

Environmental risk assessment in coal mining with methane degassing

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Abstract. The environmental directives within the European Union consider the necessary environmental protection, establishing strict protocols for controlling methane emissions in mining operations. On the other hand, the exploitation of coal mines has found in the degasification of methane an end in itself, providing a fuel of undoubted energy value that can be easily transformed into electrical or calorific energy. All this must be accompanied by a mining control that establishes the extraction of methane and the prior degasification of the layers as a fundamental task to guarantee the safety of coal mining. Following developments under the Research Fund for Coal and Steel “DD-MET” project (Advanced methane drainage strategy-technology employing underground directional drilling technology for major risk prevention and greenhouse gases emission mitigation), this paper will analyze the related problems, establishing a comparative scenario between Polish and Spanish mines. In Polish mines, it is essential to ensure maximum methane extraction, as the degassed methane has a high economic value in long shafts, while in Spanish mines, the priority is to minimise degassing to control the environmental impact of closed mines.

1.- Introduction

Methane is the main contributor to the formation of ozone which is a dangerous air pollutant, exposure to which causes 1 million premature deaths each year. In addition, methane is also a powerful greenhouse gas. However it can have positive effects, the methane can be a resource to generate electrical energy or steam for industrial purposes or domestic uses.

For these reasons it is important to carry out an assessment of the possible environmental impact of methane whenever you work with it and therefore in coal mining. In the case of coal mining, methane can be found in different situations. It may be associated with coal seams in methane pockets. It can be found infiltrated in the coal seams (it is extracted by degassing). It can crawl into the mine vent. And finally it can be released in the closed mines.

Obviously the presence of methane will be associated with the state of the mine and therefore its control and environmental impact will depend on each particular case. The best way to control its environmental impact is to capture and extract it in a controlled manner but sometimes methane is found in places that we do not know or cannot access to extract it, so

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it is also necessary to carry out measurements on the surface to verify that methane levels do not suppose a danger to people or the environment.

There are three main processes to get natural gas production where methane is recovered from coal seams [1].

1. Coal Bed Methane (CBM) refers to the recovery of natural gas from unmined coal seams. The methane is recovered by injecting carbon dioxide or nitrogen.
2. Coal Mine Methane (CMM) refers to the recovery of methane from active mines, either as pre-drainage prior to coal extraction, or, from the disturbed strata immediately following coal extraction.
3. Abandoned Mine Methane (AMM) refers to the removal of methane following cessation of coaling operations and mine closure.

The three processes are illustrated in Fig 1 [2].

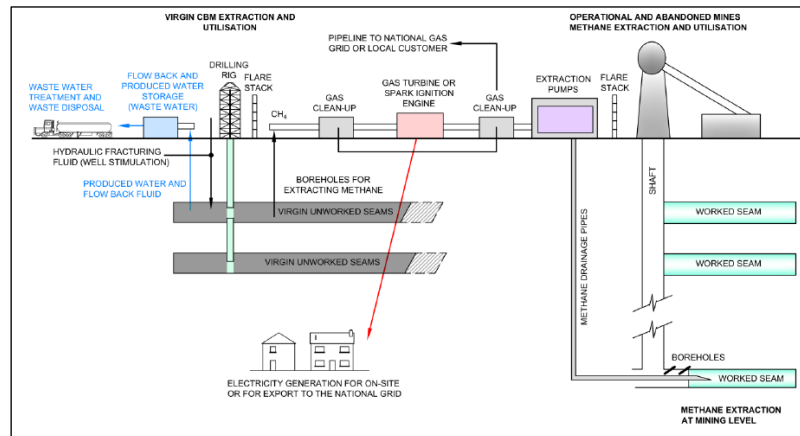


Figure 1: Options for methane extraction and utilisation (adapted from DTI 2001a)

2.- Management of methane in two cases studies: Mysłowice Wesoła coal mine (Poland) vs Nicolasa coal mine (Spain)

The measures for the protection of the environment against methane that are adopted in the exploitation of a coal mine are directly linked to the role that methane plays in the exploitation, ranging from a simple control of its concentration on the surface to complex underground mines. in which methane is used as a resource for power generation.

In this article we present the cases of the Wesola (Poland) and Nicolasa (Spain) mines in their performance against methane and environmental control (see Fig. 2).



a) Mysłowice-Wesoła coal mine



b) Nicolasa coal mine

Figure 2. Pozos a) Mysłowice-Wesoła shaft y b) Nicolasa shaft

Wesoła (Poland) is a large mine in the south of Poland in Katowice, Silesian Voivodeship, 260 km south-west of the capital Warsaw and owned by Polska Grupa Górnicza, PGG.

