Original Article

Underground Drainage Cleaning Accident Prevention

M.Ragu[1], Dr.S.David Blessley[2]

[1]*Mechanical Engineering, (Industrial safety Engineering), Francis Xavier Engineering College Tamil Nadu,Tirunelveli.*
[2]*Assistant Professor, Francis Xavier Engineering College,Tamilnadu, India.*

Abstract: Manual cleaning of underground drainage systems is grossly inadequate and one of the world's most dangerous occupations that expose sewage workers to toxic gases, oxygen deficiency, structural collapse and fatal accidents. The deaths are mostly due to inhalation of toxic gases such as methane (CH_4), hydrogen sulfide (H_2S), ammonia (NH_3) and carbon monoxide (CO) that can be found in the mines. While many different aspects of emergency response systems is more efficient than in the past, they are not fit for purpose within an underground sewage treatment works. This project work involves smart accident prevention and emergency response mechanism for under ground drainage cleaning by developing an intelligent AI protocol based monitoring system with automated lift control device along emergency gas suction mechanism. Composed of advanced gas and environmental sensors, the system continuously monitors toxic gas with detecting oxygen concentration, temperature and workers activity. With the help of an AI module, these systems can identify abnormal real-time conditions (floods, mudslides, etc.), analyze data to predict adverse conditions and adopt preventive measures. For example, when the system identifies the presence of hazardous gases in large quantities, it uses a high-capacity gas suction mechanism to vigorously extract toxic gases present within and create an oxygen-rich environment. Simultaneously, an automatic lift control system kicks into gear to transport the worker outside of the underground space for safety reasons. It works as a complement with GSM/IoT communication modules to notify supervisors. Our proposed solution reduces degeneracy on manual supervision, keeps workers safe at all times, provides high speed of emergency response and lastly reduces deaths in sewage working. A smart, holistic life-saving underground drainage formulation that combining the intelligence technology and machine hydraulics to allow one hide from such disasters with AI sensor network + mechanical lift-up mechanism.

Keywords: AI-Based Safety, Gas Detection, Emergency Evacuation, IoT Monitoring.

I. INTRODUCTION

Urban and rural contexts are profoundly sensitive to under-drainage systems that sustain sanitation and public health. These systems bravely carry off waste, sewage and industrial discharge from residential areas and commercial sectors. Nonetheless, cleaning up and servicing this latter type of drainage is still the riskiest job with them all even though these systems are by far the best, especially in developing nations with humans still being actively engaged. Sewage workers often have to crawl underground into small spaces like manholes, septic tanks and sewer pipes. These environments may have pollutants, pathogens and high humidity in addition to low oxygen. It is only by exposure to such environments that serious medical issues develop, culminating in loss of consciousness and even death.

Accidents in the underground drainage system can be due to various reasons but one of the significant reason is the stored hazardous gases such as methane (CH_4), hydrogen sulfide (H_2S), ammonia (NH_3), carbon monoxide (CO). Much like the gases you would encounter in a regular dumpster, these materials are colorless and sometimes odorless when suspended or in a candescent state, which makes them harder to detect without proper sensing equipment. Even short contact can be lethal. Also, in close environments another very important risk factor come out from sewage: oxygen deficiency. When oxygen levels fall below safe thresholds, workers may become light-headed and struggle to breathe before rapidly losing consciousness. In many reported cases, long before any rescue operation can be set in motion, workers asphyxiate and fall to the ground on the chamber floor. Manual cleaning of the sewer system still pervades in spite of the directives, rules and regulations they can also be misled by economic constraints or lack of infrastructure. Although many emergency response systems are designed to react quickly, supervisors may need time before they realize that a worker has gone missing or is in danger. This delay significantly increases the risk of deadly effects. String of recent developments in the areas of embedded systems, sensor networks, AI and automation has opened a new vista for safety at workplace. This smart monitoring system with automated emergency mechanisms will help reduce the human risk and respond to them on time.

