Science of the Total Environment 543 (2016) 514–523

Contents lists available at ScienceDirect

Science of the Total Environment

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

A new approach to estimate fugitive methane emissions from coal mining in China

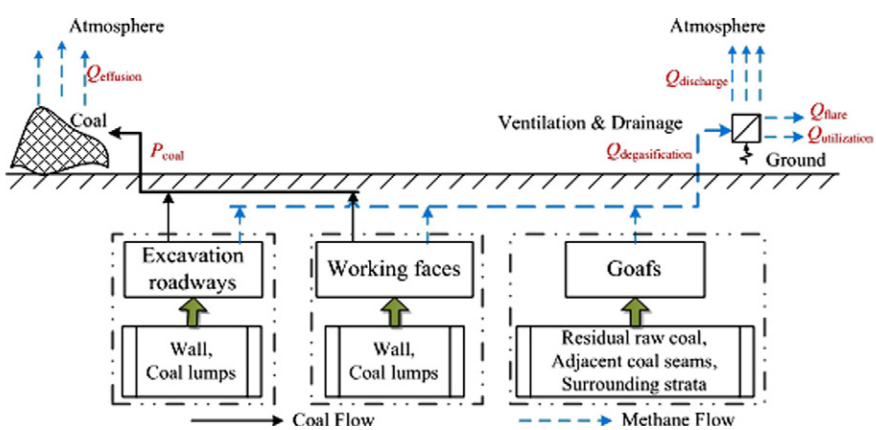
Yiwen Ju [a,b,*], Yue Sun [a,b], Zhanyou Sa [c], Jienan Pan [d], Jilin Wang [e], Quanlin Hou [a,b], Qingguang Li [a,b], Zhifeng Yan [a,b], Jie Liu [c]

[a] Key Laboratory of Computational Geodynamics of Chinese Academy Sciences, Beijing 100049, China
[b] College of Earth Science, University of Chinese Academy Sciences, Beijing 100049, China
[c] Department of Safety Engineering, Qingdao Technological University, Qingdao 266520, China
[d] School of Resources and Environment, Henan Polytechnic University, Jiaozuo 454000, China
[e] School of Resources and Geosciences, China University of Mining and Technology, Xuzhou 221116, China

HIGHLIGHTS

- Propose a new method to estimate fugitive methane emissions from coal mining.
- New method has accurate prediction for CMM emissions without activity data updating.
- Mining influence coefficient involved in new method is determined in range 1.3–1.9.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 26 July 2015
Received in revised form 4 November 2015
Accepted 4 November 2015
Available online 21 November 2015

Editor: D. Barcelo

Keywords:
Greenhouse gas
Methodology
Methane emission
Coal mining
China

ABSTRACT

Developing a more accurate greenhouse gas (GHG) emissions inventory draws too much attention. Because of its resource endowment and technical status, China has made coal-related GHG emissions a big part of its inventory. Lacking a stoichiometric carbon conversion coefficient and influenced by geological conditions and mining technologies, previous efforts to estimate fugitive methane emissions from coal mining in China has led to disagreeing results.

This paper proposes a new calculation methodology to determine fugitive methane emissions from coal mining based on the domestic analysis of gas geology, gas emission features, and the merits and demerits of existing estimation methods. This new approach involves four main parameters: in-situ original gas content, gas remaining post-desorption, raw coal production, and mining influence coefficient. The case studies in Huaibei–Huainan Coalfield and Jincheng Coalfield show that the new method obtains the smallest error, +9.59% and 7.01% respectively compared with other methods, Tier 1 and Tier 2 (with two samples) in this study, which resulted in +140.34%, +138.90%, and −18.67%, in Huaibei–Huainan Coalfield, while +64.36%, +47.07%, and −14.91% in Jincheng Coalfield.

* Corresponding author at: Key Laboratory of Computational Geodynamics of Chinese Academy Sciences, Beijing 100049, China.
E-mail address: juyw03@163.com (Y. Ju).

http://dx.doi.org/10.1016/j.scitotenv.2015.11.024

Compared with the predominantly used methods, this new one possesses the characteristics of not only being a comparably more simple process and lower uncertainty than the "emission factor method" (IPCC recommended Tier 1 and Tier 2), but also having easier data accessibility, similar uncertainty, and additional post-mining emissions compared to the "absolute gas emission method" (IPCC recommended Tier 3). Therefore, methane emissions dissipated from most of the producing coal mines worldwide could be more accurately and more easily estimated.

1. Introduction

The tremendous progress of human socio-economy since the Industrial Revolution has simultaneously created various positive and negative effects on the earth's system, with a significant amount of pertaining to global climate change (Steffen et al., 2015). The most recent assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) has demonstrated that the global average temperature has risen by 0.85 °C from 1880 to 2012, and warming is predicted to continue to increase 0.3–0.7 °C in the period of 2016 to 2035 (IPCC, 2014). While the root cause of global warming has not yet been agreed upon (Lindzen, 2007; Wang, 2010), there is no doubt that reducing emissions of greenhouse gases could mitigate global warming to a certain extent (Montzka et al., 2011; IPCC, 2014).

