Science of the Total Environment 574 (2017) 707–715

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

An improved method for estimating GHG emissions from onshore oil and gas exploration and development in China

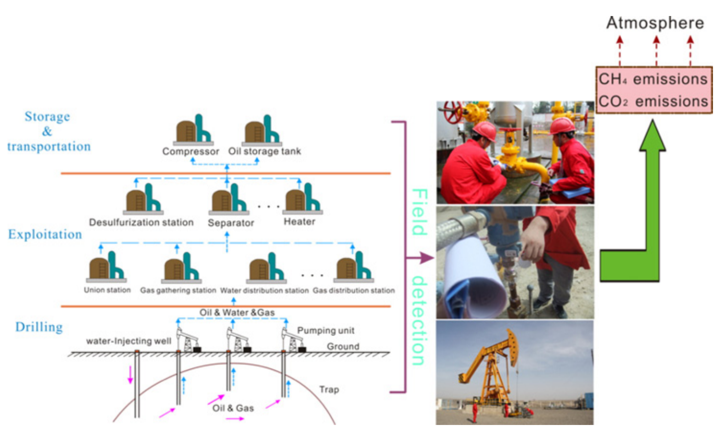
Guojun Chen [a], Shuang Yang [a,b,*], Chengfu Lv [a,*], Jiaai Zhong [a], Zuodong Wang [a], Zhongning Zhang [a], Xuan Fang [a], Shutong Li [a], Wei Yang [c], Lianhua Xue [a]

[a] Key Laboratory of Petroleum Resources, Gansu Province/Key Laboratory of Petroleum Resources Research, Institute of Geology and Geophysics, Chinese Academy of Sciences, Lanzhou 730000, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China
[c] PetroChina Research Institute of Petroleum Exploration & Development-Northwest, Lanzhou 730020, China

HIGHLIGHTS

- Present a first effort to systematically measure GHG emissions from ONG exploration and development in China;
- An improved method is proposed to estimate GHG emissions from ONG systems;
- The GHG emissions of ONG systems in China were seriously overrated by IPCC method.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 10 May 2016
Received in revised form 6 September 2016
Accepted 6 September 2016
Available online 14 October 2016

Editor: D. Barcelo

Keywords:
Greenhouse gas
Calculation method
Methane emission
Carbon dioxide emission
Oil and gas exploration and development
China

ABSTRACT

Greenhouse gas (GHG) emissions from oil and gas exploration and development are major contributors to emission inventories in oil and natural gas (ONG) systems. For the developing countries, including China, studies of this aspect of the industry, being at an early stage, lack a unified method of calculation, and this leads to varied projections of national emissions. In this paper, progress is reported on direct measurement of CH_4 and CO_2 emissions along the oil and gas value chain, for four oil and gas fields. An improved calculation method (classification calculation method), which considers the production status of each type of oil and gas field in China, is proposed for the first time in this study. Based on in situ measurement, it is used to estimate the national CH_4 and CO_2 emissions from the process of petroleum exploration and development. The results showed that CH_4 and CO_2 emissions in 2013 were 73.29×10^4 and 20.32×10^4 tonnes, respectively (in CO_2 equivalent: 1559.36×10^4 tonnes). Compared with the results (731.52×10^4 tonnes of CH_4, 1031.55×10^4 tonnes of CO_2, $16{,}393.48 \times 10^4$ tonnes of CO_2 equivalent) in 2013 determined by the Tier 1 method of the Intergovernmental Panel on Climate Change (IPCC), the carbon emissions from field measurement method were much lower than that of IPCC method, which indicated that carbon emissions of ONG systems in China were severely overrated by IPCC. Hence, the GHG emission results reported herein could fundamentally improve the knowledge and understanding of GHG emissions from ONG exploration and development in China.

* Corresponding authors.
E-mail addresses: yangshuanggo@foxmail.com (S. Yang), bailu2005@163.com (C. Lv).

http://dx.doi.org/10.1016/j.scitotenv.2016.09.051

1. Introduction

At present, global warming is considered one of the biggest environmental problems (Glagolev et al., 2008; Jeon et al., 2010; Steffen et al., 2015; Xu et al., 1999). The gases contributing most to the greenhouse effect are CO_2 and CH_4 (Amjad et al., 2011), accounting for approximately 60% and 15–20% of global greenhouse effect (Houghton et al., 1992; Rodhe, 1990; Shindell et al., 2009). CO_2 concentrations in the atmosphere increased from 370 to 392 ppm over the period 2000–2011 (Harsono et al., 2013), while global CO_2 emissions reached 34,475.64 MMT in 2010 (WRI, 2014), CH_4 concentrations increased from 1.52 to 1.81 ppm during 1978–2012 (WMO, 2012) and global CH_4 emissions reached 7195.56 MMT CO_2eq in 2010 (WRI, 2014). Despite the comparatively low concentration of CH_4 as compared to CO_2 in the atmosphere, its global warming potential (GWP) is 25 times that of CO_2 given a 100-year time horizon (Griggs and Noguer, 2002; IEA, 2008). The International Panel on Climate Change (IPCC) reports have demonstrated that the global mean sea level has risen by 0.19 m over the period 1901–2010 and the global average temperature increased by 0.85 °C over the interval 1880–2012 (IPCC, 2014). Global warming potential is expected to accelerate in the coming decades (Bradley, 2001; Hansen et al., 2002; Katyal, 2009), and Dlugokencky et al. (2011) claimed that a reduction in CH_4 emissions would rapidly benefit the global climate; thus, it is particularly imperative to investigate and reduce GHG emissions to mitigate global warming to a certain extent (Choudhary et al., 2008).

