Daftar Isi: https://iopscience.iop.org/issue/1755-1315/1339/1

IOPscience Journals Books Publishing Support Login

IOP Conference Series: Earth and Environmental Science

Table of contents

Volume 1339

2024

Previous issue Next issue

The 6th International Conference on Earth, Science, Mineral, and Energy 09/11/2023 - 09/11/2023 Yogyakarta, Indonesia

Accepted papers received: 12 April 2024

Published online: 13 May 2024

Open all abstracts

Preface

Geological Science and Engineering

IOP Conference Series: Earth and Environmental Science

COUNTRY

United Kingdom

Universities and research institutions in United Kingdom

Media Ranking in United Kingdom

SUBJECT AREA AND CATEGORY

Earth and Planetary Sciences
- Earth and Planetary Sciences (miscellaneous)

Environmental Science
- Environmental Science (miscellaneous)

Physics and Astronomy
- Physics and Astronomy (miscellaneous)

PUBLISHER

IOP Publishing Ltd.

H-INDEX

48

PUBLICATION TYPE

Conferences and Proceedings

ISSN

17551307, 17551315

COVERAGE

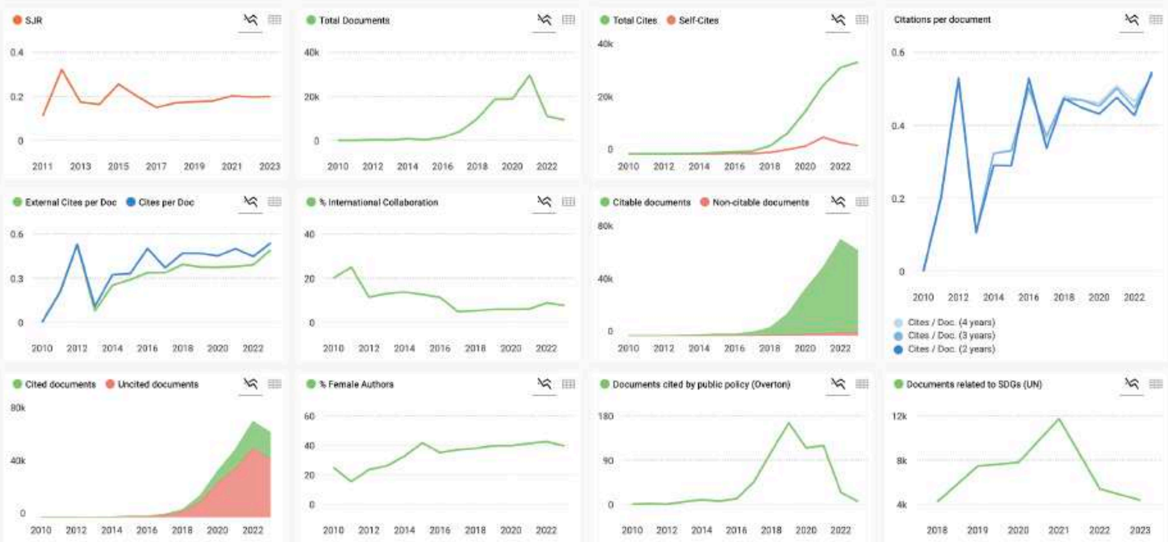
2010-2023

INFORMATION

Homepage

How to publish in this journal

ees@ioppublishing.org



← Show this widget in your own website

Just copy the code below and paste within your html code:

<a href="https://www.scimag

SCImago Graphica

Explore, visually communicate and make sense of data with our **new data visualization tool.**

IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Preface

To cite this article: 2024 *IOP Conf. Ser.: Earth Environ. Sci.* **1339** 011001


6TH International Conference of Earth Science, Mineral and Energy
ICEMINE
"Accelerating the Advancements in Lower Carbon Energy for A Sustainable Environment"
2023

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 011001 doi:10.1088/1755-1315/1339/1/011001

Preface

Greetings and a warm welcome to the expansive compilation of research and scholarly contributions presented in the Proceedings of the ICEMINE 2023. In the spirit of intellectual exploration and collaboration, this voluminous collection encapsulates the diverse and profound discussions that unfolded during the conference. As we delve into the following pages, readers will encounter a comprehensive exploration of knowledge, innovation, and interdisciplinary collaboration within the overarching theme of ICEMINE 2023.

ICEMINE 2023 is the 6th International Conference hosted by the Faculty of Mineral Technology, Universitas Pembangunan Nasional "Veteran" Yogyakarta, Indonesia. The conference was held at Grand Keisha Hotel, Yogyakarta, Indonesia, on the 9th of November 2023. The theme of this year's program is *"Accelerating the advancements in lower carbon energy for a sustainable environment"*.

We extend our appreciation to our esteemed partner university, whose unwavering dedication and scholarly contributions have significantly enriched the contents of this conference proceedings. In collaboration with our partner universities, Trisakti University and PEM Akamigas, UPN Veteran Yogyakarta creates an academic platform that fosters diverse perspectives, innovative ideas, and interdisciplinary exchange. Their insightful research and collaborative spirit have undeniably elevated the quality of discourse within our academic community, fostering an environment conducive to intellectual growth and innovation.

Furthermore, we would like to express our profound gratitude to our sponsors, whose generous support has been pivotal in bringing this event to success. Their unwavering commitment to advancing research and cultivating intellectual exchange underscores the importance of their role in shaping the trajectory of our academic disciplines.

Reflecting on Sustainability in Indonesia

In recent years, the imperative to decrease carbon emissions and shift towards energy sources with lower carbon footprints has become exceptionally crucial. Emphasizing the importance of transitioning to cleaner energy sources is paramount for preserving our environment and addressing climate change. The significance of advancing lower carbon energy technologies cannot be overstated, as they play a vital role in mitigating the adverse impacts of climate change and ensuring a sustainable environment for future generations. As scholars and researchers, we carry a distinct responsibility to accelerate the development of these technologies, driving innovation, encouraging critical thinking, and offering the expertise and solutions needed to forge a more sustainable future.

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 011001 doi:10.1088/1755-1315/1339/1/011001

The chosen theme for ICEMINE 2023, *Accelerating the advancements in lower carbon energy for a sustainable environment,* resonates with the evolving landscape of academic inquiry and technological advancement. This theme has served as a catalyst for researchers to delve into various aspects, spanning the theoretical frameworks to practical applications. The rich tapestry of this proceedings volume mirrors the comprehensive exploration undertaken by the conference participants, representing a mosaic of perspectives that collectively contribute to the ongoing narrative of Sustainability.

Within this volume lies a plethora of research, articles, case studies, and theoretical explorations carefully curated from the vast pool of submissions and presentations at the conference. These contributions, emanating from a global community of earth science scholars, reflect the breadth and depth of insights shared during ICEMINE 2023. The contributions cover a wide spectrum of earth sciences, which are:

1. Geological Science and Engineering
2. Geophysics, Geomatics and Geochemistry
3. Earth Resources Project Evaluation and Valuation
4. Petroleum and Geothermal Engineering
5. Mining and Metallurgical Engineering
6. Taxation and Policy
7. Conservation, Geoheritage and Geopark
8. Disaster Management
9. Reclamation and Environmental Issues

Navigating the future: a vision for what lies ahead

As we engage with the contents of this proceedings volume, let us not only celebrate the documented achievements but also contemplate the trajectory of our respective fields. The ideas presented here have the potential to seed new research directions, innovative solutions, and transformative advancements. Readers are encouraged to interact critically with the content, fostering discussions and collaborations that transcend traditional academic silos. The interdisciplinary nature of the contributions invites us to explore the intersections of knowledge, where groundbreaking ideas often emerge from the convergence of diverse perspectives. May the knowledge shared within this volume inspire future generations, spark new avenues of inquiry, and contribute to the advancement of our collective understanding.

