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An Analysis of Blasthole Condition towards Toxic Fumes Generation from Blasting Activities in Surface Mine

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Abstract. One impact of blasting activities is the release of toxic fumes capable of disturbing living creatures around the blasting zone. Fumes are affected by several factors, including blasthole conditions. Measurement for this research was performed in a coal mine called PT. Kaltim Prima Coal in Kalimantan, Indonesia, to investigate the impact mentioned above through a quantitative method, which was performed directly in the field. The results show that the formed CO gas level ranged between 60.34 – 360.29 ppm, while the formed NO2 gas level ranged between 0.3 – 3.16 ppm, with average temperature and relative humidity of the blastholes at 31°C and 77.01%, respectively. Based on these results, the temperature and relative humidity conditions in the blastholes have a linear effect on the formation of toxic fumes by 84%. Considering the average wind speed at the measurement sites was 2.14 m/s, the trend of decreasing toxic fumes, time variables, and threshold limit values of exposure for humans of up to 15-minutes, it can be concluded that the safe time for workers to return to the site is less than 1 minute.

1. Introduction

Blasting is a method extensively used in civil engineering and mining industry. Apart from its efficiency in dismantling rocks, it also has several adverse impacts on the environment and humans (workforce) [1], [2]. Direct adverse impacts from this conventional rock dismantling method are flying rocks, ground vibrations, excess air pressure, broken backbone, and generation of fumes [3]–[5]. Fumes are gases having toxic properties due to the imbalanced chemical reaction during blasting activities. The gases formed are CO and NOx. Both post-explosion fumes are direct products of the detonation process. The release of these fumes can negatively affect human health and safety and the environment within the radius of the blast sites [6]. Since NOx is unstable and soluble in air, its concentration will decrease rapidly after air movements, such as wind and ventilation. CO is relatively more stable, however, it is the main cause of poisoning. Once the CO concentration reaches its peak, it will not disappear quickly. It will take time to disappear, and this dynamic affects worker safety [7].

NO_X is nitrogen oxide (NO) and nitrogen dioxide (NO_2). These gases are hazardous and capable of causing severe health risks to the exposed workers. There is a difference between nitrogen oxide and nitrogen dioxide in terms of exposure effect towards the humans body. An example of this difference is the hazardous threshold concentration (ppm) and length of exposure of each toxin. NO2 with a concentration of 805 ppm can cause lethal choking in just 15 seconds of exposure, while NO with a concentration of 8,000 ppm and an exposure time of 60 seconds only causes loss of consciousness. [8]. Many studies and measurements on fumes, especially in underground mines, have been done for the past few years. Analysis 11 toxic fumes generation in underground mines has been developing rapidly, one of which is by using a one-dimensional mathematical model and three-dimensional CFD numerical simulations to analyze the concentration and movement of fumes from blasting activities. [9], [10]. However, only a handful of measurements and analyses are carried out in open-pit mining with the application of the same methodology, i.e. qualitative methodology through visual observation of the types of the formed toxic fumes to determine the hazard level. [1], [8], [11], [12]. Research progresses on the toxic fumes measurement between open-pit and underground mines are significantly different [13].

Classification of toxic fumes generated from explosions based solely on visual observations cannot be used as a standard representing the level of hazard toxic fumes may pose. Based on the results of measurements using a gas detector, the white toxic gas still contains CO and NO_2, making it highly hazardous for mine workers, especially the blasting crews who carry out post-blast inspection [14]. Furthermore, the colour of the blasted fumes cannot be adequately classified due to the dust generated by the cutting materials from blasthole drilling. The formed dust makes it challenging to distinguish gasses. Therefore, clear measurement standards are needed to measure toxic fumes formed in open-pit mines. Standard methods to measure the level of toxic fumes resulting from explosions that can be performed safely, quickly and accurately are also required. This research was conducted in PT. Kaltim Prima Coal (PT. KPC), a coal mine in East Kalimantan, Indonesia.

2. Methods

The research was conducted using action research and experimental methods with qualitative and quantitative approaches. The action research method aims to calculate the levels of toxic fumes formed from detonation, and the experimental method aims to find the right way to collect toxic fumes data.

2.1 Research Site

PT Kaltim Prima Coal, also known as PT KPC, is a company operating coal mining activities by applying the open-pit mining method and selling coal to domestic and international customers from various industrial sectors. PT KPC can produce more than 50 million tons of coal per year, while it requires blasting activities as a method of excavation. PT Kaltim Prima Coal exports most of its products to various countries in Asia, America, Europe, and the Mediterranean. At the same time, it only sells approximately 3% of its total production in the domestic market. The location of this research is PT KPC, Sangatta Sub-district, East Kutai Regency, East Kalimantan Province, Indonesia.