Mysłowice-Wesola represents one of the largest coal reserve in Poland having estimated reserves of 232 million tonnes of coal. The annual coal production is around 3 million tonnes. The Wesola mine has one main shaft and several support shafts for mine ventilation and other auxiliary activities. Wesola uses longwall and header mining system exploitation.

Nicolasa coal mine is the last active coal mine in Asturias in which 400 people work in three main shafts. Nicolasa is owned by the public company Hunosa. Nicolasa is the main shaft of the mine and produces 150.000 tons of coal to supply the nearby thermal power station of La Pereda. The Nicolasa shaft will stop producing as soon as Hunosa obtains 50 MW in the renewables auction, at which time it will feed the power plant with biomass. Monsacro shaft is close to Nicolasa shaft and it's used for the ventilation of Nicolasa mine. Finally, Barredo shaft, as Monsacro shaft is used for the ventilation of the mine and for feeding a District Heating with warm water. Currently several schools and a hospital benefit from energy savings from the geothermal use of mine water from Barredo shaft. Nicolasa uses soutirage system exploitation.

Close to both mines there are a thermal power stations (see Fig 3).



a) Wesola power plant

b) La Pereda power plant near Nicolasa

Figure 3. Power plants a) near Wesola shaf and b) near Nicolasa shaft.

In the table below we can see the comparative situations of Wesola mine and Nicolasa mine (see Table 1).

Table 1. Comparison of mining and energy exploitations.

	Wesola coal mine	Nicolasa coal mine
Mine activity	Longwall method In coal exploitation	Soutirage mining In the process of closing scheduled for 2023
Control de metano	Extraction and drainage of CH ₄ employing underground directional drilling technology	Superficial control of emissions CH ₄ .
Power generation.	Electricity Generación with coal and gas.	<ul style="list-style-type: none"> • The attached power station is fueled by coal, but in the recent future the power station will be feed with biomass. • Hot water for Distric Heating

3.- Coal mine methane drainage and degasification .

Around 95% of the methane present in the coal seams is adsorbed on the internal surface of the coal by the Van der Waals forces existing between the methane molecules and the carbon particles. It is estimated that coal has an internal surface of 50 to 2,500 m²/g, due to the nanometric size of its abundant micropores, a fact that gives it a great methane adsorption

capacity. The remaining 5% is in free form in the cracks, fissures, and fractures that exist within the coal seam.

When a hole is created inside the mine, a pressure relaxation zone is produced around the hole, which in turn is surrounded by another zone of overpressure. These changes cause the appearance of fractures in both zones, causing methane to flow into the hole. First of all, the free gas from the cracks will do so. And then the adsorbed gas moves slowly towards the cracks and from them to the gap. This phenomenon is called degassing.

In the case of Wesola, this degassing process is carried out before to starting the coal for its energy use. To do this, a series of boreholes are carried out on the wall and on the roof of the coal seam to collect both the methane from the fissures and the absorbed methane. The collected methane is taken abroad through a transport network that works in depression to the filtering plant and pumping to the gas network. The process that is carried out in depression minimizes the possibility of methane leaks to the surface. In the event of an extraordinary flow of methane or a failure in the filtering and pumping plant that could give rise to a methane explosion, it can be burned in a controlled manner with the environmental risks that may occur in a plant that burns gas to produce energy

Experience in industrialised countries shows that investment in good gas drainage practices results in less mine downtime due to gassy mine conditions, safer mining environments, and the opportunity to utilise more gas and reduce mine methane emissions.

Gas purity of less than 30% methane in air should be considered unacceptable for both safety and efficiency reasons. The maintenance of gas purity in underground drainage systems depends on the quality of borehole sealing, the systematic regulation of individual boreholes, and the suction pressure applied at the surface extraction plant. Increasing suction in an effort to increase gas flow will introduce more air and hence reduce the gas purity, so it could be more interesting to reduce the flow to improve gas purity [5].

To avoid the possible ignition of explosive atmospheres, action is taken on several ways. On the one hand, the mine ventilation is acted on to insufflate clean air from outside that dilutes the methane concentration below 5%. Concentration at which the explosive atmosphere ceases to be dangerous. The control of the concentration is carried out with methanometers or greymeters. When the coal is ripped, it will be partially degassed and will continue to degas while being transported outside. The speed with which it degassing depends on various factors such as the granulometry of the coal, the temperature and its concentration. The methane that is released in this degassing process is diluted in the atmosphere by mixing with the air from the ventilation. Therefore, its environmental risks are controlled by safety measures for explosive atmospheres formed by methane.

Remember that ventilation, in addition to controlling the concentration of methane gas and other flammable and toxic gases, its objectives are to deliver breathable fresh air to the workers, control mine air temperature and humidity and remove dust. Methane is considered the principal pollutant and the most hazardous gas for ventilation system specifications. If the selected ventilation system design is capable of removing or satisfactorily controlling the primary pollutant, it is assumed that the lesser pollutants will be adequately controlled or removed at the same time.

