waste (CAW) in fields, and combustion of sugarcane bagasse in sugar mills' boilers releases the rest of the carbon to the atmosphere in the form of CO₂. The sugar industry is, therefore, considered GHG neutral. However, other (non-CO₂) gases are emitted from burning of bagasse as fuel. Emissions of these gases (such as methane) are net emissions and are to be accounted for as energy emissions. With this in view, the National Physical Laboratory (NPL), New Delhi, in collaboration with the National Federation of Co-operative Sugar Factories Ltd., New Delhi, has measured, using gas chromatography, the emission levels of methane in the flue gas sample collected from the stack of a sugar mill's boilers. The results of the analysis and a preliminary estimate of the likely methane emissions from the Indian sugar industry are presented in this paper.

Keywords: Global warming, methane emissions, greenhouse gas emissions, ghg, energy and environment, bagasse burning.

INTRODUCTION

With the increase in world population, more and more natural resources are being transformed into goods and services. This is resulting in a decrease in biological diversity, degradation and contamination of ecosystems and air pollution. At the same time, the proportion in the atmosphere, of the radiatively important trace gases (also called greenhouse gases) such as carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and chlorofluorocarbons (CFCs) is increasing. There is evidence to suggest that, within the next few decades, this increase in greenhouse gases will substantially increase global mean temperature, disturb rainfall patterns, and cause sea-level rises. These gases are mostly anthropogenic and only part of their contributions are from natural sources. The radiative forcing (global warming potential) for each gas is different. For example, radiative forcing due to CH₄ and N₂O is 21 and 206 times higher than that due to CO₂ respectively (Anon, 1990). Chlorofluorocarbons are 10,000 to 18,000 times more effective than CO₂ (Anon, 1992). So, even though the concentration of these gases in the atmosphere is much lower than CO₂, they can contribute significantly to global warming due to their higher radiative forcing.
To fulfil the objectives of India’s communication to the United Nations Framework Convention on Climate Change (UNFCCC), the National Physical Laboratory (NPL) has been involved in the preparation of a National Inventory of Greenhouse Gases (Narang, 1996), using the IPCC (Inter-governmental Panel on Climate Change) methodology. In the IPCC methodology of reporting national GHG emissions (Anon, 1995a), CO₂ emissions from biomass used as fuel are considered zero on a net basis as CO₂ produced gets recycled for its growth. This encourages countries having surplus biomass to go in for its use as a source of energy. However, non-CO₂ emissions like those of CH₄ resulting from its burning do add to the national budget. It is, therefore, necessary to measure the emission factors of such GHG’s from biomass use such as in the traditional and improved cookstoves in the household sector (Narang, 1995, 1998) and in various other combustion devices in the commercial and industrial sector. With this in view, NPL, in collaboration with the National Federation of Co-operative Sugar Factories Ltd., New Delhi, has measured, using gas chromatography, the emission levels of methane in the flue gas sample collected from the stack of a sugar mill’s boilers. The results of the analysis and a preliminary estimate of the likely methane emissions from the Indian sugar industry are presented in this paper.

BACKGROUND INFORMATION

Cane Availability and Processing Technology in India

India produces about 270 million tons of sugarcane per annum spread over an area of about 4 million hectares. However, only about half of this is crushed by the 412 sugar mills and the remaining half is utilized for seed, jaggery and khandsari. Mills have an average crushing capacity of about 2,500 ton cane per day (the cane crushing capacity of a sugar factory in India varies from 1000 to 10,000 ton per day). The duration of the crushing season varies from state to state and from year to year. The all-India average season duration has varied between 130 to 180 days during the last four years. The average season duration may be taken as 150 to 160 days in a year (Anon, 1998).

Almost all sugar mills extract juice through the milling process after cane preparation through a set of two knives or a single set of knives followed by a fixed hammer fibrizer, swing hammer fibrizer or a shredder. The quantity of mill wet bagasse is about 29-34 % of cane, the national average being 30-32 % of cane, varying from year to year. The mill wet bagasse contains 45-46 % fibre, 4-5 % inorganic salts and the rest is moisture. The ash content is 1-1.5 % on a wet basis and the alkali content in ash is between 8-12 %. Almost all sugar mills burn 85-90 % of their bagasse in the boilers and the balance is saved for outside sale. There is hardly any supplementary fuel except for initial start-up. The boiler pressure is generally in the range of 22-45 Ata.

