Estimation of Methane from Hydrocarbon Exploration and Production in India

A. K. Pathak, K. Ojha

Abstract—Methane is the second most important greenhouse gas (GHG) after carbon dioxide. Amount of methane emission from energy sector is increasing day by day with various activities. In present work, various sources of methane emission from upstream, middle stream and downstream of oil & gas sectors are identified and categorised as per IPCC-2006 guidelines. Data were collected from various oil & gas sector like (i) exploration & production of oil & gas (ii) supply through pipelines (iii) refinery throughput & production (iv) storage & transportation (v) usage. Methane emission factors for various categories were determined applying Tier-II and Tier-I approach using the collected data. Total methane emission from Indian Oil & Gas sectors was thus estimated for the year 1990 to 2007.

Keywords—Carbon credit, Climate change, Methane emission, Oil & Gas production

I. INTRODUCTION

RAPID advances in technology and improved living standard of the society necessitate abundant use of fossil fuels which on the other hand poses two major challenges to any nation. One is fast depletion of fossil fuel resources; the other is environmental pollution. During the past century human civilization has substantially added huge amount of greenhouse gases to the atmosphere by burning fossil fuels such as coal, natural gas, oil and gasoline to power cars, factories, utilities and appliances [1]. The added gases — primarily carbon dioxide and methane — are enhancing the natural greenhouse effect, and likely contributing to an increase in global average temperature and related climate changes. Methane is the second most important greenhouse gas (GHG) after carbon dioxide with 100 year global warming potential of 23 which means that it is 23 times as harmful as carbon dioxide, accounting for ~18% of total climate forcing. It has an atmospheric lifetime of ~12 years. Effect of methane on tropospheric and stratospheric chemistry could be major impact on global climate change [2]-[3]. The main sources of methane emission to the atmosphere are naturally occurring wetlands, agriculture, the energy sector, and landfills and waste. Amount of methane emission from energy sector is increasing day by day as energy consumption goes on increasing to keep space with the economic growth of various countries with time. As per Economic Intelligence Service report, India [4], energy consumption of India increases from 97.9 MTOE in 1980-81 financial year to 413.8 MTOE in the year 2007-08.

A. K. Pathak is with Department of Petroleum Engineering, Indian School of Mines, Dhanbad, India-826004 (phone: +91-326-2235430; fax: +91-326-2296632; e-mail: akhilendra_pathak@yahoo.co.in).

K. Ojha , is with Department of Petroleum Engineering, Indian School of Mines, Dhanbad, India-826004 (e-mail: keka_ojha@yahoo.com).

This results in crucial change in total amount of methane emission to atmosphere, though emission factor of methane is reduced with adaption of new preventive technology. Methane emission not only creates threat to the environment, it leads to huge revenue losses. On adoption of efficient technology, methane can be captured and utilized in a number of ways.

Due to emissions of methane India lost her revenue in financial year 2006-07 is about $ 2.284 billion from natural gas production itself at the rate of US$247 per M^3 [4]. In addition to this, loss from production of oil; transportation, refining, storage and others accounts more gas emission. However, it is worth to mention here that methane emission from oil & gas industry shares only 15% of the total methane emission to atmosphere. Determination of country methane factor is a broad subject consisting of study about various factors affecting the methane emission directly or indirectly, effect of emission on environment, global worming or climate change and their mitigation techniques. As per IPCC guideline, amount methane gas emission from sources depends on the climate of region, adopted technology various steps; general methods cannot be applicable for every country or every technology [5]. Country specific study is essential to take preventive measure for reduction in green house gas emission. Objective of the present study is intended to determine of methane emission from exploration and exploitation of Indian oil and gas fields only; which may be extended further.

For fulfillment of the goal set in the objectives, the following studies have been carried out

➤ Possible sources of the methane emission from various activities are identified.

➤ Tier II approach of IPCC guidelines (2006) have been followed for calculations of methane emission factors from various sources.

➤ Production data and adopted technological data from various fields were collected, as the emission factor is very much dependent on the type of oil & gas, technology adopted for processing the gas with the climate of the region.

