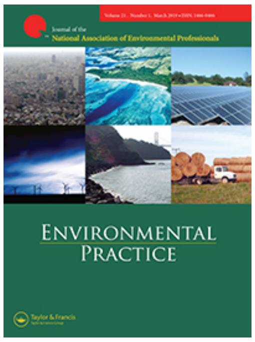

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Better accounting of greenhouse gas emissions from Indian coal mining activities — A field perspective

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PERSPECTIVES FROM THE FIELD

Better accounting of greenhouse gas emissions from Indian coal mining activities — A field perspective

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ABSTRACT

Fugitive methane emissions from coal mining activities have been frequently talked about in the literature due to concerns about climate change. However, indirect and direct CO_2 emissions may also result from coal mining processes. The indirect CO_2 emissions include those from diesel combustion from equipment while direct CO_2 emissions are a relatively new area of research and have been recently brought into the purview of the Intergovernmental Panel on Climate Change (IPCC) inventory guidelines. We discuss some of the preliminary results which can give some directions into the potential research areas for better accounting of greenhouse gas emissions from coal mining activities. These have been derived from practical studies undertaken at selected coal mines in India.

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Carbon footprint; CO_2 emissions; coal mining; greenhouse gas inventory; indirect and direct emissions

Highlights

- Considering indirect and direct CO_2 emissions in coal mining processes can have significant life-cycle implications.
- Better data collection and accounting associated with these tasks is advocated here in view of changing role of coal in energy systems.
- Suggestions for improved inventory preparation have been made in this note.

Greenhouse gas emissions from coal mining and handling activities are important contributors to global greenhouse gas (GHG) emissions. As per the guidelines of the Intergvernmental Panel on Climate Change (IPCC), fugitive methane emissions may result due to breakage, handling, processing or transport of coal during both mining or post-mining stages. Some CO_2 emissions might also occur as a result of low-temperature oxidation or uncontrolled combustion (IPCC 2006). The fugitive methane emissions have been continually reported by major coal producing countries to be significant. For instance, the share of coal mining to total methane emissions from the energy sector ranged close to 20% during the last two decades in the United States (EPA 2018). Similarly, coal mining emissions contribute to half of China's total methane emissions (Zhang and Chen 2010) but there have been some positive trends since significant proportion of the methane tends to be utilized after drainage (Ju et al. 2016). Controlling these emissions to a greater extent can offer centralized sources of GHG abatement as well as some localized avenues of energy generation and thus such initiatives are receiving global focus. Several climate policies are now focusing on their mitigation, and utilizing carbon pricing mechanisms on this end will ensure holistic long-term decarbonization, which may not be possible with management only on the combustion end. This is especially significant since methane mitigation will likely be critical to meeting long-term decarbonization objectives (Collins et al. 2018)

India, which is the second largest coal producer after China, has seen a significant increase in coal production which is further projected to increase due to developmental targets (Garg et al. 2017). Again, coal mining activities have a substantial contribution to the greenhouse gas (GHG) emissions, of which the larger share of emissions from such activities are fugitive methane emissions. These emissions were estimated even before inventorying measures were

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properly implemented because the gas presented a safety hazard (Banerjee 1987).

As part of the Methane Campaign of the Council of Scientific and Industrial Research (CSIR), our group was involved in developing the methane emission coefficients for various categories of Indian coal mines (Banerjee et al. 1994a). With improved considerations on emission inventory preparation through the national communications (NATCOM) projects, detailed methane emission factors have been developed not just for the mining processes but also the residual methane emissions that occur during transport and handling of the coal (Singh and Kumar 2016). On one level, these emissions are significant because it has been suggested to use 20-year methane global warming potential (Singh and Singh 2018). However, in this brief piece, we cover some of the advances that could take place in GHG inventorying by accounting for the CO_2 emissions during coal mining projects.

Coal mining processes use significant heavy machinery and other infrastructure and it is pertinent to discuss the relative carbon footprint of each of these processes. We have carried out preliminary studies at two opencast mines of the Central Coalfields Limited (CCL)—Piparwar and Ashoka. The results showed that while fugitive methane emissions did account for more than 3/4th of the total carbon footprint of the coal mining process, around 22.5% emissions also resulted from diesel combustion of the auxiliary processes. This has some interesting ramifications, because process improvements in such stages could result in large potential fuel savings (Sahoo et al. 2014). We also noticed that over the years, improvement in the management of the mining processes has led to the reduction of the emissions from diesel combustion. Tracking these emissions is not only interesting mathematically, but it may also be argued that these emissions result only because coal mining is taking place. Thus, if a life-cycle analysis of coal mining processes is carried out with one tonne of coal as the functional unit, these emissions do occupy a little under one-fourth of the carbon footprint without considering the combustion end of the coal.