Cordially yours,

Dr. Widyawanto Prastistho

Chairperson ICEMINE 2023

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 011001 doi:10.1088/1755-1315/1339/1/011001

Steering Committee

Dr. Ir. Sutarto, M.T.
Geological Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

Dr. Ir. Barlian Dwinagara, M.T.
Mining Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

Dr. Ir. Basuki Rahmat, M.T.
Geological Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

Ir. Bambang Bintarto, M.T.
Petroleum Engineering,Universitas Pembangunan Nasional Veteran Yogyakarta

Organizing Committee

Chairperson
Dr. Widyawanto Prastistho
Environmental Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

Vice Chair
Yohana Noradika Maharani, PhD
Disaster Management, Universitas Pembangunan Nasional Veteran Yogyakarta

Secretary
Lysa Dora Ayu Nugraini, S.T., M.T.
Geomatics Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

Husna Muizzati Shabrina, S.T., M.T.
Environmental Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

Finance
Intan Paramita Haty, S.T., M.T.
Geological Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

Dian Rahma Yoni, S.T., M.Eng.
Geological Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

Sponsorship
Dr. Kharisma Idea, S.T., M.T.
Petroleum Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 011001 doi:10.1088/1755-1315/1339/1/011001

Editorial and Article Management

Moch Prahastomi Muttahari S, S.T., M.Sc
Geological Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

M Firdaus Al Hakim, ST, M.Eng
Geophysical Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

Publication and Program

Nuha Amiratul Afifah, S.T., M.Eng
Environmental Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

Peter Pratistha Utama, S.T., M.Eng
Geological Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

Riska Aprilia Triyadi, S.T., M.Eng
Enivornmental Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 011001 doi:10.1088/1755-1315/1339/1/011001

Scientific Committee

Head of Scientific Committee

Editorial Board

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 011001 doi:10.1088/1755-1315/1339/1/011001

Dian Rahma Yony, S.T., M.T.
Geological Engineering, UPN Veteran Yogyakarta

Dr. Kharisma Idea, S.T., M.T.
Petroleum Engineering, UPN Veteran Yogyakarta

RR. Desi Kumala Isnani, S.T., M.Eng
Geological Engineering, UPN Veteran Yogyakarta

Nuha Amiratul Afifah, S.T., M.T
Environmental Engineering, UPN Veteran Yogyakarta

Husna Muizzati Shabrina, S.T., M.T.
Environmental Engineering, UPN Veteran Yogyakarta

Peter Pratistha Utama, S.T.., M.Eng
Geological Engineering, UPN Veteran Yogyakarta

Dr Shindy Rosalia, S.T., M.T.
Geophysical Engineering, ITB

Septyo Uji Pratomo, S.T., M.T.
Geological Engineering, UPN Veteran Yogyakarta

Ristiyan Ragil Putradianto, S.T., M.T.
Petroleum Engineering, UPN Veteran Yogyakarta

Allen Haryanto Lukmana, S.T., M.T.
Petroleum Engineering, UPN Veteran Yogyakarta

Dr. Shofa Rijalul Haq, S.T., M.Eng
Mining Engineering, UPN Veteran Yogyakarta

KEYNOTE SPEAKERS

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 011001 doi:10.1088/1755-1315/1339/1/011001

BEST PRESENTERS

Naufal Setiawan	The Prospect of Typhoon Landfall Observation Utilizing L-band InSAR	Geomatics Engineering UPNVY
Andra Y Ginting	The Effectiveness of Soil Washing as a Remediation Method on Oil Spill Contaminated Soil (Case Study: Wonocolo Traditional Oil Mine)	Environmental Engineering UPNVY
Muhammad Irvingia Al Farizzi	Telomoyo Volcano Complex Geotourism: An In-Depth Analysis and Future Development	Geological Engineering UPNVY
David Michael	Optimizing the Impact of Rheological Properties on Bentonite Prehydrated- Based Drilling Mud Through the Utilization of Prehydration	Trisakti University
Muhammad Naufal Hisya Himendra	Comparative Analysis of The Use Emulsion and Watergel Explosive on Fragmentation at PT Dahana Site Kaltim Jaya Bara, East Kalimantan	Mining Engineering, Trisakti University
Nungky N. Wijayanti	Determination of Perforation to Obtain the Optimum Rate in "NKY" Well Of "MWA" Field	Petroleum Engineering, UPNVY
Kyeong Park	Geoparks and Sustainability - Korean Case	Sungshin Women’s University, South Korea

IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Study of CO Gas Dilution in Forcing Ventilation System at Ramp Down KKRB 4 Utama, Pongkor, West Java

To cite this article: R Yulianti *et al* 2024 *IOP Conf. Ser.: Earth Environ. Sci.* **1339** 012028

Study of CO Gas Dilution in Forcing Ventilation System at Ramp Down KKRB 4 Utama, Pongkor, West Java

R Yulianti[1*], P N Hartami[1], R Aryanto[1], M K Herdyanti[1], Suliestyah[1], D L Pattiruhu[1]

[1]Mining Engineering, FTKE, Universitas Trisakti, Jakarta, Indonesia

*corresponding author's: ririnyulianti@trisakti.ac.id

Abstract. CO is a hazardous gas formed from the reaction of explosives that lack oxygen balance. These explosives have the potential to generate toxic gases, including CO. It is crucial to minimize CO concentration at the work site by ensuring proper air circulation. This study aims to examine the impact of varying ducting distances on CO gas dilution, using the gas diffusion coefficient value as a basis. The research method employed is observational, involving the assessment of CO gas dilution in the tested tunnel at varying distances from the working front to the sensor. The research was conducted on the Ramp Down KKRB 4 Utama. Result of the research is the most ideal carbon monoxide reduction time at RD KKRB 4 Utama is shown at sensor placement distance 1 using the blow system, where A Sensor takes 2.21 hours and B Sensor takes 1.06 hours to reach a concentration level below the TLV (Threshold Limit Value) 50 ppm.

1. Introduction

The location of mines poses a high risk of danger, especially underground mines. With highly limited working conditions and space, the potential hazards are so significant [1]. These conditions can lead to work accidents, which can occur due to unsafe actions and unsafe conditions [2]. Among the various factors that contribute to an unsafe location in underground mines, toxic and hazardous gases can disrupt activities at the workplace, making it necessary to plan for proper air ventilation to ensure that work can be carried out safely and comfortably [3].

In underground mining, ventilation plays a crucial role in supporting every task [4]. Ventilation in underground mines functions to supply fresh air into the mine, which is needed for the availability of clean air for workers in the mine and for all processes that require oxygen inside the mine [5]. Additionally, ventilation functions to remove heat that accumulates in underground mines due to the activities carried out by workers and the equipment used [6].

CO gas is caused by incomplete combustion resulting from blasting activities and the operation of heavy machinery in underground mines [7]. The nature of CO gas is colorless and odorless. CO gas is highly dangerous, so its presence needs to be carefully monitored, especially during blasting at the working front. At the research site in PT Antam UBPE Pongkor, carbon monoxide (CO) gas resulting from blasting often becomes an obstacle. Referring to the Director General of Minerals and Coal's Decision No.185K/37.04/DJB/2019 [8], the volume of CO gas should not exceed 0.005% or 50 ppm and not more than 0.04% or 400 ppm for an exposure time of 15 minutes. The timing of the reduction of CO gas is important to consider during blasting in the development tunnel because if CO gas does not dissipate when workers re-enter for work, it can cause poisoning[9]. To meet the needs of air and heat flow and to dilute toxic gases in underground mines, careful calculations are required for the placement of ventilation ducts, fan speed, and good air circulation conditions, ensuring that fresh air and heat can circulate properly, thereby creating a safe and comfortable working environment [10]. The purpose of this research is to study how quickly CO gas dissipates at the observation distance used. The ventilation system used at the research site for Ramp Down KKRB 4 Utama (RD KKRB 4 Utama) is forcing system as given in Figure 1, where this system provides a blast of fresh air to the working front [5].

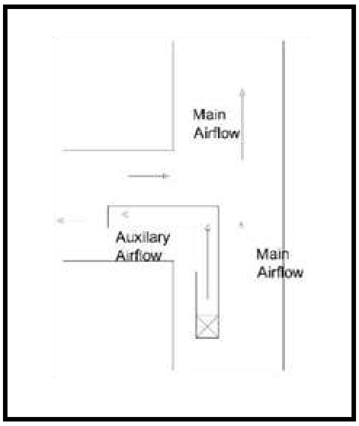


Figure 1. Forcing system

2. Method

The research was conducted at PT Antam UBPE Pongkor using the observation method. Observations were made by testing several different observation distances, resulting in data on the quality and quantity of air. The data on air quality resulted in the concentration of CO gas in parts per million (ppm).

The measurement of tunnel dimensions was carried out using the Leica Disto D2, which is used to measure the length, width, and height of the tunnel in meters. The measurement of tunnel dimensions was adjusted according to the actual conditions and the progress of the tunnel. Figure 2 is Leica Disto D2, the device utilized for measuring the dimensions of tunnels.

