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Smart Helmet for Sanitation Workers: Thermal + Gas Warning System

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Abstract: ***Sanitation workers operating in sewage and waste management environments are highly exposed to hazardous conditions such as toxic gases and elevated temperatures, which can lead to serious health risks and fatalities [1]. To address this issue, this paper proposes a Smart Helmet designed to detect harmful environmental conditions and provide real-time alerts. The helmet is equipped with gas sensors capable of detecting methane (CH_4), carbon monoxide (CO), ammonia (NH_3), and hydrogen sulfide (H_2S), along with a temperature sensor to monitor abnormal heat levels [2]. An ESP32 microcontroller continuously processes sensor data and compares it with predefined safety thresholds. When unsafe conditions are detected, the system immediately alerts the worker through a buzzer, LED indicators, and a vibration motor, ensuring awareness even in noisy or low-visibility environments. In addition to local alerts, the system supports optional IoT-based communication to transmit real-time notifications to supervisors, enabling faster response and improved safety management [3]. The proposed system is cost-effective, portable, and scalable, making it suitable for deployment in both confined and open waste environments. Furthermore, it can be extended for data logging and analysis to identify high-risk zones and improve safety planning. Overall, the Smart Helmet provides an efficient solution for enhancing worker safety and contributes to the development of smarter and safer urban infrastructure.***

Index Terms: Smart Helmet, Gas Detection, Thermal Monitoring, ESP32, IoT, Worker Safety

I. INTRODUCTION

Sanitation workers are very important for keeping our communities clean and healthy. They do jobs like cleaning sewers collecting waste and taking care of drainage systems. These jobs can be very dangerous because they are often around bad air not enough oxygen and very high temperatures [1]. This can make them very sick. Even hurt them badly. They can breathe in gases like methane, carbon monoxide, ammonia and hydrogen sulfide, which can give them breathing problems hurt their brains and even make them pass out [2]. In some places sanitation workers do not have the equipment to keep them safe [3]. They do not have machines to check the air for bad gases. The machines that do exist are often very expensive and big so they are not easy to wear [3]. Some machines need to be used by hand and do not check the air all the time, which means they might not find hazards away. Now we have new technologies like small computers, sensors and the Internet of Things [4].

These can help us make affordable safety tools that workers can wear. These tools can check the air and temperature in time find hazards quickly and send alerts right away [4]. They can also help people in charge monitor what is happening from away and make plans to keep workers safe. That is why we made a Smart Helmet for sanitation workers. It can check the air for gases and check the temperature to make sure it is not too hot [5]. It uses a computer to get the information make decisions and send alerts. If it finds something it will send alerts in different ways like making noise, flashing lights and vibrating so the worker will know even if it is loud or hard to see. The Smart Helmet can also send messages to people in charge if something bad happens so they can help away [5]. We made it to be affordable, small and easy to use so many sanitation workers can use it.

The main thing we did was make a tool that checks for air and high temperatures and is also affordable and easy to use. We hope the Smart Helmet will help keep workers safe make communities cleaner and help make cities better places to live. The Smart Helmet is a help for sanitation workers because it checks the air and temperature all the time and sends alerts right away. This can help reduce the number of workers who get hurt or sick. We think the Smart Helmet is a tool for keeping sanitation workers safe and healthy. The Smart Helmet is also very good for cities because it helps keep communities clean and healthy. It is an example of how we can use new technologies to make cities better places to live [4]. We hope that many cities will use the Smart Helmet to help keep their sanitation workers safe. Sanitation workers do important jobs and they deserve to be safe [1]. The Smart Helmet is a step, towards making that happen.

We are very happy to have made something that can help keep workers safe and healthy. The Smart Helmet also has the potential to

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support long-term safety improvements by collecting and storing environmental data over time [7]. This data can be analyzed to identify high-risk areas, frequent hazard conditions, and patterns in gas exposure and temperature variations. Such information can help authorities and organizations make better decisions, improve safety policies, and plan preventive measures.

By using this data-driven approach, the system not only protects individual workers but also contributes to overall workplace safety management and smart city development. The system is designed to be simple and user-friendly so that workers can use it without special training [8]. It can be easily worn as part of daily safety equipment and does not interfere with normal work activities. The compact design and low cost make it suitable for large-scale use in different environments. This makes the Smart Helmet a practical solution for improving safety in real working conditions [9].

II. LITERATURE REVIEW

Research has been done to make sure workers are safe in places using special devices and systems that check the air for bad gases [1]. The World Health Organization says that people who clean up waste are at risk of getting very sick from breathing in air and working in bad conditions. They need the safety gear and systems that can check the air in real time to reduce the risks of getting hurt on the job [1]

Someone made a helmet that can check the air for bad gases like methane and hydrogen sulfide [2]. This helmet was made to help people who work in spaces. It showed that the air in these spaces can be very bad and that the helmet can alert workers when the air is not safe.. This helmet only works in small spaces and does not have a way to check for high temperatures.

The Occupational Safety and Health Administration talked about how to stay safe when working around gases [3]. They said that traditional ways of checking the air are not good for devices that people wear because they are too big and too expensive. There is a helmet that uses the internet to send information to supervisors [4]. This way supervisors can check on workers. Help in case of an emergency.. This helmet is mainly for people who work in factories and does not have special features for people who clean up waste or check for many kinds of hazards at the same time. Someone else made a helmet that can check the air and temperature [5]. This helmet showed that using sensors can be very helpful for safety. It is not cheap and not many people can use it. The World Health Organization and other groups say that workplaces need to be safe and that people need to be able to check the air and get warnings when it is not safe [6]. They also say that people need the gear to protect themselves.

