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Greenhouse gas emissions from shallow uncovered coal seams

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ABSTRACT

This study discusses a method of quantifying emissions from surface coal mining that has been trialled in Australia. The method is based on direct measurement of surface emissions from uncovered coal seams in mine pits, concurrent measurement of residual gas content of blasted coal in mine pits, and measurement of pre-mining gas content of the same seam from cores retrieved from exploration boreholes drilled away from active mining. The results from one of the mines studied are presented in this paper. In this mine, the pre-mining gas content of the target seam was measured using cores from an exploration borehole away from active mining. Gas content varied from 0.7 to 0.8 m^3/t and gas composition varied from 16% to 21% CH_4 (84–79% CO_2). In-pit measurements included seam surface emissions and residual gas content of blasted and ripped coal. Residual gas content varied from 0.09 to 0.15 m^3/t, less than twofold across the mine pit. Composition of the residual gas was in general 90% CO_2 and 10% CH_4, with slight variation between samples. Coal seam surface emissions varied from 1.03 to 7.50 mL of CO_2-e per minute and per square meter of the coal seam surface, a sevenfold variation across the mine pit.

1. Introduction

Australia produces 400×10^6–500×10^6 tons of bituminous coal annually with about 79% from open cut mining (surface mining) in terms of *Australian Atlas of Minerals Resources, Mines and Processing Centres*. Although the gas content of Australian coal seams at shallow depths (mostly less than 100 m) is low, the emitted gas from a surface mine can be significant, in view of significant volumes of overburden and coal seams removed and mined. When overburden, which contains organic-rich horizons and uneconomic coal seams, is blasted and removed, large amounts of gas are released from coal seams. Gas is also released from uncovered and exposed coal seams.

Over the past two decades, several Australian studies have attempted to quantify emissions from coal mining [1–5]. While the determination of emissions from underground mining has been quite straightforward, quantifying emissions from surface mining has been a significant challenge. This is because the numerous sources of emissions are spread over large area (Fig. 1), and estimation are generally associated with significant uncertainty [1,5]. This paper presents the results of a study that was part of a succession of projects to develop a practical accurate method of estimating fugitive emissions from coal mining. In the course of this study, a direct method of measurement of gas escape from uncovered coal seams in mine pits was developed, and mine emissions were estimated based on the gas release rate from uncovered coal seams. Concurrent residual gas contents of samples from blasted and ripped coal seams in mine pits were also measured to indicate lost gas during the removal of overburden strata.

In the next sections, after a brief description of the methods of measurement of gas content and surface gas emissions from uncovered coal seams, the method applied to an open coal mine in the Hunter Coalfield is presented. At the time of this study this coal mine was extracting coal from a depth of 60 m.

2. Methods

The objective of this study was to determine whether it is possible to estimate fugitive emissions from an open-cut coal mine based on measuring the gas remaining in a coal seam (residual gas content) once the overburden has been removed, together with the direct measurement of the emission rate from the surface of the uncovered coal seams.

2.1. Measurement of gas content of coal

Large lump samples of coal, at least a few kilograms in mass, were collected from a target coal seam as soon as the seam was uncovered and blasted. Coal samples were then sealed in purpose-built, gas-tight canisters. The gas contents of coal were determined in three stages, using a fast desorption method [6,7]. This

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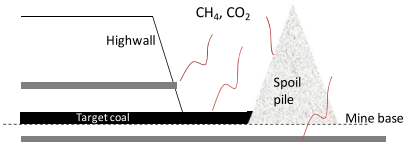

Fig. 1. Greenhouse gas emitted from numerous sources across an open cut mine.

method significantly reduces the time of measurement and increases the accuracy of the determination [8]. Measurements were generally done at the mine site inside an equipped mobile gas laboratory (Fig. 2).

The three stages of gas content determinations deliver three components of gas content.

$$Q_m = Q_1 + Q_2 + Q_3 \quad (1)$$

where Q_1 is the lost gas during collection of the sample before sealing it in a gas-tight canister; Q_2 the gas desorbed in the canister; Q_3 the gas desorbed during crushing of the coal sample; and Q_m the sum of the these component.

2.2. Measurement of rate of emissions from coal surface

The gas emitted from an exposed coal seam surface is collected in an instrumented chamber placed onto the coal surface. The edges of the chamber in contact with the coal surface was partially sealed using fine coal particles (Fig. 3). Ambient air was sucked into the chamber at a constant flowrate (F_{air}) to dilute excessive gas concentration, and the concentration of CH_4 and CO_2 gases in the chamber were continuously measured over a given period of time. The flux of gas (F_g) is calculated using the temporal concentration of gas in the chamber (c) and background gas concentration outside the chamber (c_b), at an elevated position not affected by surface emissions:

$$F_g = \frac{F_{air}}{A}(c - c_b) + \frac{V_c}{A}\frac{dc}{dt} \quad (2)$$

where A is the area of the chamber base in contact with the coal seam; and dc/dt the variation in gas concentration inside the chamber with time.

Fig. 2. CSIRO mobile gas laboratory for measurement of gas content of coal on mine site.

Fig. 3. Gas emitted from exposed coal into an instrumented chamber that monitors gas concentration over an extended period of time.

3. Results

Surface emissions from an in-pit uncovered coal seam and the gas content of blasted coal were measured at coal mines of the Hunter Valley Coalfield in New South Wales, Australia. The results from one of the participating mines are reported here.

3.1. Gas content of blasted coal from uncovered coal seams

Blasted lump coal samples were collected from five locations in the pit and measured for the remaining gas content of coal. The seam had been exposed for about three days before the samples were collected. The gas desorbed from coal was a mixture of CH_4 and CO_2, with the latter being dominant. Table 1 shows that the gas content of blasted coal varies between 0.09 and 0.15 m^3/t, with an average gas content of 0.12 m^3/t. The average gas composition of the desorbed gas is 10.2% CH_4 and 89.8% CO_2.

3.2. In situ pre-mining gas content of coal

To evaluate the amount of gas released from targeted seam during the removal of overburden strata, an exploration surface borehole a few kilometres away from the mining area was drilled to a depth of 100 m and crossed a number of coal seams. The gas contents of the seams varied from 0.4–3.7 m^3/t with larger gas contents corresponding to the deeper seams. Gas composition varied with depth, from almost pure CO_2 near the ground surface to 90% CH_4 at the depth of 95 m. At a mining depth of about 60 m, the measured virgin gas content of the targeted seam was 0.80 m^3/t. About 18% of this gas was CH_4 and 82% was CO_2.

3.3. Gas emissions rate from exposed coal

Emissions from the exposed coal surface were measured as soon as a coal seam in the pit was uncovered. However, mining conditions and safety issues did not allow immediate access to the sites. Access to the sites is required for the relatively long period of time (several hours) to deploy equipment and monitor of gas concentration evolution in the measuring chamber. Measurement of surface emissions were possible 2–3 days after the seam was uncovered. Table 2 presents the measurements of surface emissions in five locations. The overall emitted gas consists of 1.6% CH_4 and 98.4% CO_2. The difference in composition of the gas desorbed from gas content testing and that from surface emissions

Table 1
Gas content of blasted coal.

Location	Gas content (m^3/t)	Gas composition (%)	
		CH_4	CO_2
Location a	0.15	10.3	89.7
Location b	0.15	9.5	90.5
Location c	0.13	9.5	90.5
Location d	0.09	10.8	89.2
Location e	0.09	10.6	89.4
Average	0.12	10.2	89.8
Standard deviation	0.03	0.6	0.6