Journal of Information Systems Engineering and Management
20--, Vol(Iss)
e-ISSN: 2468-4376
https://jisem-journal.com/

Research Article

A Smart Mining Safety System: Real-Time Environmental Sensing and Rapid Emergency Response

Kiran Ingale[1], Sanika Kadam[2] ,Vedika Kadam[3],Aditya Kale[4],Venkatesh Korde[5]

[1]*Vishwakarma Institute of Technology* Pune, Maharashtra, India

[2] *Vishwakarma Institute of Technology* Pune, Maharashtra, India

[3]*Vishwakarma Institute of Technology* Pune, Maharashtra, India

[4] *Vishwakarma Institute of Technology* Pune, Maharashtra, India

[5] *Vishwakarma Institute of Technology* Pune, Maharashtra, India

ARTICL E INFO

Received: dd Month 20-- Accepted: dd Month 20--

ABSTRACT

Introduction: As the Coal mining environments posses significant safety hazards due to the presence of toxic gases such as carbon monoxide and methane, which are harmful for health too, as well as extreme change in temperature and humidity. Assuring the safety and health of mine workers requires real-time monitoring of both environmental and health conditions .The development of a smart, integrated safety system that continuously tracks and monitors gas concentrations, varying temperature, humidity of atmosphere including pulse rate and blood oxygen levels of the workers.The system integrates various sensors which are interfaced with the ESP8266 microcontroller, which enable wireless communication with a central monitoring unit via Wi-Fi. For unusual readings alerts are sent to the control room by buzzer and , providing rapid emergency response to the workers . And so this real-time system is specially designed to enhance the safety of the workers and reduce the risks of underground mining operations.

Objectives: The project mainly focuses to develop a real-time and low-cost system for safety of workers and to prevent the accident causing factors for coal mines. It continuously monitors the harmful gases like carbon monoxide , methane along with temperature and humidity of atmosphere inside the coal mine, along with it monitoring the pulse rate and oxygen levels of workers working in mine. The sensors which we have used in this system to collect the data are MQ7, MQ4, DHT11, and MAX30102 . ESP8266 is the microcontroller which is used to process the data and send wirelessly to ThingSpeak for monitoring it . The system also triggers alerts whenever any unsafe conditions occurs and also ensure timely response to look after worker safety.

Methods: This system was developed with the goal of improving the safety of workers in underground mining environments. It keeps track of potentially dangerous gases, monitors workers' vital signs like pulse rate, and observes environmental factors such as temperature and humidity. At the heart of the system is the ESP8266 microcontroller, which handles all the data collection and processing from the connected sensors. For gas detection, the setup uses the MQ7 sensor for carbon monoxide and the MQ4 sensor for methane—both chosen for their importance in identifying harmful gas concentrations. The MAX30102 sensor is responsible for monitoring the pulse rate, while temperature and humidity readings are gathered through the DHT11. Whenever any readings go beyond safe limits, the system immediately triggers real-time alerts to warn workers and supervisors. All collected data is sent wirelessly using Wi-Fi to a ThingSpeak dashboard, allowing for continuous remote monitoring. The sensors are connected using GPIO, analog, digital, and I²C interfaces, ensuring smooth and efficient communication. To confirm its

reliability, the system was thoroughly tested in conditions that closely mimic real mining scenarios, and it responded well in detecting hazards promptly.

Results: Our system was able to successfully monitor key aspects of underground mining safety in real time. It picked up dangerous levels of gases like carbon monoxide and methane with reliable accuracy, triggering warnings when those levels crossed safe limits. Also side by side gas detection, it also tracked environmental factors such as temperature and humidity, helping to identify risky conditions. For health monitoring, the system kept an eye on workers' pulse and oxygen levels, and sent out alerts promptly when anything seemed out of the ordinary.

Conclusions: In wrapping up this research paper, it's clear that putting together gas sensors, environmental monitors, and health trackers into one system can really help make coal mines safer. During testing, the system did its job by catching unsafe situations early, which is exactly what's needed underground. There were a few hiccups, like occasional sensor errors and some trouble with the network, but those are problems that can be worked out with more work and regular checks. All in all, this project shows that with the right tools and a bit of fine-tuning, we can take real steps toward better safety for miners.