2.2 Post-blast fumes

Post-blast fumes are toxic nitrogen oxides and direct byproducts of the detonation process. We can easily identify it as a yellow or orange post-blast cloud. Nitrogen oxides can also be produced from burning reactions and secondary oxidation of NO to NO2 as the post-blasing fumes are mixed with air. The most commonly used explosive product in the mining industry is ammonium nitrate fuel oil (ANFO) [8].

2.3 Blasthole temperature, relative humidity and wind velocity

Data collection on the temperature and humidity of the blastholes was carried out before filling explosives into the holes [15]. We measured temperature and humidity in the blastholes using the TSI 9545-A. The measurement was carried out by inserting a probe into the blastholes at a minimum depth of 3 inches (7.5 cm) from the hole mouth to improve the accuracy of the measurement results (TSI Velocity Calc operation and service manual). The measurement took place until the temperature and humidity were constant, approximately 10 seconds after the insertion probe was inserted into the holes.

Wind direction and speed data were collected before blasting. Wind direction is determined through flag direction in the blasting area, and wind speed is measured using an anemometer, Krisbow KW06-653. The speed measurement was carried out at the higher elevation blasting area, such as an

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embankment confining the blasting area. The measurement lasted for ±10 minutes to ensure accurate results. In addition, wind direction and speed measurements are used as supporting data in drawing a toxic fumes distribution map and determining the level of post-detonation toxic fumes reduction during the measurement.

2.4 The levels of CO and NO_2 fumes generated from the blasting

Wind direction must be considered when measuring the toxic fumes generated from the blasting. Therefore, a drone was used in the measurements. Therefore, the drone's flying route must be opposite the wind to allow the toxic fumes to move towards the drone. The drone used was the DJI Phantom 4 Pro+ with a maximum speed (S) of 45 m/hour, a maximum altitude of 500 m, and a maximum remote-control range of 4 miles (6.4 km). A gas detector was tied using rope to the drone leg, as shown in Figure 3a. The drone flew immediately after the detonation was performed. Since PT AEL Indonesia used an electronic detonator product, the frequency of the drone signal could interfere with the detonation. The gas detector used was the MSA Altair 5x, which can measure CO, O_2, H_2S, and NO_2 gases, and the alarm limit levels can be set for STEL, TWA, and high alarm conditions, as shown in Figure 1a. MSA Altair 5x can measure CO gas up to 2,000 ppm, NO_2 up to 20 ppm, and H_2S up to 200 ppm. The droneand the MSA Altair 5X gas detector used in the measurement are available in Figure 1b.

(a) (b)

Figure 1. Tools for measurement a. Gases measured by MSA Altair 5x; b. Drone used to carry

3. Results and Discussion

3.1. Blasthole and Weather Conditions

This study measures blasthole temperature and humidity as supporting factors in toxic fumes generation. The temperature and humidity values in the blastholes are strongly affected by the weather and conditions of the blastholes. Wind direction and speed were measured to determine the direction and distance of the fumes' movement at a specific time and to predict the locations significantly affected by the fumes scattered in the wind direction. Data on wind direction and speed were measured before the blasting. Wind direction data was used as supporting data in measuring fume levels using a drone, while wind speed data was the basis for predicting fume movement. Table 1 shows the temperature and humidity of the blastholes and the velocity of wind in every blasting location.

Table 1. Blastholes, wind and fumes conditions for every location

Date (2019)	Location	Temperature (°C)	Relative humidity (%)	Wind velocity (m/s)	Number of wet holes	Percentage of wet holes (%)	CO (ppm)	NO_2 (ppm)
23 Nov	Peri 309	31.61	75.91	2.46	16	7	150.86	1.05
25 Nov	Tania 549	32.67	72.92	2.02	140	92	111.81	0.30
28 Nov	Melawan 098	28.92	82.53	1.83	48	40	324.79	2.11

30 Nov	Tania 558	29.73	79.3	2.68	0	0	195.23	1.80
3 Dec	Melawan 108	31.09	74.21	3.61	128	78	60.34	0.75
5 Dec	Melawan 110	30.84	77.39	2.13	80	67	207.65	1.35
7 Dec	Peri 323	30.91	74.43	1.00	0	0	76.32	1.05
15 Dec	Tania 573	31.91	75.58	2.58	32	23	90.52	0.45
16 Dec	Peri 326	31.38	78.89	1.92	97	78	227.18	1.50
18 Dec	Melawan 130	30.3	76.51	1.31	83	58	95.84	1.20
23 Dec	Tania 577	31.03	75.51	2.05	58	98	115.36	0.45
26 Dec	Peri 338	31.63	80.94	2.19	24	27	243.15	1.95
31 Dec	Mustahil 148	31.23	75.58	1.08	10	20	360.29	3.16