Recent studies also show that Internet of Things based monitoring systems can improve worker safety by providing real time alerts and remote supervision [7]. These Internet of Things based monitoring systems allow us to collect data all the time and help us identify conditions quickly [7]. They can send information to supervisors so that supervisors can take action in case of danger and improve safety management of the workplace. Data driven safety systems can also help us analyze conditions over time and support better decision making for workplace safety improvements [8]. These data driven safety systems can identify risk areas and help us plan preventive measures [8]. This makes Internet of Things based monitoring systems and datadriven safety systems useful not for individual worker safety but also for improving safety at a larger level in the workplace [8]. Wearable safety devices are becoming more important because they can be used easily by workers in environments [9]. These wearable safety devices are designed to be lightweight and simple so that they do not disturb work activities of workers [9].

Wearable safety devices provide monitoring and instant alerts, which helps workers react quickly to unsafe conditions in the workplace [9]. There is still a need for a system that is cheap can be worn and can check the air and temperature and send information over the internet. This system should be special for people who clean up waste. The Smart Helmet is being made to fill this need. It will be an affordable system that can help workers in both small and open spaces. The Smart Helmet will have features such as gas detection and thermal monitoring and will be able to send information over the internet. The Smart Helmet is for sanitation workers will help them stay safe.

III. PROBLEM STATEMENT

Sanitation workers are always going into environments like sewers and waste management sites. These places have bad air and it is very hot. Sanitation workers can get very sick from this. They can have problems breathing and even die. The air in these places can have things like methane and carbon monoxide. Sanitation workers can breathe these things in. Get hurt. Sometimes you cannot. Smell these bad things in the air. This makes it more dangerous for sanitation workers. It is also very hot in these places. This can make sanitation workers feel sick or get hurt from fires. With all these dangers many sanitation workers do not have the right equipment to stay safe. The equipment that is available is often very expensive and hard to use. Some sanitation workers have suits that can help keep them safe but these suits only work in certain places and do not always detect all the dangers. We need something that can help keep sanitation workers safe.

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We need something that's cheap and easy to use. Sanitation workers need something that can detect air and high temperatures. They need something that can warn them when they are in danger. The Smart Helmet is an idea that can help sanitation workers. The Smart Helmet can detect things in the air and high temperatures. It can also send messages to supervisors so they can help sanitation workers when they are in danger. The Smart Helmet is designed to help keep sanitation workers safe.

The Smart Helmet is for sanitation workers. Sanitation workers will use the Smart Helmet to stay safe. The Smart Helmet will help sanitation workers detect dangers like air and high temperatures. The Smart Helmet will also help supervisors keep sanitation workers safe. The Smart Helmet is an idea because it can help keep sanitation workers safe and healthy. Sanitation workers will be able to work in conditions, with the Smart Helmet.

- Sanitation workers are exposed to hazardous environments including sewage systems and waste management sites, where toxic gases and high temperatures are present.
- Harmful gases such as methane (CH_4), carbon monoxide (CO), ammonia (NH_3), and hydrogen sulfide (H_2S) pose serious health risks.
- These gases are often invisible and difficult to detect without proper monitoring systems, increasing the risk of accidents.
- Existing safety solutions are either expensive, bulky, or require manual operation, making them unsuitable for continuous wearable use.
- There is a lack of affordable and portable systems that provide real-time monitoring of environmental conditions.
- The proposed Smart Helmet integrates gas detection and thermal monitoring in a wearable form.

The system provides real-time alerts through buzzer, LED, and vibration mechanisms to ensure immediate awareness.

IV. OBJECTIVE

1) The goal is to create a Smart Helmet for sanitation workers
2) That they can wear every day while they work. This helmet will keep watching out for their safety all the time when they're in dangerous places.
3) It will find gases like methane, carbon monoxide, ammonia and hydrogen sulfide that are in the air where they handle sewage and waste. It will do this in time so the workers know right away if there is a problem.
4) The helmet will also check the temperature around them to see if it gets too hot which can be bad for their health or even cause fires.
5) If something is wrong the helmet will let the workers know with a noise, flashing lights and vibration so they can tell something is wrong even if it is noisy or they cannot see very well.
6) The helmet has a computer that collects information about the environment all the time so it can find hazards quickly and accurately.
7) It can also send messages to the supervisors away so they can respond quickly and keep the workers safe.
8) We want this system to be cheap and easy to use so sanitation workers can use it without needing to learn a lot of things.
9) We hope that the Smart Helmet will help prevent accidents, injuries and health problems for sanitation workers by warning them about dangers before they happen.
10) The Smart Helmet is a way to make the workplace safer and to help create safer cities using new technology.
11) The Smart Helmet is, for sanitation workers. It will help them stay safe.
12) We are making the Smart Helmet to keep sanitation workers safe.
13) Sanitation workers will wear the Smart Helmet. It will watch out for them.

Another objective is to create a solution that is affordable, compact, and easy to use, making it suitable for real working environments. The system also focuses on enabling real-time communication with supervisors using Internet of Things technology, which helps in faster response during emergencies. Overall, the objective is to reduce risks, improve worker safety, and provide a practical and efficient solution for sanitation work environments..

V. PROPOSED SYSTEM

The system they are talking about is made to work reliably in really tough working environments. The sensors in the system are set up to detect gas concentrations and temperature variations within a certain range. The microcontroller processes this information quickly.

Makes sure there is hardly any delay between detecting something and sending out an alert. This fast response is very important in stopping accidents because even a short delay in detecting gases or high temperatures can have serious consequences.

The system is built to work well in environmental conditions, which makes it good for real-world sanitation work. Another important thing about the system is that it is easy to use. The Smart Helmet does not need any operation and the worker can use it without special training. When the system is turned on automatically starts checking the environment and sending out alerts when necessary. The alerts are designed to be easy to notice so the worker can quickly understand the warning signals.