How can results from two surface coal mines be translated into the overall Indian coal sector? Underground coal mining is extremely important in regards to the fugitive methane emissions. The emission factor for Indian underground coal mining activities is 2.5–20 times higher than opencast mines. Similarly, emissions for coal handling are 6.5–21 times higher for coal mined-out underground (MoEF 2010). Moreover, machinery use in underground coal mining is also higher, which means CO_2 emissions from energy inputs are also likely to be higher for the usage of mining machineries. Currently, room-and-pillar method of mining is the most popular method of underground mining in India (Kushwaha et al. 2010). This method uses the continuous miner technology, which is a high energy consuming machinery. Similarly, significant energy is consumed for ventilation of underground mines, which can be optimized using control settings of ventilation equipment and flow (Kurnia et al. 2014). Another popular method of mining is the longwall method, for which predictive methane emission equations have been developed (Banerjee et al. 1994b). This process is also a highly mechanized process. But, the energy consumption of the machinery can itself be influenced by the cuttability (and other factors of ease of mining) of the seams which, in turn, can be influenced by a variety of factors including the origin and depth of mining (Singh et al. 2011, 2002). As a result, estimating overall GHG emissions for underground mines is an involved task and opens up an interesting research question for the future. Moreover, studying underground mines for this purpose is also important because most of the opportunities of methane mitigation by recovering coal mine methane (CMM; i.e., simultaneous coal and gas production) or ventilation air methane (VAM which refers to gainful utilization of diluted methane from ventilation systems) exist primarily in underground coal mines.

Another important consideration for better accounting of the GHG emissions is the accounting of fugitive CO_2 emissions from coal mines themselves. These emissions are being currently considered within the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2016). Our hypothesis was that these emissions result due to slow oxidation of the coal and unlike fugitive methane emissions, they do not have any link to the volume of coal production. This is because while the source of the methane is coal itself, the CO_2 generation should be a fairly recent process, caused due to air flow within the coal workings. Thus, while methane is released from the coal matrix itself, CO_2 is generated on the coal surface and therefore mechanisms for emission measurement should be different. With this aim, we carried out preliminary studies on twelve measuring sites within three coal mines in the Jharia coalfield in India. We found that there was significant correlation (R^2 = 0.7067) between air quantity and the quantity (or make) of CO_2, as shown in Figure 1. Further, when multivariate regression was carried out, we found that the p-value for air quantity was 0.06, making it statistically more significant than coal production, which had a p-value of 0.38. While statistical significance is yet to be achieved due to lesser number of data points, which are highly localized geographically, our preliminary conclusion seems to be that the air quantity is a much greater determinant to the CO_2 emissions than coal production. It is suggested to carry out further field trials to get results which are valid to a greater statistical significance. Having said that, the CO_2 emission levels estimated in these mines (upto 5.44 m^3/t-coal) are significant and can further augment the GHG emission inventory of India. For practical cost reduction measures, it is suggested that measurements for CO_2 and methane emissions are carried out simultaneously at mines.

There is another crucial point which requires systematic assessment based on pilot data. Methane drainage has been discussed by several practitioners in the Indian context. Most notably, drainage at seam XVI of the Moonidih mine has been proposed by Coal India Ltd (CIL 2017). For the proposed project at Moonidih, it has been estimated that with a project cost of US$ 20 million, upto 78 m^3-CH_4/year would be recovered (CMPDI/BCCL 2010). A pertinent research question is how to properly estimate and apportion fugitive methane emissions. Significant primary data collection for three coalfields (Raniganj, Jharia and Bokaro) has been done by us—whereby gas content of over 10 m^3/t was seen for some coal blocks and the content of methane emission in the ventilation air of over 0.5% was also observed in active mines (Singh and Hajra 2018). The utility of methane drainage is to reduce the rate of methane emission during coal mining—this process is called coal mine methane (CMM) recovery. However, as an unconventional gas well, leakage of methane may be expected during well completion and other processes—the magnitude of which has not been determined in any Indian