Figure 2. Measurement of tunnel dimensions

The measurement of CO gas concentration is carried out in order to obtain the curve results of the gas dilution reduction process. The process of collecting data on CO gas concentration uses robotic hardware with Arduino coding software. The hardware used will be placed on the tunnel wall, with its two sensors positioned at an initial distance of 50 meters from the working front for the first sensor and 25 meters from the first sensor for the second sensor with two observation distance. Figure 3 depicts the robotic equipment employed to measure CO gas within the tunnel, while Figure 4 illustrates the schematic showcasing the positioning of the sensor during the research within the tunnel. Table 1 displays the observed distances utilized in the research.

Table 1. Observation distance

Parameter	Observation Distance 1	Observation Distance 2
Distance A Sensor to Working Front (m)	50	51.3
Distance B Sensor to Working Front (m)	75	76.3
Length of The Tunnel Observed (m)	76.74	78.04

Figure 3. Robotic hardware device for measuring CO gas concentration

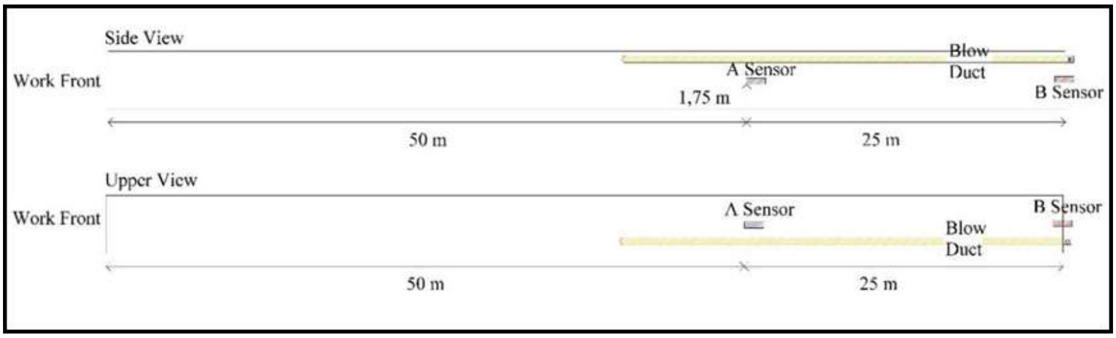


Figure 4. The schematic of the placement of robotic hardware in the tunnel

Ansys Fluent is used to identify the direction of airflow occurring in the tunnel. The data used consists of tunnel dimensions. The creation of tunnel dimensions is followed by the creation of a mesh in the simulation tunnel. The creation of this mesh is useful to ensure that the created geometry is well-structured and orderly. The smaller the mesh, the more accurate the results obtained.

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 012028 doi:10.1088/1755-1315/1339/1/012028

Equations are used to determine the conditions of the airflow. Viscosity (μ), density (ρ), and the diameter of the airway are three parameters that affect the flow conditions (d). The Reynolds number is the relationship between μ, ρ, and d, which has the same dimensions as velocity and can be studied using the following equation:

$$Re = \frac{\rho v d}{\mu} \tag{1}$$

Explanation:
Re: Reynolds Number v: air velocity (m/s)
μ: dynamic viscosity of airflow (Ns/m^2)
ρ: air density (kg/m^3)
d: airway diameter (m)

The direction of laminar or turbulent flow is determined by the Reynolds number. If the value of Re is less than 2,000, the flow is identified as laminar flow. If the value of Re is greater than 4,000, the flow is identified as turbulent flow. If the value of Re falls within the range of 2,000 and 4,000, the airflow is referred to as transitional flow.

The diffusion coefficient describes the dispersion of chemicals released in a closed flow in laminar flow. The diffusion coefficient is a function of molecular diffusion in the radial direction and the velocity profile of the closed channel in the axial direction. The diffusion coefficient is known as the virtual diffusion coefficient, and it is determined by observing the concentration distribution at the observation location. It is proportional to turbulent flow. The equation for the diffusion coefficient in laminar flow can be seen in this equation written by Taylor (1974):

$$D = 10{,}1\ r\ u' \tag{2}$$

$$u' = \frac{\sqrt{r}}{\sqrt{\rho}} = u\,\frac{\sqrt{f}}{\sqrt{8}} \tag{3}$$

Explanation:
D: Laminar flow diffusion coefficient (m^2/s)
u': Friction velocity (m/s)
r: Diameter of the orifice (m) τ: Shear stress (Pa)
u: Mean velocity of air flow (m/s) ρ: Fluid mass density (kg/m^3)
f: Friction factor

The following equation can be calculated using Taylor's test principle (1954), where the concentration follows the Gaussian distribution theory with the assumption of one dimension:

$$C_{(x,t)} = \frac{v}{2A\sqrt{\pi D t}}\ \exp\left(\frac{-(x-ut)^2}{4Dt}\right) \tag{4}$$

Explanation:
$C_{(x,t)}$: Tracer concentration at position x and time t
D : Diffusion coefficient (m^2/s)
A : Cross-sectional area of the channel pipe (m^2)
V : Initial gas volume (ml)
u : Mean air flow velocity (m/s)
t : Time (s)
v : Length of the airflow (m)

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 012028 doi:10.1088/1755-1315/1339/1/012028

3. Result and discussion

The research was conducted at the Kubang Kicau location at the working front of the access tunnel, namely Ramp Down KKRB 4 Utama (RD KKRB 4 Utama) at PT Antam UBPE Pongkor. The CO gas under investigation is the CO gas resulting from blasting, which is measured at the end of each shift. Data collection at each working front was conducted three times to ensure the accuracy of the results. Table 2 explain the primary data of vent duct at RD KKRB 4 Utama.

Table 2. Primary data of vent duct at RD KKRB 4 Utama

Parameter	Observation Distance 1	Observation Distance 2
Diamater (m)	0.60	0.6
Area (m^2)	0.28	0.28
Perimeter (m)	0.89	0.89
Distance A Sensor to Working Front (m)	50	51.3
Distance B Sensor to Working Front (m)	75	76.3
Length of The Tunnel Observed (m)	76.74	78.04
Air velocity at the corner of the vent duct (m/s)	1.72	1.60
Air flow rate (m^3/s)	0.49	0.46

The type of airflow in the tunnel at the research site can be determined by the Reynolds number. The Reynolds number is obtained from calculations of air density, air flow velocity, and the diameter of the cross-section at the research site. The air flow velocity used is the average of the measurements taken at 16 observation points at the working front. All conditions have known Reynolds number values, and the results indicate that there is no airflow present at RD KKRB 4 Utama.

The testing diffusion coefficient is obtained using the Taylor equation (1954), as in equation 2. The required data includes the diameter of the tunnel airflow, the average air flow velocity, and the friction factor obtained from the Reynolds number value using the Colebrook equation, due to the rough tunnel surface conditions in the field. Table 3 represents the values of the diffusion coefficient during data collection in the field for RD KKRB 4 Utama, which includes the initial testing diffusion coefficient value when carbon monoxide (CO) gas resulting from the blast is at the 0-second mark. The value of the testing diffusion coefficient is very low because the CO gas has not yet been fully diluted.

The testing diffusion coefficient is obtained using the Taylor equation (1954), as in equation 2. The required data includes the diameter of the tunnel airflow, the average air flow velocity, and the friction factor obtained from the Reynolds number value using the Colebrook equation, due to the rough tunnel surface conditions in the field. Table 4 represents the values of the diffusion coefficient during data collection in the field for RD KKRB 4 Utama, which includes the initial testing diffusion coefficient value when carbon monoxide (CO) gas resulting from the blast is at 0 seconds. The value of the testing diffusion coefficient is very low because the CO gas has not yet been fully diluted.

Table 3. The values of the Taylor (1954) testing diffusion coefficient in each tunnel under various conditions

Observation Distance	Average Velocity (m/s)	Reynolds Number	Friction Factor	Friction Velocity (m/s)	Testing Difusion Coefficient (m^2/s)
1	0.00	0.00	2.57	0.00	0.00
2	0.00	0.00	2.46	0.00	0.00

The research was conducted at 2 different observation distances based on the progress of the tunnel

and the actual placement of the fan in the field. The maximum smoke clearing process can be determined when there is good air circulation and the decrease in CO gas occurs rapidly.
Figure 5 shows the graph of carbon monoxide (CO) gas concentration over time at RD KKRB 4 Utama at observation distance 1.