This makes the system practical for use and increases the chances that sanitation workers will actually use it. The system also tries to improve safety by making communication and monitoring better. With the help of Internet of Things technology the system can send real-time information to supervisors so they can keep an eye on workers at the same time. If there is an emergency they can take action away which helps reduce the severity of accidents. The system can also. Analyze the information it collects to find patterns, high-risk areas and frequent hazards.

This information can be used to make safety measures and create a safer working environment for sanitation workers in the future. The system is really focused on making the Smart Helmet a useful tool, for sanitation workers.

VI. SYSTEM ARCHITECTURE

The system architecture of the proposed Smart Helmet is designed to ensure continuous monitoring, processing, and alert generation for sanitation workers working in hazardous environments. The system consists of three main parts: input components, processing unit, and output components.

A. ESP32 Microcontroller

The ESP32 Microcontroller is the brain of the Smart Helmet system [3]. It does a lot of things. The ESP32 Microcontroller receives information from all the sensors that are connected to it. Then it looks at this information. Makes decisions based on what it thinks is safe or not. The ESP32 Microcontroller is really good at doing lots of things and it does not use a lot of power. It also has Wi-Fi and Bluetooth built into it [1]. This makes it perfect for things that need to be connected to the internet. The Smart Helmet can send messages to people in charge if something is wrong. The ESP32 Microcontroller makes sure everything in the system works quickly and smoothly.

B. Gas Sensors (MQ Series)

Gas Sensors like the MQ-2, MQ-135 and others are used to ind gases in the air [6]. These Gas Sensors can find gases like methane, carbon monoxide, ammonia and hydrogen sulfide. These gases are often found in places where sewage and waste are handled [2]. The Gas Sensors work by feeling the changes in the air when different gasesre around. They always check the air. Send signals to the ESP32 Microcontroller. These sensors are good for testing because they are not expensive.. They need to be set up correctly so they give the right information.

C. Temperature Sensor

The Temperature Sensor, which can be something like the LM35 or the DHT11 is used to check how hot or cold it is [5]. It helps find temperatures that're not safe for workers. The LM35 gives precise temperature readings. The DHT11 can measure temperature and how humid it's. This helps find situations that could be dangerous like it being too hot or a potential fire. The information from the Temperature Sensor goes to the ESP32 Microcontroller. Then it checks if the temperature is safe or not. If it is not safe it sends an alert.

D. Buzzer

The Buzzer is a device that makes a noise to warn the worker if something is wrong [8]. It is controlled by the ESP32 Microcontroller. Makes a noise as soon as it finds something wrong with the gases or temperature. This way the worker knows away if there is a problem and can do something about it.

E. LED Indicators

LED Indicators are lights that show what is happening with the system [4]. Different colors can mean things. For example green might mean everything is okay and red might mean there is danger. These lights are useful in places where it's hard to see or hear. They do not use a lot of energy and last a long time so they can be used all the time.

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F. Vibration Motor

The vibration motor is used to provide tactile feedback to the worker. It vibrates when a hazardous condition is detected, ensuring that the alert is noticed even in extremely noisy environments where sound alerts may not be effective [6]. This feature improves the reliability of the alert system by providing multiple modes of notification, increasing the chances of immediate response from the worker.

G. Power Supply

The power supply unit provides the required electrical energy to all components of the system. A rechargeable battery is commonly used to ensure portability and continuous operation during working hours [7]. Proper power management is important to maintain system efficiency and ensure that the helmet operates reliably without frequent interruptions.

This feature helps supervisors monitor the condition of workers and take immediate action in case of emergencies. It also supports data logging and analysis for improving long-term safety planning.

H. GPS Tracker

In the Smart Helmet for Sanitation Workers the GPS module is used to track where the worker is in time. This helps to keep the worker safe when they're in a bad situation. The GPS module works with the ESP32 microcontroller and the Internet of Things system to keep an eye on the workers location. The GPS module gets signals from satellites all the time. Figures out exactly where the worker is. It does this by using latitude and longitude. This information is sent to the ESP32 microcontroller. The microcontroller looks at the information. Sends it to the people who are monitoring the worker using Wi-Fi or a cell phone signal. This way the supervisors know where the worker is at all times. The GPS module is really helpful in emergency situations. If the system detects air or high temperatures it alerts the worker. It also sends the workers location to the supervisors.