II. METHODOLOGY

A. Identification of Sources of Methane Emission from the Oil & Gas Industry

The IPCC guidelines define a two level hierarchical structure for source categories related to the oil and gas industries: (i) uncontrolled emission -missions related to oil & emissions relating to gas and (ii) controlled emission via venting and flaring emissions relating to both oil and gas

The main emission sources included in the first category are leakage, evaporation and accidental releases, i.e. uncontrolled sources. Emissions from venting and flaring are activities that

World Academy of Science, Engineering and Technology
International Journal of Chemical and Molecular Engineering
Vol:6, No:4, 2012

are managed as part of normal operations at field processing facilities and oil refineries. Each of these major categories is in turn divided into several subcategories as mentioned in Table 1. Venting and flaring emissions occur at several stages of the oil and gas production process. The structure of the categories means that a single process can contribute greenhouse gas emissions to two or more categories of emissions.

Venting refers to the controlled release of unburnt gases to the atmosphere. Venting at oil and gas processing facilities is mainly associated with the release of CO_2, which is extracted from the raw gas stream in the course of gas processing. Because separation of the other components of the gas stream from the CO_2 is incomplete, the vented CO_2 contains small quantities of CH_4. Venting of CH_4, meaning that CH_4 is released to the atmosphere without combustion in a flare, also occurs at a number of locations.

Flaring refers to the controlled release to combustion of a mixed flammable gas stream. At oil and gas processing plants, flared gas may arise from crude oil processing or natural gas processing. Where there is no market for gas separated from the wellhead production stream, the gas is re-injected or flared.

As per data provided by Centre for Monitoring Indian Economy (CMIE), [6] India had 5382 oil producing wells, 807 gas producing wells, 3040 dry wells, 198 wells under tests, 2738 service wells in 2005-06. In 2008-08 India has produced 34117 Mt oil and 31350 MMCM gas from all the fields.

B. Estimation of methane emission from various activities in the oil and gas sector

Natural gas containing methane is generally vented directly or flared to the atmosphere during the different stages like exploration, production, refining, transportation and distribution. Methane emission factors during various categories of operations have been determined. Activity data on oil and gas production for each category of oil and gas is collected. Oil and Gas activity data is multiplied by methane emission factor of respective category to obtain estimates of methane emission from oil & gas sector.

Extensive field investigation was made to determine methane emission factor for different categories of oil & gas fields. It has also been determined for various activities such as exploration, handling and subsequent refining and transportation. Measurements have been carried out in the fields of various oil and gas producing companies in different basins of the country.

C. Methane emission from oil & gas sectors

Tier II approach was made to determine the methane emission from production activities of oil. The Tier 1 approach of the IPCC guidelines was used to evaluatethe methane emissions from the exploration, refining, transportation and storage. Oil activity data is multiplied by methane emission factor of respective to obtain estimates of methane emission from above oil activities. It is noted that the emission factor used in Tier-I was near to the low range of emission factors.

The Tier-II approach of the IPCC 2006 [7] guidelines was used to evaluate the methane emission from production activities of gas and Tier-I approach is used for all other the above mentioned activities. For evaluation of total methane emission, gas production data is multiplied by methane emission factor of respective category to obtain the estimates of methane emission from above gas activities. The sources of methane emission from various sources are already mentioned in Table 1.

III. ESTIMATION OF METHANE EMISSION FROM FLARING

A. Calculation of Methane Emission from flaring of methane gas produced from oil and gas activities

In order to obtain the methane emission factor, the following parameters were determined for various production activities:

- The production GOR (m^3/m^3) to get the total gas produced during oil and/or gas production
- Q_{oil}, total annual oil production
- The conservation efficiency (CE) of gas: to be evaluate to understand the amount of gas which has been utilized.
- The flare efficiency (FE) of the flare tower has to be known to evaluate the conservation efficiency.

The percentage of the total gas (X_{flared}, in fraction) which has been flared out of the total gas produced.

These data were collected from one oil field in India to evaluate the methane emission factor of flaring of oil and gas for the country using simple material balance approach. (TIER-II)

The equation 1 [7] has been used to evaluate the factor.
The above equation is equally applicable for gas production also, and total annual gas production is used in place of $Q_{OIL} \times GOR$

$$E_{CH4} = GOR \times Q_{OIL} \times (10CE) \times X_{flared} \times A \qquad (1)$$

Where,

$$A = M_{CH4} \times (1 - FE) \times y_{CH4} \times 42.3 \times 10^{-6}$$

World Academy of Science, Engineering and Technology
International Journal of Chemical and Molecular Engineering
Vol:6, No:4, 2012

