

**ANALYSIS OF SENSOR-BASED MONITORING METHODS FOR
REDUCING FIRE HAZARDS IN OPEN-PIT MINING CONDITIONS**

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Abstract. Endogenous fires occurring in open-pit mining operations have a significant impact on industrial safety, environmental sustainability, and economic efficiency. In particular, the spontaneous heating and combustion of coal in coal open-pit mines lead to the emission of harmful gases into the atmosphere, failure of technical equipment, and hazardous conditions for human health. This article analyzes the importance, operating principles, and effectiveness of sensor-based monitoring systems in reducing fire hazards under open-pit mining conditions.

The article aims to analyze the significance of sensor-based monitoring methods in reducing fire hazards in open-pit mining conditions, study their operating principles, and develop scientific recommendations for their effective application.

Keywords: endogenous fire, open-pit mine, sensor monitoring, IoT, thermal sensor, gas sensor, artificial intelligence, safety, forecasting.

Introduction. In the field of Mining Engineering, ensuring fire safety in open-pit mines is considered one of the most urgent scientific and practical issues. In particular, the spontaneous heating of coal caused by oxidation with atmospheric oxygen and the occurrence of endogenous fires in coal mines result in numerous economic and environmental problems.

Under open-pit mining conditions, high temperatures, improper air circulation, technological fractures, and gas accumulation further increase the risk of fire hazards. In such environments, conventional visual observation methods are insufficient for the timely detection of hazards. Therefore, in recent years, sensor-based monitoring technologies have been widely implemented in industrial safety systems.

Sensor-based monitoring systems make it possible to monitor temperature, gas concentration, humidity, and smoke levels in real time. This creates opportunities for the early detection of endogenous fires and enables rapid preventive response measures.



a) Temperature Sensor, b) Gas Sensor, c) Optical Sensor, d) Ultrasonic Sensor

Figure 1. Sensors enabling early detection of fires in open-pit mines.

Table 1

Types and classification of sensor detectors for early process detection

No	Component	Function	Description
1	Thermal sensors	Temperature monitoring	Detects combustion at an early stage through temperature increase
2	Gas analyzers	Measures CO ₂ and CH ₄ concentrations	Assesses the risk of combustion or gas emission
3	Automatic valves	Controls the release of gas or foam	Activated when sensors send a signal
4	Control panel	Manages the entire process	Operated by an operator or through an automatic algorithm
5	Inert gas generator	Produces CO ₂ or N ₂ gas	Restricts air inflow to suppress combustion

The study examines the possibilities of using sensors that monitor temperature, gas environment, smoke, and infrared radiation. Thermal sensors detect the early stages of the heating process, while gas sensors record changes in the concentrations of CO, CO₂, CH₄, and O₂. In addition, the article highlights the possibilities of remote data transmission using IoT technologies and data analysis based on artificial intelligence algorithms.

The results indicate that sensor-based monitoring systems are highly effective in the early detection of fire hazards in open-pit mines, timely implementation of preventive measures, and prevention of emergency situations. In the future, the

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introduction of drones, cloud-based databases, and digital modeling technologies may further improve the reliability of monitoring systems.