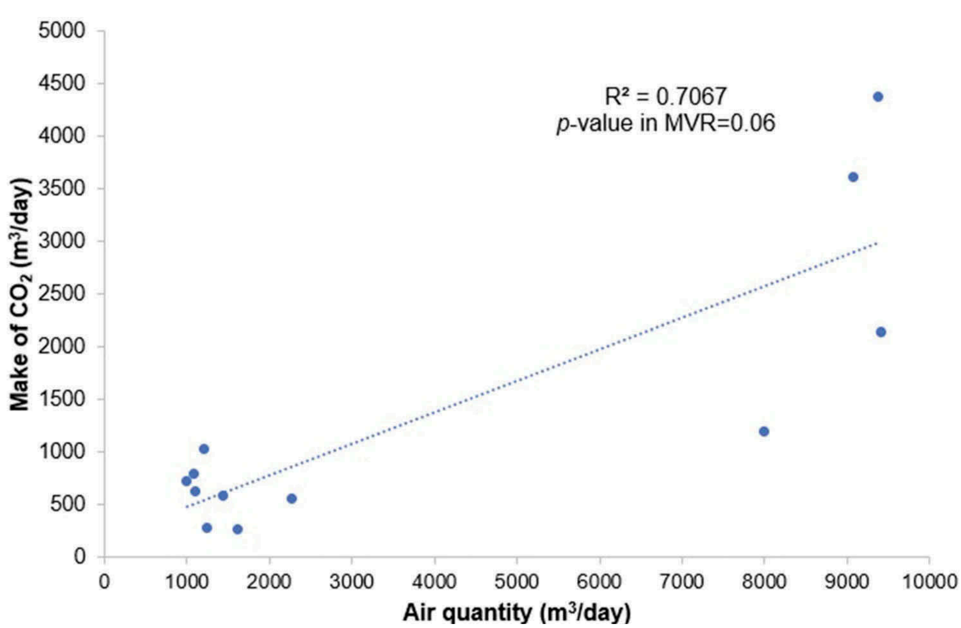

Figure 1. Plot of make of CO2 versus the air quantity. Here, the p-value is obtained in a multivariate regression specifically when considering air quantity as a variable alongside coal production. MVR: multivariate regression.

exercise so far. Proper accounting for these emissions during the well-completion stage can significantly change the cost-feasibility of the CMM operations. For instance, Hummel et al. (2018) estimate the CMM capture cost to be $ 0.95–6.02/MMBtu. However, if additional leakage of methane occurs while CMM operations, how would the system boundary of life-cycle emissions be affected, and would the global warming potential of this methane be large enough to cause change to the economic feasibility of the CMM project?

Thus, we conclude with the point that while significant advances have been made in fugitive methane emission estimation in the past two decades, some improvements could be made for better evaluating GHG emissions from coal sector.

- First, diesel use as part of the coal mining project itself might be prudent as such emissions result because of coal production activities and have been shown to be quite significant in our two case study mines. In a life-cycle perspective, accounting for direct as well as indirect emissions is important because the major mitigation strategy in the coal sector, i.e., CO_2 capture and storage (CCS) will actually result in an increase of mining-related emissions due to parasitic load on the capture front.
- Further, estimating CO_2 emissions in tandem with fugitive methane emissions will not only result in more robust GHG inventories but also be economically practical since a large part of estimation in terms of field studies will be largely repetitive. Here, it is important to find better correlation of such emissions to the air flow within mines.
- If coal use reduces in the future, methane emissions will necessarily reduce but CO_2 emissions will largely be dependent on the mine ventilation required for safe operation of the mines. This might mean that CO_2 emissions from slow-oxidation can have much more significant contributions (in terms of emissions per tonne of coal mined) when existing coal mines have reduced dispatch in view of coal transitions.
- With increased importance of CMM utilization in China, India, and other coal-dependent economies, it is important to consider the leakage of methane in degasification systems which might be quite significant in well completion stages.

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Disclosure

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References

Banerjee BD. 1987. A new approach to the determination of methane content of coal seams. Int J Min Geolog Eng. 5 (4):369–76.

