

An Unusual Near-Surface Geohazard in Nepal: A case study of Smoke Emission at Hupsekot, Nawalpur

Prakash Luitel^{1*}, Shashi Tamang², Mani Khanal¹ and Deen Bandhu Parajuli³

¹Department of Mines and Geology, Kathmandu, Nepal

²Dhaubadi Iron Company Limited, Kathmandu, Nepal

³Nepal Academy of Science and Technology (NAST), Lalitpur, Nepal

(*Corresponding E-mail: prakashluitel@dmgnepal.gov.np)

Abstract: The emergence of smoke and localized ground heating at Hupsekot Rural Municipality, Nawalpur, Nepal, prompted a multidisciplinary preliminary investigation of a potentially hazardous near-surface process. The smoke-emitting zone occurs in fractured, locally altered carbonaceous shale associated with grey and purple shale and subordinate calcareous sandstone of the Post-Gondwana Surkhet Group. Field mapping, four community interviews, rock sampling, gas measurements, XRF, XRD, and spring-water analyses were used to characterize the event. Smoke escaped through multiple openings amid disturbed rock and scorched vegetation. Reported carbon monoxide readings were higher at three vents than approximately 1 m away, while low oxygen readings indicated possible localized atmospheric hazards; instrument units and conditions require verification. Water collected near the smoke zone had an in-situ pH of 2.5, and XRD reference matching indicates quartz as a principal crystalline phase and suggests pyrite in selected samples; XRF screening shows variable sulfur and iron with substantial inter-test inconsistencies. The evidence motivates a working hypothesis involving fracture-mediated oxygen and water access, possible sulfide oxidation, heat accumulation, and carbonaceous-material smouldering.

Keywords: *Carbonaceous shale, Pyrite oxidation, Subsurface smouldering; Geological hazard*

Introduction

Smoke emerging directly from a natural rock mass, accompanied by ground heating and vegetation damage, represents an unusual hazard requiring evaluation of both geological conditions and potential combustion processes. In Hupsekot, smoke emissions from the hillside created public concern over atmospheric exposure, ground instability and water quality. This work presents the initial field and laboratory observations and evaluates an explanatory mechanism without treating its causal steps as established. The investigation was designed primarily for reconnaissance and hazard assessment rather than definitive thermal or combustion characterization.

Location and geological setting

The site lies at Hupsekot Rural Municipality Ward No. 6, Pelega, Nawalpur. The exposed succession is interpreted as Post-Gondwana (Surkhet Group)

sedimentary rocks, dominated locally by black carbonaceous shale with grey to purple shale and minor calcareous sandstone. A disturbed slope with rock fractures and a nearby landslide-affected zone provides the geomorphic context; the chronology of fracture development relative to smoke onset is uncertain.

Methodology

A joint investigation involving the Department of Mines and Geology (DMG), Dhaubadi Iron Company Limited (DIDL), and NAST documented smoke outlets, rock alteration, slope disturbance and associated hazards. Eleven rock samples (HP-1–HP-11) were collected from the vent vicinity and surrounding areas for preliminary XRD and handheld-XRF assessment. Gas readings were acquired at three vents and at nearby comparison positions. Four local questionnaires described event history and perceived impacts; these testimonies were treated as qualitative evidence. Separate in-situ water pH measurements provided initial hydrochemical context.



Figure 1, Smoke emission at the Hupsekot investigation site (field photograph from the site investigation).

Observations and results

Field observations indicate smoke issuing from several openings in the fractured and locally burnt or altered rock mass. Interviewees reported acrid odour, hot ground, smoke variability and occasional respiratory or eye discomfort; one recalled a broadly similar episode at a different locality. Similar conditions were observed on site. Vent-specific gas records report carbon

monoxide (CO) readings of 72.50, 247.62 and 87.49, compared with 16.40, 7.90 and 6.76 at approximately 1 m from the corresponding vents. Oxygen values were reportedly lower at the vents.

XRD patterns identify quartz as the dominant crystalline phase, with tentative pyrite matches in some samples. Handheld-XRF results indicate aluminosilicate-rich compositions with variable iron and sulfur contents, including notably high sulfur levels in burnt HP-2 and selected HP-4 samples.