In this project, it is proposed to design an intelligent underground drainage accident prevention system which is embedded with the information of environmental sensing, hazard detection using AI, automatic gas suction and emergency lift evacuation mechanism. It continuously checks the status of work and environmental conditions in real time. Gas sensors

detect harmful gases such as methane, hydrogen sulfide, ammonia gas and carbon monoxide. The oxygen sensor monitors the level of oxygen, and temperature & humidity sensors also monitor environmental conditions. Motion sensors and camera modules monitor workers movement and behavior.

A sensor module uses an AI-enabled hazard detection algorithm powered by the data captured from its sensors. Through the patterns in gas concentration, oxygen levels and shifts in the environment around it, the system can sense situations that may need attention before they become fatal. The apparatus is designed to autonomously trigger a high-volume gas suction feature upon detecting that the levels of gas exceed allowable safety limits. This mechanism is employed to drain toxic gases from underground chambers and help restore relatively corrosive environmental conditions.

Besides, there is an automatic lift control device — it works for the emergency exit. The AI system activates the lift mechanism at high danger levels or beats based on the worker's movement. This system incorporates GSM or IoT based alert modules to allow fast communication. In addition, these send real-time alerts to supervisors and, if necessary to municipalities or emergency services for quick response and assistance.

AI integration is not responsive safety, it's predictive safety instead. Instead of waiting for accidents to occur, the system continuously scrutinizes information about its surroundings for dangerous patterns — and intervenes before they can cause injury. It has potential for reducing needs of human supervision and increasing safety in below ground sewage work. It is aimed to promote smart city initiates and also encourages tech support to vulnerable-bed workers.

In summation, an AI substrate based prevention and realization of disaster drains the four together with feel, voluntary action, communication and escape. Traditional underground drainage operations & maintenance processes used methods that are now long outdated. Assembling a solution from gas detection + intelligent analysis + automated suction means having one integrated approach that can massively decrease victim numbers, while protecting the workforce purpose of the workflow (for instance within O&M), but at times also modernizing how an operation essentially works; e.g., suppose for example when new platforms like cloud are generally put in place only near buildings/sites.

II. LITERATURE SURVEY

Underground drainage and sewers remain a significant occupational risk, where workers can be completely surrounded by poisonous fumes or an oxygen-poor atmosphere. Recent studies note the need for low-cost in-situ gas monitoring systems of CH_4, H_2S, NH_3 and CO [44], such as within sealed environments. Advanced sensing technologies, such as electrospun nanomaterials and semiconductor-based gas sensors, have greatly improved the sensitivity and selectivity in hostile environment [1], [4]. The explosive potential of methane is one reason that detection is essential to safety underground. In such grim situation, fiber optic-based methane sensing system and tunable diode laser absorption spectroscopy (TDLAS) techniques have emerged as a suitable solution for very high precision multi-point monitoring capability [2], [5]. The systems respond faster and are more accurate than standard gas sensors.

One of the most toxic gases found in drainage is hydrogen sulfide, which can be lethal even at low concentrations. Previous experiments of MEMS based hydrogen sulfide sensors and metal-oxide semiconductor (MOx) sensors provide good detection for room temperature which can be used in portable/embedded safety systems [4],[8]. Such advances allow for the development of wearable and stationary devices that can monitor workers carrying out sewage work. Low-cost sensor nodes have also been proposed for methane and hazardous gas detection in urban infrastructures [3] to allow such scalable deployments. These sensor nodes include wireless communication modules and low-power architectures, which are the essential components of the smart sewer monitoring systems. Recent works would be for the monitoring system based on IoT for manholes, drainage networks, etc [1]. The application of IoT (Internet of Things) in Smartguard and similar applications enables us to transfer environmental data from the site to control center aspires for fast emergency response [9], [10]. These gas sensors are used in conjunction with water level sensors and communication modules for comprehensive monitoring. There are a few articles that designed an automatic manhole observation system with the sense of IoT to save workers in peril. These systems come with alarm triggers, GSM notifications and cloud-based dashboards for municipal authorities [19], [23]. Such frameworks enhance transparency and allow remote monitoring of confined-space work.