Banerjee BD, Singh AK, Garg PC. 1994b. Modelling inflow of methane from coal seams into longwall workings. Int J Rock Mech Min Sci Geomech Abstr. 31:85–86.

Banerjee BD, Singh AK, Kispotta J, Dhar BB. 1994a. Trend of methane emission to the atmosphere from Indian coal mining. Atmos Environ. 28(7):1351–52.

CIL. 2017. Annual reports and accounts 2016-17, Coal India Limited. [accessed 2017 June 28]. https://www.coalindia.in/DesktopModules/DocumentList/documents/Annual_Report_&_Accounts_2016_17_Deluxe_English_07112017.pdf.

CMPDI/BCCL. 2010. Coal mine methane project opportunity – moonidih CMM project. 2010 Methane to Markets Partnership Expo. [accessed June 28, 2017]. https://www.globalmethane.org/expo-docs/posters/CoalMines/CM_IN_Project_Moonidih-from-ARI_FINAL.pdf.

Collins WJ, Webber CP, Cox PM, Huntingford C, Lowe J, Sitch S, Chadburn SE, Comyn-Platt E, Harper AB, Hayman G, et al. 2018. Increased importance of methane reduction for a 1.5 degree target. Environ Res Lett. 13 (5):054003.

EPA. 2018. Inventory of U.S. greenhouse gas emissions and sinks: 1990-2016. [accessed 2018 Dec 24]. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016.

Garg A, Shukla PR, Parihar S, Singh U, Kankal B. 2017. Cost-effective architecture of carbon capture and storage (CCS) grid in India. Int JGreenhouse Gas Control. 66:129–46.

Hummel JA, Ruiz FA, Kelafant JR. 2018. Quantifying the benefits of coal mine methane recovery and use projects: case study on the application of in-mine horizontal pre-drainage boreholes at gassy coal mines in India and the optimization of drainage system design using reservoir simulation. Environ Technol Innovation. 10:223–34.

IPCC. 2006. 2006 IPCC Guidelines for national greenhouse gas inventories – volume 2 (energy). [accessed 2018 Dec 24]. https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html.

IPCC. 2016. 44th Session of the IPCC – decisions adopted by the panel. [accessed 2018 Jun 27]. http://www.ipcc.ch/meetings/session44/p44_decisions.pdf.

Ju Y, Sun Y, Sa Z, Pan J, Wang J, Hou Q, Liu J, Yan Z, Liu J. 2016. A new approach to estimate fugitive methane emissions from coal mining in China. Sci Total Environ. 543:514–23.

Kurnia JC, Sasmito AP, Wong WY, Mujumdar AS. 2014. Prediction and innovative control strategies for oxygen and hazardous gases from diesel emission in underground mines. Sci Total Environ. 481:317–34.

Kushwaha A, Singh SK, Tewari S, Sinha A. 2010. Empirical approach for designing of support system in mechanized coal pillar mining. Int J Rock Mech Min Sci. 47(7):1063–78.

MoEF. 2010. India - second national communication to the United Nations framework convention on climate change. New Delhi, India: Ministry of Environment and Forests, Government of India.

Sahoo LK, Bandyopadhyay S, Banerjee R. 2014. Benchmarking energy consumption for dump trucks in mines. Appl Energy. 113:1382–96.

Singh AK, Hajra PN. 2018. Coalbed methane in India: opportunities, issues and challenges for recovery and utilization. Cham, Switzerland: Springer International Publishing.

Singh AK, Kumar J. 2016. Fugitive methane emissions from Indian coal mining and handling activities: estimates, mitigation and opportunities for its utilization to generate clean energy. Energy Procedia. 90:336–48.

Singh R, Mandal PK, Singh AK, Kumar R, Sinha A. 2011. Coal pillar extraction at deep cover: with special reference to Indian coalfields. Int J Coal Geol. 86(2):276–88.

Singh R, Singh AK, Mandal PK. 2002. Cuttability of coal seams with igneous intrusions. Eng Geol. 67(1):127–37.

Singh U, Singh AK. 2018. Improved climate change understanding and projections for coal businesses create urgent need to initiate stronger measures toward coalbed methane in India. Carbon Management. 9:83–85.

Zhang B, Chen GQ. 2010. Methane emissions by Chinese economy: inventory and embodiment analysis. Energy Policy. 38(8):4304–16.