Keywords: **ESP8266 NordMCU Microcontroller, Mining Safety, MQ7 Sensor, MQ4 Sensor, MAX30102, DHT11 Sensor, Wireless Monitoring, Alert System, Worker Health**

INTRODUCTION

To ensure the safety of the workers underground in the coal mine is a challenge due to the hazardous and harsh environment. Different toxic gases such as carbon monoxide and methane, as well as the fluctuating temperatures and humidity level, are some of the factors which could lead to a severe incident or explosion, or could also cause a long-term health issue. In the past, these factors have caused numerous tragedy incidents, and that's why there is the need for safety measures. Along with monitoring the different conditions in the mine, we also need to physiologically see the well-being of miners. Long-term exposure to the air quality inside the mine and the different elevated temperatures causes stress, fatigue, and unexpected emergencies. Therefore, to create a system which could simultaneously track the health and send the response, this research, which we have made, combines all the factors and provides a solution for the detection of gas, sensing the environment, and also monitoring the workers' health. The key components for this system are the MQ7 and MQ4 sensors for the detection of harmful gases, the DHT11 sensor for temperature and humidity, and the MAX30102 for pulse rate and oxygen levels of the worker. These sensors monitor and send the data to ThingSpeak. All the sensors process the data, which is then handled by the ESP8266 microcontroller, supporting wireless communication. This is connected with ThingSpeak, which can monitor the data and form different graphs from various sensors.

This system does not only monitor but also provides early warnings. The primary goal of this system is to deliver a low-cost, wireless monitoring solution that offers real-time and continuous supervision of both environmental and health conditions, thereby minimizing risks and enhancing security.

OBJECTIVES

The main objective to build this project was to make a real-time and a low-cost monitoring system specially for workers of coal mines and ensure proper atmosphere ,workers are faced to harmful and drastic environmental conditions. This system mainly focuse s on continuous monitoring of both the mine atmosphere as well as health of the workers working underground to prevent accidents and long-term risk of health . It also focuses to detect various hazardous gases and its concentration to analyse it , gases such as carbon monoxide (CO) ,methane (CH_4), parallelly it also keeps the track on other environmental factors such as temperature and humidity, which can vary drastically and cause serious concerns. Also to address the well-being of the mine workers physically, this also monitors their pulse rate and oxygen saturation and monitors it continuously using health sensor . MQ7 and MQ4 gas sensors, a DHT11 sensor are other main components used in this system along with temperature and humidity for atmosphere, and the MAX30102 sensor for health monitoring.ESP8266 microcontroller collect this data and process it after which as this microcontroller supports wireless communication all the data is sent to ThingSpeak which is a IoT platform used for real-time monitoring and graphic visualization for easy understanding . Whenever the readings go below the certain fixed value the system generates alert, which enables quick responses from the control room to manage the uncertain conditions and rescuing the people . As this solution is designed to improve standards of safety by continuous observing and sending the early warnings, for quick interventions to reduce the risk and protect workers of mine .

METHODS

3.1 System Architecture

We built the system with three main goals in mind: to detect the harmful gases, track all health signs like pulse rate, and monitor the environment around all workers. Everything runs through a small but powerful microcontroller, the ESP8266, which basically acts as the system's brain. It constantly checks the data coming in from different sensor, and if it notices something goes wrong spike in gas levels or unusual health reading then it sends out alerts right away. There's also a real-time alarm system in place, both on-site and remotely, so people can respond quickly when something's wrong. The whole idea is to keep everyone safe without any delays so they can work without any tension.

3.2 Hardware Component

In gas sensor the hardware component are mq7 and mq4 sensor etc Gas Sensor like

A. MQ7 Sensor :

The MQ7 sensor is used to detect carbon monoxide (CO), a gas that's frequently found in underground mining environments. It works by heating a tin dioxide (SnO_2) layer, which changes its electrical resistance when CO is present. This variation in resistance is then converted into a digital signal that the microcontroller can interpret.

B. MQ4 Sensor :

The MQ4 sensor detects methane, a highly flammable gas present in mines. It uses similar principles to the MQ7 sensor, making it sensitive to methane concentrations. This sensor is crucial for preventing explosions and ensuring safe air quality

C. Data processing and alert method :

All the data from the sensors is processed by the ESP8266 microcontroller, which acts as the brain of the system. Each sensor is configured with specific safety thresholds. For gas detection, the limits align with established safety standards for carbon monoxide and methane. When it comes to temperature and humidity, thresholds are defined based on conditions that could heighten risks in certain parts of the mine for instance, extreme heat or moisture that could increase the likelihood of hazardous events.