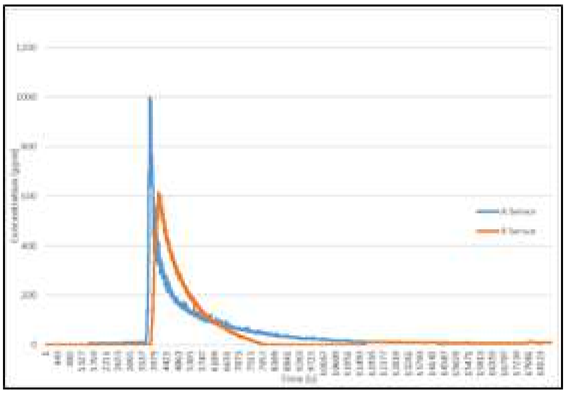


Figure 5. Graph of carbon monoxide (CO) concentration over time at RD KKRB 4 Utama at observation distance 1

At this observation distance, it can be seen that the dilution process for the two sensors differs significantly. This is because, considering the position of the sensors, A Sensor is closer to the working front and positioned in the middle of the blow duct's length, resulting in a longer CO gas dilution process compared to B Sensor. The dilution process at A Sensor takes 2.21 hours, while B Sensor requires 1.06 hours to reach a concentration level below the TLV (Threshold Limit Value) 50 ppm. The significant time difference is also attributed to the presence of an exhaust duct at the end of the RD KKRB 4 Utama tunnel with a fan power of 37 kW. This causes the CO concentration to dissipate faster at B Sensor compared to A Sensor, which is positioned farther from the exhaust duct.

Referring to the Director General of Minerals and Coal's Decision No.185K/37.04/DJB/2019 [8], which stipulates a 400 ppm concentration limit for a 15-minute CO gas exposure, the conditions at RD KKRB 4 Utama already meet this requirement because the 15-minute CO gas exposure concentration at RD KKRB 4 Utama is 383.43 ppm.

The value of the graphic method diffusion coefficient is obtained from the carbon monoxide (CO) gas dispersion graph according to the actual field conditions, considering the position of the vent duct and the air velocity in the blow duct. The value of the graphic method diffusion coefficient is empirically derived based on the Taylor diffusion coefficient (1954) using equation 4 with a curve matching method (trial and error in Microsoft Excel Solver).

At observation distance 2, it can be observed that the dilution of the two gases at A Sensor and B Sensor is not significantly different. Referring to the Director General of Minerals and Coal's Decree No. 185K/37.04/DJB/2019 [8], which stipulates a 400 ppm concentration limit for a 15-minute CO gas exposure, the conditions at RD KKRB 4 Utama at observation distance 2 already meet this requirement, as the 15-minute CO gas exposure concentration at RD KKRB 4 Utama is 337.54 ppm.

The dilution process at A Sensor takes 2.59 hours, while B Sensor requires 2.34 hours to reach a concentration level below the TLV 50 ppm. The CO gas dissipation time in observation placement 2 does not yet meet the company's requirements, which is 2 hours. Sensor one requires a longer time for CO gas dilution because A Sensor is closer to the working front, which is the source of CO gas due to blasting activities.

Another factor that can be observed is the presence of holes in the flexible blow duct. These holes in the flexible blow duct are intentionally created by the workers at the working front due to the hot working conditions, necessitating a flow of fresh air under the flexible blow duct through the holes. During blasting, these holes enlarge, reducing the airflow at the end of the flexible blow duct and limiting the optimal expulsion of CO gas at the working front. Figure 6 shows the holes in the flexible blow duct at observation distance 2.

Figure 6. Holes in the flexible duct at RD KKRB 4 Utama at observation distance 2

Figure 7 represents the analysis of CO gas concentration data testing under Condition 1 at RD KKRB 4 Utama, with the CO gas concentration graphic method results at B Sensor using equation 4, resulting in the empirically derived diffusion coefficient.

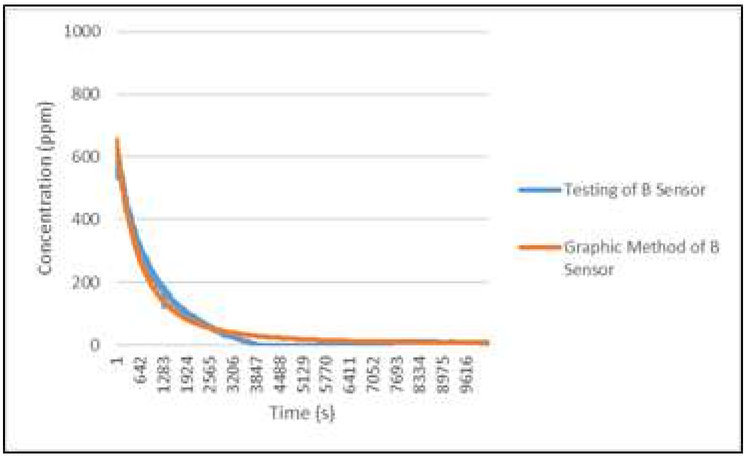


Figure 7. Graph of carbon monoxide (CO) concentration over time at RD KKRB 4 Utama at observation distance 1

The results of the experiment using the matching curve method are the method graphic diffusion coefficient values. Table 4 represents the diffusion coefficient values from the decrease in carbon monoxide (CO) gas concentration.

Table 4. Graphic method diffusion coefficient values from the decrease in carbon monoxide (CO) gas concentration at various observation distances

Observation Distance	Air Velocity (m/s)	Graphic Method Diffusion Coefficient (m^2/s)		
		A Sensor	B Sensor	Average
1	0	146.50	129.98	138.24
2	0	95.46	126.11	110.79

After analyzing the data from the RD KKRB 4 Utama field on carbon monoxide (CO) gas resulting from blasting, the data processing results in the table show that at observation distance 1, the graphic method diffusion coefficient obtained is the highest, with the distance from the working front to the blow duct being 40.64 m and the air velocity at the end of the blow duct being 1.72 m/s. The CO gas dissipation time is relatively fast compared to the dissipation of CO gas under other conditions at RD KKRB 4 Utama, which is 1.07 hours. CO gas requires 1.06 hours at B Sensor, with a peak value at B Sensor of 616.1 ppm. Figure 8 shows a bar chart comparing the diffusion coefficients of each sensor testing under various different conditions at RD KKRB 4.

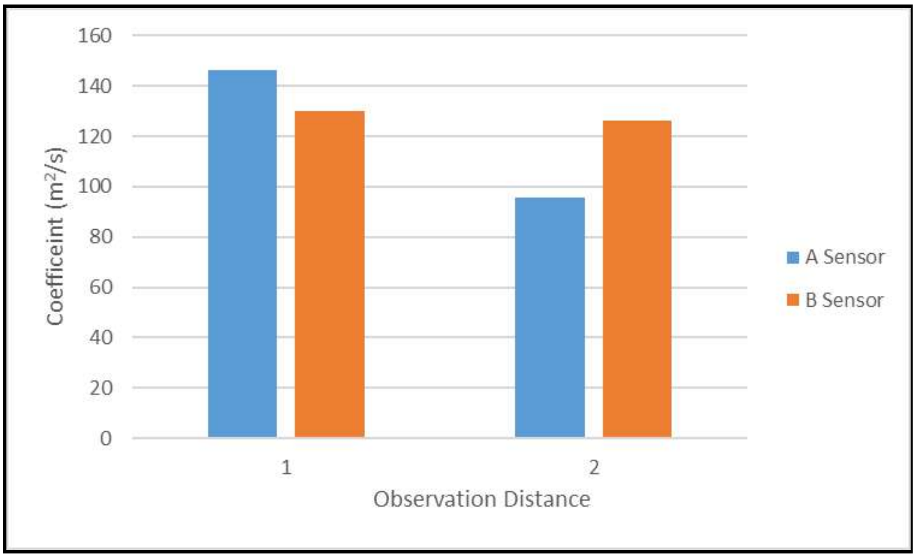
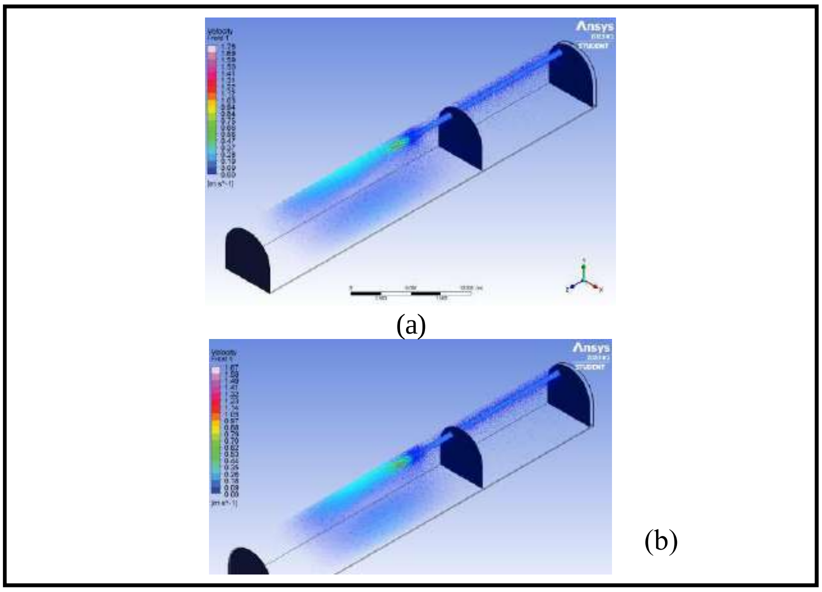


