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Research Article

Assessing Coal Mine Gas Impacts on Workers at Yayo Conventional Underground Coal Mine, Oromia, Ethiopia

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Abstract

Underground coal mining presents significant health and safety challenges, primarily due to the accumulation and emission of hazardous gases. This study investigates the occurrence, impact, and control of such gases at the Yayo Underground Coal Mine, located in the Illubabor Zone of the Oromia Region, Ethiopia. The Yayo mine, being one of the few operational underground coal mines in the country, provides a relevant case for assessing gas-related risks and developing appropriate safety strategies in Ethiopia. Field investigations, interviews, and review of operational records revealed the presence of four major hazardous gases: methane (CH_4), carbon monoxide (CO), carbon dioxide (CO_2), and hydrogen sulfide (H_2S). These gases are released from coal seams, equipment operations, and decomposition of organic matter, and pose serious risks including fire and explosion, oxygen displacement, and respiratory illnesses. The study found that some areas of the mine experience gas concentrations that approach or exceed acceptable exposure limits, endangering both miners' health and mine product. The assessment also highlighted several limitations in the current mitigation measures at Yayo, including inadequate ventilation systems, the absence of real-time gas monitoring devices, limited use of personal protective equipment (PPE), and lack of worker training. These deficiencies significantly increase the risk of gas-related accidents and long-term health effects. To improve safety, the study recommends the implementation of modern mechanical ventilation systems, deployment of portable and fixed gas detectors, and mandatory use of self-contained breathing apparatus (SCBA) in high-risk zones. Furthermore, it advocates for enhanced government regulation, periodic safety audits, and structured training programs for mine workers.

Keywords

Coal Mine Gas, Methane, Carbon Monoxide, Yayo Coal Mine, Mine Safety, Occupational Health, Ventilation, Gas Detection

1. Introduction

Coal stands as a fundamental primary energy resource, possessing substantial reserves globally, and particularly within Ethiopia. Its widespread utility in power generation, industrial processes, and domestic heating underscores its critical role in the global energy landscape. However, the extraction of coal, especially from underground mines, is inherently fraught with significant hazards due to the pervasive presence and potential accumulation of toxic and flammable gases. These gases originate from various sources, including the coal seams themselves, surrounding rock strata, decaying organic matter, and the operational activities within the mine.

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This paper meticulously examines the multifarious sources, critical properties, and pervasive impacts of these hazardous gases within the Yayo Underground Coal Mine, with a primary and unwavering focus on developing and implementing robust health and safety measures. By analyzing the current challenges and reviewing potential mitigation strategies, this research aims to contribute to the development of a more secure and sustainable coal mining operation in Ethiopia. The insights gleaned from this study are intended to serve as a valuable resource for mine operators, regulatory bodies, and policymakers, facilitating informed decision-making to safeguard human lives and optimize resource extraction. The overarching goal is to transform the Yayo mine into a model of best practice in underground coal mining safety, thereby fostering a healthier workforce and more efficient operations.

Coal is a primary energy resource with substantial reserves in Ethiopia. However, its extraction, particularly in underground mines, results in hazardous conditions due to the presence of toxic and flammable gases. In the Yayo coal mine, such gases pose risks to miners and affect operational efficiency. This paper examines the sources, properties, and impacts of these gases, with a focus on health and safety measures. [1].

2. General Information of the Study Area

The Yayo coal mine is strategically situated in the Achibo Sombo area, approximately 535 kilometers west of Addis Ababa, the capital city of Ethiopia. This geographical positioning places it within the Illubabor Zone of the Oromia Region, an area renowned for its agricultural productivity and nascent industrial development. The region is characterized by a subtropical moist climate, which influences both the surface conditions and, indirectly, some aspects of the underground environment. The abundant rainfall and lush vegetation are typical of this climatic zone.