When this research was conducted, rainfall was high enough to result in high humidity values in the blastholes because rainwater entered the blast holes. The measurements were carried out in different weather conditions; sunny weather, with temperatures ranging from 33°C - 36°C and humidity ranging from 65% - 73%; cloudy weather, with temperatures ranging from 30°C - 32°C and humidity ranging from 73% - 78%; and the weather after rain with temperatures ranging from 27 - 30°C and humidity between 78% - 85%.

3.2. Fumes Measurement

The method of fume level measurements using a drone was considered very effective and safe. The measurements were performed in safe blasting-distance areas of 500 meters. The drone was released to fly after detonations were conducted in the areas because the drone signal could interfere with the Base Station signal. Gas contents measured in every blasting location are available in Table 1. We used visual weighting or fume classification as a standard because no other standards are available to classify fumes generated from blasting in open-pit and underground mines based on their contents, as shown in Figure **4.** Fumes are classified based on visual observation of the colour of the generated fumes, in which the colour indicates the hazard level of the fumes [8].

3.3. Analysis

Weather and the materials in the blasting locations affect the temperature and humidity of the blastholes. The blastholes' humidity has an average value of 70% - 80%. High moisture values found in the blastholes are caused by the presence of water in the holes, which is due to the high groundwater level at the locations and rainwater. High-water content in the blastholes causes a decrease in blastholes temperature, so water vapour formation increases the humidity value in the blastholes. Based on the results of the fume level measurements by a drone, the greater the humidity value of the blastholes, the higher the fumes content is.

Based on the linear regression value shown in Figure 2, a hypothesis can be drawn: blasthole's humidity affects Zero Oxygen Balance conditions in explosives, resulting in Negative Oxygen Balance or the explosive mixture lacking oxygen value and resulting in CO gas. A deeper analysis of the effect of hole humidity on chemical mixture and reactions of explosives is required. Thus the hypothesis that blasthole humidity reduces the oxygen content in explosives and explosive reactions can be proven. Blastholes humidity in other mine sites needs to be investigated, as each has different conditions. Meanwhile, different conditions in mine sites lead to valuable materials and minerals diversity. The average condition of the blasthole in every wet blasting location is caused by the presence of water in it, as shown in Table 1. The use of S320 DRN 100 Eco emulsion with an emulsion percentage of 80%

and AN-prill 20% has increased the level of explosive resistance to water. Therefore, wet blastholes resulting from water presence do not affect the formation of toxic fumes.

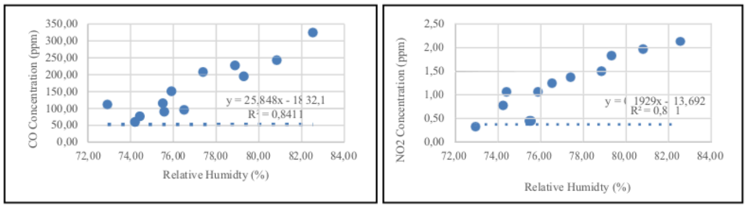

Figure 2. Graphic of relative humidity to the formation of NO_2 and CO gas

The number of blastholes filled with water was affected by weather and the presence of groundwater in rocks. A high percentage of holes filled with water can affect the temperature and humidity of the blastholes due to the increased water level in the blastholes. Based on measurement data of the water content in rocks tested at PT KPC geotechnical laboratory, a comparison can be performed against the level of toxic fumes formed using a linear regression equation, as shown in Figure 3.

The linear regression value of the water content factor in the rock on the formed CO and NO2 gas content has a low level of confidence (R2). This is because the water content measurement in rocks using drilling and cutting samples did not reflect the actual conditions in the blastholes, while measurement provided less accurate data. Therefore, the water content in rocks does not significantly affect the formation of toxic gases (fumes) generated from blasting.