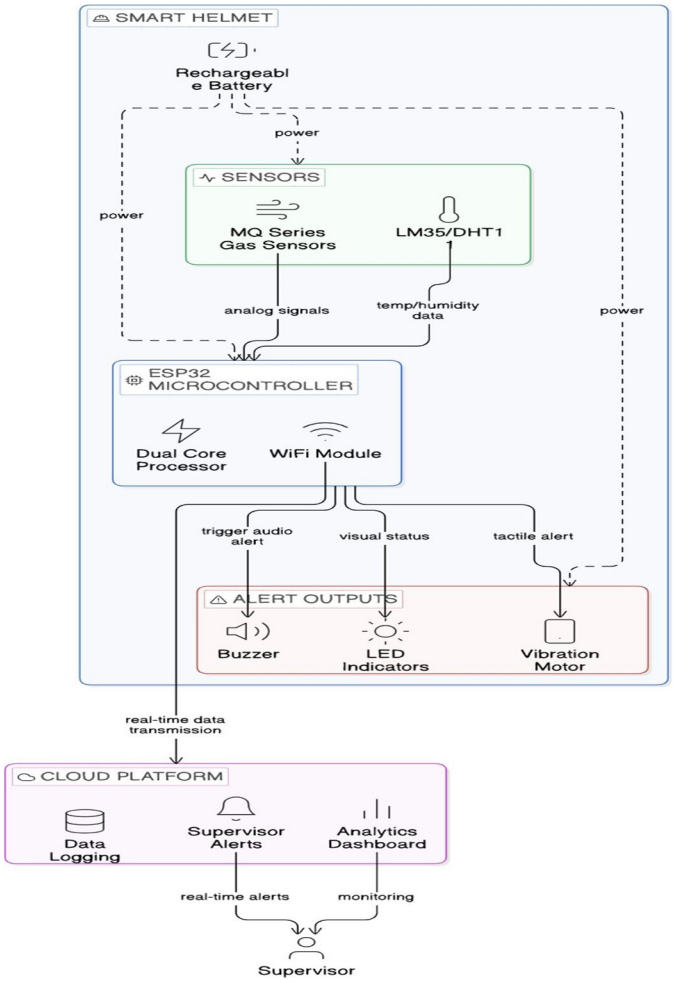


Fig. 1. System Architecture of Smart Helmet For Sanitation Workers

I. Monitoring Dashboard

The dashboard is an important part of the Smart Helmet system that helps supervisors monitor the condition of sanitation workers in real time. It displays information collected from the helmet such as gas levels, temperature, and alert status. The data is sent from the ESP32 microcontroller through the Internet of Things system and is shown on a screen such as a mobile phone, computer, or web application. This allows supervisors to keep track of multiple workers at the same time and understand the working conditions without being physically present at the location. The dashboard shows values of gases like methane, carbon monoxide, ammonia, and hydrogen sulfide, along with temperature readings. It can also display warning messages when any value goes beyond safe limits. These warnings help supervisors take quick action and provide support to workers in dangerous situations. The dashboard may also include indicators such as safe, warning, and danger levels using colors like green, yellow, and red to make it easy to understand the situation quickly.

VII. METHODOLOGY

The Smart Helmet system for sanitation workers is designed to detect gases and abnormal temperature conditions. It provides real-time alerts using embedded systems and Internet of Things technology. The Smart Helmet system integrates sensors, a microcontroller, communication modules and alert mechanisms. This ensures monitoring of environmental conditions and worker safety. The Smart Helmet system is divided into the stages:

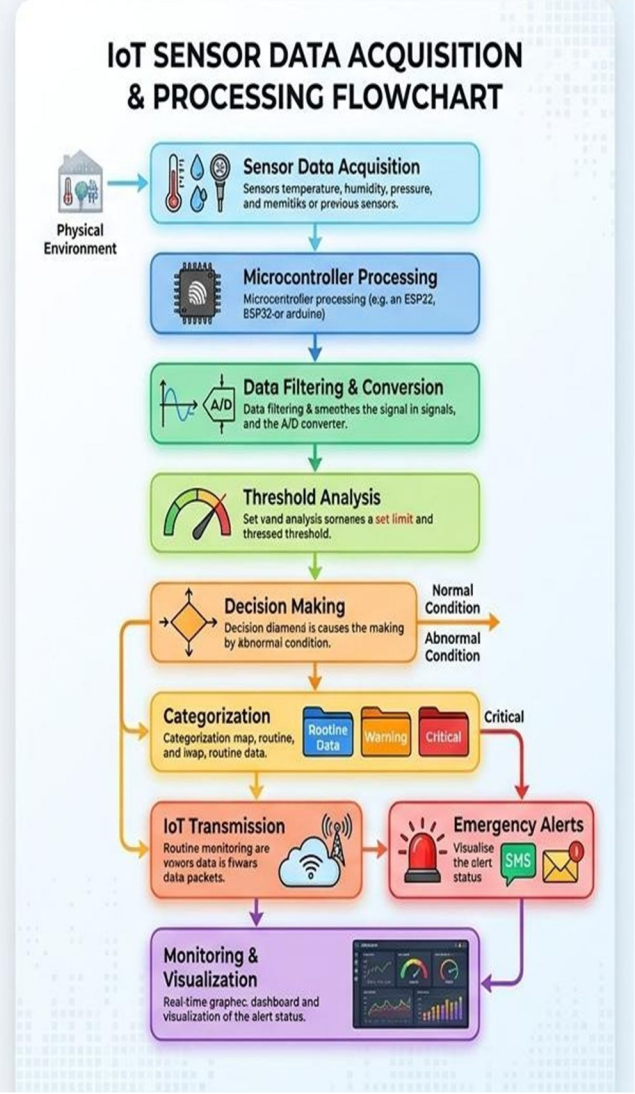


Fig. 2. Methodology Flowchart of Smart Helmet for Sanitation Workers

A. Sensor Data Acquisition

The Smart Helmet incorporates gas sensors and temperature sensors to monitor parameters in real time. The gas sensors detect the presence of gases such as methane, carbon monoxide and hydrogen sulfide. These gases are commonly found in confined sanitation environments. The temperature sensors measure temperature and detect abnormal heat levels. The sensors operate by converting parameters into electrical signals. These signals are either analog or digital. The analog signals are continuously sampled. The digital sensors communicate through protocols. The sensor placement within the Smart Helmet is carefully designed. This ensures exposure to the surrounding environment while maintaining user comfort. The Smart Helmet system performs calibration. This maintains measurement accuracy. Reduces drift over time. The Smart Helmet system is designed to ensure the safety of sanitation workers.