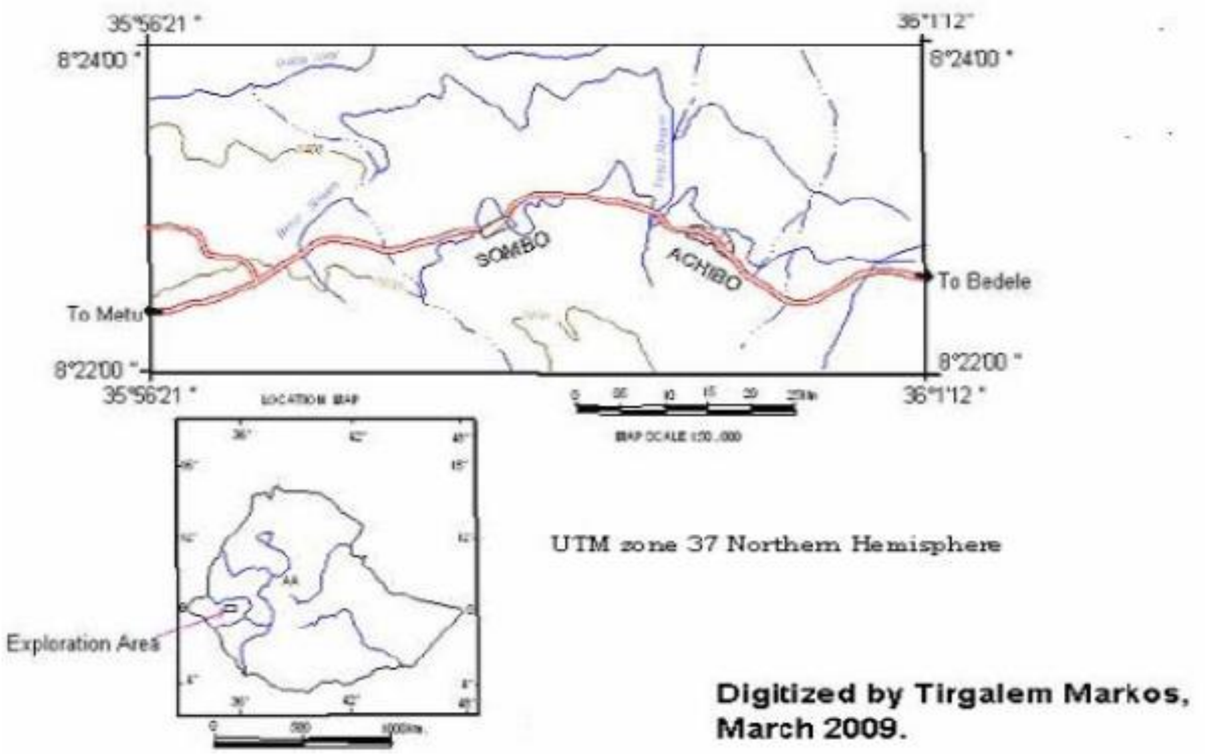

Figure 1. *Location map of the study area.*

Accessibility to the Yayo coal mine is facilitated by a well-established road network connecting it from major towns such as Jimma and Nekemte. These transportation arteries are vital for the movement of personnel, equipment, and extracted coal, linking the mine to broader markets and supply chains. The immediate vicinity of the mine is home to several local populations who are primarily engaged in agricultural activities, particularly coffee and chat farming. These communities often have settlements in close proximity to the mine, highlighting the intricate social and economic interface between the mining operations and the local populace. The presence of these communities necessitates a careful consideration of the mine's environmental and social impacts, including those related to gas emissions and their potential dispersion. [7].

The geological setting of the Yayo coal basin is characterized by specific sedimentary formations that host the coal seams. These formations play a crucial role in the generation and entrapment of mine gases. Understanding the stratigraphy and structural geology of the area can provide valuable insights into potential gas reservoirs and migration pathways within the mine. Figure 1 provides a detailed location map of the study area, illustrating its geographical context and accessibility. The map also indicates the UTM Zone 37 Northern Hemisphere coordinates, which are essential for precise geographical referencing and spatial analysis of the mine site. The digitization by Tirgalem Markos in March 2009 suggests the long-standing interest and previous mapping efforts in this significant coal-producing region. The visual representation aids in comprehending the mine's remoteness yet its connection to established urban centers, underscoring the logistical challenges and opportunities inherent in its operation. [2, 13].

3. Materials and Methods

To achieve a comprehensive understanding of coal mine gas impacts and mitigation strategies at the Yayo Underground Coal Mine, a multi-faceted research methodology was employed, integrating both primary and secondary data collection techniques. This approach ensured a robust and holistic analysis of the complex challenges posed by hazardous gases in an underground mining environment.

3.1. Methodology

The research design for this study was inherently dependent on the acquisition of relevant and current data directly from the Yayo underground conventional coal mining operation. This direct engagement was crucial to ensure the validity and applicability of the findings and subsequent recommendations.