D. Communication Setup :

Communication between the project and the control room is handled through the ESP8266's which has built-in Wi-Fi capability. This enables data to be sent wirelessly from deep within the mine to a control station no matter what is distances. Wi-Fi is ideal for this setup because it offers low latency and supports multiple simultaneous connections. As a result, sensor readings can be transmitted regularly and in real time. The data is displayed on a ThingSpeak dashboard, which allows continuous tracking of environmental and health parameters, ensuring that any critical changes are immediately visible to monitoring personnel.

E. Circuit Design :

The sensors are connected to the ESP8266 microcontroller in a way that make sure smooth and efficient data flow. For gas detection, the MQ7 and MQ4 sensors are attach to the analog input pins, where their output signals are converted from analog to digital so the microcontroller can read and interpret the data accurately. The DHT11 (temperature) and any additional temperature sensors are connected with digital input pins, with the sensor modules themselves handling the data formatting before sending it along. For health monitor the MAX30102 sensor communicates through the I²C interface, which allows for reliable and quick data transmission with minimal lag. This project ensures that all sensor readings reach the microcontroller promptly, enabling real-time monitor and response.

F. Testing Protocols :

To make sure our project could handle the kind of tough and risky environments you'd typically find in underground mines, we ran a series of thorough tests in a specially designed setup. This setup was built to mimic real mining conditions as closely as possible. One of the first things we looked at was how accurate our sensor are. We tested them to different levels of gas conc and checked how well they responded under various environment situations. This helped us confirm that the sensors could pick up even small changes in gas levels, which is really important for early detection and safety.

SYSTEM ARCHITECTURE

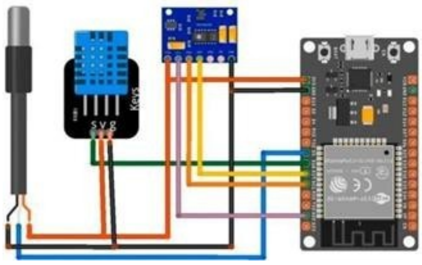

Fig 1: Connections of DHT11, MAX30100, DS18B20 and sensors with NodeMCU

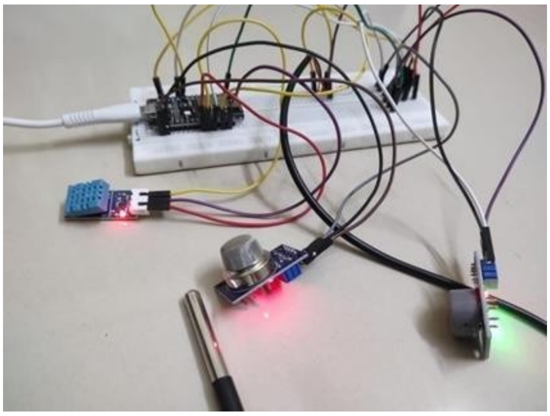

Fig 2: Connections between MQ7, MQ4, DHT11 sensor with NodeMCU

RESULTS

5.1 System Performance and Sensor Accuracy :

The project is made only for real-timemonitor of dangerous gases, environment conditions, and to see worker health. In tests conducted under controlled conditions, several key observations emerged. Regarding gas detection, the MQ 7 sensor reliably identified carbon monoxide (CO) concentrations as low as 10 parts per million. When CO levels surpassed 35 ppm, the system generated an alert, consistent with recognized safety standards. Similarly, the MQ-4 sensor for methane detection performed effectively: it detected methane starting at 100 ppm and triggered alerts at the critical threshold of 500 ppm. In terms of environmental monitoring, the DHT11 sensor consistently recorded ambient temperatureand humidity. It measured temperatures ranging from 18°C to 30°C and humidity levels between 30% and 85%. These readings are crucial because extreme environmental conditions can increase risk; for example, high humidity or temperature fluctuations may increase the likelihood of an explosion when flammable gases are present. For monitoring worker health sensor MAX30102 sensor is used which gives continuous measurements of heart rate and blood oxygen saturation. The system is set to send alerts if a worker’s heart rate fell below 50 beats per minute (bpm) or exceeded 100 bpm. Such derivation can indicate potential health issues, avioding this kind of sitiuation is compromising safety.

5.2 Alerting and Communication System Data :

Communication between the sensors and the control room ran smoothly due to the ESP8266 microcontroller. The data was wirelessly transmittedover Wi-Fi, enabling continuous monitoring from the control room. Immediate notifications were sent if the system detected hazardous gas levels, unsafe environmental changes, or concerning health parameters. Additionally, an integrated buzzer system provided on-site warnings, essential for fast evacuation in emergencies. This prompt alerting mechanism proved dependable for notifying both workers and control room staff of any dangers.