B. Microcontroller Processing

A microcontroller is used as the central processing unit of the Smart Helmet system. It is responsible for interfacing with all sensors collecting data and executing the embedded program logic. The microcontroller performs analog-to-digital conversion for analog sensor inputs. It processes digital sensor signals through communication interfaces. The incoming data is filtered to remove noise and fluctuations. The microcontroller also synchronizes data acquisition at fixed time intervals. This maintains consistency. The embedded firmware ensures power management. This is critical for systems like the Smart Helmet. The Smart Helmet system uses a microcontroller to process the data. The microcontroller is the brain of the Smart Helmet system. It makes sure that the Smart Helmet system works correctly.

C. Data Analysis and Threshold Checking

The processed sensor data is analyzed by comparing it with predefined threshold values. These thresholds are determined based on environmental safety standards. The Smart Helmet system checks if the gas concentration is above a defined limit. It checks if the temperature is exceeding a degree. For example the Smart Helmet system checks the gas concentration. If the gas concentration is above a defined limit it indicates toxicity. The Smart Helmet system also checks the temperature. If the temperature is exceeding a degree it indicates a thermal hazard. The Smart Helmet system may implement -level thresholds. This classifies conditions into safe, caution and dangerous zones. The Smart Helmet system ensures real-time detection of situations.

D. System Decision and Categorization

Based on the threshold comparison results the Smart Helmet system performs decision-making. It categorizes the condition into distinct states. The states are condition, warning condition and danger condition. The Smart Helmet system uses embedded control logic. This logic ensures that the Smart Helmet system responds depending on severity. The Smart Helmet system is designed to protect sanitation workers.

E. Internet of Things-Based Data Transmission

The Smart Helmet system integrates Internet of Things communication modules. These modules transmit real-time data to a platform or server. The collected sensor data is uploaded at intervals or upon detection of abnormal conditions. The transmitted data includes gas concentration levels, temperature readings, helmet status and alert indicators. The Smart Helmet system enables accessibility through web dashboards or mobile applications. The Smart Helmet system uses data transmission protocols. These protocols ensure data integrity and reliability. The Smart Helmet system allows supervisors to monitor workers simultaneously.

F. Emergency Alert Mechanism

When hazardous conditions are detected the Smart Helmet system activates an emergency alert mechanism. The alert system includes both remote notifications. The local alerts include a buzzer for warning, LED indicators for visual alert and an optional vibration motor, for tactile feedback. The remote alerts include SMS notifications and push notifications via application.

G. Monitoring and Visualization

A monitoring interface is developed using a web-based or mobile application dashboard. This interface displays real-time data collected from the Smart Helmet. The data includes gas levels, temperature readings and system status.The dashboard provides visualization of sensor trends real-time status indicators and historical data storage and retrieval. The Smart Helmet system enables -user monitoring capability.

Supervisors can monitor helmets simultaneously. This enables supervision of sanitation workers. The Smart Helmet system applies data analytics to records. This helps identify patterns. Improve safety measures. The Smart Helmet system is designed to protect sanitation workers and ensure their safety.

VIII. ALGORITHMS / MODELS USED

To guarantee ongoing monitoring and prompt reaction to dangerous situations, the Smart Helmet system employs a structured algorithm. Below is a detailed explanation of each algorithmic step:

A. Setting up

The Smart Helmet is first powered by a rechargeable battery. Every part, including the temperature sensor, gas sensors, ESP32 microcontroller, and alert devices, is turned on and ready to go. The system is prepared to carry out real-time monitoring thanks to this initialization [1].

B. Set Up the Parts

The ESP32 sets up all linked parts, such as sensors and output devices, in this step. Input/output pins are set, and communication between sensors and the microcontroller is established. The system as a whole operates smoothly when initialization is done correctly [2].

C. Establish Threshold Values

The system stores predetermined safety limits for temperature and gas concentrations. These cutoff points establish whether an environment is safe or dangerous and are based on safety regulations. Methane, carbon monoxide, ammonia, hydrogen sulfide, and temperature levels, for instance, are all subject to limits [3].

D. Examine Sensor Information

Data from the surrounding environment is continuously gathered by the temperature and gas sensors. While temperature sensors gauge heat levels, gas sensors identify hazardous gases. The ESP32 receives the gathered data in real time for processing [4].

E. Analyze and contrast data

After processing the incoming sensor data, the ESP32 compares each value to its matching threshold limit. This comparison aids in determining whether or not the conditions found fall within safe bounds. The system's decision-making process depends on this step [5].

F. Verify Safe Conditions

The system keeps monitoring without sending out an alert if every sensor value is within the safe ranges. This increases system efficiency by guaranteeing continuous observation without needless warnings [6].

G. Identify Dangerous Situations

The system detects a hazardous situation if any temperature or gas concentration surpasses the predetermined threshold. In order to prevent delays that might result in accidents, this detection is done instantly [7].

H. Turn on the Alert System

The system initiates the alert mechanisms upon detecting a hazardous condition. LEDs offer visual alerts, the vibration motor creates tactile feedback, and the buzzer sounds an alert. The worker will always be informed thanks to this multi-alert system [8].

I. Use IoT to Send Data

Supervisors can receive real-time data and alerts from the ESP32 via its integrated Wi-Fi module. Gas levels, temperature readings, and alert status are among the data that is transmitted. This enables prompt emergency response and remote monitoring [2].

J. Repeat the Procedure

The system ensures real-time monitoring and prompt reaction to any changes in environmental conditions by repeatedly repeating the aforementioned steps in a loop [1].