3.1.1. Primary Data Collection Methods

1. Observation during Apprenticeship Time: Direct observation played a pivotal role in gathering firsthand information. During an apprenticeship period at the Yayo coal mine, researchers were able to systematically observe various aspects of the mining operations. This included, but was not limited to, the general ventilation practices, the types of machinery used, the visible signs of gas emissions (e.g., changes in air quality, audible gas leaks), the use of personal protective equipment by miners, and the overall adherence to safety protocols. Field observations provided invaluable qualitative data regarding the practical realities of gas management within the mine.
2. Interviewing Personnel: In-depth interviews were conducted with various personnel working at the Yayo coal mine. This included miners, supervisors, safety officers, and management staff. The interviews were structured to gather diverse perspectives on gas-related issues, including:
   1) Miners' direct experiences with gas exposure, their perception of risks, and their understanding of safety procedures.
   2) Supervisors' insights into operational challenges related to gas control, emergency response procedures, and training effectiveness.
   3) Safety officers' perspectives on existing safety protocols, equipment availability, and areas for improvement.
   4) Management's views on investment in safety technologies, regulatory compliance, and long-term safety strategies. Interviews provided rich qualitative data on the human element of mine safety, shedding light on perceptions, challenges, and proposed solutions from those directly involved in the operations.

3.1.2. Secondary Data Collection Methods

1. Documented Reports of Yayo Coal Mining Project: Accessing and analyzing existing documented reports from the Yayo coal mining project was a crucial secondary data source. These documents included:
   1) Safety reports and incident logs, which provided data on past gas-related accidents, near misses, and monitoring results.
   2) Ventilation plans and designs, offering insights into the planned and actual air circulation systems within the mine.
   3) Environmental impact assessments, which may have contained data on baseline gas levels and anticipated emissions.
   4) Production records, which could indirectly indicate areas of high gas liberation associated with specific mining fronts. Analyzing these internal documents provided a historical context and quantitative data where available.
2. Internet Sources: Extensive research was conducted using internet-based literature to gather broader information on coal mine gases, their properties, global mitigation strategies, and relevant regulatory frameworks. This included peer-reviewed journals, government publications, industry best practice guidelines, and academic databases. This helped in benchmarking current practices at Yayo against international standards and identifying cutting-edge technologies and methodologies.
3. Pre-Field Work Data Collection: Before conducting the fieldwork, a significant amount of data and relevant information was gathered to lay the groundwork for the thesis fulfillment. This involved preliminary literature reviews, understanding the general context of coal mining in Ethiopia, and formulating initial research questions.
4. Post-Field Work Analysis: Following the completion of fieldwork, further discussions were held to delve deeper into the characteristics of mining operations at

Yayo, their specific impacts on workers and the surrounding environment, and potential mitigation measures. Information provided by partners and research members, reflecting their perceptions, was meticulously recorded and later used to cross-check data obtained from coal mine workers at the site, ensuring data triangulation and enhancing the reliability of the findings.

5. Further Reading and Professional Consultation: In the post-field work phase, additional reading of relevant textbooks, manuals, and academic literature was undertaken. Furthermore, information was gathered through consultations with professional workers in the mining industry, who provided expert insights and validated the findings based on their extensive experience.

3.2. Data Limitations

It is important to acknowledge that equipment limitations during the study restricted the accuracy of precise quantitative gas measurements. While qualitative observations provided substantial insights, the absence of advanced, real-time gas monitoring equipment meant that the study relied more heavily on inferential data and reported observations for gas concentrations. This limitation underscores the urgent need for technological upgrades within the Yayo mine to facilitate more accurate and continuous gas monitoring in the future. Despite this, the combination of observational insights, interviews, and document analysis provided a comprehensive qualitative understanding of the gas-related challenges.

4. Results

The comprehensive study conducted at the Yayo Underground Coal Mine yielded significant findings regarding the types of hazardous gases present, their detrimental impacts on workers, and potential measures for mitigating these effects. The results underscore the critical need for enhanced safety protocols and technological interventions.

4.1. Identification of Mine Gases

The fieldwork and data collection at the Yayo coal mine unequivocally identified the presence of four primary hazardous gases: carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), and hydrogen sulfide (H_2S). Each of these gases poses distinct threats to the mining environment and personnel.