Figure 8. Graph of carbon monoxide (CO) concentration over time at RD KKRB 4 Utama at observation distance 1

The results of the testing diffusion coefficient calculation using the Taylor equation (1954) differ from the graphic method diffusion coefficient values obtained using the matching curve method (trial and error in Microsoft Excel). The testing diffusion coefficient is obtained when CO gas is initially blasted, thus not undergoing complete turbulence, whereas the graphic method diffusion coefficient is obtained when perfect turbulence occurs in the airflow, and the CO gas undergoes dilution from the peak concentration until complete dissolution. The diffusion coefficient is greater than the testing diffusion coefficient because when the airflow experiences perfect turbulence, CO gas will be diluted rapidly. In the RD KKRB 4 Utama simulation, the ratio of the graphic method coefficient to the testing coefficient ranges from 138 to 314 times. Table 4 represents a comparison of the graphic method diffusion coefficient (Dx) with the analytical diffusion coefficient (DA).

After conducting simulations using the physical tunnel model, Ansys Fluent software was used to determine the airflow turbulence. Observation distance 1 showed a high diffusion coefficient value during the simulation when air recirculation did not occur. Carbon monoxide (CO) gas is diluted rapidly because the placement of the blow duct is appropriate. This condition will be optimal if it follows the company's regulations, which state that if the end of the blow duct is more than 30 meters away, the blow duct will be advanced. The clean air blown by the blow duct goes directly to the working front and undergoes turbulence to dilute the CO gas. Subsequently, the contaminated air containing CO gas is sucked out by the exhaust duct located outside the tunnel without experiencing air recirculation. Figure 9 shows airflow at RD KKRB 4 Utama observation distance 1 (a) and 2 (b).



(a)

(b)

Figure 9. Airflow at RD KKRB 4 Utama observation distance 1 (a) and observation distance 2 (b)

4. Conclusion

The most ideal carbon monoxide reduction time at RD KKRB 4 Utama is shown at sensor placement distance 1 using the blow system, where A Sensor takes 2.21 hours and B Sensor takes 1.06 hours to reach a concentration level below the TLV 50 ppm. Referring to the Director General of Minerals and Coal's Decree No. 185K/37.04/DJB/2019, which stipulates a 400 ppm concentration limit for a 15-minute CO gas exposure, the conditions at RD KKRB 4 Utama at placement distance 1 already meet this requirement, as the 15-minute CO gas exposure concentration at RD KKRB 4 Utama is 383.43 ppm. Adjustments to the blow duct and improvements to the flexible duct are necessary to optimize CO gas smoke clearing at the research site. This can be seen from the coefficients of each condition. The larger the diffusion coefficient value, the easier it is for CO gas to be diluted.

5. References

[1] Yulianti R, Hartami P N, Tuheteru E J and Maulana Y, Pertambangan J T and Teknologi F 2023 Analisis penurunan konsentrasi gas karbon monoksida (CO) pada saluran ventilasi di area belokan menggunakan model fisik terowongan skala laboratorium **11** 42–53

[2] Gillies A, Wu H and Shires D 2004 Development of an assessment tool to minimize safe after blast re-entry time to improve the mining cycle *Proc. Tenth US/North Am. Mine Vent. Sm* 1–9

[3] Yulianti R, Hartami P N and Hidayat T 2022 Penurunan konsentrasi gas karbon monoksida dengan model fisik terowongan skala laboratorium *J. Teknol. Miner. dan Batubara* **18** 59–67

[4] Harnoko A W, Priagung Widodo N and Ihsan A Analisis dilusi gas karbon monoksida pada permuka kerja terowongan horizontal dengan model fisik skala laboratorium

[5] Mcpherson M J 1993 *Subsurface Ventilation*

[6] Yulianti R, Widodo N P and Gautama R S 2021 Kondisi resirkulasi udara terhadap penurunan sumber panas di dalam tambang bawah tanah *J. Geomine* **8** 228

[7] Menéndez J, Merlé N, Fernández-Oro J M, Galdo M, de Prado L Á, Loredo J and Bernardo-Sánchez A 2022 Concentration, propagation and dilution of toxic gases in underground excavations under different ventilation modes *Int. J. Environ. Res. Public Health* **19**
[8] ESDM K 2019 Kepmendirjen minerba no.185K/37.04/DJB/2019 35–6
[9] Hanif P, Gani A and Widodo N P 2019 Study of re-entry time post blasting at ciguha pt antam UBPE pongkor underground gold mine
[10] Yuan L, Thomas R A and Zhou L 2017 Characterization of a mine fire using atmospheric monitoring system sensor data *Min. Eng.* **69** 57-62

Acknowledgments
The expression of gratitude is conveyed to PT Aneka Tambang UBPE Pongkor for providing the opportunity in the data collection process and publishing the manuscript. The author also extends thanks to Trisakti University, especially the Faculty of Earth Technology and Energy, for the financial support provided through the research fund.

Study of CO Gas Dilution in Forcing Ventilation System at Ramp Down KKRB 4 Utama, Pongkor, West Java

by Ririn Yulianti FTKE

Submission date: 02-Sep-2024 05:56PM (UTC+0700)
Submission ID: 2250756268
File name: Jurnal_1.pdf (1.13M)
Word count: 4121
Character count: 20548

IOP Conference Series: Earth and Environmental Science

Study of CO Gas Dilution in Forcing Ventilation System at Ramp Down KKRB 4 Utama, Pongkor, West Java

To cite this article: R Yulianti *et al* 2024 *IOP Conf. Ser.: Earth Environ. Sci.* **1339** 012028

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 012028 doi:10.1088/1755-1315/1339/1/012028

Study of CO Gas Dilution in Forcing Ventilation System at Ramp Down KKRB 4 Utama, Pongkor, West Java

R Yulianti[1*], P N Hartami[1], R Aryanto[1], M K Herdyanti[1], Suliestyah[1], D L Pattiruhu[1]

[1]Mining Engineering, FTKE, Universitas Trisakti, Jakarta, Indonesia

*corresponding author's: ririnyulianti@trisakti.ac.id

Abstract. CO is a hazardous gas formed from the reaction of explosives that lack oxygen balance. These explosives have the potential to generate toxic gases, including CO. It is crucial to minimize CO concentration at the work site by ensuring proper air circulation. This study aims to examine the impact of varying ducting distances on CO gas dilution, using the gas diffusion coefficient value as a basis. The research method employed is observational, involving the assessment of CO gas dilution in the tested tunnel at varying distances from the working front to the sensor. The research was conducted on the Ramp Down KKRB 4 Utama. Result of the research is the most ideal carbon monoxide reduction time at RD KKRB 4 Utama is shown at sensor placement distance 1 using the blow system, where A Sensor takes 2.21 hours and B Sensor takes 1.06 hours to reach a concentration level below the TLV (Threshold Limit Value) 50 ppm.

1. Introduction

The location of mines poses a high risk of danger, especially underground mines. With highly limited working conditions and space, the potential hazards are so significant [1]. These conditions can lead to work accidents, which can occur due to unsafe actions and unsafe conditions [2]. Among the various factors that contribute to an unsafe location in underground mines, toxic and hazardous gases can disrupt activities at the workplace, making it necessary to plan for proper air ventilation to ensure that work can be carried out safely and comfortably [3].

In underground mining, ventilation plays a crucial role in supporting every task [4]. Ventilation in underground mines functions to supply fresh air into the mine, which is needed for the availability of clean air for workers in the mine and for all processes that require oxygen inside the mine [5]. Additionally, ventilation functions to remove heat that accumulates in underground mines due to the activities carried out by workers and the equipment used [6].