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Parameter	Safe Range	Warning Level	Danger Level
Methane (CH_4)	0 – 1000 ppm	1000 – 5000 ppm	> 5000 ppm
Carbon Monoxide (CO)	0 – 50 ppm	50 – 200 ppm	> 200 ppm
Ammonia (NH_3)	0 – 25 ppm	25 – 100 ppm	> 100 ppm
Hydrogen Sulfide (H_2S)	0 – 10 ppm	10 – 50 ppm	> 50 ppm
Temperature	20 – 35°C	35 – 45°C	> 45°C

Table 1. Measurement Values and Threshold Limits of Gas

Condition Detected	Buzzer	LED Status	Vibration	IoT Alert
Safe Condition	OFF	Green	OFF	No
Moderate Gas/Temperature	ON (Low)	Yellow	ON	Yes
High Gas/Temperature (Danger)	ON (High)	Red	ON (Strong)	Yes (Emergency)

Table 2. Alert Actions Based on Conditions

IX. RESULTS AND DISCUSSION

The Smart Helmet system's ability to identify dangerous gases and temperature changes was assessed in a variety of environmental settings. The sensors were tested by subjecting them to temperature changes and regulated gas concentrations. Methane (CH_4), carbon monoxide (CO), ammonia (NH_3), hydrogen sulfide (H_2S), and temperature were all continuously monitored by the system, and the results were compared to predetermined safety thresholds. The outcomes of these tests show how reliable and efficient the suggested system is for real-time monitoring.

Test	Value
T1	CH_4=300, CO=20, NH_3=10, H_2S=5, T=28°C, Safe, No Alert
T2	CH_4=800, CO=40, NH_3=20, H_2S=8, T=33°C, Safe, No Alert
T3	CH_4=1800, CO=110, NH_3=55, H_2S=22, T=37°C, Warn, Alert
T4	CH_4=4200,CO=230, NH_3=110, H_2S=55, T=41°C, Danger, Alert
T5	CH_4=6500,CO=380, NH_3=180, H_2S=95, T=47°C, Critical, Alert

Table 3. Measured Results Under Different Conditions

A. *Detailed Discussion of Results*

The Smart Helmet system really works well when it comes to monitoring what is going on around us and responding to levels of risk. When we first tested the Smart Helmet system the Smart Helmet system did a job of keeping track of gases like methane and carbon monoxide and ammonia and hydrogen sulphide along with the temperature. All of these things stayed within the limits that we had set and the Smart Helmet system did not send out any alerts.

This is important because it means the Smart Helmet system is stable and will not send out alarms when everything is okay. As things changed and the risk level got a bit higher we saw that the gas levels and temperature went up. The Smart Helmet system noticed this. Sent out a warning, which is exactly what it is supposed to do. The Smart Helmet system alerted the worker with a buzzer and a light and a vibration which's really important because it gives the worker a chance to do something before things get bad. The Smart Helmet system is not just reacting to what's happening it is also trying to prevent bad things from happening in the first place. When things got really bad the Smart Helmet system responded quickly. The alerts got louder and more noticeable so the worker would know that something was wrong. The Smart Helmet system is really good at responding which is important because delays can be really bad.

The Smart Helmet system can send out alerts, which makes it more reliable, even in situations that are challenging. When things got extremely bad the Smart Helmet system did everything it could to keep the worker safe. It kept sending out alerts and using the internet to communicate with the monitoring system. This allowed the supervisors to know what was going on in time which is really helpful in emergency situations. The Smart Helmet system does not just keep the worker safe it also helps the supervisors keep everyone safe. The results show that the Smart Helmet system works well in all of the situations that we tested. The Smart Helmet system is good at detecting what is going on responding quickly and sending out alerts. The internet part of the Smart Helmet system makes it more useful by allowing remote monitoring.

However we did learn that the sensors need to be calibrated to work accurately and things like humidity can affect the readings a bit. Despite these limitations the Smart Helmet system is a practical and efficient solution for keeping sanitation workers safe in bad environments. The Smart Helmet system is also a solution, which means it can be used in many different situations. Overall the Smart Helmet system is a good tool, for improving safety.

B. *System Performance and Usability*

The Smart Helmet system was tested to see how well it works. It was checked for how accurate it's how fast it responds how reliable it is and how efficient it is at finding bad conditions. The system was good at finding gases like methane and carbon monoxide. It could also tell when the temperature changed. The sensors were good at finding changes in the environment. The ESP32 microcontroller could process the information right away without any delay. The system responded fast and sent out alerts as soon as it found something bad. This is very important for keeping sanitation workers safe.

The Smart Helmet system also worked well when it was tested for reliability. It kept working without stopping. Always gave the right information. The system has ways to alert the worker like a buzzer and a light and it also vibrates. This means the worker will always know when something is wrong even if it is loud or hard to see. The system can also send information to a computer so someone can watch from away and help if there is an emergency.

C. *Advantages of Proposed System*

1) *Real-time Monitoring*: The system continuously monitors environmental conditions such as gas concentrations and temperature without any interruption. This ensures that even small changes in the environment are detected immediately. Continuous monitoring is very important in hazardous areas like sewers, where conditions can change suddenly and become dangerous within seconds.
2) *Accurate Gas Detection:* The Smart Helmet is designed to detect harmful gases like methane, carbon monoxide, ammonia, and hydrogen sulfide with good accuracy. These gases are often invisible and cannot always be detected by smell, making them highly dangerous. The use of gas sensors helps in identifying these risks early and improves overall safety.
3) *Fast Response Time:* The ESP32 microcontroller processes sensor data in real time and generates alerts almost instantly when unsafe conditions are detected. This fast response is critical because delays in warning can lead to serious health risks or accidents. The system ensures that workers are notified without delay.
4) *Multi-Alert Mechanism:* The system uses three types of alerts—buzzer (sound), LED indicators (visual), and vibration motor (tactile). This combination ensures that the worker receives warnings in multiple ways. Even if one alert method fails or is not noticeable, the other methods ensure that the warning is delivered effectively.

