# Enviro-Alert Helmet: A Wearable IoT Solution for Safety, Hazard Detection, And Rapid Response

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**Abstract**

This paper introduces a smart helmet system designed to enhance worker safety in industrial settings through real-time health and environmental monitoring. Equipped with advanced sensors, the helmet detects hazards like extreme temperatures, high noise levels, and toxic gases, continuously capturing data on both the worker's health and their environment. This information is wirelessly transmitted to a central monitoring system, giving supervisors real-time visibility into working conditions. In critical situations where safety thresholds are breached, automated alerts are sent to both the worker and remote supervisors, enabling swift intervention and reducing accident risk. Additionally, the system's long term data collection supports trend analysis, helping organizations implement preventive measures based on cumulative insights. This comprehensive solution advances workplace safety by combining immediate alert capabilities with continuous monitoring and data driven risk management in hazardous environments.

***Keywords:*** **Industrial safety, smart helmet, real-time health monitoring, occupational health, emergency alert system, environmental hazard detection**

## 1. INTRODUCTION

Industrial safety has progressed remarkably since the Industrial Revolution, an era when factories, mines, and mills rapidly transformed economies but introduced significant hazards for workers. The emphasis on maximizing production led to conditions filled with dangerous machinery, toxic chemicals, and unstable structures. Workers faced frequent accidents and chronic health problems, with only minimal safety measures in place, such as basic protective gear and rudimentary emergency protocols. These efforts were often inadequate, unable to address the complex risks posed by the large-scale industrial environment.

In response to the rising number of workplace incidents and public concern, governments began introducing regulations to improve worker safety. The UK's Factory Acts, among the earliest reforms, aimed to limit working hours and set age restrictions on labourers, establishing an early framework for worker protection. These initial regulations underscored the importance of safeguarding workers and set the groundwork for more structured safety measures. As understanding of occupational health advanced, countries worldwide adopted comprehensive frameworks, shaping the foundation of modern workplace safety protocols.

By the mid-20th century, developed nations had implemented extensive occupational safety laws and established regulatory bodies to uphold worker welfare. A key milestone in the U.S. was the Occupational Safety and Health Act (OSHA) of 1970, which introduced industry-wide safety standards and emphasized employer accountability for maintaining safe workplaces. This shift toward a preventive approach high- lighted accident prevention as a primary objective, marking a significant move from reactive responses to proactive safety management. Such developments strengthened the commitment to worker health as a fundamental right, reinforcing preventive safety as the cornerstone of industrial work environments.

Today, advancements in wearable technology have further transformed industrial safety. Innovations like smart helmets equipped with GPS, health, and environmental sensors provide real-time monitoring of factors like fatigue, heat stress, and gas exposure, enabling rapid responses to potential risks. These wearables, which facilitate immediate alerts and swift interventions, represent a leap in preventive care that surpasses traditional safety practices. Alongside improved safety, wearables enhance productivity by allowing hands-free communication and access to instructions, creating work environments that are not only safer but also more efficient and resilient. This integration of health monitoring and operational efficiency signifies a new era in workplace safety, where technology and well-being are both prioritized.

## 2. RELATED WORKS

Advancements in smart helmet systems have opened new possibilities for ensuring safety in high-risk industrial environments. Campero Jurado et al. (2020) introduced the Smart Helmet 5.0, an IoT and AI enabled device that continuously monitors environmental factors such as air quality, temperature, and lighting. By providing real time alerts, the system ensures rapid responses to hazardous conditions, significantly reducing accident risks [1]. Similarly, Charde et al. (2020) developed a helmet tailored for coal mining operations using ZigBee technology. This system detects harmful gases and environmental changes, instantly alerting miners and control stations to mitigate risks [2].

Altamura et al. (2019) proposed the SAFE helmet, designed specifically for industrial settings. This system integrates sensors to monitor environmental hazards like gas leaks and flames while tracking vital signs such as heart rate and body temperature. Alerts are transmitted in real-time to supervisors, enabling timely interventions during emergencies [3]. Byeon et al. (2018) developed a smart helmet featuring wireless communication capabilities to monitor workplace conditions. This system aims to reduce emergency response times by providing live updates to administrators, thus enhancing worker safety [4].
Choi and Kim (2021) provided a systematic review of smart helmets across various applications, including worker safety and health monitoring. Their study identified emerging trends in sensor technology, microcontrollers, and wireless communication systems, emphasizing their potential to improve occupational safety [5].