Profile of Boilers in the Indian Sugar Industry

According to a survey on industrial boilers carried out by the National Productivity Council (Anon, 1995b), New Delhi, on behalf of the Department of Industrial Development, Ministry of Industry, Government of India, there are about 30,000 industrial boilers working in various sectors of the Indian industry. Almost half operate below the working pressure of 11 Ata. It may be interesting to note that almost 85 % have a generation capacity of less than 3 ton/h of steam, while another 5 % have a generation capacity varying between 3-15 ton/h. The remaining 10 % have a generation capacity of more than 15 ton/hr. Data on fuel used are incomplete but major fuels used are coal/oil and bagasse/other biomass.
It is estimated that the total number of boilers in the Indian sugar industry are in the range of 1200 to 1300, almost 98% of which are operating on mill wet bagasse as regular fuel during cane crushing operations. However, in some of the older sugar mills, firewood/furnace oil is also used occasionally as a start-up/supplementary fuel during breakdowns etc.

Types of furnaces Used

The following types of furnaces are in vogue for bagasse fired boilers (Kulkarni, 1995):

i) **Step Grate Furnace:** These were employed in boilers installed before 1965 and are generally associated with boilers having a working pressure of 11 Ata and a capacity below 15 ton/h. Essentially these furnaces involve burning of bagasse in thin piles on a step grate, using atmospheric air for combustion without any preheating, and operate on natural draught. These require high excess air of about 60-70%. Because of the inherent weakness of the design, smoldering takes place.

ii) **Horseshoe Furnace:** These were employed in boilers installed during the period 1965 to 1985, and are generally associated with boilers having a working pressure of 22 Ata and capacity between 20-30 ton/h. These furnaces involve burning of bagasse in piles in horseshoe type cells using preheated air for combustion, and induced draught fan for evacuation of flue gases from the boilers to the stack so as to maintain a balanced draught in the furnace chamber. This type uses excess air of about 40 to 50%. Smoldering takes place in this type too, though on a much smaller scale than in step grate furnace.

iii) **Spreader Stoker Dumping Grate Furnace:** These furnaces have been almost a standard practice in most of the boiler installations since 1986, and have generally been associated with boilers having a working pressure ranging between 22 to 65 Ata (majority of the installations being 33/45 Ata) and capacity between 30-70 ton/h. These furnaces use a mechanical/pneumatic stoker for spreading bagasse inside the furnace, which ensures burning in suspension. Since ash content in bagasse is low, dumping grate bars are installed and these are operated every 3-4 hours to dump accumulated ash in a pit for manual removal. These furnaces employ secondary air at high pressure (500 mm water gauge) to ensure complete combustion of volatiles/ bagasse fines and carbon monoxide etc. The excess air required is in the range of 35-40%. No smoldering takes place.

iv) **Other types of Furnace:** There are other types of furnace e.g. an inclined water cooled grate furnace, which is an improved version of horseshoe furnace, whereby bagasse is burnt in thin piles over the water cooled inclined grate bars using preheated air. Another type is a pulsating grate furnace that is an improved version of the step grate furnace. The latest is a travelling grate furnace, which is an improved version of spreader stoker dumping grate furnace and is generally used in higher capacity boilers i.e. above 60 ton/h or where coal or other high ash fuel is intended to be used as supplemental fuel. Fluidised bed combustion of bagasse was also tried in two or three sugar mills but without much success.

**MATERIALS AND METHODS**

For ascertaining the presence of methane, flue gas samples have to be collected from the stack of a sugar mill and analysed in the laboratory by gas chromatography for methane emission. This is done by obtaining the area/height plots of the standard samples of CH₄ and CO₂ and of the flue gas sample of the mill. These are then used to determine the ratio of CH₄ to CO₂ in the sample.
Further, by material balance calculations, the emission factor of methane per ton of bagasse burnt is calculated. Knowing the bagasse content in the cane, this can then be related to the amount of cane crushed per season to determine the annual methane budget of the mill.

Sugar Mill and its Combustion System

For the purpose of this study, flue gas samples were collected from the stack of the Palwal Cooperative Sugar Mills Ltd., Palwal in Haryana. The mill, which was set-up in 1984-85, has an installed milling capacity of 1250 ton/day, but is presently crushing at an average rate of about 1600 ton/day. The combustion system in this sugar mill comprises two boilers, each having a capacity of 20 ton per hour of steam at 22 Ata. Each boiler has two horseshoe cells in which preheated air is used to burn the mill wet bagasse. The steam is used to run three turbines, one of which is run as a turbo-alternator and two as prime movers for the milling system.

Flue Gas Sampling

Samples of flue gas were collected in Tedlar bags by an extractive sampling method, wherein a small stream of representative sample is drawn from the stack/chimney using the Grab Sampling Technique. Envirotech APM 620 was used as Grab Sampler in conjunction with Envirotech Stack Velocity Monitor APM 602.