1. Methane (CH_4): Methane is a colorless, odorless, and highly flammable gas that is a natural byproduct of the coalification process, the geological transformation of plant matter into coal. It is often adsorbed within the coal seams and released during mining operations as the coal is fractured and exposed. The primary danger of methane in underground mines is its explosive potential. When mixed with air in concentrations between 5% and 15% (lower and upper explosive limits, respectively), methane can ignite, leading to devastating explosions. Even below explosive limits, high concentrations can displace oxygen, leading to asphyxiation. [3].
2. Carbon Monoxide (CO): Carbon monoxide is a highly toxic, colorless, odorless, and tasteless gas, often referred to as the "silent killer". It is primarily generated in underground coal mines through incomplete combustion, such as from mine fires, explosions, or the operation of diesel machinery with poor ventilation. CO has a much higher affinity for hemoglobin in the blood than oxygen, forming carboxyhemoglobin, which reduces the blood's oxygen-carrying capacity. Even at low concentrations, prolonged exposure can lead to severe health effects, including headaches, dizziness, nausea, and ultimately, unconsciousness and death due to oxygen deprivation to vital organs. It is a critical indicator of combustion events. [9].
3. Hydrogen Sulfide (H_2S): Hydrogen sulfide is an extremely toxic gas with a characteristic rotten-egg smell at low concentrations. However, at higher, more dangerous concentrations, it rapidly paralyzes the olfactory nerves, rendering the smell undetectable, which makes it particularly insidious. H2S can be produced from the decomposition of organic matter in water or from the reaction of sulfides in coal and rock with acidic mine water. Exposure to H2S can cause respiratory paralysis, eye irritation, headaches, and in severe cases, immediate collapse and death due due to its direct toxic effects on the central nervous system and respiratory system. [4].
4. Carbon Dioxide (CO2): Carbon dioxide is a common component of mine air and can be generated from various sources, including coal oxidation, blasting operations, and the respiration of miners. While not classified as toxic at low levels, CO_2 poses a significant threat because it is denser than air and tends to accumulate in low-lying areas, displacing oxygen. High concentrations of CO_2 can lead to asphyxiation by reducing the available oxygen for breathing. Symptoms of CO_2 exposure include increased breathing rate, headaches, dizziness, and ultimately, loss of consciousness and death.

4.2. Impact on Workers

The presence of these hazardous gases at the Yayo Underground Coal Mine has severe and multifaceted impacts on the health and safety of miners. The study's findings reveal a concerning pattern of risks directly attributable to gas exposure.

1. Respiratory Diseases: Prolonged exposure to mine

gases, particularly toxic ones like CO and H2S, and even high concentrations of CO_2, can lead to a range of severe respiratory diseases. This includes chronic bronchitis, emphysema, silicosis (exacerbated by poor air quality and dust), and other occupational lung diseases. The continuous inhalation of contaminated air irritates and damages the respiratory tract, impairing lung function over time.

2. Reduced Cognitive Functions: Exposure to gases like CO, which reduces oxygen delivery to the brain, can lead to impaired cognitive functions. Miners may experience reduced alertness, difficulty concentrating, impaired judgment, and slower reaction times. These effects not only impact their long-term health but also significantly increase the risk of accidents in the complex and hazardous mining environment.
3. Fatalities: The most catastrophic impact of uncontrolled mine gases is the potential for immediate fatalities. Explosions caused by methane ignition, acute poisoning from high concentrations of CO or H_2S, and asphyxiation due to oxygen displacement by CO_2 can all lead to rapid and often irreversible loss of life. The history of coal mining globally is replete with tragic examples of multi-fatality incidents directly linked to gas explosions or suffocation. [6].

A major exacerbating factor identified in the Yayo mine is the pervasive lack of adequate gas detection equipment and insufficient ventilation systems. Without reliable and continuous gas monitoring, miners may be unaware of dangerous gas levels until it is too late. Inadequate ventilation means that hazardous gases are not effectively diluted or removed from the mine workings, allowing them to accumulate to dangerous concentrations. These deficiencies create a highly hazardous working environment where miners are constantly at risk of acute or chronic gas exposure, underscoring the urgent need for substantial improvements in safety infrastructure. [5].