5.3 System Limitations and Challenges:

While the system performed well in controlled enviroment , we come across some challenges during testing. Over time, we see small inconsistencies in the readings from the MQ sensor, which means it would need to be checked regularly to keep the data accurate. This is a common issue with chemical sensors and can be managed in the final version by setting up a regular maintenance schedule. We also ran into problems with the ESP8266 Wi-Fi module in underground areas— thick walls and interference made the signalweak, leading to poor connectivity. A possible fix for this could be using a mesh network or switching to a stronger communication protocol like ZIGBEE better suited for all such condition. Another issue was with the MAX30102 health sensor. Although it worked well in the prototype, its accuracy dropped in the dusty and humid environment of the coal mine. Dust on the sensor’s surface sometimes affected the readings, so using it in mines which is sourrounded by sand is not feasible one thing we can do is adding a protective layer might help.

5.4 Comparison to Existing Systems:

Compared to the nowadays safety systems used by miners in coal mines, our idea birngs an approch an advanced multi sensor idea by combining gas, environmental, and health monitor sensors. Standard systems generally focus on gas detection alone, while our integrated health monitoring can identify early signs of health risks, which also allow for a early safety approach. Furthermore, our Wi-Fi-based real time alert system provide an advantage over traditional wired solutions by allowing for faster responses and easy monitoring in even remote sections of the mine.

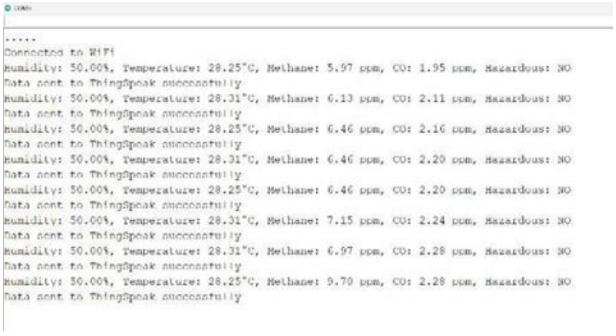

Fig 3: Data Displayed on Serial Monitor of Arduino IDE

Fig 4: Methane Gas Data displayed on ThingSpeak

Fig 5: CO Gas Data displayed on ThingSpeak

Fig 6: Humidity Data displayed on ThingSpeak

Fig 7: Temperature Data displayed on ThingSpeak

FUTURE SCOPE

6.1 Integration with Advanced Communication Technologies:

Advanced Communication Technologies like LoRaWAN or 5G will help in long range data transmission like underground mines and is more scalable. This will help in real time monitoring and quick emergency alerts.

6.2 Predictive Analytics and AI-Based Hazard Forecasting:

Based on historical sensor data generated and analysed by AI and Machine Learning models, the system can identify patterns and can predict the hazards like gas leaks, temperature rise, etc. This will reduce the risk of accidents by giving early warnings.

6.3 Expansion to Multi-Parameter Environmental Monitoring:

By integrating additional environmental sensors to monitor parameters like air pressure, humidity, dust concentration, etc. more data generation and collection will happen. This will help in understanding more about mine conditions and worker safety.

6.4 Cloud-Based Data Management and Analysis:

Cloud based management will be easier as we can easily access data from anywhere, we can store data and analyze it which will help in monitoring mine conditions.

6.5 Automated Emergency Response and Evacuation Systems:

We can build a function which will automatically give emergency response during hazardous conditions and will guide to show safe paths, which will save time and protect workers during danger.

6.6 Energy Efficient and Self-Sustaining Operation:

By making systems more sustainable using energy harvesting technologies like solar panel or kinetic energy modules, we can provide continuous power to sensors and communication devices. This will be very helpful in remote or deep underground areas where regular power supply is difficult.

DISCUSSION

The system showed promising results when it came to real-time detection of hazardous gases, monitoring of environmental conditions, and tracking the health of mine workers. During testing, both the MQ7 and MQ4 sensors were able to accurately detect carbon monoxide and methane, successfully identifying concentrations near critical safety thresholds. The DHT11 sensor performed trustworthy capturing temperature and humidity readings that remains well within the expected range throughout testing. In terms of he alth monitoring, the MAX30102 sensor worked effective at tracking both heart rate and oxygen saturation levels. It quickly reports any abnormal values, ensuring alerts were also generated without any delay.All these alerts are being communicated in two way s the first one is wirelessly to a central dashboard via Wi-Fi and second one is locally using an onboard buzzer, allowing for immediate awareness and response. However, a few practical limitations were found during testing. The sensors sometime experienced drift over some time, Wi-Fi connectivity was inconsistent in deeper underground sections, and the MAX30102 struggled with accuracy in environments with excessive dust. To overcome these challenges, routine sensor calibration, adopting mesh network protocols like ZigBee for more stable communication, and equipping sensors with protective enclosures are suggested. Despite of these issues, the project offers a significant improvement over traditional safety methods, providing a more responsive, wireless, and integrated approach to ensuring miner well-being.