Flue Gas Analysis

Flue gas samples collected in Tedlar bags were brought to the laboratory for methane analysis by gas chromatography using:

i) Perkin Elmer gas chromatograph (model Sigma-2000)
ii) A 3 m x 3 mm stainless steel column packed with porapak-Q
iii) Ni/Zr catalytic converter to convert CO$_2$ and CO to CH$_4$
iv) Flame Ionization Detector (FID)
v) High purity IOLAR-1 nitrogen gas as carrier
vi) Standard gas mixtures of 512 ppmv CO$_2$ and 2 ppmv CH$_4$ in nitrogen

The column was maintained at 50°C with a carrier nitrogen gas flow of 15 ml/min and the Flame Ionization Detector was kept at 350°C.

RESULTS AND DISCUSSION

The area/height plots of the standard samples of CH$_4$ and CO$_2$ and of the flue gas sample are shown in Figs 1 to 3. The calculation of CH$_4$/CO$_2$ ratio in the sample is shown in Table 1.
Fig. 1 – Area/height plot of 2 ppm CH₄ Standard

<table>
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<th>Pk</th>
<th>Reten</th>
<th>Peak</th>
<th>Area</th>
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<td>%</td>
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1 Peak: Total Area: 359
Height: 25

Fig. 2 – Area / Height plot of 512 ppm CO₂ Standard

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<th>Peak</th>
<th>Area</th>
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</tr>
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<td>100.00</td>
<td>3218</td>
<td>100.00</td>
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1 Peak: Total Area: 51877
Height: 3218
Fig. 3 - Area / Height plot of Flue Gas Sample

### Area/Height Percent

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<td>0.098</td>
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<tr>
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<td>99.952</td>
<td>99.887</td>
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2 Peaks: Total Area: 2327482
Height: 99985

Table 1. Calculation of CH₄/CO₂ ratio in the sample.

<table>
<thead>
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<th>Plot No.</th>
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<th>Gas Concentration</th>
<th>Remarks</th>
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<td>350</td>
<td>2 ppm CH₄</td>
<td>Standard</td>
</tr>
<tr>
<td>2</td>
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<td>512 ppm CO₂</td>
<td>Standard</td>
</tr>
<tr>
<td>3</td>
<td>1106</td>
<td>6.5 ppm CH₄</td>
<td>By calculation</td>
</tr>
<tr>
<td>3</td>
<td>2326376</td>
<td>22960 ppm CO₂</td>
<td>By calculation</td>
</tr>
</tbody>
</table>

Emission Factor of Methane

Basis
Carbon in mill wet bagasse = 100 kg mill wet bagasse
(24.6 % from ultimate analysis)
\ CO₂ produced = 24.6 kg
= 2.05 kg mole
= 2.05 kg mole
= 90.2 kg
CH₄/CO₂ Ratio = 6.5/22960 (From Table 1)
= 0.00028
Emission Factor of CH\(_4\) = 0.00028 x 2.05 x 16 kg/100 kg bagasse
= 0.0092 kg/ton of mill wet bagasse

Emission Factor of CO\(_2\) = 902 kg/ton of mill wet bagasse

**Methane Emissions from the Mill**
Cane crushed (actual) = 1600 ton/day
Bagasse content = 29% of cane
Bagasse produced = 1600 x 0.29
= 464 ton/day

Assuming 400 tonnes per day is burnt in the mill furnace and with 150 days per annum of crushing season,

Methane Emissions from the mill = (0.092 x 400 x 150)/1000
= 5.52 ton/annum

**Methane Emissions from the Sugar Industry**

Crystal sugar production in the country has been around 13 million tonnes during each of the crushing seasons 1996/97 and 1997/98. With an average sugar recovery of 10% on cane, about 130 million ton of sugarcane is milled in the industry, producing about 40 million ton of bagasse. As 85-90% of it is used as fuel, about 35 million tons/annum is burnt in the sugar mills.

It is anticipated that GHG emissions from the step grate furnace will be much higher than those from the horseshoe furnace and since most mills have either a step grate or horseshoe furnace, it will be safe to assume an average emission factor of 0.2 kg methane/ton of bagasse burnt. Thus, total annual methane budget from the sugar industry is likely to be about 7,000 tons.