A variety of human activities (Fig. 1) can become sources of manmade GHG emission (Duxbury et al., 1993; IPCC, 2007; Yuan et al., 2012; Steffen et al., 2015). The energy supply for these activities is the second largest CH_4 emission source, accounting for 37% of the global CH_4 emissions produced by human activities (emissions of 2713.2 $MtCO_2$eq in 2010: EPA, 2012). Furthermore, oil and natural gas systems (ONG) are the leading CH_4 emission source in the field of energy supply, with emissions of 1677.3 $MtCO_2$eq in 2010 (EPA, 2012).

GHG emissions from ONG systems are projected to increase by 26% between 2010 and 2030 (EPA, 2013). The absence of systematic direct in situ measurements along infrastructures used in the process of oil and gas exploration and exploitation, limits the opportunity to evaluate GHG emission reduction strategies (Burnham et al., 2012). Clearly, there is limited understanding of GHG emissions from oil and gas exploration and exploitation facilities, including those in the United States (Howarth et al., 2011). Anifowose and Odubela (2015) presented a modest attempt to estimate CH_4 emissions from the System 2C crude oil transport pipeline in Nigeria. Allen et al. (2013) first carried out a series of studies measuring CH_4 emissions at natural gas production sites in the US. To date, there has been no similar measurement study to gather scientific estimates, or to locate specific sites of emission in the oil and gas infrastructures in China. Presentation of carbon emissions produced by the energy activities in China is missing from the literature. Based on the IPCC method, there have been several studies of the national-scale inventories of CH_4 emissions in China's oil and natural gas industry for year 1980–2007 (Liu et al., 2008; Zhang et al., 2014). However, because of the lack of measurement data and complex & volatile emission sources in ONG systems, not all the estimates acquired essentially are well reflective of the real situation in China. Therefore, the scientific quality and accuracy of such estimates are inadequate (IPIECA, 2011; Penman et al., 2000; Zhu et al., 2015). This is because default emission factors in the IPCC method include the performance of average GHG emission levels in developing countries but do not fully reflect current situation in China's oil and gas industries, given the advancement and development of technology. Moreover, the default emission factors were applied to the whole petroleum system in IPCC method, without considering the production status of each field in China (CCCCS, 2000). Furthermore, those estimates tended to focus mainly on CH_4 emissions and to ignore CO_2 emissions.

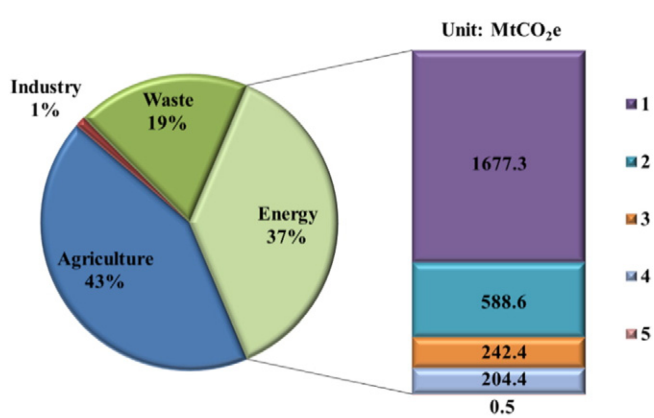


Fig. 1. Global methane emissions from energy activities in 2010, categorized by source (inlet: methane emission by sector) (EPA, 2012): 1-Natural Gas and Oil System; 2-Coal Mining Activities; 3-Stationary and Mobile Combustion; 4-Biomass Combustion; and 5-Other Energy Sources.

In view of the above-mentioned facts, there is still limited estimate about the GHG emissions from ONG systems in China. The estimates in previous report still cannot reflect the actual situation. To understand and estimate the actual emission of China's ONG systems, a more accurate method, which can reflect the current situation of oil and natural gas fields in China, is urgently required.

The purpose of this paper is twofold. First, establish an emission factor (country-specific factor) which is suitable for China's ONG systems by measuring several representative oil and gas fields. Next, perform a detailed estimate of carbon emissions in China during 2010–2013. The national estimates based on field measurement are compared with those by IPCC method. This comparison could provide reliable basic data and a more scientific basis for policy making to alleviate global warming.

2. Methodology

2.1. Conventional methodology (IPCC Tier 1) for estimating GHG emissions

At present, there is no uniform calculation method for estimating the GHG emissions from oil and gas systems around the world. The Tier 1 approach (IPCC, 2006), of which the given emission factors have come to be seen as applying to all developing countries, has been widely employed to estimate GHG emissions of ONG systems in China. According to the recommendations of conventional method, where the emissions are equal to an emission factor multiplied by the corresponding activity factor along the ONG chain (category), the GHG emissions from oil and natural gas systems can be calculated as indicated in Formula 1 and Formula 2.

$$E_{gas,industry\ sement} = A_{gas,industry\ sement} \cdot EF_{gas,industry\ sement} \quad (1)$$

$$E_{gas} = \sum E_{gas,industry\ segment} \quad (2)$$

where, E_{gas} is the emission (Gg), $A_{industry\ segment}$ is the activity factor (number of new drillings, testing wells, well servicing and production wells, oil and gas production), $EF_{industry\ segment}$ is the emission factors (Gg/unit of activity), E_{gas} is the total emissions of industry segments. The exploration and development data corresponding to active factors of different categories in the IPCC method, which were used to calculate the GHG emissions of ONG systems, were collected from the statistical yearbook (CNPC, 2014; CPC, 2014).

2.2. An improved method for estimating GHG emissions

Because of the limitations of the IPCC method, an improved method (classification calculation method) that better considers the actual