Generally, air is drawn (sucked) through a mine by exhaust fans located on the surface. Thus, the air pressure in the mine is below atmospheric pressure. In the event of fan failure, the ventilation pressure in the mine rises, preventing an instantaneous release of gas from worked areas.

On the other hand, action is taken to avoid sources of ignition of explosive atmospheres using equipment and materials specially designed according to article 43 of DIRECTIVE 2014/34/EU, of the European Parliament and of the Council, of February 26, 2014, by which They establish the essential health and safety requirements [3].

Finally, if we have not managed to prevent the ignition of the explosive atmosphere, protection measures are available to reduce the propagation of an explosion after it has occurred and are important second lines of defense. Post-failure methane mitigation is no substitute for prevention.

In addition protection measures we have the use of explosion-proof enclosures that prevent the possible propagation of an explosion inside a machine. These preventive measures can be complemented with the use of barrier devices in the galleries that prevent an explosion from spreading to the rest of the mine, such as the dispersion of water or inert rock dust to cool and extinguish it.

4.- Comparative analysis of the environmental control of methane between Wesola and Nicolasa.

Regarding the exploitation and use of methane gas, both are currently in different situations. At Nicolasa no use is made of methane gas and only a double control of its presence is carried out, on the one hand its presence is controlled in the work galleries and in the ventilation networks to prevent the formation of explosive atmospheres and on the other. On the other hand, a control is carried out at the surface level to detect possible methane leaks due to the fracturing of the ground by the action of mining activity.

In Wesola, the situation is totally different, methane being a resource that is exploited for power generation. The environmental control of methane is carried out at three levels. On the one hand, as in Nicolasa, it is necessary to control its concentration in the working galleries and in the ventilation networks (see Fig. 4) and on the surface due to leaks that may occur through fracturing of the land by mining action. But in Wesola there is also a third control performance throughout the network of the degassing process.

Methane is an explosive gas in the range of 5% to 15% methane in air. Its transport, collection, or use within this range, or indeed within a factor of safety of at least 2.5 times the lower explosive limit and at least two times the upper limit, is generally considered unacceptable because of the inherent explosion risks.

The primary aim of gas control systems is to prevent explosions and asphyxiation risks in underground coal mines. Controlling methane at an active longwall face so that methane concentrations in the return airway do not exceed 1% generally requires only using ventilation techniques. However, if higher methane flows are expected from the working face, a combination of ventilation and methane drainage must be used.

If content of methane is above 2%, it is necessary to: turn off the electrical network, immobilize machines and other devices, notify the nearest traffic supervision person, take additional measurements to determine the cause of exceeding the methane concentration, and control the accumulation of methane.

Increasing the differential surface fan pressure applied at a mine may have only negligible effect on airflows in the most remote parts of the mine. For this reason, increasing surface fan pressure may not solve a problem of shortfall in ventilating airflows in remote working areas.

Suppose methane content above 3% is found in the excavation. In that case, it is necessary to: turn off the electrical network or cause it to be turned off by the dispatcher, immobilize machines and other devices, notify the closest traffic supervision person, immediately withdraw people from the endangered excavations, and carry out combating the accumulation.

If, as a result of measurements above the casing, the content of 5% methane or more is found, the following should be done: immediately stop work in the excavation, conduct additional measurements to determine the size of methane accumulation and methane outflow places, notify the nearest traffic supervision person and take steps to eliminate the risk.

desorbing. In addition, the exploitation of coal itself, and the development of the mine itself, is opening new fronts, and therefore more points for that can be desorbing methane. Unfortunately, before the imminent end of the exploitation of carbon, it makes no sense to tackle projects so dependent on mining activity.

In the case of anomalous measurements above the permitted values, it is necessary to check the sealing of the galleries and, in any case, check the facilities so that deep coal combustion does not take place. In some cases, combustion has been detected in old mining pits and even in debris that can significantly affect the environment.

In these cases, superficial measurement procedures can range from sampling with methane measuring devices located on the ground, fixed or drone-mounted infrared cameras. Also the incorporation of sensors in satellites have allowed a more extensive detection [7]. Obviously, the further away the device with which we make the measurements, the less accuracy we will have.