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5) *Effective in Harsh Environments*: Sanitation workers often work in noisy, dark, and confined spaces where traditional alert systems may not work properly. The Smart Helmet is designed to function effectively in such environments by providing vibration alerts and bright LED signals, ensuring that warnings are not missed.
6) *IoT-Based Communication:* The integration of Internet of Things technology allows the system to send real-time data and alerts to supervisors. This feature enhances safety by enabling continuous monitoring from a remote location and ensures that help can be provided quickly in case of an emergency.
7) *Remote Monitoring Capability:* Supervisors can monitor the working conditions of multiple workers at the same time using a dashboard or mobile application. This improves coordination and allows for faster decision-making, especially in emergency situations where immediate action is required.
8) *Improved Worker Safety:* The system provides early warnings before conditions become critical, helping workers take preventive actions such as leaving the area or using protective equipment. This significantly reduces the chances of accidents, injuries, and long-term health issues.
9) *Low Cost and Affordable:* The system is designed using cost-effective components, making it affordable for large-scale deployment. This is especially important in developing regions where expensive safety equipment may not be accessible.
10) *Compact and Wearable Design:* All components are integrated into a helmet, making the system portable and easy to wear. The design ensures that the worker's comfort is not compromised, allowing them to perform their tasks efficiently without any inconvenience.

D. Limitations

Sensor Calibration: The gas sensors that are used in the system like the MQ series sensors are not very expensive. They do not always give very accurate readings. These sensors need to be set up before they can be used. If this is not done properly the system may give readings, which can lead to false alarms or it may not detect bad gases. Over time the sensors may not work well as they used to so they need to be checked and set up again.

1) *Environmental Influence:* The way the sensors work can be affected by things like how humid it's how much dust is around if the temperature is changing a lot and if there are many different gases in the air. For example, if it is very humid or there is a lot of dust in the sewer it can affect the readings of the sensors. This can make the system not work well in real life situations so we may need to add some filters or find ways to make it work better.
2) *Power Consumption:* The Smart Helmet is always on. Checking the environment, which means it needs power all the time. The system uses sensors, alert systems and it can talk to the internet, which uses a lot of power. This means the battery may run out of power faster especially if it is always on or if it is sending a lot of alerts. We need to charge it.
3) *Maintenance Requirement:* The system needs to be checked and fixed regularly to make sure it works properly. The sensors can get dusty. Be exposed to bad chemicals, which can affect how they work. We need to clean them set them up again and replace some parts to keep them working over time

X. FUTURE SCOPE

The Smart Helmet system has strong potential for further improvement and expansion in the future. One important area of development is the use of more advanced and highly accurate gas sensors. By replacing the current sensors with industrial-grade sensors, the system can provide more precise and reliable measurements, reducing errors and improving overall performance.

A. Use of Advanced Gas Sensors

The Smart Helmet is a tool and the use of advanced gas sensors is very important. Advanced gas sensors like infrared-based sensors can be used in the future to make the Smart Helmet better. These sensors are very good at detecting gases and they are very accurate. They can also respond quickly to changes in the air. This means that the Smart Helmet will be less likely to give alarms and it will be more reliable in critical situations. The Smart Helmet with gas sensors will be very useful for people who work in dangerous places.

B. Cloud Storage and Big Data Management

The Smart Helmet can also be connected to the internet using cloud storage and big data management. This will allow a lot of data to be stored and analyzed. The data can be used to identify trends and patterns. This will help to make the workers safer. The cloud storage and big data management system will also allow supervisors to access the data from anywhere. This will make it easier for them to manage their workers and make sure that they are safe.

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C. Artificial Intelligence and Machine Learning Integration

Intelligence and machine learning can also be used to make the Smart Helmet better. These technologies can be used to analyze the data that is collected by the Smart Helmet. They can help to predict when something bad might happen. For example the Smart Helmet can use intelligence and machine learning to predict when there might be a gas leak. This will give the workers a warning before something bad happens. The Smart Helmet with intelligence and machine learning will be very useful for people who work in dangerous places.

D. Enhanced Battery Technology and Power Optimization

The battery life of the Smart Helmet can also be improved. New battery technologies like lithium-polymer batteries can be used to make the Smart Helmet last longer. The Smart Helmet can also be designed to use power. This will make the battery longer. The Smart Helmet can be put into sleep mode when it is not being used. This will help to save power and make the battery longer.

E. Improved Communication Technologies

The communication system of the Smart Helmet can also be improved. New communication technologies like LoRa, GSM, NB-IoT or 5G can be used. These technologies will provide range and connectivity. They will be very useful in areas where the Wi-Fi signal's weak. The Smart Helmet will be able to send and receive data easily. This will make it more useful for people who work in areas.

F. Automatic Emergency Response System

The Smart Helmet can also be designed to respond in emergency situations. For example it can send an SOS message. Activate an alarm. It can also notify emergency services. This will help to keep the workers safe. The Smart Helmet will be able to respond in emergency situations

G. Enhanced Durability and Rugged Design

The Smart Helmet can also be made durable. It can be designed to withstand environments. It can be made waterproof, dustproof and heat-resistant. The electronic components can be protected with a casing. This will make the Smart Helmet longer. It will be able to withstand handling and harsh environments.

Overall, the future scope of the Smart Helmet system focuses on improving accuracy, expanding features, enhancing usability, and integrating advanced technologies to create a more efficient and reliable safety solution for sanitation workers.