CO gas is caused by incomplete combustion resulting from blasting activities and the operation of heavy machinery in underground mines [7]. The nature of CO gas is colorless and odorless. CO gas is highly dangerous, so its presence needs to be carefully monitored, especially during blasting at the working front. At the research site in PT Antam UBPE Pongkor, carbon monoxide (CO) gas resulting from blasting often becomes an obstacle. Referring to the Director General of Minerals and Coal's Decision No.185K/37.04/DJB/2019 [8], the volume of CO gas should not exceed 0.005% or 50 ppm and not more than 0.04% or 400 ppm for an exposure time of 15 minutes. The timing of the reduction of CO gas is important to consider during blasting in the development tunnel because if CO gas does not dissipate when workers re-enter for work, it can cause poisoning[9]. To meet the needs of air and heat flow and to dilute toxic gases in underground mines, careful calculations are required for the placement of ventilation ducts, fan speed, and good air circulation conditions, ensuring that fresh air and heat can circulate properly, thereby creating a safe and comfortable working environment [10]. The purpose of this research is to study how quickly CO gas dissipates at the observation distance used. The ventilation system used at the research site for Ramp Down KKRB 4 Utama (RD KKRB 4 Utama) is forcing system as given in Figure 1, where this system provides a blast of fresh air to the working front [5].

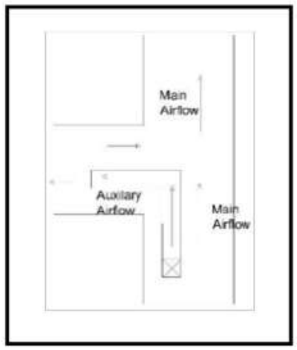


Figure 1. Forcing system

2. Method

The research was conducted at PT Antam UBPE Pongkor using the observation method. Observations were made by testing several different observation distances, resulting in data on the quality and quantity of air. The data on air quality resulted in the concentration of CO gas in parts per million (ppm).

The measurement of tunnel dimensions was carried out using the Leica Disto D2, which is used to measure the length, width, and height of the tunnel in meters. The measurement of tunnel dimensions was adjusted according to the actual conditions and the progress of the tunnel. Figure 2 is Leica Disto D2, the device utilized for measuring the dimensions of tunnels.

Figure 2. Measurement of tunnel dimensions

The measurement of CO gas concentration is carried out in order to obtain the curve results of the gas dilution reduction process. The process of collecting data on CO gas concentration uses robotic

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 012028 doi:10.1088/1755-1315/1339/1/012028

hardware with Arduino coding software. The hardware used will be placed on the tunnel wall, with its two sensors positioned at an initial distance of 50 meters from the working front for the first sensor and 25 meters from the first sensor for the second sensor with two observation distance. Figure 3 depicts the robotic equipment employed to measure CO gas within the tunnel, while Figure 4 illustrates the schematic showcasing the positioning of the sensor during the research within the tunnel. Table 1 displays the observed distances utilized in the research.

Table 1. Observation distance

Parameter	Observation Distance 1	Observation Distance 2
Distance A Sensor to Working Front (m)	50	51.3
Distance B Sensor to Working Front (m)	75	76.3
Length of The Tunnel Observed (m)	76.74	78.04

Figure 3. Robotic hardware device for measuring CO gas concentration

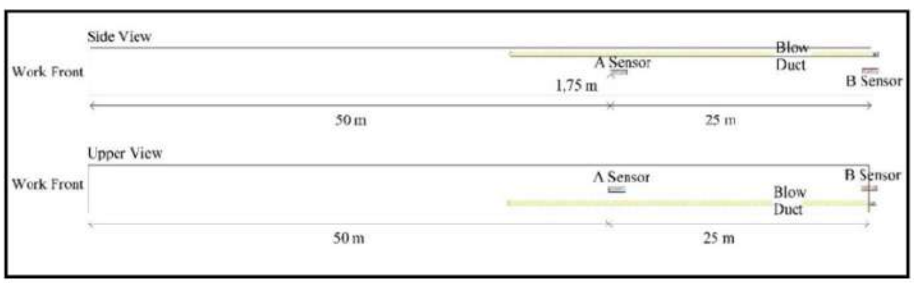


Figure 4. The schematic of the placement of robotic hardware in the tunnel

Ansys Fluent is used to identify the direction of airflow occurring in the tunnel. The data used consists of tunnel dimensions. The creation of tunnel dimensions is followed by the creation of a mesh in the simulation tunnel. The creation of this mesh is useful to ensure that the created geometry is well-structured and orderly. The smaller the mesh, the more accurate the results obtained.

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 012028 doi:10.1088/1755-1315/1339/1/012028

Equations are used to determine the conditions of the airflow. Viscosity (μ), density (ρ), and the diameter of the airway are three parameters that affect the flow conditions (d). The Reynolds number is the relationship between μ, ρ, and d, which has the same dimensions as velocity and can be studied using the following equation:

$$Re = \frac{\rho v d}{\mu} \qquad (1)$$

Explanation:
Re: Reynolds Number v: air velocity (m/s)
μ: dynamic viscosity of airflow (Ns/m^2)
ρ: air density (kg/m^3)
d: airway diameter (m)

The direction of laminar or turbulent flow is determined by the Reynolds number. If the value of Re is less than 2,000, the flow is identified as laminar flow. If the value of Re is greater than 4,000, the flow is identified as turbulent flow. If the value of Re falls within the range of 2,000 and 4,000, the airflow is referred to as transitional flow.

The diffusion coefficient describes the dispersion of chemicals released in a closed flow in laminar flow. The diffusion coefficient is a function of molecular diffusion in the radial direction and the velocity profile of the closed channel in the axial direction. The diffusion coefficient is known as the virtual diffusion coefficient, and it is determined by observing the concentration distribution at the observation location. It is proportional to turbulent flow. The equation for the diffusion coefficient in laminar flow can be seen in this equation written by Taylor (1974):

$$D = 10{,}1\ r\ u' \qquad (2)$$

$$u' = \frac{\sqrt{r}}{\sqrt{\rho}} = u\,\frac{\sqrt{f}}{\sqrt{8}} \qquad (3)$$

Explanation:
D: Laminar flow diffusion coefficient (m^2/s)
u': Friction velocity (m/s)
r: Diameter of the orifice (m) τ: Shear stress (Pa)
u: Mean velocity of air flow (m/s) ρ: Fluid mass density (kg/m^3)
f: Friction factor

The following equation can be calculated using Taylor's test principle (1954), where the concentration follows the Gaussian distribution theory with the assumption of one dimension:

$$C_{(x,t)} = \frac{v}{2A\sqrt{\pi D t}} \exp\left(\frac{-(x-ut)^2}{4Dt}\right) \quad (4)$$

Explanation:
$C_{(x,t)}$: Tracer concentration at position x and time t
D : Diffusion coefficient (m^2/s)
A : Cross-sectional area of the channel pipe (m^2)
V : Initial gas volume (ml)
u : Mean air flow velocity (m/s)
t : Time (s)
v : Length of the airflow (m)

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 012028 doi:10.1088/1755-1315/1339/1/012028

3. Result and discussion

The research was conducted at the Kubang Kicau location at the working front of the access tunnel, namely Ramp Down KKRB 4 Utama (RD KKRB 4 Utama) at PT Antam UBPE Pongkor. The CO gas under investigation is the CO gas resulting from blasting, which is measured at the end of each shift. Data collection at each working front was conducted three times to ensure the accuracy of the results. Table 2 explain the primary data of vent duct at RD KKRB 4 Utama.

Table 2. Primary data of vent duct at RD KKRB 4 Utama

Parameter	Observation Distance 1	Observation Distance 2
Diamater (m)	0.60	0.6
Area (m^2)	0.28	0.28
Perimeter (m)	0.89	0.89
Distance A Sensor to Working Front (m)	50	51.3
Distance B Sensor to Working Front (m)	75	76.3
Length of The Tunnel Observed (m)	76.74	78.04
Air velocity at the corner of the vent duct (m/s)	1.72	1.60
Air flow rate (m^3/s)	0.49	0.46

The type of airflow in the tunnel at the research site can be determined by the Reynolds number. The Reynolds number is obtained from calculations of air density, air flow velocity, and the diameter of the cross-section at the research site. The air flow velocity used is the average of the measurements taken at 16 observation points at the working front. All conditions have known Reynolds number values, and the results indicate that there is no airflow present at RD KKRB 4 Utama.

The testing diffusion coefficient is obtained using the Taylor equation (1954), as in equation 2. The required data includes the diameter of the tunnel airflow, the average air flow velocity, and the friction factor obtained from the Reynolds number value using the Colebrook equation, due to the rough tunnel surface conditions in the field. Table 3 represents the values of the diffusion coefficient during data collection in the field for RD KKRB 4 Utama, which includes the initial testing diffusion coefficient value when carbon monoxide (CO) gas resulting from the blast is at the 0-second mark. The value of the testing diffusion coefficient is very low because the CO gas has not yet been fully diluted.