In mining environments, IoT based solutions have gained traction for improving worker safety. Eldemerdash et al. (2020) introduced a helmet equipped with sensors to monitor conditions such as temperature, humidity, and gas levels. The system sends real-time alerts to control rooms, ensuring timely responses to potential hazards [6]. Roja and Srihari (2018) proposed a helmet that monitors hazardous gases and helmet removal, transmitting data via GPRS to a remote server for effective monitoring and intervention [7].

Another significant development comes from Kumar et al. (2021), who designed a smart helmet for coal miners. Their system incorporates sensors to detect harmful gases, temperature fluctuations, and vibrations. Using LoRa and GSM technologies, the helmet enables long range communication, ensuring that alerts are promptly relayed to supervisors [8].

Kim et al. (2021) presented a Bluetooth based proximity warning system tailored for underground mines. This system focuses on preventing accidents by alerting workers when they are too close to hazardous areas or machinery, leveraging Blue- tooth's low-power, short-range communication capabilities [9].

For motorbike riders, Divyasudha et al. (2019) developed a helmet that integrates accident detection, alcohol level monitoring, and hazardous gas detection. This system uses cloud-based communication networks to send real-time alerts to emergency contacts, enhancing road safety [10].

Other notable contributions include the work of Sandaruwan et al. (n.d.), who adopted Kansei Engineering principles to design smart helmets for worker safety in mining. Their helmet incorporates sensors to monitor environmental parameters such as temperature, humidity, and gas concentrations, with wireless communication ensuring timely interventions [11]. Addition- ally, Sanjay et al. (2019) utilized ZigBee technology to create a helmet for miners, focusing on monitoring temperature, humidity, and atmospheric pressure. The system provides reliable communication over long distances, significantly improving worker safety in mining environments [12].

Sowmya et al. (2022) proposed a smart helmet system specifically for detecting hazardous events in the mining industry. The helmet is equipped with sensors to track air quality, collisions, and helmet removal, sending data in real time to control centres via IoT technologies [13]. Additionally, Rasli et al. (2013) introduced a helmet for motorcyclist safety that integrates sensors to detect speed, accident likelihood, and helmet presence. The system prevents the vehicle from starting unless the helmet is securely worn [14].

Finally, Behr et al. (2016) developed a helmet designed to detect air quality issues and hazardous events in mining environments. By integrating sensors and wireless communication, the system ensures that critical safety parameters are continuously monitored, reducing the likelihood of accidents [15].

These studies collectively highlight the transformative potential of wearable IoT technologies in improving safety and operational efficiency. With advancements in sensor accuracy, communication protocols, and ergonomic designs, smart helmets are emerging as essential tools for ensuring safety in industrial and mining environments.

## 3. PROPOSED SYSTEM

The proposed system focuses on integrating advanced sensor technologies and wireless communication into a smart helmet designed to enhance workplace safety. The helmet incorporates a range of sensors, including heart rate, blood pressure, and temperature monitors, as well as environmental sensors to detect humidity, heat, and hazardous gases like smoke or gas leaks. These sensors provide real-time data on workers' health and environmental conditions, ensuring continuous monitoring in industrial and high-risk environments. The wireless communication capabilities, enabled by a Wi-Fi module, facilitate seamless transmission of this data to centralized monitoring systems. This real-time feedback mechanism enables supervisors to assess and respond to potential risks promptly, significantly reducing the likelihood of accidents and health emergencies.

The system prioritizes accuracy, reliability, and user comfort to encourage widespread adoption across industries. Its proactive design identifies and addresses health and environmental risks before they escalate, fostering a safer and more efficient work environment. The real-time monitoring and analysis framework enhances decision-making capabilities, ensuring that safety protocols are implemented effectively. By leveraging wearable technology, this project not only aims to improve current occupational safety standards but also lays the foundation for future advancements in predictive analytics and AI-driven safety systems, ultimately promoting worker well-being and reducing workplace accidents.