Ventilation and gas control is also key in underground environments. Researches on methane generation and management in sewer systems have demonstrated techniques to reduce the exposure of toxic gases through extraction systems and forced ventilation [6], [22]. High-Performance airflow control reduces hazardous gas accumulation. Recent advances in AI and machine learning have made it possible to predict hazards in confined space. Transformer-based models are used for class classification of harmful gas concentration levels and also trend prediction [7]. These models help to increase the reliability of decisions made from automated safety systems. Real-time computer vision tier-2 artificial intelligence-based worker monitoring systems have been implemented in construction and mining sectors for identification

of abnormal behavior or immobility of a worker [13], [14]. The same methods as previously described can be adjusted to the sewage environment to monitor worker posture, movement and distress states. According to this network, deep learning models combine information from both multimodal sensor networks (operating environmental and visual data simultaneously) [15], [29]. Then gas concentration data is combined with worker activity monitoring to improve accuracy of hazard detection in these multimodal approaches. Wearable sensor technologies have also been tested to observe the safety of confined-space work [7]. Edge AI empowered Wearable systems can facilitate the real-time tracking of worker vitals, movement profiles and environmental conditions [28]. Such systems could offer an additional layer of safety by identifying health emergencies.

Recent research has introduced RL-based control of ventilation to adapt airflow and gas extraction in underground spaces [26]. Intelligent control systems optimize gas capture while minimizing energy consumption. The second trending area of research is predictive maintenance ventilation and suction systems. This can be realized by using data-based methods, for instance: AI-oriented models related to anoma lie detection guaranteeing the continuous functioning of extraction fans and emergency devices [25]. Reliable system operation is essential during high-risk operations. It is also important to have emergency evacuation procedures in confined spaces, according to studies. In hazardous environments, fully automated lift control systems that allow for quick evacuation have been proposed, equipped with fail-safe motor controls and backup propulsion [24].

Together gas monitoring, AI hazardous detection, IoT communication and automated evacuation form a tailored safety architecture. Safety science studies emphasize the importance of a unified approach that combines (1) sensing, (2) prediction and (3) response systems in an attempt to reduce fatalities in high-risk occupations [30].

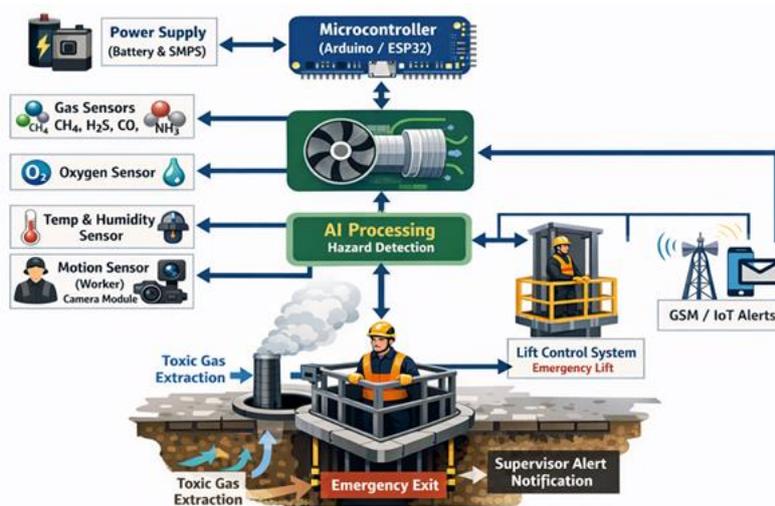## III. SYSTEM IMPLEMENTATION

A. Architectural Diagram

Figure 1 : Proposed Design using AI Technology

Architectural designed plot of AI based underground drainage safety system which avoids accident and assist blackhole workers in keeping emergency response time less. The environmental sensing part, artificial intelligence processing, gas extraction mechanism, communication module and the emergency lift control system is comprised in it. These blocks represent the fundamental functional units and also when integrated together, they form a complete safety layer.