Interpretation & possible mechanism

The possible geological mechanism (Figure 2) is that slope movement or other fracturing created pathways for air and water to penetrate the organic-rich, potentially sulfide-bearing shale. If pyrite is present and actively oxidizing, associated acidity and localized exothermic reactions could contribute to heating (Rimstidt and Vaughan, 2003; Nordstrom, 1982). Heat retention might then support self-heating and, under favorable but unverified thermal and oxygen conditions, subsurface smouldering. Smoke and gases could migrate along open discontinuities.

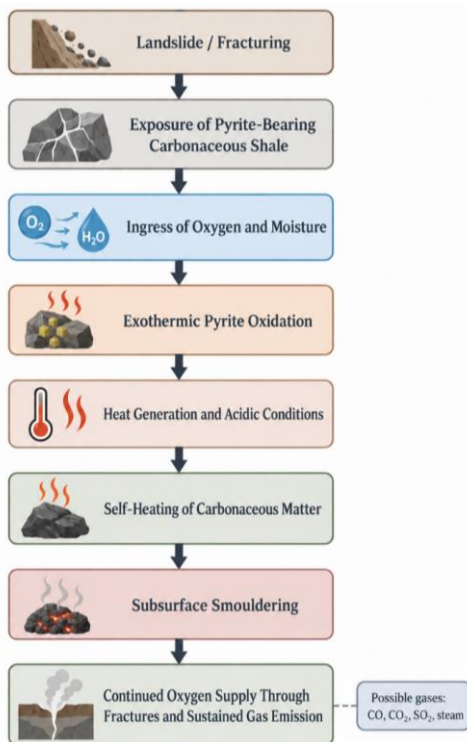


Figure 2, Possible Geological Mechanism

Hazard implication and recommendation

The primary hazards associated with the Hupsekot event include exposure to hazardous gases and oxygen-deficient conditions near active smoke vents, along with potential subsurface heating, vegetation fires, instability of fractured rock masses, and deterioration of water quality. As an immediate precaution, access to

active smoke-emitting zones should be restricted until a site-specific hazard assessment is completed.

Further investigations should focus on monitoring gas concentrations, ground temperatures, and thermal anomalies, supported by detailed mineralogical, geochemical, and thermal analyses. Engineering interventions affecting subsurface airflow, thermal conditions, or slope stability should only proceed after proper technical assessment.

Conclusion

The Hupsekot event represents an unusual near-surface geological phenomenon characterized by smoke emission from fractured carbonaceous shale, localized thermal alteration, anomalous gas concentrations, and acidic water. Preliminary mineralogical and geochemical findings suggest that sulfide oxidation may contribute to localized heating and acidification, potentially creating conditions favorable for subsurface smouldering. However, the source of heat, ignition mechanism, and relationship between these processes remain uncertain. Further integrated geological, geochemical, and thermal investigations, along with systematic monitoring, are essential to establish the underlying mechanism and assess potential hazards to the local community.

References

- Petroleum Exploration Promotion Project (PEPP). (1998). Geological map of exploration Block-5 (Chitwan, Western Central Nepal) (Scale 1:250,000) [Geological map]. Department of Mines and Geology, Government of Nepal.
- Nordstrom, D. K. (1982). Aqueous pyrite oxidation and the consequent formation of secondary iron minerals. In *Acid Sulfate Weathering* (pp. 37–56). Soil Science Society of America.
- <https://doi.org/10.2136/sssaspepub10.c3>
- Onifade, M., and Genc, B. (2019). Spontaneous combustion liability of coal and coal-shale: A review of prediction methods. *International Journal of Coal Science & Technology*, 6, 151–168.
- <https://doi.org/10.1007/s40789-019-0242-9>
- Rimstidt, J. D., and Vaughan, D. J. (2003). Pyrite oxidation: A state-of-the-art assessment of the reaction mechanism. *Geochimica et Cosmochimica Acta*, 67(5), 873–880.
- [https://doi.org/10.1016/S0016-7037\(02\)01165-1](https://doi.org/10.1016/S0016-7037(02)01165-1)