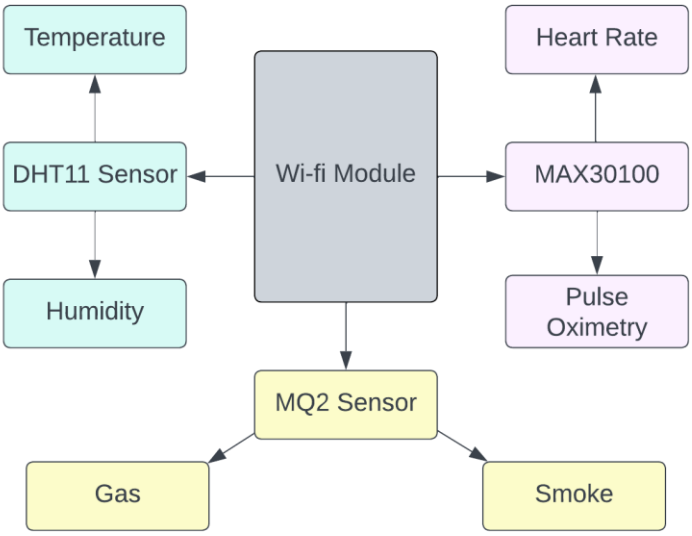


Fig. 1. Block Diagram

### *3.1 Hardware and Software Specification*

*3.1.1 Hardware specification:* The system is designed to integrate essential components for efficient, low-power IoT data collection, tailored to workplace safety. At its core, a Wi-Fi-enabled microcontroller serves as the primary processing unit and communication hub. This microcontroller supports reliable wireless connectivity while offering multiple I/O pins for seamless sensor integration. Its built-in data processing capabilities reduce dependency on external processors, ensuring a compact and energy-efficient solution suitable for wearable applications. The flexibility of the microcontroller also allows for easy programming and customization to meet specific safety requirements.

Key sensors integrated into the system include a heart rate and blood oxygen module that utilizes optical sensing for non-invasive health monitoring. This sensor's lightweight design and real-time tracking capabilities make it ideal for wearable safety devices used in high-risk industrial settings. A temperature and humidity sensor provides dual environmental monitoring, ensuring workers' conditions are maintained within safe thresholds. Operating on low power and requiring minimal I/O resources, this sensor enhances data collection efficiency without compromising the system's overall performance. Additionally, hazardous gas detection capabilities are incorporated to identify smoke or gas leaks promptly. Together, these components enable the helmet to deliver accurate real-time monitoring of health and environmental risks, supporting proactive safety measures and worker well-being.

*3.1.2 Software specification:* The Arduino IDE is an open-source development environment designed for programming Arduino microcontrollers, offering a user-friendly interface, extensive library support, and seamless code editing, compiling, and uploading. It includes a built-in serial monitor for real time debugging and data monitoring, with cross platform compatibility (Windows, macOS, and Linux). In the smart helmet project, the Arduino IDE is used to program the microcontroller that manages various sensors and components, such as hazardous gas detection, temperature monitoring, and impact sensors. The IDE allows for efficient code writing, real time testing, and debugging, ensuring that the helmet functions effectively by processing sensor data and triggering appropriate responses like alerts or emergency system activation.

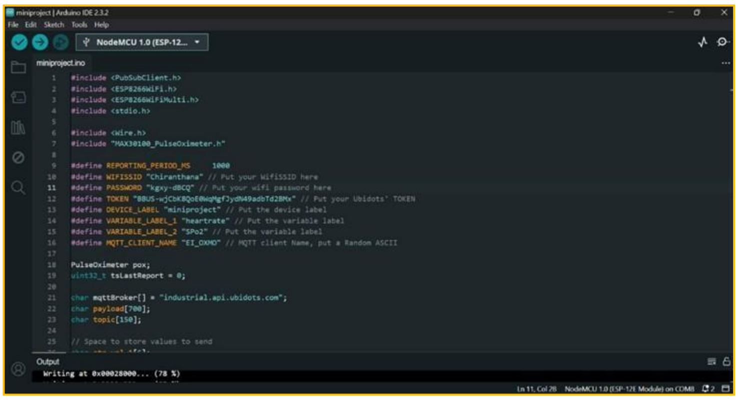


Fig. 2. Arduino platform

Ubidots is a versatile IoT platform that enables businesses to create data-driven applications with minimal coding, sup- porting real-time monitoring, customizable alerts, and sched- uled reporting for improved decision-making. With integration options for various IoT devices, Ubidots provides seamless cloud-based SCADA visualizations across industries such as manufacturing, energy, and predictive maintenance. In a smart helmet system, Ubidots can monitor health and environmental metrics collected by sensors, displaying real-time data on customizable dashboards. Alerts can be configured to notify supervisors if safety parameters, like heart rate or temperature, exceed safe limits, enhancing response times and ensuring worker safety.