This is the main overview image — power supply unit (is placed on top in the architecture and its responsible for supplying electrical energy to all components in system. It features a battery backup and an SMPS (Common Mode Power Supply to facilitate continuous working. Since underground environment as a high-stake area the fail-safe power supply is essentially important for sensor monitoring or communication and emergency evacuation systems. Microcontroller: These are the Arduino or ESP32, they serve as a central control unit of the system. It receives data from various sensors, processes input signals, and manages output devices like motors and alarms. It is responsible for connecting all of the hardware components to the AI processing module & synchronizing them.

On the sensing side, several gas sensors are deployed using different nanostructured metal oxides to detect toxic gases such as methane (CH_4), hydrogen sulfide (H_2S), carbon monoxide (CO) and ammonia (NH_3). Such gases are common

in sewer systems and can poison, suffocate or explode. Continuous monitoring in real time detection of abnormal concentration level. This underground chamber has an oxygen sensor to quantify the breathable gas inside. Oxygen starvation is one of the most common cause of death that can happen to workers in restricted areas. "If it detects that the oxygen level is too low, it identifies at-risk students and transfers them to a safe room," she says. The thermal links contribute to monitoring environmental conditions that have an impact on gas reaction, and worker health: tracking dryness/wetness. Extended high temperatures with humidity can cause gas build-ups and can lead to hot or dangerous working conditions. The more these parameters are monitored, the better one can predict hazards.

There is a passive and a camera module, to monitor worker movement/position. It interprets the immobility or abnormal behavior of a worker in an area as a possible emergency. This feature adds a layer of safety beyond gas detection by keeping an eye on the worker's physical condition.

Its intelligence, an AI processing unit lies at the system's heart. It processes live data from gas and oxygen sensors, environmental sensors, as well as worker monitoring devices. The AI module runs on predefined thresholds and predictive algorithms to detect hazardous conditions which in turn triggers appropriate preventive or emergency actions. When toxic gas levels exceed safety limits, the gas suction system will activate. The mechanism is a fan unit connected to an extraction motor blower that sucks the hazardous gasses out of the underground chamber and expels them to safety outside. This gives breathable air and brings down immediate danger.

However, if dangerous conditions develop at the most crucial time; then lift control system will trigger evacuation of worker through emergency exit. Multi-function and multifaceted, these elements combine to form a highly intelligent, automated life-saving system that greatly enhances the safety of sewage operators during sewerage operations. Notification GSM or IoT alert modules Supervisors/Authorities

B. Circuit Diagram
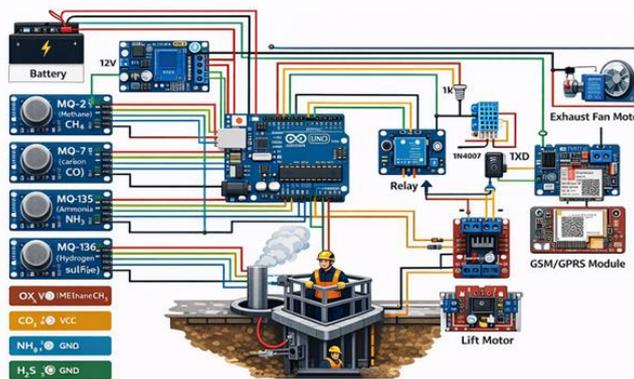
Figure 2 : Circuit Design using Arduino

Figure illustrates full hardware set-up of AI based underground drainage safety system. Arduino UNO microcontroller is the prime component of circuit which acts as Processor and Control unit. It reads input signals from a few environmental and gas sensors while controlling output devices such as motors, relays, and communication modules. We can use an Arduino power supply module, a 12V battery is used as the input power supply for this project. By establishing proper ground connections, all the components function in a stable and noise-free manner.

The gas sensing component consists of MQ-series gas sensors, which include the following:MQ-2 (methane $[CH_4]$),MQ-7 (carbon monoxide [CO]),MQ-135 (Ammonia $[NH_3]$)and MQ-136 (hydrogen sulfide or H_2S) These sensors track identification levels of harmful gases in the drainage system. Each sensor output is connected to the analog input pins of arduino and read them in real time. Another integrated sensor that checks the Oxygen levels and sense O2deficiency. Together, these sensors form an integrated monitoring system to ensure that one doesn't get exposed to toxins.