The testing diffusion coefficient is obtained using the Taylor equation (1954), as in equation 2. The required data includes the diameter of the tunnel airflow, the average air flow velocity, and the friction factor obtained from the Reynolds number value using the Colebrook equation, due to the rough tunnel surface conditions in the field. Table 4 represents the values of the diffusion coefficient during data collection in the field for RD KKRB 4 Utama, which includes the initial testing diffusion coefficient value when carbon monoxide (CO) gas resulting from the blast is at 0 seconds. The value of the testing diffusion coefficient is very low because the CO gas has not yet been fully diluted.

Table 3. The values of the Taylor (1954) testing diffusion coefficient in each tunnel under various conditions

Observation Distance	Average Velocity (m/s)	Reynolds Number	Friction Factor	Friction Velocity (m/s)	Testing Difusion Coefficient (m^2/s)
1	0.00	0.00	2.57	0.00	0.00
2	0.00	0.00	2.46	0.00	0.00

The research was conducted at 2 different observation distances based on the progress of the tunnel

and the actual placement of the fan in the field. The maximum smoke clearing process can be determined when there is good air circulation and the decrease in CO gas occurs rapidly.
Figure 5 shows the graph of carbon monoxide (CO) gas concentration over time at RD KKRB 4 Utama at observation distance 1.

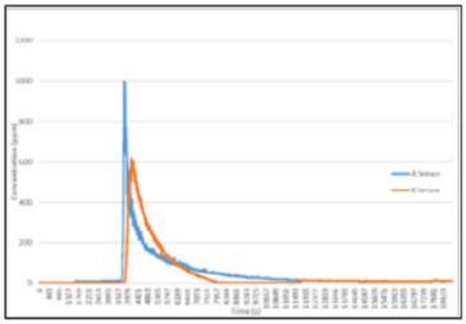


Figure 5. Graph of carbon monoxide (CO) concentration over time at RD KKRB 4 Utama at observation distance 1

At this observation distance, it can be seen that the dilution process for the two sensors differs significantly. This is because, considering the position of the sensors, A Sensor is closer to the working front and positioned in the middle of the blow duct's length, resulting in a longer CO gas dilution process compared to B Sensor. The dilution process at A Sensor takes 2.21 hours, while B Sensor requires 1.06 hours to reach a concentration level below the TLV (Threshold Limit Value) 50 ppm. The significant time difference is also attributed to the presence of an exhaust duct at the end of the RD KKRB 4 Utama tunnel with a fan power of 37 kW. This causes the CO concentration to dissipate faster at B Sensor compared to A Sensor, which is positioned farther from the exhaust duct.

Referring to the Director General of Minerals and Coal's Decision No.185K/37.04/DJB/2019 [8], which stipulates a 400 ppm concentration limit for a 15-minute CO gas exposure, the conditions at RD KKRB 4 Utama already meet this requirement because the 15-minute CO gas exposure concentration at RD KKRB 4 Utama is 383.43 ppm.

The value of the graphic method diffusion coefficient is obtained from the carbon monoxide (CO) gas dispersion graph according to the actual field conditions, considering the position of the vent duct and the air velocity in the blow duct. The value of the graphic method diffusion coefficient is empirically derived based on the Taylor diffusion coefficient (1954) using equation 4 with a curve matching method (trial and error in Microsoft Excel Solver).

At observation distance 2, it can be observed that the dilution of the two gases at A Sensor and B Sensor is not significantly different. Referring to the Director General of Minerals and Coal's Decree No. 185K/37.04/DJB/2019 [8], which stipulates a 400 ppm concentration limit for a 15-minute CO gas exposure, the conditions at RD KKRB 4 Utama at observation distance 2 already meet this requirement, as the 15-minute CO gas exposure concentration at RD KKRB 4 Utama is 337.54 ppm.

The dilution process at A Sensor takes 2.59 hours, while B Sensor requires 2.34 hours to reach a concentration level below the TLV 50 ppm. The CO gas dissipation time in observation placement 2 does not yet meet the company's requirements, which is 2 hours. Sensor one requires a longer time for CO gas dilution because A Sensor is closer to the working front, which is the source of CO gas due to blasting activities.

Another factor that can be observed is the presence of holes in the flexible blow duct. These holes in the flexible blow duct are intentionally created by the workers at the working front due to the hot working conditions, necessitating a flow of fresh air under the flexible blow duct through the holes. During

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 012028 doi:10.1088/1755-1315/1339/1/012028

blasting, these holes enlarge, reducing the airflow at the end of the flexible blow duct and limiting the optimal expulsion of CO gas at the working front. Figure 6 shows the holes in the flexible blow duct at observation distance 2.

Figure 6. Holes in the flexible duct at RD KKRB 4 Utama at observation distance 2

Figure 7 represents the analysis of CO gas concentration data testing under Condition 1 at RD KKRB 4 Utama, with the CO gas concentration graphic method results at B Sensor using equation 4, resulting in the empirically derived diffusion coefficient.

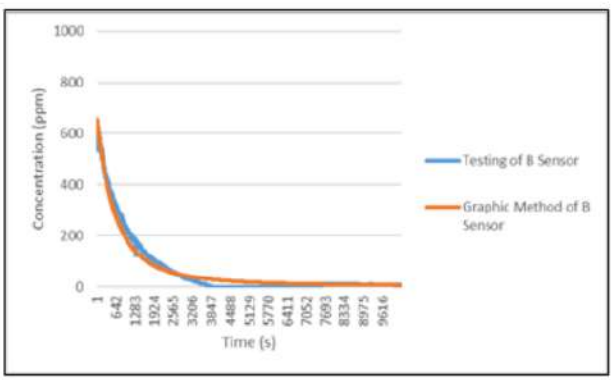


Figure 7. Graph of carbon monoxide (CO) concentration over time at RD KKRB 4 Utama at observation distance 1

The results of the experiment using the matching curve method are the method graphic diffusion coefficient values. Table 4 represents the diffusion coefficient values from the decrease in carbon monoxide (CO) gas concentration.

Table 4. Graphic method diffusion coefficient values from the decrease in carbon monoxide (CO) gas concentration at various observation distances

Observation Distance	Air Velocity (m/s)	Graphic Method Diffusion Coefficient (m^2/s)		
		A Sensor	B Sensor	Average
1	0	146.50	129.98	138.24
2	0	95.46	126.11	110.79

After analyzing the data from the RD KKRB 4 Utama field on carbon monoxide (CO) gas resulting from blasting, the data processing results in the table show that at observation distance 1, the graphic method diffusion coefficient obtained is the highest, with the distance from the working front to the blow duct being 40.64 m and the air velocity at the end of the blow duct being 1.72 m/s. The CO gas dissipation time is relatively fast compared to the dissipation of CO gas under other conditions at RD KKRB 4 Utama, which is 1.07 hours. CO gas requires 1.06 hours at B Sensor, with a peak value at B Sensor of 616.1 ppm. Figure 8 shows a bar chart comparing the diffusion coefficients of each sensor testing under various different conditions at RD KKRB 4.

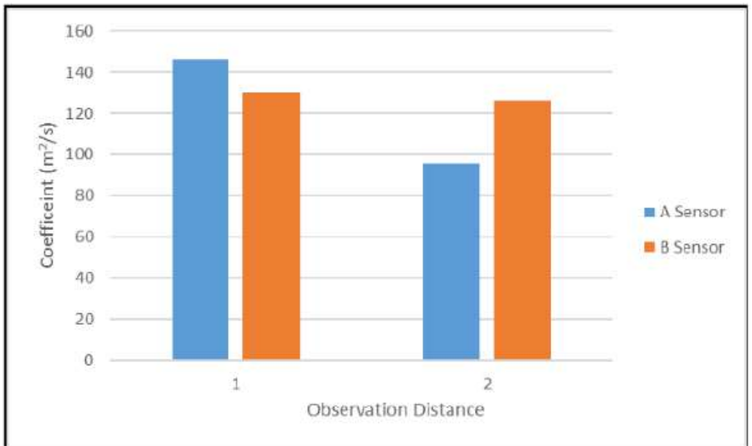


Figure 8. Graph of carbon monoxide (CO) concentration over time at RD KKRB 4 Utama at observation distance 1

The results of the testing diffusion coefficient calculation using the Taylor equation (1954) differ from the graphic method diffusion coefficient values obtained using the matching curve method (trial and error in Microsoft Excel). The testing diffusion coefficient is obtained when CO gas is initially blasted, thus not undergoing complete turbulence, whereas the graphic method diffusion coefficient is obtained when perfect turbulence occurs in the airflow, and the CO gas undergoes dilution from the peak concentration until complete dissolution. The diffusion coefficient is greater than the testing diffusion coefficient because when the airflow experiences perfect turbulence, CO gas will be diluted rapidly. In the RD KKRB 4 Utama simulation, the ratio of the graphic method coefficient to the testing coefficient ranges from 138 to 314 times. Table 4 represents a comparison of the graphic method diffusion coefficient (Dx) with the analytical diffusion coefficient (DA).