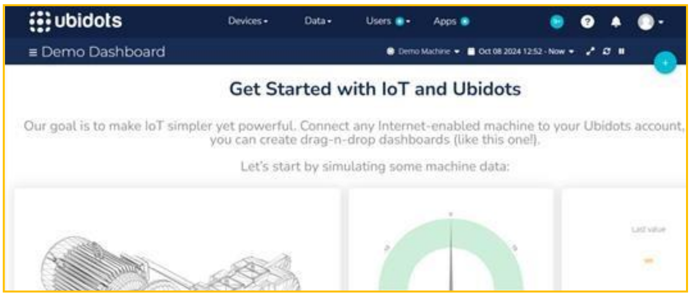


Fig. 3. Ubidots IOT platform

## 4. RESULTS AND DISCUSSION

Figures 4 and 5 illustrate real-time monitoring dashboards for tracking heart rate and blood oxygen levels (SpO2), respectively, providing continuous insights into workers' cardiovascular and respiratory health. The heart rate dashboard (Fig. 4) displays trends within the typical range of 60–100 bpm, alerting supervisors to fluctuations outside this range for timely interventions, such as addressing stress or fatigue. The SpO2 dashboard (Fig. 5) monitors blood oxygen levels, starting at 99% and gradually decreasing to 97%, staying within the safe range of 90–100%. Simulation results confirm the system's accuracy in identifying potential health risks and ensuring worker safety through real-time alerts.


Fig. 4. Real-time display of heartrate


Fig. 5. Real-time display of SPO2

The gas sensor dashboard (Fig. 6) tracks hazardous gas levels in real time, alerting supervisors to dangerous concentrations of methane, LPG, and carbon monoxide. It enables early detection of leaks, ensuring timely intervention to prevent accidents. Continuous monitoring allows for quick adjustments, maintaining a safe environment. This system helps minimize health and safety risks associated with gas exposure in industrial settings.

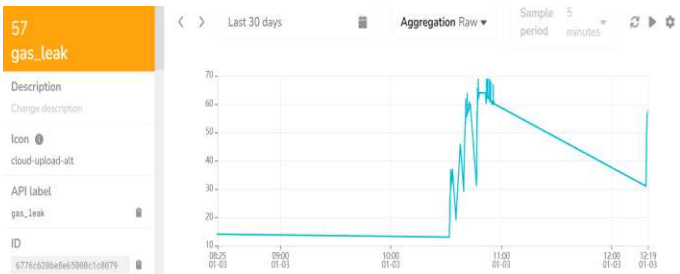


Fig. 6. Real-time display of gas leak

Figures 7 and 8 showcase real-time monitoring dashboards for temperature and humidity, ensuring safe and comfortable working conditions. The temperature dashboard (Fig. 6) tracks both environmental and body temperatures, enabling supervisors to monitor fluctuations and promptly address extreme conditions to prevent heat stress or hypothermia. Similarly, the humidity dashboard (Fig. 7) displays trends over 30 days, highlighting a gradual decrease from 45% to below 40%. This real-time monitoring helps maintain humidity within the optimal range of 30–60%, reducing risks of dehydration or respiratory issues. These tools allow precise environmental adjustments, prioritizing worker safety and well-being.

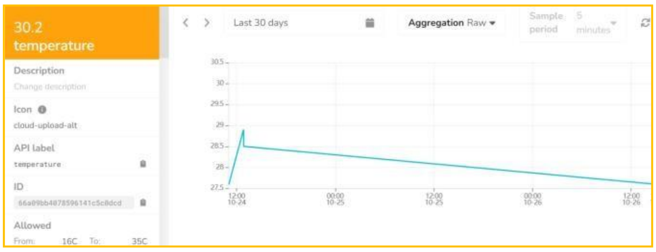


Fig. 7. Real-time display of temperature


Fig. 8. Real-time display of humidity

Fig.9 shows the real-time monitoring dashboard of the smart helmet system, capturing critical metrics such as humidity, heart rate, blood oxygen (SpO2), and temperature.


