

Spontaneous Combustion of Coal: Mechanisms, Influencing Factors, and Prevention Strategies

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Abstract—One of the major issues in coal mining is spontaneous combustion, which also poses a significant storage and transportation challenge. It causes serious risks to public safety, financial losses, and environmental issues. The chemical and physical mechanism underlying coal's self-heating behavior is reviewed in this work, along with the main influencing factors—coal rank, particle size, moisture content, and storage conditions—and the historical case study. Additionally, detecting methods and preventive strategies are identified. The study concludes with suggestions for lowering the risk of spontaneous combustion as well as guidelines for the future.

Index Terms—Coal, Self Heating, Spontaneous combustion, spontaneous heating.

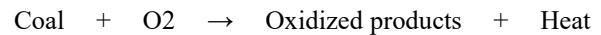
I. INTRODUCTION

The process (chemical or biological) by which a material heats up and may ignite without the need for an external heat source is called spontaneous heating, sometimes referred to as spontaneous combustion or self-heating. This happens as a result of a gradual oxidation process, in which heat is produced more quickly than it can be released, raising the temperature to a point where the material can ignite. If the heat is not sufficiently released, it may build up and ignite the material. Stockpiles, silos, bunkers, and underground mining operations can all experience this phenomenon. The phenomena, which can result in difficult-to-control flames that could linger for decades, poses a major risk to infrastructure, human life, and the environment.

II. MECHANISM OF SPONTANEOUS COMBUSTION

A. low-temperature oxidation

Low-temperature oxidation, in which coal reacts with air oxygen even at room temperature, is the first step of spontaneous combustion. Heat is produced gradually by this exothermic reaction:



Heat builds up as coal oxidizes if it is not efficiently released. The temperature gradually rises and may ignite if the rate of heat generation outpaces the rate of heat dissipation.

B. Self-heating and thermal runaway

The process goes into a self-heating phase if the heat from oxidation is not eliminated. Temperature boosts the coal's reactivity, which speeds up oxidation even further. If there is enough oxygen present, a thermal runaway state eventually develops, resulting in smoldering and open flames.

III FACTORS INFLUENCING SPONTANEOUS COMBUSTION

(A) Coal rank

Because they include more moisture and volatile stuff, lower-rank coals (such as lignite and sub-bituminous) are more reactive and have a greater tendency to self-heat. Anthracite and bituminous coals, which are higher in rank, are more stable.

Coal Rank	Spontaneous Combustion Tendency
Lignite	Very High
Sub-bituminous	High
Bituminous	Moderate
Anthracite	Low

B. Particle Size

More surface area for oxidation is provided by smaller coal particles. Compared to lump coal, fines and dust present a greater danger of combustion.

C. Moisture Content

Moisture affects the exothermic oxidation reactions as well as heat dissipation. While too much water can prevent heat buildup and air penetration, moderate moisture can encourage oxidation by boosting reactivity.

D. Storage Condition

Environmental elements are important, including compaction, stockpile geometry, airflow, and ambient temperature. Excessive airflow adds additional oxygen and poor ventilation can trap heat, both of which can lead to combustion.

IV CASE STUDIES OF THE PAST

A. The Mine Fire at Centralia, Pennsylvania, USA

The Centralia fire, one of the most well-known coal fires, started in 1962 as a result of inappropriate trash disposal close to a mine entrance. The village was evacuated as a result of the decades-long underground fire.

B. India's Jharia Coalfield

Over a century, there have been multiple subterranean fires in Jharia, a significant coal mining district in India. Land subsidence, dangerous air quality, and resident displacement

V. MONITORING AND DETECTION

A. Gas Surveillance

One early sign of self-heating is the release of hydrocarbons, carbon dioxide (CO₂), and carbon monoxide (CO). Real-time sensors and gas chromatography are frequently employed.

B. Thermal Imaging

In mines and coal stacks, infrared thermography can identify hotspots. It offers an early warning technique that is non-invasive.

C. Temperature Probes

Thermocouples are inserted into silos or stockpiles to measure temperature at different depths. Risk evaluation is aided by routine monitoring.

VI PREVENTION AND MITIGATION STRATEGIES

A. Appropriate Stockpile Design

- To minimize heat accumulation, minimize height and bulk.
- To lessen oxygen intrusion, make sure the soil is compacted.
- To avoid long-term storage, rotate your goods.

B. Use of Inert Gas

When Carbon Dioxide or Nitrogen gas is injected into coal piles, Oxygen is replaced and combustion is inhibited.

C. Surface Sealants

Applying sealants or foams on coal surfaces lowers moisture evaporation and Oxygen penetration.

D. Chemical Inhibitors

Phosphates and salts are examples of antioxidants that can be used to prevent or postpone oxidation.

VII ENVIRONMENTAL AND SAFETY IMPACTS

Particulate matter, sulfur oxides, and greenhouse gasses are released by spontaneous coal fires, which exacerbate air pollution and global warming. In addition, fires damage land quality, impact mine stability, and directly endanger human health.

VIII PROSPECTS FOR THE FUTURE

Real-time risk factor analysis is becoming possible with the development of sophisticated predictive models that use AI and machine learning. Additional investigation is required to:

- Create oxidation indices that are standardized.
- Create sealants that can mend themselves.
- Employ biodegradable inhibitors to protect the environment.

IX CONCLUSION

Coal spontaneous combustion is still a complicated and hazardous occurrence that is impacted by a number of physical and chemical variables. A multidisciplinary strategy combining appropriate storage procedures, real-time monitoring, and technology intervention is necessary for effective risk mitigation. Future developments will be essential to

reducing the frequency and severity of coal fires around the world.

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