4.3. Possible Reduction Measures of Impacts of Mine Gas on Workers in Underground Mining

Based on the identification of gases and their impacts, the study proposes several critical measures to reduce the risks posed by mine gases to workers in underground mining environments:

1. Reduce the Emission of Gases by Using Best Technology Currently Available: Implementing modern mining technologies that minimize gas liberation during extraction processes is crucial. This can include techniques like optimized blasting patterns that reduce coal fragmentation and subsequent gas release, or advanced drilling methods that allow for targeted methane drainage before mining commences.
2. Use Electric Power for Zero Emission: Transitioning from diesel-powered machinery to electric equipment wherever feasible significantly reduces the emission of harmful combustion gases (like CO and NOx) and particulate matter into the mine atmosphere. Electric vehicles also produce less heat, contributing to better mine climate control.
3. Develop New Emission Control Technology to Reduce the Emission of Gases: Investing in research and development for innovative gas emission control technologies is essential for long-term sustainability. This could involve novel adsorption materials for gas capture, bio-filtration systems, or advanced catalytic converters for exhaust gases. [8, 12].
4. Wearing a Self-Contained Breathing Apparatus (SCBA) Will Protect Workers' Health in the Oxygen Deficient Atmosphere: SCBAs provide an independent supply of breathable air, protecting workers in environments with oxygen deficiency or high concentrations of toxic gases. Miners should be adequately trained in the proper use, maintenance, and limitations of SCBAs, and these devices must be readily available and regularly inspected.
5. Installation of Ventilation System Inside Underground Mines to Reduce the Emission of Gases and to Render the Gases: A well-designed and efficiently operated mechanical ventilation system is the cornerstone of gas control in underground mines. This involves installing powerful fans to circulate fresh air throughout the mine workings, diluting hazardous gases to safe levels, and sweeping them out of the mine. Different ventilation strategies (e.g., forcing, exhausting, hybrid) and systems (e.g., primary, auxiliary) must be tailored to the specific mine layout and gas emission rates.
6. Design and Operate Processes and Activities to Minimize Emission, Release, and Spread of Substances Hazardous to Health: Mine planning and operational procedures should be designed with gas control as a primary consideration. This includes optimizing mining sequences to avoid accumulating gas pockets, ensuring proper sealing of old workings, and minimizing spontaneous combustion risks.
7. Control Exposure by Measures That Are Proportionate to the Health Risk: A robust risk assessment framework is necessary to identify, evaluate, and prioritize gas-related risks. Control measures should then be implemented based on the hierarchy of controls: elimination, substitution, engineering controls (e.g., ventilation), administrative controls (e.g., work procedures, training), and finally, personal protective equipment (PPE). The measures adopted must be commensurate with the level of identified risk.
8. Inform and Train All Employees on the Hazards and Risks from Substances with Which They Work and the Use of Control Measures Developed to Minimize the Risks Associated with Mine Gas: Comprehensive and

ongoing training programs are vital. All miners and supervisory staff must be thoroughly educated on the properties and dangers of mine gases, how to recognize symptoms of exposure, the function and proper use of gas detection equipment, emergency procedures, and the correct application of all control measures, including PPE. Regular refresher training should be mandated.

9. Use Suitable Personal Protective Equipment: Beyond SCBAs, miners should be provided with and trained to use other appropriate PPE, such as gas masks with specific filters (where applicable and appropriate for the gas), and general mine safety attire that can offer some protection in adverse conditions. The selection of PPE must be based on the specific gas hazards identified. [8, 12].

5. Discussion

The findings from the Yayo Underground Coal Mine reveal significant challenges concerning hazardous gas emissions and their impact on worker safety and operational efficiency. The current state of safety protocols and technological infrastructure necessitates urgent intervention and the implementation of robust mitigation measures. This section discusses the proposed mitigation strategies and essential policy and operational recommendations.

5.1. Mitigation Measures

Effective control of mine gases at the Yayo coal mine requires a multi-pronged approach, integrating advanced technology with stringent operational protocols.

1. Installation of Mechanical Ventilation Systems: As identified in the results, inadequate ventilation is a primary contributor to gas accumulation. The immediate and critical step is to design and install state-of-the-art mechanical ventilation systems. This involves:

1) Main Fans: Powerful surface fans to draw fresh air into the mine and exhaust contaminated air. The size and number of these fans must be calculated based on the mine's volume, gas emission rates, and the number of personnel.

2) Auxiliary Fans: These smaller fans are crucial for ventilating active working faces, sumps, and other dead-end headings where main ventilation might be insufficient. They ensure localized air circulation and gas dilution.

3) Ventilation Network Design: The entire mine requires a carefully designed ventilation network, including air shafts, raises, drifts, and stoppings, to ensure that air flows efficiently and effectively to all active areas and sweeps out hazardous gases. Regular maintenance and monitoring of airflow are essential to prevent recirculation and ensure optimal performance. The design must also account for future mine expansion.