In the environmental monitoring part we have DHT series sensor it is a temperature and humidity sensors its job will be to detect very harsh underground conditions. It exploits a motion sensor module to track the movement and inactivity or lack of motion gaming worker. The sensors send input signals to the microcontroller digitally and so that the system can assess environmental hazards and worker safety. This provides the ability for safe atmospheric monitoring with the added benefit of motion detection providing an aspect to physical safety as well. This two=pyramid safety mechanism assures organiational firmness and calibrate=ractic responsiveness.

A relay module with an exhaust fan motor is used to extract toxic gases in the output control section. In case the gas level exceeds safety level, the arduino turn on a relay to operate an exhaust fan. For an emergency evacuation, a motor driver

module is used to control the lift motor mechanism. The speed and direction of the lift system is controlled using motor driver. The protection diode (shown here as 1N4007) is present to avoid damage due to back EMF when the load is inductive, like a motor.

The GSM/GPRS module serves as the interface of PC communication and alert system. MCM sends alert messages to supervisors or local authority (to warn the drivers) if any hazardous condition is detected. This enables prompt response and emergency coordination. The full circuit, which is detailed below, combines sensing + processing + communication + actuation to form an integrated safety system. Then you put all of these things together, and you have a smart in general, automated accident prevention system specifically for underground sewage workers
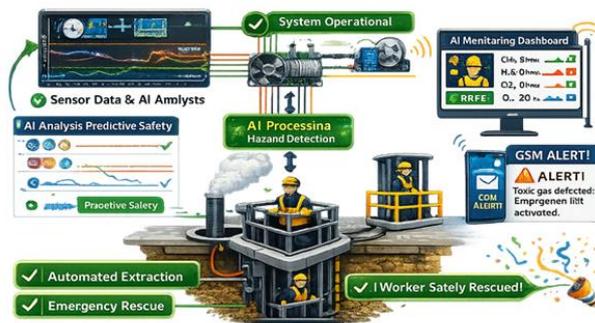
IV. RESULTS AND DISSCUSION

Figure 3 : Expected Results

Output image shows the successful implementation performance measure of AI-Based Underground Drainage Safety System. We present a variety of subsystems acting in unison to ensure 100% worker protection within PHYTHS operating hazardous sewer space. The following from sensor data and AI analysis example on detecting toxic gases—methane (CH_4), hydrogen sulfide (H_2S), carbon monoxide (CO); oxygen levels, monitored in real-time, captured and displayed in a monitoring dashboard. It analyzes the environmental data and predicts hazardous conditions before they are dangerously exceeded. If the concentration of gas in that chamber becomes harmful, a process like automatic extraction is triggered right away extracting toxic gases from the chamber and thus bettering air quality. In the event of an extreme danger, the emergency lift control system can be activated that provides rapid upward transport of the worker from underground space. Simultaneously GSM alert module sends immediate alerts to supervisory staff for timely intervention. Safe Status Levels are conducted after the corrective action has already taken place and will help to confirm that hazards were avoided and worker safely recovered. They capture system reliability, automation efficiency, and predictive intelligence, and visually mark how the introduction of AI-device coordination with IoT/sensor technology packs together to easily promote the maritime industry into world-beating safety standards. This research outcome presents a high-response, automated accident avoidance system which can be used to minimize the mortality rate for sewage workers as well as to provide evidence timely protection services.

V. COMPARATIVE AANALYSIS

Traditional hardware implementation demands significant manual engagement, leading to high exposure and delayed response to any emergency. Sensor-based logical systems contribute to safety by automating the detection of hazards, but cannot exceed the levels programmed into their threshold values.