**CONCLUSIONS**

In a wider context, one purpose of this study was to initiate an estimation of national GHG emissions from industrial processes, which are required for reporting to the UN-FCCC. There are many other industrial processes from which GHG’s are emitted. A study from a sugar mill was considered interesting as the sugar industry claims to be GHG neutral. It may, however, be pointed out that the basis of these estimates is a study of CH\(_4\) emissions from just one mill and only one type of furnace. More studies are planned and the estimates will require to be updated as and when more data are available. But there is a definite indication that the sugar industry, which is considered GHG free, may not be so because of non-CO\(_2\) emissions. The global warming potential of CH\(_4\) being substantially higher than CO\(_2\), methane emissions from the sugar industry may be required to be considered in estimating the total methane budget of the country.

It is, therefore, imperative that a systematic study be carried out to have extensive measurements done, in sugar mills which are representative of various types of furnaces in use under different operating conditions, and to make estimates of all non-CO\(_2\) GHG’s. It will then be possible to estimate, approximately, the emissions from the sugar industry as a whole. The results of this exercise will then be used in suggesting mitigation options.
ACKNOWLEDGEMENTS

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REFERENCES


EMISIONES DE METANO EN LA COMBUSTIÓN DEL BAGAZO
EN LAS FÁBRICAS DE AZÚCAR

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RESUMEN

Cuando se reportan las emisiones nacionales de gases de efecto invernadero (GHG en inglés) del sector de energía, la metodología del Panel Intergubernamental sobre Cambios Climáticos (IPCC en inglés) requiere que la emisión neta de la combustión de la biomasa se trate como cero ya que el CO₂ producido se recircula. La caña de azúcar, como otras biomassas, utiliza CO₂ atmosférico para su crecimiento y convierte éste en azúcar y materiales celulósicos. El carbono en el azúcar se descompone mediante procesos biológicos y es finalmente liberado a la atmósfera, mientras que la descomposición de los residuos agrícolas de la caña en el campo y la combustión del bagazo en las calderas de las fábricas de azúcar liberan el resto del carbono a la atmósfera en forma de CO₂. La industria azucarera por tanto se considera neutral de gases de efecto invernadero (GHG). No obstante, otros gases (no-CO₂) se emiten en la combustión del bagazo. La emisión de estos gases (como el metano) son emisiones netas y deben contabilizarse como emisión de energía. En vista de ésto el National Physical Laboratory (NPL), en Nueva Delhi, en colaboración con la National Federation of Cooperative Sugar Factories Ltd. empleando cromatografía gaseosa, ha medido los niveles de emisión de metano en las muestras de gases efluentes tomados en las chimeneas de las fábricas de azúcar. Se presentan los resultados de los análisis y un estimado preliminar de las emisiones de metano de la industria azucarera india.

Palabras clave: Calentamiento global, Emisiones de metano, Emisiones de gases de efecto invernadero, GHG, Energía y Ambiente, Combustión de bagazo.

EMISSIONS DE MÉTHANE DE LA BAGASSE BRÛLÉE DANS
LES USINES SUCRIÈRES

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RÉSUMÉ

La méthodologie du Comité Intergouvernemental sur les Changements de Climats (IPCC) exige que, pour les rapports sur les taux nationaux d’émissions de gaz de serre (GHG) du secteur d’énergie, les émissions de CO₂ de la combustion de biomasse soient traitées comme zéro sur une base nette, puisque le CO₂ produit est recyclé pour la croissance de cette biomasse. La canne à sucre, comme autres biomasses, utilise du dioxyde de carbone atmosphérique pour sa croissance et la convertit en sucre et matières cellulosiques. Le carbone dans le sucre se décompose à
travers des procédés biologiques et est finalement libéré dans l’atmosphère, pendant que les déchets de la culture de la canne (CAW) dans les champs et la combustion de la bagasse de canne dans les chaudières des sucreries, libèrent le restant du carbone dans l’atmosphère sous forme de CO2. L’industrie sucrière est, de ce fait, considérée neutre en GHG. Cependant, d’autres gaz (autres que le CO2) sont émis avec l’utilisation de la bagasse comme combustible. Des émissions de ces gaz, (tels que le méthane), sont des émissions nettes et doivent être considérées comme des émissions d’énergie. Ainsi, le Laboratoire National de Physique (NPL), New Delhi, en collaboration avec la Fédération Nationale de la Coopérative des Industries du Sucre Ltd., New Delhi, a mesuré, en utilisant la chromatographie en phase gazeuse, les niveaux d’émission de méthane dans un échantillon de gaz de cheminée, prélevé dans la cheminée d’une chaudière d’usine sucrière. Les résultats de cette analyse et l’estimation préliminaire des émissions possibles de méthane dans l’industrie sucrière indienne, sont représentés dans cette communication.

**Mots clés :** émissions de méthane, emissions de gaz de serra, GHG, Energi et Atmosphère, combustion de la bagasse.