After conducting simulations using the physical tunnel model, Ansys Fluent software was used to determine the airflow turbulence. Observation distance 1 showed a high diffusion coefficient value during the simulation when air recirculation did not occur. Carbon monoxide (CO) gas is diluted rapidly because the placement of the blow duct is appropriate. This condition will be optimal if it follows the company's regulations, which state that if the end of the blow duct is more than 30 meters away, the blow duct will be advanced. The clean air blown by the blow duct goes directly to the working front and undergoes turbulence to dilute the CO gas. Subsequently, the contaminated air containing CO gas is sucked out by the exhaust duct located outside the tunnel without experiencing air recirculation. Figure 9 shows airflow at RD KKRB 4 Utama observation distance 1 (a) and 2 (b).

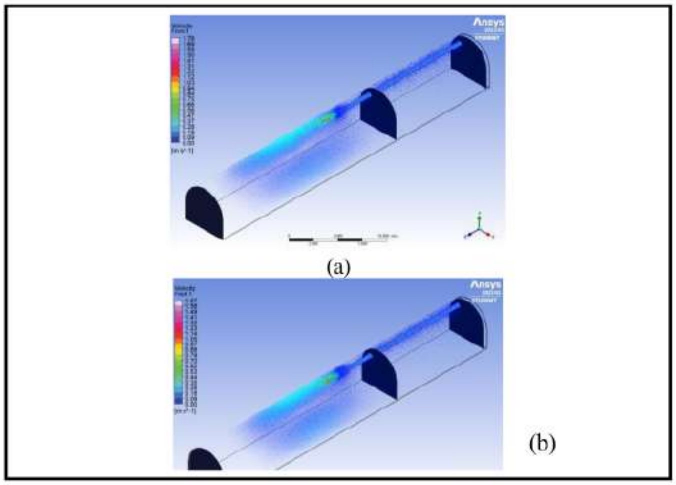


Figure 9. Airflow at RD KKRB 4 Utama observation distance 1 (a) and observation distance 2 (b)

4. Conclusion

The most ideal carbon monoxide reduction time at RD KKRB 4 Utama is shown at sensor placement distance 1 using the blow system, where A Sensor takes 2.21 hours and B Sensor takes 1.06 hours to reach a concentration level below the TLV 50 ppm. Referring to the Director General of Minerals and Coal's Decree No. 185K/37.04/DJB/201 which stipulates a 400 ppm concentration limit for a 15-minute CO gas exposure, the conditions at RD KKRB 4 Utama at placement distance 1 already meet this requirement, as the 15-minute CO gas exposure concentration at RD KKRB 4 Utama is 383.43 ppm. Adjustments to the blow duct and improvements to the flexible duct are necessary to optimize CO gas smoke clearing at the research site. This can be seen from the coefficients of each condition. The larger the diffusion coefficient value, the easier it is for CO gas to be diluted.

5. References

[1] Yulianti R, Hartami P N, Tuheteru E J and Maulana Y, Pertambangan J T and Teknologi F 2023 Analisis penurunan konsentrasi gas karbon monoksida (CO) pada saluran ventilasi di area belokan menggunakan model fisik terowongan skala laboratorium **11** 42–53

[2] Gillies A, Wu H and Shires D 2004 Development of an assessment tool to minimize safe after blast re-entry time to improve the mining cycle *Proc. Tenth US/North Am. Mine Vent. Sm* 1–9

[3] Yulianti R, Hartami P N and Hidayat T 2022 Penurunan konsentrasi gas karbon monoksida dengan model fisik terowongan skala laboratorium *J. Teknol. Miner. dan Batubara* **18** 59–67

[4] Harnoko A W, Priagung Widodo N and Ihsan A Analisis dilusi gas karbon monoksida pada permuka kerja terowongan horizontal dengan model fisik skala laboratorium

[5] Mcpherson M J 1993 *Subsurface Ventilation*

[6] Yulianti R, Widodo N P and Gautama R S 2021 Kondisi resirkulasi udara terhadap penurunan sumber panas di dalam tambang bawah tanah *J. Geomine* **8** 228

[7] Menéndez J, Merlé N, Fernández-Oro J M, Galdo M, de Prado L Á, Loredo J and Bernardo-Sánchez A 2022 Concentration, propagation and dilution of toxic gases in underground excavations under different ventilation modes *Int. J. Environ. Res. Public Health* **19**
[8] ESDM K 2019 Kepmendirjen minerba no.185K/37.04/DJB/2019 35–6
[9] Hanif P, Gani A and Widodo N P 2019 Study of re-entry time post blasting at ciguha pt antam UBPE pongkor underground gold mine
[10] Yuan L, Thomas R A and Zhou L 2017 Characterization of a mine fire using atmospheric monitoring system sensor data *Min. Eng.* **69** 57-62

Acknowledgments
The expression of gratitude is conveyed to PT Aneka Tambang UBPE Pongkor for providing the opportunity in the data collection process and publishing the manuscript. The author also extends thanks to Trisakti University, especially the Faculty of Earth Technology and Energy, for the financial support provided through the research fund.

Study of CO Gas Dilution in Forcing Ventilation System at Ramp Down KKRB 4 Utama, Pongkor, West Java

ORIGINALITY REPORT

23%	18%	13%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	discovery.researcher.life Internet Source	8%
2	Widyawanto Prastistho, Ika Wahyuning Widiarti. "The effect of calcination on natural calcareous bentonite for Mn and Fe adsorption in aqueous solution", IOP Conference Series: Earth and Environmental Science, 2024 Publication	2%
3	Lisa Samura, Cahaya Rosyidan, Mustamina Maulani, Suryo Prakoso et al. "Physical property comparison of polymeric KCl sludge composition and polyamine at different temperatures", IOP Conference Series: Earth and Environmental Science, 2024 Publication	2%
4	Mustamina Maulani, David Michael, Asri Nugrahanti, Cahaya Rosyidan, Lisa Samura, Bayu Satiyawira, Andry Prima. "Optimizing the impact of rheological properties on	2%

bentonite pre-hydrated based drilling mud through the utilization of pre-hydration", IOP Conference Series: Earth and Environmental Science, 2024
Publication

5	Submitted to Fakultas Teknologi Kebumian dan Energi Universitas Trisakti Student Paper	1%
6	D F Yudiantoro, Afrilita, S Pambudi, A Subandrio et al. "Geotourism of Telomoyo Volcano complex: an in-depth analysis for future development", IOP Conference Series: Earth and Environmental Science, 2024 Publication	1%
7	Submitted to School of Business and Management ITB Student Paper	1%
8	digibuo.uniovi.es Internet Source	1%
9	Submitted to University of Adelaide Student Paper	1%
10	publikationen.bibliothek.kit.edu Internet Source	1%
11	"2020 International Conference on Applications and Techniques in Cyber Intelligence", Springer Science and Business Media LLC, 2021	1%

Publication

12	Ivan Logachev, Konstantin Logachev, Olga Averkova. "Local Exhaust Ventilation - Aerodynamic Processes and Calculations of Dust Emissions", CRC Press, 2019 Publication	1 %
13	J Minár, S Mankovsky, O Šipr, D Benea, H Ebert. " Correlation effects in fcc-Fe Ni alloys investigated by means of the KKR-CPA ", Journal of Physics: Condensed Matter, 2014 Publication	<1 %
14	iopscience.iop.org Internet Source	<1 %
15	oa.las.ac.cn Internet Source	<1 %
16	www.mdpi.com Internet Source	<1 %
17	doctorat.ubbcluj.ro Internet Source	<1 %
18	David V. Chadderton. "Building Services Engineering Spreadsheets", Routledge, 2002 Publication	<1 %
19	Sharan, M.. "The process of gas exchange in the pulmonary circulation incorporating the contribution of axial diffusion", International Journal of Bio-Medical Computing, 198703 Publication	<1 %

Exclude quotes	Off	Exclude matches	< 15 words
Exclude bibliography	On		