Parameter	Normal Human Implementation	Logical Implementation (Sensor Based)	AI–IoT Sensor Based Implementation (Proposed System)
Monitoring Method	Manual inspection and basic mechanical tools	Sensors detect gas and environmental parameters	Multi-sensor system with AI-based real-time analysis
Gas Detection	No automatic gas detection	Gas sensors trigger alarms at thresholds	AI predicts hazardous trends before reaching critical levels
Oxygen Monitoring	Not available	Basic oxygen sensor monitoring	Continuous oxygen analysis with predictive risk detection
Worker Monitoring	Manual supervision only	Limited motion detection	Motion + camera + AI behavior analysis
Decision Making	Human dependent	Predefined threshold-based	Intelligent trend-based decision-

		logic	making using AI algorithms
Emergency Response	Manual rescue operation	Alarm-based response	Automated gas section & automatic lift evacuation
Gas Removal System	Manual ventilation	Fan activation based on threshold	Smart adaptive suction with AI optimization
Communication	No remote alert system	SMS alert via GSM (optional)	Real-time IoT cloud monitoring & GSM alerts
Response Time	Slow (depends on human action)	Moderate (sensor triggered)	Very fast (automated AI-triggered actions)
Accuracy	Low	Moderate (threshold-based)	High (data-driven prediction & multi-parameter analysis)
Reliability	Low	Moderate	High (redundant sensors + AI validation)
Scalability	Difficult to scale	Scalable with sensor addition	Highly scalable with IoT cloud integration
Cost	Low initial cost	Moderate cost	Higher initial cost but long-term safety benefit
Safety Level	Poor	Improved	Maximum safety with automation & early detection
Human Dependency	Fully dependent on humans	Partially automated	Minimally dependent on humans
Data Storage	No data logging	Limited local data logging	Cloud storage, analytics, historical data tracking
Maintenance	Manual inspection	Periodic sensor calibration	Predictive maintenance using AI analytics
System Intelligence	No intelligence	Rule-based logic	Machine learning and predictive intelligence
Failure Detection	No early warning	Threshold-based warning	Early anomaly detection and preventive prevention
Overall Efficiency	Low	Moderate	High and optimized

The AI–IoT–Sensor-based system consists of predictive hazard detection, automated evacuation, intelligent gas removal and real-time remote monitoring for underground sewage workers' safety

VI. CONCLUSION

Thus, the AI-Based Underground Drainage Safety System serves as a feature-rich and well-rounded solution to mitigate accidents and protect sewage laborers working in hazardous confined areas. This monitoring systems consists of advanced gas sensor, oxygen level sensor, environmental sensor, hazard identification based on AI (Artificial Intelligence), automated extraction of gases, evacuation through lift in emergency place and GSM/IoT communication. This sort of predictive safety can prevent the risk before it poses a near-fatal reality unlike conversion of traditional manual or basic sensor based systems. Automating the emergency procedures assists in response and eliminates any human dependency thereby ensuring more lives to be saved along with health risk reduced. In a nutshell, the proposed framework is useful in improving operational performance, consolidating worker safety standards and also paving way for smart infrastructure using AI & IoT.

VII. REFERENCES

[1]   C. Zou, Y. Li, J. Wang, et al., "Photoelectric H_2S Sensing Based on Electrospun Hollow CuO–SnO$_2$ Nanotubes for Room-Temperature Detection," Sensors, vol. 24, no. 19, art. 6420, 2024.

[2]   L. Ma, X. Zhao, H. Chen, et al., "A Non-Source Optical Fiber Sensor for Multi-Point Methane Detection," Sensors, vol. 24, no. 15, art. 5031, 2024.

[3]   D. Furuta, A. Smith, B. Jones, "Design and Evaluation of a Low-Cost Sensor Node for Methane Monitoring," Atmos. Meas. Tech., vol. 17, pp. 2103–2120, 2024.

[4]   X. Tian, Z. Liu, "Design and Simulation of an Ultra-Low-Power Hydrogen Sulfide (H_2S) MEMS Sensor," Micromachines, vol. 15, no. 3, art. 295, 2024.

[5]   Z. Li, H. Wang, "Design and Research of Methane Sensor Based on Tunable Diode Laser Absorption Spectroscopy (TDLAS)," SPIE Proc., vol. 13231, paper 3039993, 2024.

[6]   F. Hou, L. Zhang, "Methane Production Mechanism and Control Strategies for Urban Sewers," Water, vol. 16, art. 3618, 2024.

