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A Tier 3 method to estimate fugitive gas emissions from surface coal mining

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ABSTRACT

Fugitive coal seam gas emissions from open cut coal mines (surface mining) arise when coal and associated strata are blasted, fractured and disturbed as part of the mining process. This liberates the seam gas that is trapped within coal seams. The Intergovernmental Panel on Climate Change recommends using an emission factor (*EF*) approach as the basis for estimating fugitive coal seam gas emissions. The *EF* is the volume of gas (m^3) released per tonne of coal produced. Three levels of accuracy are associated with estimation of these emissions: Tiers 1, 2 and 3, each having increasing levels of accuracy. Tiers 1 and 2 provide average *EF* values for the whole country or the coal basin, while Tier 3 provides *EF* values specific to a coal mine. Until recently, Australian open cuts used nominal *EF* values of 3.2 m^3/t and 1.2 m^3/t for the two main coal producing states of New South Wales and Queensland, respectively. These values were used for all mines in these states, irrespective of the level of 'gassiness' of specific coal seams and strata. During the last few years, we have developed a new method for Australian open cut mining that is specific to each mine site. The proposed Tier 3 method, which has been adopted by the National Greenhouse and Energy Reporting, considers the coal seams and clastic rock horizons as gas reservoir units that release their gas during mining. The primary data required are the in situ gas content and gas composition of coal and carbonaceous rocks contained within the column of strata called the 'gas release zone'. In this methodology, regions of similar gas content and reservoir properties are termed as 'gas zone'. A small number of drillings are required to characterise the gas zone and to provide inputs to the model.

This paper describes this new method of estimating fugitive gas emissions from surface coal mining. To illustrate the procedure of the calculations, the method is applied to an active Australian open cut coal mine.

1. Introduction

Australia is a major producer of coal. It has about 72 billion tonnes of identified bituminous coal resources, with about 363 million tonnes (Mt) of saleable bituminous coal production for the 2009–10 financial year (Australian Coal Association, 2009; Resources and Energy Statistics, 2012). About 275 Mt (76%) of the total saleable coal was produced in open cut mines. Fugitive emissions from all coal mines for the year 2009 were estimated at 28.7 Mt carbon dioxide equivalents (CO_2-e), which is 5.3% of Australia's total man-made greenhouse gas emissions (Australian National Greenhouse Accounts, 2011). While the bulk of emissions is from underground coal mining, about 30% of emissions come from open cut mining. In 2007, the *National Greenhouse and Energy Reporting* (*NGER*) *Act 2007* was established, which required Australian coal mines to report their annual fugitive emissions. The first annual reporting period was from 1 July 2008. A carbon pollution tax has also been introduced by the Australian government to reduce greenhouse gas emissions. It takes effect from 1 July 2012.

Developing accurate and practical methods to estimate emissions from coal mining in Australia has been an ongoing research activity since the early 1990s, following the Kyoto conference on climate change (Saghafi and Williams, 1992, 1996; Saghafi et al., 1997, 2005; Williams and Saghafi, 1993). In underground mining, gas is released into the mine's drainage and ventilation systems. Therefore, total emissions from coal can be estimated with relative ease. In contrast, in open cut mining, coal seam gas (CSG) is released from diffuse sources and emitted directly to the atmosphere. Therefore, estimating CSG emissions is not straightforward and can be uncertain. Open cut mines have a multitude of gas emission sources, including open exploration boreholes, extracted coal seams, removed overburden carbonaceous and other gas-bearing sedimentary rocks, thin and ashy coal seams tipped in spoil piles, standing highwall, and underburden coal and rocks. These emission sources are spread widely across the mine lease, and the diffused nature of emissions makes direct measurement inaccurate and difficult.

Emissions from mining are generally quantified using the concept of an emissions factor (*EF*), or specific emission. This terminology is similar to the one used for mine safety purposes in underground mining, where specific emission presents the volume of gas released into the coal face for each tonne of coal extracted (see e.g. Boxho et al., 1980; Creedy, 1993; Creedy et al., 1997). To quantify fugitive

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emissions from mining, generic *EF* values have been suggested and used while measured established values have been unavailable. The Intergovernmental Panel on Climate Change (IPCC, 2006) recommends using *EF* with a tier qualifier. The three levels of accuracy, namely Tiers 1, 2 and 3, are defined as follows:

- Tier 1: *EF* is a generic number. Tier 1 numbers are only applied if no data on gas content and emissions are available for the coal basin and country.
- Tier 2: *EF* is basin-specific. Its value is an average number for one or several coal basins.
- Tier 3: *EF* is mine-specific. It is determined by measuring emissions from an individual mine and is therefore the most accurate (see e.g. the IPCC, 2006 report for more official definitions of these terms).

In the following sections, after a brief history of the evolution of methods of measuring and evaluating CSG emissions from open cut mining in Australia, the details of the new Tier 3 method are presented. The new Tier 3 model has been adopted by the Australian NGER (National Greenhouse and Energy Reporting, 2009) and recommended to open cut coal mines for evaluation of their CSG emissions.