REFRENCES

[1] S. R. Deokar and J. S. Wakode, “Advanced Coal Mine Safety Monitoring and Auto Alert System Using LoRa,” *CVR Journal of Science and Technology*, vol. 20, pp. 1–5, 2023

[2] N. Renuka, P. Saisree, S. Chandana, M. Salman, and B. Deepak, “IoT Based Underground Worker Safety System,” *International Journal for Research in Applied Science and Engineering Technology (IJRASET)*, vol.

10, no. 6, pp. 1–6, Jun. 2022. DOI: 10.22214/ijraset.2022.47521

[3] A. R. Katkar, R. P. Shete, D. M. Tajane, U. B. Phiske, and B. E. Shinde, "IoT Based Mining, Tracking and Worker Safety Helmet," *International Journal for Research in Applied Science and Engineering Technology (IJRASET)*, vol. 12, no. 4, pp. 1–6, Apr. 2024. DOI: 10.22214/ijraset.2024.64538.

[4] L. Scalambrin, A. Zanella, and X. Vilajosana, "LoRa Multi-Hop Networks for Monitoring Underground Mining Environments," *arXiv preprint arXiv:2310.20515*, Oct. 2023.

[5] Mangesh Rudrawar, Shivam Sharma, Madhuri Thakur, and Vivek Kadam, "Coal mine safety monitoring and alerting system with smart helmet," ITM Web of Conferences, vol. 44, pp. 01005, 2022. https://doi.org/10.1051/itmconf/20224401005

[6] S. S. Gopisetty, K. S. R. Anjaneyulu, K. V. S. S. S. S. Prasad, and B. S. S. S. S. Prasad, "An IoT system for monitoring and alerting safety in coal mines," E3S Web of Conferences, vol. 497, Article no. 03001, 2025.https://doi.org/10.1051/e3sconf/202561603001

[7] P. D. Hemapriya, R. Rajalakshmi, S. Ramya, G. Sangeetha, and D. Subhulakshmi, "Coal mine safety and health monitoring system," International Journal of Engineering Research & Technology, vol. 10, no. 4, pp. 120 –124, 2021.https://www.ijert.org/coal-mine-safety-and-health-monitoring-system

[8] Madhu Nakirekanti, Dr.Raja Murali Prasad, Eliyaz Mahammad, K.Narsimha Reddy, and D. Khalandar Basha, "Coal mining safety monitoring system," International Journal of Mechanical Engineering and Technology, vol. 8, no. 12, pp. 542–550, 2017 https://iaeme.com/Home/issue/IJMET?Volume=8&Issue=12

[9] Sri Divya, Pingili Siddartha, Pilli Pranay, Sailla Prashanth, Nallaganti Venu, "IOT–BASED COAL MINE SAFETY MONITORING AND ALERTING SYSTEM", International Research Journal of Modernization in Engineering Technology and Science, Volume:06/Issue:04/April -2024,e-ISSN: 2582-5208, DOI : https://www.doi.org/10.56726/IRJMETS53126

[10] Prof. A.H.Ansari, Karishma Shaikh, Pooja Kadu, Nikam Rishikesh, "IOT Based Coal Mine Safety Monitoring and Alerting System", International Journal of Scientific Research in Science, Engineering and Technology, Print ISSN: 2395-1990, Online ISSN : 2394-4099 (www.ijsrset.com), doi : https://doi.org/10.32628/IJSRSET2183188

[11] Aditi Nagrale, Roshani Wakodikar, Priti Nakade, Ketan Marothi, Kalyani Raut Dr. Ganesh Regulwar and Ms. Pushpa Chutel, "Coal Mine Safety Monitoring and Alert System ", International Journal of Advanced Research in Science, Communication and Technology (IJARSCT), Volume 4, Issue 3, April 2021, ISSN (Online) 2581-9429

[12] Hemapriya.P.D, Rajalakshmi.R, Ramya.S, Sangeetha.G, Subhulakshmi.D, " COAL MINE SAFETY AND HEALTH MONITORING SYSTEM", International Journal of Engineering Research & Technology (IJERT), Volume 11, Issue 03, ISSN: 2278-0181