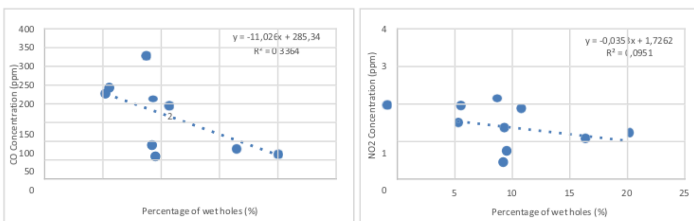

Figure 3. Graphic of wet hole percentage to the NO_2 and CO gas formation

4. Conclusion

The blasting fumes formed during blasting activities in PT KPC are CO gas and NO2 gas. The maximum CO gas content formed due to blasting activities is 360.29 ppm, while the maximum NO2 gas content formed due to blasting activities is 3.16 ppm. The water condition parameter in the blastholes has no significant effect on the formation of fumes, but relative humidity in the blastholes affects fumes formation resulting from the blasting activities. Based on the Threshold Limit Value (STEL) and the relatively fast reduction of toxic fumes, it can be stated that workers can enter the blasting areas in less than one minute after detonation.

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References

[1] Sućeska M, Tumara B S, Škrlec V, and Stanković S 2021 Prediction of concentration of toxic gases produced by detonation of commercial explosives by thermochemical equilibrium calculations *Defence Technology*, doi: 10.1016/j.dt.2021.10.011

[2] Hartami P N *et al.*, 2021 Simulation of Surface Delay Modification to Reduce Blasting Vibration at PT Agincourt Resources *Indonesia Mining Journal,* volume 4:109-117.

[3] Al-Bakri A and Hefni M 2021 A review of some nonexplosive alternative methods to conventional rock blasting *Open Geosciences* 13(1):431-442 doi: 10.1515/geo-2020-0245.

[4] Mária Hernád and Kugyela Lóránd 2012 Risk of Carbon Monoxide Intoxication in Explosions *Hadmernok vol. 2*

[5] Maulana Y, Hartami P N, Fitriyani O, and Nugroho B 2022 Study of Simulation of Ignition Patterns of Explosion Vibration at PT Semen Indonesia Tbk *Indonesia Mining Journal* volume 5:33-34.

[6] Chen J, Qiu W, Rai P and X. Ai 2021 Emission Characteristics of CO and NOxfrom Tunnel Blast Design Models: a Comparative Study *Polish Journal of Environmental Studies* 30(6):5503–5517 doi: 10.15244/pjoes/136482.

[7] Huang R, Shen X, Wang B and X. Liao 2020 Migration characteristics of CO under forced ventilation after excavation roadway blasting: A case study in a plateau mine *Journal of Cleaner Productio,* volume 267, 122094 doi: 10.1016/j.jclepro.2020.122094.

[8] Onederra I, Bailey V, Cavanough G, Torrance A, Torrance A and Torrance A 2012 Understanding main causes of nitrogen oxide fumes in surface blasting *Mining Technology*, volume 121: 151-159 doi: 10.1179/1743286312y.0000000019.

[9] Menéndez J *et al.* 2022 Concentration, Propagation and Dilution of Toxic Gases in Underground Excavations under Different Ventilation Modes *International Journal of Environmental Research and Public Health* 19(12), 7092; doi: 10.3390/ijerph19127092.

[10] Torno S and Toraño J 2020 On the prediction of toxic fumes from underground blasting operations and dilution ventilation. Conventional and numerical models *Tunneling and Underground Space Technology* 96(2):103194; doi: 10.1016/j.tust.2019.103194.

[11] Araos M and Onederra I 2015 Development of a novel mining explosive formulation to eliminate nitrogen oxide fumes *Mining Technology* 124(1):1743286314Y.000; doi: 10.1179/1743286314y.0000000074.

[12] D. of Natural Resources, "Queensland Guidance Note," 2017. [Online]. Available: https://www.resources.qld.gov.au/ data/assets/pdf_file/0010/212500/qld-guidance-note-20-mgmt-oxides-nitrogen.pdf

[13] Mainiero R J 1997 A Technique for Measuring Toxic Gases Produced by Blasting Agents *Proc 23rd Annual Conference on Explosives and Blasting Technique*. Cleveland, OH: International Society of Explosives Engineers, 1997 Jan; :595-604

[14] Department of Education and Safe Work Australia, 2018. *Workplace exposure standards for airborne contaminants*. [Online]. Available: https://www.safeworkaustralia.gov.au/sites/default/files/2022-09/workplace_exposure_standards_for_airborne_contaminants_-_1_october_2022.pdf

[15] McCaffrey M A and Su B Y 2001 Subsurface migration of toxic fumes from surface construction blasting *Paper presented at the DC Rocks 2001, The 38th U.S. Symposium on Rock Mechanics (USRMS),* Washington, D.C., July 2001. Paper Number: ARMA-01-0381

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