TABLE I
CATEGORIES OF EMISSION IN THE OIL AND GAS SECTOR

Petroleum Products	Process	Sources of Methane Emission
Oil	Exploration (for both oil & gas)	Fugitive emissions (excluding venting & flaring) from oil drilling, drill stem testing and well completion.
	Production & upgrading	Fugitive emission from well head, well servicing , extraction facilities, gas re-injection, produced water treatment etc.
	Refining	Various facilities for upgradation, refining and blending
	Transportation, storage and Distribution	Pipelines, marine tankers, tank trucks, rail cars etc.
		Evaporation losses from storage, filling and uploading activities and fugitive equipment leakage
	Others	Oil spills and other accidental releases, waster oil treatments facilities and oilfield waste disposal facilities
Natural Gas	Exploration	Fugitive Emission from well drilling, drill stem testing and well completions
	Production and processing	From various nodes surface and sub-surface assembly, pipe lines, gas treatment plants
	Transmission, storage and distribution	Similar to oil, but emission is more pronounces
	Other	Well blow-outs, pipeline ruptures, dig-ins etc.
Venting and Flaring	Venting	Gas Venting
	Flaring	Flares

B. The Activity Data on Oil and Natural gas Systems

National activity data in respect of oil and natural gas systems for the years 1990 to 2007 was presented here.
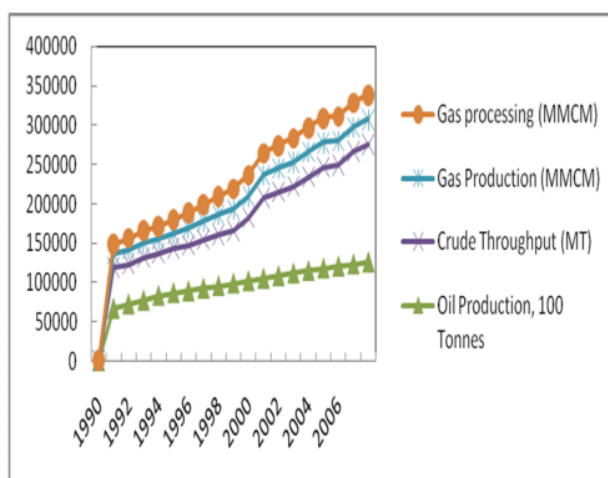

Fig. 1 Activity Data for Oil and Natural Gas Systems

Activity data have been collected from Indian Petroleum and Natural Gas Statistics [8,9] and CMIE publications [6] . The activity data for various years has been presented in Fig 1.

IV. ESTIMATION OF METHANE EMISSION FACTOR AND TOTAL METHANE EMISSION

India specific methane emission factors have been evaluated for oil production and venting and flaring activities. For other activities including oil refining, transportation and storage of oil, gas production, processing, transmission and other leakages default emission factors of IPCC have been considered. The values of emission factors used in this report for different activities are summarized in Table 2.

Total methane emission estimates from different activities of oil and natural gas systems in India have been calculated from the above activity data and emission factors. The emission inventory for various years has been presented in Fig 2.

V. CONCLUSION

Methane emission factors for various activities in Oil and Gas sectors have been evaluated and annual methane emission have been determined accordingly using IPCC 2006 guidelines.

Principle of material balance had been used for evaluation of methane emission for production of oil and gas and Tier I approach had been used for other activities. The results showed that the methane emission is within the tolerable limit and comparable to any other developing and developed countries as updated technologies are being used in industry. Hence, it may be concluded that the present study will not only help in saving our nation from global warming to some extent but also help in saving revenue.

World Academy of Science, Engineering and Technology
International Journal of Chemical and Molecular Engineering
Vol:6, No:4, 2012

TABLE II
METHANE EMISSION FACTORS FOR DIFFERENT ACTIVITIES

Drilling & Exploration, (Gg/well)	Oil Production, (Gg/1000 tonnes)	Refinery Throughput, (Gg/MT)	Gas Production, (Gg /MMCM)	Gas Processing, (Gg/MMCM)	Gas distribution, (Gg/MMCM)	Leakage, (Gg/MMCM)	Flaring, (Gg/MMCM)
3×10^{-3}	3.342×10^{-4}	6.75904×10^{-05}	3.55×10^{-03}	10.66×10^{-03}	10.66×10^{-03}	6.481×10^{-03}	6.41×10^{-04}