4) Continuous Monitoring: The ventilation system needs continuous real-time monitoring of airflow and fan performance to identify and address any anomalies promptly.

2. Deployment of Gas Detectors and Alarms: The current lack of sufficient detection equipment at Yayo significantly escalates risks. The implementation of advanced gas detection systems is paramount:

1) Personal Gas Detectors: Every miner should be equipped with a personal, multi-gas detector capable of continuously monitoring levels of CH_4, CO, CO_2, and H_2S. These devices must be intrinsically safe, regularly calibrated, and capable of providing audible and visual alarms when gas concentrations exceed pre-set alarm limits.

2) Fixed Gas Monitoring Systems: Strategically placed fixed gas sensors throughout the mine, particularly in high-risk areas such as active faces, return airways, electrical installations, and ventilation shafts, are essential. These systems should be networked to a central control room, providing real-time data and enabling immediate response in case of alarm conditions.

3) Automated Alarms and Shutdown Systems: Where feasible, gas detection systems should be integrated with automated alarm systems and, in critical areas, with automated shutdown systems for electrical equipment or machinery to prevent explosions in the event of high methane concentrations.

3. Use of Self-Contained Breathing Apparatus (SCBA): While ventilation and detection are primary engineering controls, SCBAs serve as critical personal protective equipment for emergency situations. Miners must be:

1) Trained: Rigorously trained in the proper donning, use, maintenance, and limitations of SCBAs. This training should include practical exercises in realistic mine conditions.

2) Accessible: SCBAs must be strategically placed at readily accessible locations throughout the mine, including refuge chambers and escape routes.

3) Inspected: Subject to regular inspection and maintenance to ensure their operational readiness. This also extends to other forms of respiratory protection, such as gas masks with appropriate filters, which may be suitable for specific low-level exposures. [10]

4. Regular Health Monitoring of Miners: Beyond preventing exposure, comprehensive health monitoring programs are vital to manage the long-term health impacts on miners:

1) Pre-employment Health Screenings: To establish a baseline health status and identify any pre-existing conditions that might be exacerbated by mine work.

2) Periodic Medical Examinations: Regular check-ups, in-

cluding lung function tests, blood tests (e.g., for carboxyhemoglobin), and general health assessments, are necessary to detect early signs of occupational diseases related to gas exposure.
3) Medical Record Keeping: Detailed and confidential medical records should be maintained for all miners, allowing for longitudinal tracking of health trends and epidemiological studies.
4) Health Education: Providing miners with information on the health risks of gas exposure, the importance of reporting symptoms, and healthy lifestyle choices.

5.2. Policy and Operational Recommendations

The study identified a significant deficiency in adequate safety protocols at the Yayo mine. Addressing this requires a concerted effort involving government intervention and improved operational practices.

Government Intervention to Mandate Gas Monitoring and Safety Standards: The Ethiopian government, specifically through the Ministry of Mines and relevant regulatory bodies, must implement and rigorously enforce comprehensive regulations pertaining to mine gas management. These regulations should include:

1. Mandatory Gas Monitoring: Requiring continuous, real-time gas monitoring systems in all underground coal mines, with specified alarm and action levels for CH_4, CO, CO_2, and H_2S.
2. Ventilation Standards: Establishing minimum airflow rates and ventilation design specifications based on international best practices. [15].
3. Personal Protective Equipment Requirements: Mandating the provision and mandatory use of appropriate PPE, including SCBAs, and regular training in their use.
4. Emergency Response Plans: Requiring detailed and regularly practiced emergency response plans for gas-related incidents, including evacuation procedures and rescue operations.
5. Regular Audits and Inspections: Conducting frequent and unannounced audits and inspections by regulatory authorities to ensure compliance with safety standards. Non-compliance should be met with strict penalties.
6. Investment Incentives: Providing incentives for mines to adopt advanced safety technologies and training programs.
7. Operational Enhancements at the Mine Level: Beyond regulatory mandates, the Yayo mine management must proactively implement operational improvements:
8. Safety Culture Development: Fostering a robust safety culture where safety is prioritized above production targets, and all employees feel empowered to report hazards and suggest improvements without fear of reprisal.
9. Training and Competency: Investing in continuous training programs for all personnel, from new recruits to experienced supervisors, covering gas hazards, emergency procedures, and the use of safety equipment. Competency assessments should be conducted regularly.
10. Risk Management Framework: Implementing a comprehensive risk management framework that includes hazard identification, risk assessment, control measure implementation, and continuous review. This should specifically address gas-related risks at every stage of the mining cycle.
11. Maintenance and Calibration: Establishing a stringent schedule for the maintenance and calibration of all safety equipment, particularly gas detectors and ventilation systems, to ensure their reliability.
12. Research and Development Integration: Collaborating with academic institutions and technology providers to research and implement innovative solutions tailored to the specific challenges of the Yayo mine.