XI. CONCLUSION

The Smart Helmet for people who clean up waste is a good solution to the big safety problems they face when they are working in bad places like sewers and areas with a lot of waste. This helmet has sensors that can detect bad gases like methane and carbon monoxide and it also checks the temperature. The Smart Helmet is like a computer that uses all the information from the sensors to keep the worker safe. The system is very good at warning the worker if something's wrong. It beeps it lights up. It even vibrates to make sure the worker knows about the danger. This is really important because sometimes the worker might be in a place where they cannot hear or see well. The Smart Helmet can send messages to the supervisors too so they can help the worker if they need to. This makes it easier for the supervisors to keep all the workers safe.

The Smart Helmet is also very good at sending information to the supervisors in time. This means that they can see what is happening with all the workers at the time. They can make decisions and keep everyone safer. The helmet is not just good for the worker who wears it. It also helps the whole team. When we tested the Smart Helmet it worked well. The sensors could detect the gases and the temperature and it warned the worker when something was wrong. The helmet did not send out warnings, which is very important. The worker can wear the helmet for a time without getting tired of it.The Smart Helmet is also very affordable and easy to use. The worker does not need training to use it which makes it very practical. This is especially good for places where it's hard to get good safety equipment. The Smart Helmet is not perfect. It needs the sensors to be calibrated and sometimes the environment can affect how well the sensors work. It also needs to be connected to the internet to send messages to the supervisors. We need to make the sensors better. We need to find a way to make the helmet work even when it is not connected to the internet.

The implementation of a multi-alert mechanism, including a buzzer, LED indicators, and a vibration motor, provides immediate warnings to workers in different forms. This ensures that alerts are noticed even in challenging conditions such as noisy or low-visibility environments.

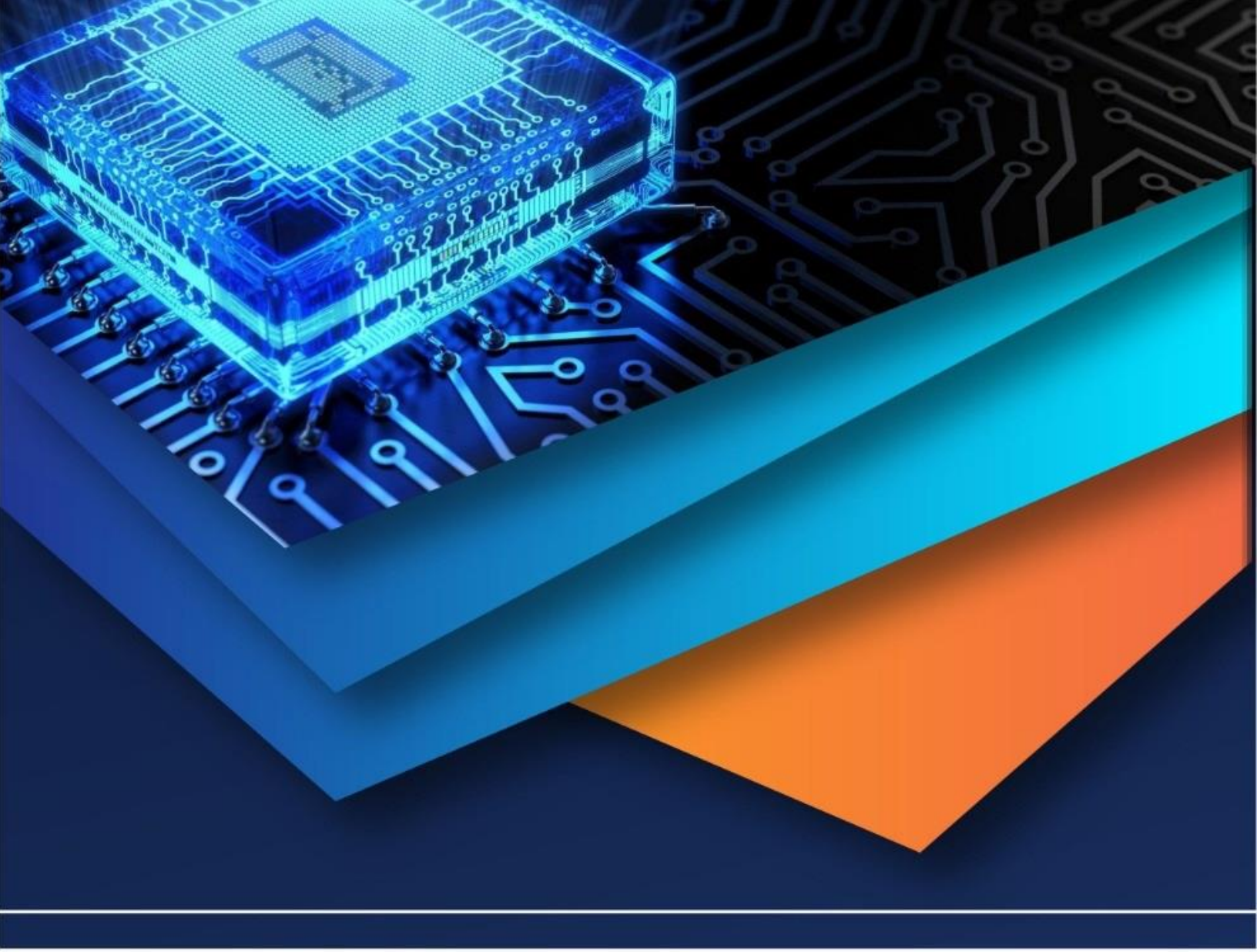
The addition of Internet of Things technology further enhances the system by enabling real-time data transmission and remote monitoring, allowing supervisors to respond quickly in case of emergencies.

In the end the Smart Helmet is a step forward for keeping people who clean up waste safe. It is an affordable way to detect hazards and warn the worker. The Smart Helmet uses technology to make the workers life safer and it can help make cities smarter. We can make the Smart Helmet better in the future and it has a lot of potential, for being used by a lot of people.

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