Table 2 – Operational CH₄ monitoring satellites with public data access

REGION, ORGANIZATION MISSION AND INSTRUMENT			GHG MONITORED DIRECTLY		
Region	Organization	Mission	CO ₂	CH ₄	N ₂ O
Canada	CSA-ESA NASA	SciSat-1 (ACE)	☑	☑	☑
Europe	EC - ESA NSO	Sentinel-5P (TROPOMI)		☑	
Europe	EUMET SAT	Metop-A/B/C (IASI)	☑	☑	☑
Italy	ASI	PRISMA (HYC)	☑	☑	
Japan	JAXA - MOE NIES	GOSAT (TANSO-FTS)	☑	☑	
Japan	JAXA - MOE NIES	GOSAT (TANSO-FTS2)	☑	☑	
US	NASA	Aqua (AIRS)	☑	☑	

Tropospheric Monitoring Instrument (TROPOMI) was launched as single payload aboard the Sentinel-5 Precursor satellite in a Sun-synchronous orbit with an overpass time of 13:30 local solar time at approximately 824-km altitude and has an expected mission lifetime of 7 years [6]. TROPOMI is a push-broom imaging spectrometer with a wide swath of 2,600 km and a ground pixel of 3.5 × 7 km at the subsatellite point (see Fig 5 and Fig 6) [8].

Absorption of solar light by CH₄ as observed in the reflected radiances allows for the retrieval of the CH₄ atmospheric abundance provided that the lightpath (see Fig 7).

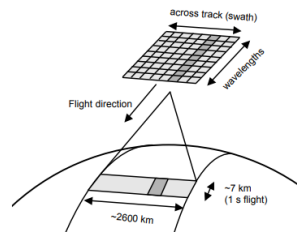


Figure 5. Sensor TROPOMI (Sentinel5P).

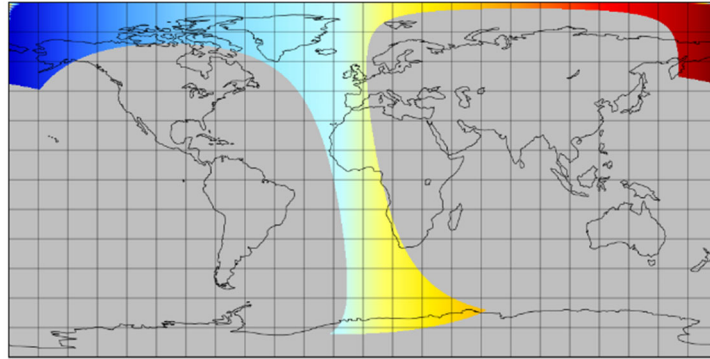


Figure 6. Measurement area of the Sentinel5P over Spain

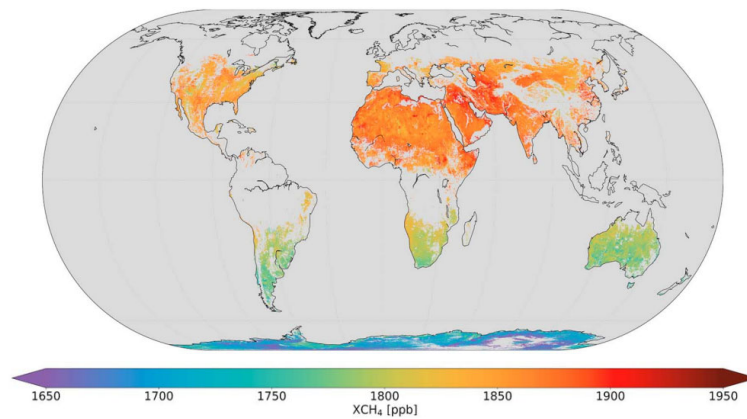


Figure 7. Cocentration of CH₄ considering column averaged dry air mixing ratio of methane [8].

There are also indirect measurement methods such as determining the methane concentration by measuring other gases such as CO₂ that have been formed by the combustion of methane. Situation that can occur in the dumps that are on fire.

5. Conclusions.

Although methane is one of the main gases that causes the greenhouse effect, mining activity is not one of its main contributors since when its presence in coal mining is high, it is exploited as an energy resource, otherwise its presence is in low concentrations that are diluted in the air without causing any increase in ambient temperature.

Coal mining operations have a double check on methane emissions. On the one hand, due to the need to avoid the presence of explosive atmospheres and, on the other hand, the measurements on the surface.

Distinguish between Poland and Spain:

In Spain, mining is in decline, so emissions have to decrease. The use of methane only has makes sense in a context of active mining, since this needs to be operating a ventilation that drags all the methane that the different layers of carbon. In addition, it is necessary to gradually open new coal layers and develop the mine, with new fronts that reactivate the desorption of the carbon layers. Unfortunately, given the imminent end of coal exploitation, it makes no sense to address projects so dependent on mining activity.

In Poland, with a mining industry that continues to maintain its strength, an exploitation horizon is still wide, a detailed control of the installation of the methane collection network up to the pumping plant is also necessary. These facilities are subject to the dynamics of the mine itself, with successive extensions, both due to the progress of the exploitation work and the closure of the already exploited workshops.

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