[7] K. Zhang, M. Liu, "Detection of Harmful H_2S Concentration Range — An Explainable Transformer Approach," Chemosensors, vol. 12, no. 9, art. 172, 2024.

[8] R. Jia, S. Patel, "High-Performance Hydrogen Sulfide Gas Sensor Based on $ZnFe_2O_4/MoO_2$ Composite," Sensors & Actuators B: Chemical, 2025.

[9] M. Bhavani, R. Vasuki, F. E. Solomon, G. Divya, "Smartguard: An IoT-Enabled Real-Time Monitoring System for Urban Manhole Safety," Proc. Conf. (IoT/Smart Cities), Dec. 2024.

[10] A. Roshan, S. Thrideep, "IoT-Based Manhole and Drainage Monitoring System," IEEE Access, 2024.

[11] A. Alqahtani, T. Hughes, "A 'Frugal' EGFET Sensor for Waterborne H_2S," Sensors, vol. 24, no. 2, art. 407, 2024.

[12] S. V. T. Tran, L. Nguyen, "Digital Technologies for Monitoring Hazardous Area Entry in Construction and Confined Spaces," Automation in Construction, 2025.

[13] V. R. Uppaluri, "Real-Time AI-Driven Hazard Detection: Integrating Computer Vision and Sensor Networks for Enhanced Mining Safety," Mining Safety Journal / Preprint, Jan. 2025.

[14] Z. Woźniak, K. Nowak, "Integrated Construction-Site Hazard Detection System Using ML and Vision," Sustainability, vol. 17, 2025.

[15] T. Mohy, "Deep Learning Enabled Computer Vision Model for Proactive Hazard Detection on Construction Sites," ITcon, 2025.

[16] J. Zhang, H. Kimura, "Review of Hydrogen Sulfide: Biological Activity and Health Impacts," Biomolecules/Reviews, 2024.

[17] "IoT Device for Sewage Gas Monitoring and Alert System," Asthana et al., Conf. Paper / ResearchGate, 2024.

[18] "Smart Safety Monitoring System for Sewage Workers," International Journal of Science and Research Archive, 2025.

[19] P. Kumar, R. Singh, "IoT-Based Automatic Manhole Observant for Sewage Worker Safety," Conference Paper / Scispace, 2024.

[20] S. V. Reddy, "Use of Low-Cost MOx Sensors and Compensation Algorithms for Reliable Gas Monitoring in Harsh Environments," Sensors Journal, 2024.

[21] A. Shaposhnik, M. Ivanov, "Selective Detection of Hydrogen Sulfide and Methane by a Single Metal-Oxide Sensor (temperature-modulation)," Sensors Review, reprint 2024.

[22] R. Gao, L. Sun, "Control of Sulfide and Methane in Sewers by Ventilation Strategies," Science of the Total Environment, 2024.

[23] "Smart Safety Monitoring of Sewage Workers Using IoT and ML," KSCST / Student Project Report, 2024.

[24] S. Venkatesh, "Emergency Lift Control Systems for Confined Space Evacuation — Design & Control Strategies," IEEE Trans. Ind. Informatics / Conf. Proc., 2025.

[25] N. Patel, H. Singh, "AI-Based Predictive Maintenance and Anomaly Detection for Ventilation and Extraction Fans in Underground Systems," IEEE Access, 2025.

[26] L. Brown, Y. Chen, "Real-Time Gas Extraction and Ventilation Control Using Reinforcement Learning," Control Engineering Practice, 2025.

[27] M. S. Alam, "Design of High-Capacity Mobile Gas Suction Systems for Rapid Decontamination in Sewers," Journal of Hazardous Materials, 2025.

[28] D. Roy, "Confined Space Worker Monitoring Using Wearable Sensors and Edge AI," Sensors (Wearables Special Issue), 2025.

[29] H. Zhao, "Multimodal AI for Worker State Assessment (vitals + vision + gas data)," IEEE Transactions on Industrial Informatics, 2026 (early access / preprint).

[30] S. Banerjee, R. Mukherjee, "Policy and Practical Guidelines for Automated Confined Space Rescue — Case Studies and Experimental Validation," Safety Science, 2024.