2. History of methods for estimating fugitive emissions from open cut mining in Australia

In the last two decades, several studies have been undertaken in the coalfields of eastern Australia to develop a method for evaluating emissions from open cut coal mining. Two methods for direct measurement of emissions – here referred to as global emissions measurement and spot emissions measurement – were initially devised and applied to some open cut mines in two main coal regions of Australia. Global emissions measurement uses air pollution techniques to assess emissions by measuring gas concentration downstream of winds sweeping through the coal mine. This method also requires measurement of wind velocity and assumptions about the shape of the plume and wind velocity distribution in the plume. Spot emissions measurement uses a chamber technique to measure emissions emanating directly from exposed surfaces, such as uncovered coal seams, spoil piles and ground surface. A purpose-built chamber covers the targeted surface, and gas accumulation in the chamber is measured to estimate gas flux emitted from the exposed surface. In the next sections, these two methods are described in more detail.

2.1. Global emissions measurement method

A global emissions measurement method was developed and applied to 17 open cut coal mines in the Sydney and Bowen Basins in the early 1990s (Saghafi and Williams, 1992; Williams et al., 1993). This method was developed using air pollution techniques, which determined emissions by measuring wind speed and gas concentration in the proximity of emission sources (one or a group of coal mines). In this method, the crosswind profile of the CSG plume was assumed. Wind speed and gas concentration were measured using an instrumented vehicle (Fig. 1). The traverses were made in the early morning (around sunrise), when mixing heights were about 50 to 100 m and methane (CH_4) concentration in the plumes was at its highest. Wind direction was measured by releasing small helium-filled balloon at the start of each traverse, while wind speed was measured with a tethersonde, which was raised to about 100 m above the ground. Our measured data were supplemented with routine meteorological measurements that some of the mines carried out as part of their operations. The ability to carry out the traverse was limited by adequate access around the perimeter of the mine, and the timing of the vehicle traverses was subject to mine operational requirements.

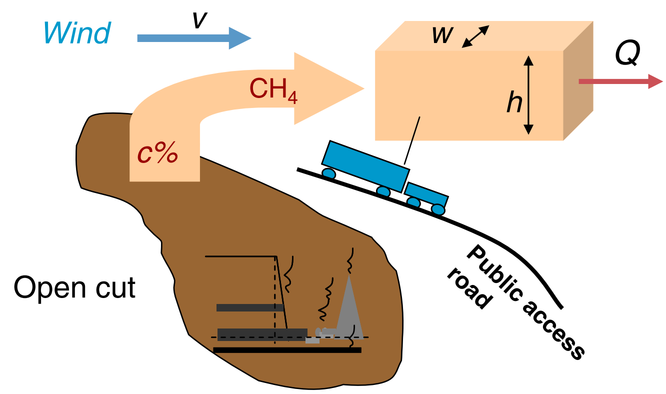

Fig. 1. Schematic of direct measurement of surface mine emissions using an air pollution technique (Saghafi and Williams, 1992; Williams et al., 1993).

If a rectangular plume with a width of *w* and a height of *h* is assumed, then the rate of gas emissions, *Q*, can be calculated as follows:

$$Q = c\,h\,w\,v \tag{1}$$

where *c* is the average cross-wind CH_4 concentration, and *v* is the wind speed. The vehicle was driven crosswind along available public access roads in the proximity of the mine lease. CH_4 concentration was averaged using a Gaussian distribution function.

Global emission measurements were undertaken using the technique illustrated in Fig. 1 at ten mines of the Bowen Basin and seven mines of the Sydney Basin (Hunter Coalfield). CH_4 was detected from all 17 open cut mines visited. The concentrations of CH_4 due to mine emissions were generally limited to 0.05–0.40 ppm for the 10 Bowen Basin mines and 0.10 to 5.50 ppm above the background concentration for the seven Sydney Basin open cut mines.

Fig. 2 shows the distribution of measured CH_4 emissions over the coal production for the ten Bowen Basin mines. These measurements were undertaken during the CSIRO field investigation campaign of 1990–92 in the Bowen Basin. Table 1 reports the raw coal production and measured emissions for these ten mines, which underwent the direct measurement of emissions. The visited mines produced 4.0 to 12.5 Mt of raw coal per year at the time of measurement (1992–93). Total coal production from these ten mines was approximately 68 Mt in the financial year 1991–92.

Measured CH_4 emissions from these open cut mines varied largely from 1.5 to 25.4 million m^3 (Mm^3) per year, totalling about 78 Mm^3

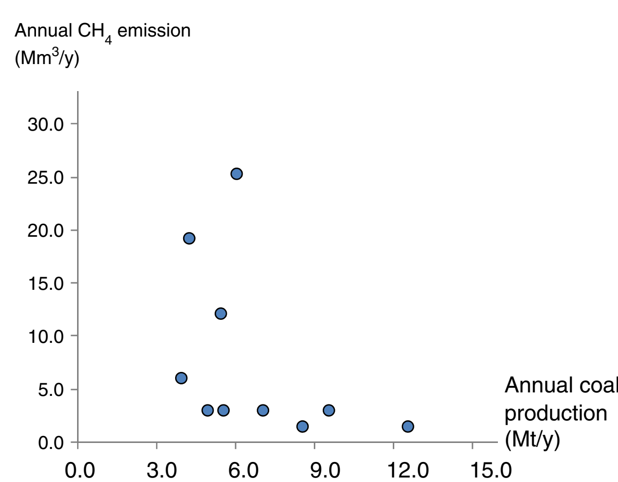

Fig. 2. Distribution of measured fugitive CH_4 emissions for ten open cut coal mines in Queensland, Australia (modified from Saghafi, 2008; Saghafi and Williams, 1992).