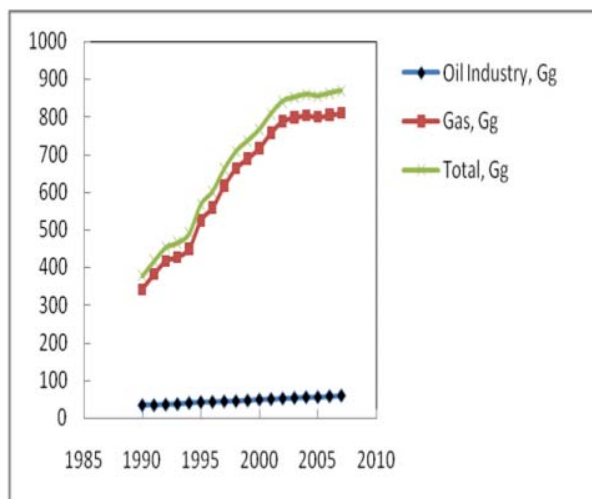
Fig. 2 Total Methane Emission From Oil & Gas Industry

NOMENCLATURE

E_{CH4} = Direct amount (Gg/y) of methane gas emitted due to flaring at oil or gas production facilities

GOR = Average gas to oil ratio (m^3/m^3 reference at 15°C and 101.325kPa

X_{flared} = Fraction of waste gas that is flared rather than vented

y_{CH4} = mole fraction of the associated gas that is composed of methane, CO_2 or NMVOC, 0.92

CE = gas conservation efficiency.

FE = flaring destruction efficiency (fraction of the gas that leaves the flare partially or fully burnt. As per IPCC guideline 2006, for oil & gas production a value o 0.98 is assumed.

M_{CH4}= molecular weight of methane (16.043)

42.3×10^{-6} = is the number of kmol per m^3 of gas reference at 101.325 kPa and 15°C times a unit conversion actor of 10^{-3} Gg/Mg which brings the results of each applicable equation to unit of Gg/y.

MMCM: million cubic cm

Gg: Giga gm

MT: Metric ton

ACKNOWLEDGEMENT

REFERENCES

[1] H Hatamian,. "Air Emission in upstream petroleum operations" , 1997, SPE 37834.
[2] M. Battle, M. Bender, T. Sowers, P.P. Tans, J. H. Buter, Elkins JW, et al., "Atmospheric gas concentrations over the past century measured in air form firm at the South Pole. Nature, 1996, 383:231.
[3] B. P. Flannery, "Climate Change: Science and Environmental Impact, Global Climate Change- A Petroleum Industry Perspective", International Industry Environmental Association. 1991.
[4] Energy, Economic Intelligence Service, Centre for Monitoring Indian Economy Pvt. Ltd., 2008.
[5] India's Initial National Communication to United Nations Framework Convention on Climate Change, 2004- Ministry of Environment & Forests, Govt. of India.
[6] Energy, Economic Intelligence Service, Centre for Monitoring Indian Economy Pvt. Ltd, 2007.
[7] J. T. Houghton, L.G. Meiro Filho, B.A. Callander, N.Harris, A. Kattenberg, and K. Maskell, eds.; IPCC/UNEP/OECD/IEA, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Paris: Intergovernmental Panel on Climate Change; Cambridge University Press, Cambridge, U.K, 1997.
[8] MoPNG (Various years 1994-95, 2000-2001, 2002-03, 2003-04, 2006-07, 2007-08) Indian Petroleum and Natural Gas Statistics, Ministry of Petroleum and Natural Gas, Government of India, New Delhi.
[9] Indian Petroleum & Natural Gas Statistics, Department of Petroleum and Natural Gas, Govt. of India, 2006-07.

Prof. A. K. Pathak The author has been serving the department as faculty since 1984. He is presently Professor and Head Department of Petroleum Engineering, Indian School of Mines, Dhanbad, India. Research area is surface activity of oil & its fraction and their effect on fluid flow through porous media. One UGC sponsored research Project has been completed. He is actively involved in development of computer soft ware and expert system on various areas of drilling system design, Directional drilling and on Horizontal Well Technology. He has presented 20 research papers in national and international conferences and in published 25 papers in national proceedings and journals.Prof. A K Pathak is a life member National Academic of Sciences India, Indian Society of Surface and Colloid Science India and Mining, Geological and Metallurgical Institute of India. He is a member of Society of Petroleum Engineers (SPE, USA) and life member of MGMI, India.

Open Science Index, Chemical and Molecular Engineering Vol:6, No:4, 2012 publications.waset.org/1504.pdf