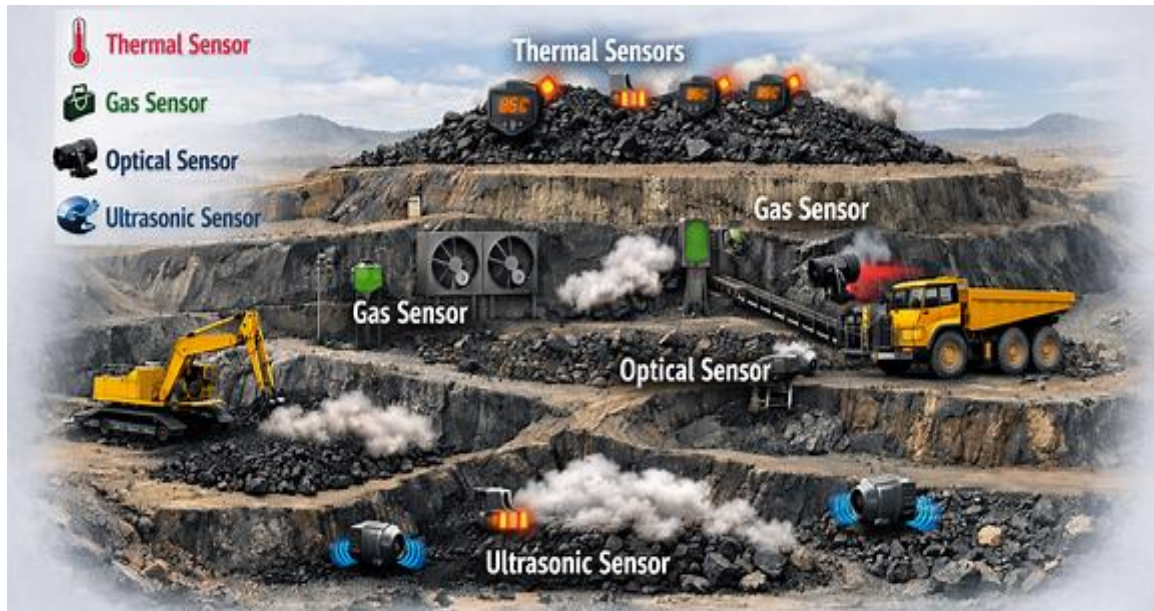


Figure 2. Optimal placement of fire-detecting sensors in coal quarries

Thermal sensors are used to detect temperature changes in open-pit mines. They make it possible to identify internal heating in coal seams, high-risk zones, and the incubation stage of spontaneous combustion.

Infrared thermal sensors enable remote monitoring and are considered effective for the rapid analysis of large areas.

Gas sensors record changes in atmospheric composition. In this process, CO is the main indicator of endogenous heating, CH₄ indicates explosion hazards, CO₂ reflects the intensity of the oxidation process, and O₂ shows the level of air exchange.

An increase in CO concentration indicates the beginning of the active oxidation process of coal.

Optical sensors detect smoke particles and infrared radiation. These devices quickly identify open combustion stages, hidden smoke emissions, and high-temperature zones.

Ultrasonic sensors are used to monitor air pressure and internal movements. They make it possible to detect cracks in pit walls or gas emission channels.

In modern open-pit mines, sensors are integrated into a unified information system through IoT technologies. In this system, data are transmitted via wireless networks, stored on a central server, and analyzed using AI algorithms.

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Artificial intelligence technologies analyze sensor data and predict hazardous trends in advance.

$$P_f = f(T, CO, CH_4, O_2, H)$$

Where:

P_f - probability of fire occurrence;

T - temperature;

CO, CH₄, O₂ - gas concentrations;

H - humidity indicator.

When the system detects hazardous indicators, it automatically performs functions such as increasing ventilation, spraying water or foam, supplying inert gas, and sending warning signals to the operator.

Conclusion. The implementation of sensor-based monitoring systems in open-pit mining conditions plays an important role in the early detection and prevention of endogenous fires. Intelligent systems based on thermal sensors, gas sensors, and IoT technologies make it possible to monitor hazardous situations in real time.

The research results show that sensor-based monitoring methods are an effective solution for improving industrial safety, reducing economic losses, and minimizing environmental risks in open-pit mines. In the future, the introduction of artificial intelligence, drones, and digital modeling technologies may further enhance fire hazard management systems.

References

1. Kutuzov B.N. *Fire Safety of Coal Deposits*. – Moscow: Nedra, 2018.
2. Ruban A.D. *Spontaneous Combustion of Coal and Methods of Control*. – Saint Petersburg, 2020.
3. *Mine Fire Prevention and Control*. International Journal of Mining Science and Technology, 2021.
4. Gulomova G.M., Aripxodjaeva M.B., Abdurakhmonov E.B. Types, properties, and characteristics of activated carbon and preparation of granular activated carbon samples using composite binders. *Technical Science and Innovation Journal*, Tashkent, 2021, pp. 61–66.

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5. Gulomova G. On the adsorbent obtained based on local Angren coal: analysis of adsorption energy properties of benzene vapors. *E3S Web of Conferences*, 461, 2023.
6. Gulomova G.M., Shamansurov S.S., Rakhmatova D.M. Development of methods for obtaining carbon adsorbents based on Angren coal and oil residues. *Occupational Safety in Industry (Bezopasnost Truda v Promyshlennosti)*, 2023(3), pp. 68–74.
7. Gulomova G., Turabekova U., Nizamova D., Mudarisova R. Problems of ensuring safety in open-pit coal mines in the Republic of Uzbekistan. *E3S Web of Conferences*, 461, 01067, 2023.
8. Gulomova G.M., Jumanazarov A.B., Yusupxodjayeva F.B. Improving an intelligent microcontroller device for monitoring fire and carbon monoxide hazards in industrial enterprises. *Scientific-Practical Electronic Journal "Fire and Explosion Safety"*, 2026, No. 1(22).
9. Gulomova G.M. Study of the chemical composition of Angren brown coal using the X-ray phase method. *Proceedings of the International Scientific-Practical Conference, SamDAQI*, April 29–30, 2026, p. 404.
10. Rakhmatova D.M., Nizamova D.O. Comparative analysis of intelligent sensor systems and traditional safety methods in coal open-pit mines. *Proceedings of the International Scientific-Practical Conference, SamDAQI*, April 29–30, 2026, p. 573.