The comprehensive implementation of these mitigation measures and policy recommendations is not merely an operational necessity but a moral imperative. It is essential for safeguarding the lives and health of miners, ensuring the long-term viability of the Yayo coal mine, and contributing to the sustainable development of Ethiopia's mineral resources. [11, 14].

6. Conclusions

The study on the Yayo Underground Coal Mine unequivocally highlights that the current uncontrolled gas emissions pose severe and unacceptable health and safety risks to the mining workforce. The presence of hazardous gases such as methane (CH_4), carbon monoxide (CO), hydrogen sulfide (H_2S), and carbon dioxide (CO_2) directly contributes to a high risk of respiratory diseases, cognitive impairments, and ultimately, fatalities among miners. The significant deficiencies in current safety protocols, particularly the lack of adequate gas detection equipment and insufficient ventilation systems, exacerbate these dangers, rendering the working environment perilous.

To transition towards a safer and more sustainable coal mining operation in Ethiopia, effective mitigation strategies are not merely beneficial but are critically essential. These strategies necessitate a dual approach involving significant technological upgrades and robust institutional oversight. Implementing advanced mechanical ventilation systems is paramount for diluting and removing hazardous gases, thereby improving overall air quality within the mine. Concurrently, the widespread deployment of sophisticated gas detectors and alarms is crucial for real-time monitoring and immediate warning of dangerous gas concentrations, enabling prompt intervention and evacuation when necessary. Furthermore, ensuring the availability and proper use of personal protective equipment, such as self-contained breathing apparatus (SCBA), is vital for protecting miners in emergency situations.

Beyond technological interventions, strengthening institutional oversight and regulatory frameworks is indispensable. Government intervention is urgently needed to mandate comprehensive gas monitoring standards, enforce strict safety protocols, and conduct regular audits to ensure compliance. Such regulatory actions would provide the necessary impetus for the Yayo mine and similar operations to prioritize worker safety.

In conclusion, enhancing worker protection must be prioritized above all else to ensure sustainable coal mining operations in Ethiopia. This research has provided a comprehensive understanding of the pervasive influence of mine gases, outlined effective mitigation measures, and shed light on their occurrences within the Yayo underground coal mine. The findings underscore the critical need for immediate and sustained efforts to create a safer working environment, thereby safeguarding the well-being of miners and contributing to the long-term viability of the Ethiopian coal industry.
This research has provided a comprehensive understanding of some of the influence of mine gases, possible mitigation measures and occurrences of mine gases. in this case in our final thesis we have discuss on different gases and impacts. Generally, we conclude that in our thesis study we are trying to discuss on different gases which are found in underground mining and also, we are discussing on the different impacts and influences of such gases on workers working in yayo underground coal mining.

Abbreviations

PM	Particulate Matter
GHG	Green House Gas
COPD	Chronic Obstructive Pulmonary Disease
PEL	Permissible Exposure Limit
TWA	Time Weighted Average
STEL	Short Term Exposure Limit
IDLH	Immediately Dangerous to Life and Health
CWP	Coal Workers Pneumoconiosis
SCBA	Self Contained Breathing Apparatus
PPM	Parts per Millon

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Author Contributions

Ephrem Tilahun: Conceptualization, Writing - original draft, Investigation, Methodology, Data curation, Formal Analysis, Validation, Resources, Writing - review & editing.

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Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Ephrem Tilahun is a Mining Engineering graduate from Aksum University. He has a keen research interest in mine safety and sustainable mining practices. I am currently serves as a researcher, focusing on environmental challenges in Artisnal Mining and processing in Ethiopia

Research Field

Ephrem Tilahun: Mine ventilation, Occupational safety in mining, Environmental impact of mining, Coal gas detection, Mine health monitoring, Mine safety technology, Toxic gas mitigation, Underground mining practices, Air quality control, Ethiopian mining policy.