Methane (CH4), the second most important anthropogenic greenhouse gas after carbon dioxide (CO_2), plays an important role in atmospheric chemistry and radiation balance, of which the global warming potential (GWP) is 28 over a time horizon of 100 years (Ghosh et al., 2015). Recent estimations have suggested that atmospheric CH_4 emissions have contributed to approximately 20% of global warming since the Industrial Revolution (Nisbet et al., 2014; Yvon-Durocher et al., 2014). Atmospheric CH_4 concentration increased from 700 ppb during pre-industrial times (Etheridge et al., 1998) to 1813.9 ppb in 2013 according to measurements by the U.S. National Oceanic and Atmospheric Administration. This findings also shows that it is increasing at a higher rate compared to the growth rate of atmospheric CO_2 concentration over the same period of time (Dlugokencky et al., 2011). The main sources of methane emissions in order of contribution are agriculture, energy activities, and waste disposal (Yusuf et al., 2012; Kirschke et al., 2013). Global methane emissions from energy activities in 2010 and 2015 are presented in Fig. 1, which shows that methane emissions in energy activities account for 38.27% and 37.7% of the total methane emissions, respectively. Furthermore, methane emissions from coal mining is roughly 600 $MtCO_2e$, making it responsible for 8–10% of anthropogenic-related CH_4 (Su et al., 2011), and these emissions are predicted to rise by 15% by 2020 (Li et al., 2015b).

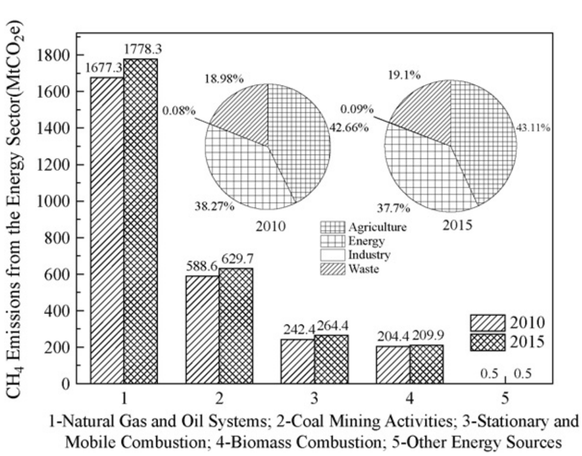


Fig. 1. Global methane emissions from energy activities, categorized by source, in 2010 and 2015 (inlet: methane emission by sectors) (EPA, 2012).

China is one of the few countries among the major world economies that uses coal as its primary energy source; more specifically, it produced 3.68 billion tons of coal in 2013, which represents 45.5% of total coal production throughout the world for that year (IEA, 2014) and accounts for 71.64% and 67.5% of China's total primary energy production and consumption, respectively, in 2013 (BP, 2014; NBSPRC, 2014). In 2007, CH_4 emissions corresponding to coal mining made up nearly 7% of the total GHG emissions in China (Chen and Zhang, 2010), which makes China the world's largest emitter of CMM (coal mine methane) (IEA, 2009). The Chinese government has taken various measures to speed up its national energy restructuring; however, since 90% of China's fossil energy reserves is coal reserves, the leading position of coal in the energy mix of China will continue to persist over the long term. Consequently, the coal-related greenhouse gas emissions that occupy a large portion of Chinese corporate GHG inventory have been attracting more attention recently.

In accordance with the principle of "common but differentiated responsibilities", the Kyoto Protocol has only appointed certain explicit quantified emission limitations and reduction commitments to developed countries, but there are no strict restrictions on developing countries, including China. However, as a large and responsible power, China has developed a series of policy processes and technical innovations to reduce GHG emissions and aims to further reduce CO_2 intensity by 40–45% from the 2005 baseline by 2020 (NDRC, 2014). To this end, China first needs to obtain better data to produce national GHG emission inventories (Wang, 2014). Unfortunately, there appears to be a discrepancy among the CMM emissions calculated by the investigators who use different estimation methods, data sources, investigated areas, and calculation precision. With Chinese methane emissions from coal mining in 2005 as an example, since that year is both the base year of China's pledge to cut CO_2 emissions and the latest official National GHG Inventory year of China (NDRC, 2012), the values vary considerably among different studies, with the highest one being about five times higher than that of the lowest value found (Table 1), causing an adverse impact on policy formulation and technology promotion regarding CMM exploitation and utilization.

In this work, based on considering rationality and the limitations of conventional computing methods, special research efforts have been made to analyze the characteristics and main controlling factors of coal-bed methane adsorption-desorption and establish regressive statistics using different data in typical coal mine areas. On this basis, a new approach that is better suited to the present conditions of China is proposed. The results of the new method are compared with those

Table 1
Estimates of the CMM emissions in China (base year: 2005).

Methane emissions/10^8 m^3	CO_2-equivalent emissions/Mt	References
90.51	136.31	Yang (2009)
140	210.83	Li and Hu (2008)
152.6	229.82	Wang et al. (2013)
170.71	257.09	EPA (2012)
192.86	271.45	NDRC (2012)
198.01	278.21	Yue et al. (2012)
250.59	377.39	Zhang et al. (2014a)
200–500	301.20–753.01	IPCC (2006)