Fig. 9. Real-time display of humidity, heart rate, SpO2, and temperature metrics monitored by the smart helmet system.

These values are updated continuously, providing supervisors with instant insights into both environmental conditions and worker health, enabling timely interventions when needed.

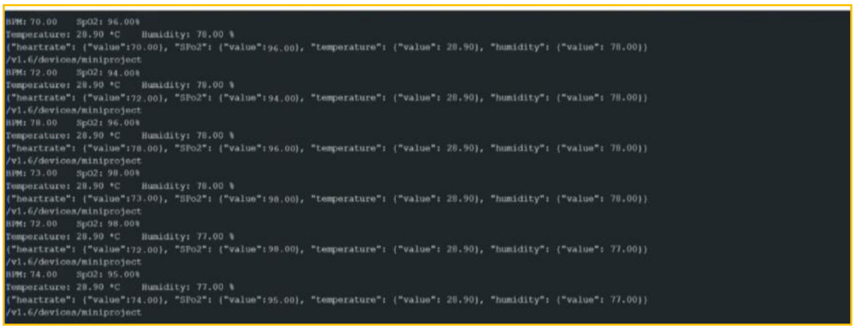


Fig. 10. Console output illustrating continuous data transmission for real-time health and environmental monitoring.

The Fig.10 displays the console output of the sensor data being transmitted in real time. It showcases how the smart helmet system logs and formats the data, with readings for heart rate, SpO2, temperature, and humidity. This console view helps illustrate the continuous data flow, essential for ongoing analysis and prompt response to any abnormal readings.

The smart helmet system elevates industrial safety by integrating real-time health and environmental monitoring, utilizing advanced sensors to track vital signs like heart rate and oxygen saturation, along with environmental factors such as temperature, humidity, and hazardous gases. This comprehensive data collection allows for proactive management of potential hazards, enabling supervisors to monitor both worker health and the surrounding conditions continuously. The system's ability to detect abnormal metrics, such as signs of worker fatigue, unsafe temperature levels, or gas leaks, ensures that health issues or hazardous changes are identified and addressed immediately, reducing the risk of accidents before they occur.

With a continuous flow of data transmitted wirelessly to a centralized monitoring station, supervisors can act quickly based on live insights. This dynamic safety framework empowers timely interventions and allows safety protocols to adapt to current conditions. As a result, workers receive precise support when needed, fostering a culture of safety where technology actively prioritizes well-being. By shifting from a reactive to a preventive safety model, the smart helmet system reduces downtime due to health-related issues, improves overall worker well-being, and strengthens workplace safety, contributing to a more secure and efficient industrial environment.

The discussion of the smart helmet system highlights its transformative potential for workplace safety and health monitoring within industrial settings. By utilizing advanced sensor technologies and real-time data transmission, the system creates a comprehensive profile of each worker's health and surrounding environmental conditions, which allows organizations to proactively manage safety risks. This approach ensures that critical health and environmental metrics are continuously monitored, enabling rapid response to emergencies, reducing the likelihood of accidents, and fostering a safer work environment. However, several challenges emerge in the deployment of such a system. Ensuring data accuracy and reliability in varying environmental conditions, as well as managing the complexities of system integration, are essential to its effective operation. Furthermore, gaining user acceptance is vital, as the helmet must be designed for comfort and ease of use to encourage consistent wearing among workers. While this innovative solution offers significant advancements in occupational health and safety, ongoing optimization is required to overcome these limitations and maximize its effectiveness in real-world applications.

## 5. CONCLUSION

In conclusion, the smart helmet system represents a significant advancement in industrial safety and health monitoring, offering a proactive approach to safeguarding workers through real-time data and responsive interventions. By enabling continuous tracking of vital signs and environmental conditions, the system supports early detection of potential risks, enhancing both individual safety and overall workplace efficiency. However, to fully realize its impact, ongoing improvements are necessary to address challenges related to data accuracy, network reliability, system complexity, and user comfort. With thoughtful refinement and commitment to user-centered design, the smart helmet has the potential to become an invaluable tool in creating safer, more responsive industrial environments. Through continuous adaptation, this technology can lead the way in establishing new standards for occupational health and safety, driving a future where worker well-being is seamlessly integrated into daily operations.

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