Monitoring Terrestrial Gamma Radiation to Characterize Mud Volcanic Activity: Evidence from the Piparo Mud Volcano, Trinidad and Tobago

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The Piparo Mud Volcano is a significant natural hazard in Trinidad and Tobago, highlighted by its violent 1997 eruption that devastated everything within a one-mile radius, displaced 31 families, killed livestock, and destroyed critical infrastructure. Such destructive events are driven by overpressurized subsurface conditions, causing mud volcanoes to act as natural vents, releasing fluidized mud and gas to the Earth's surface or seafloor. These emissions may occur gradually or in more abrupt bursts, as demonstrated during heightened activity in 2019 and 2024. These recent events underscore the urgent need for enhanced monitoring and a deeper understanding of the mud volcano's structure. Yet, despite the ongoing and severe risks posed by sporadic eruptions, current monitoring frameworks are predominantly surface-based and event-driven, offering limited insight into the deeper structural and geophysical precursors that may signal impending activity. To address this gap, this research advances the foundational work of previous investigators, who studied gamma radiation changes at the Piparo Mud Volcano, following volcanic events between 2018 and 2019. Our dataset, however, spans a broader timeframe, capturing radiation fluctuations both before and after an eruption event. This approach transforms natural radioactivity from a passive background signal to a potential predictive indicator of volcanic activity. This study pioneers a novel framework that utilizes gamma radiation monitoring to capture the precursory subsurface dynamics of the Piparo Mud Volcano. Specifically, this study aims to: (1) explore the correlation between spatial gamma radiation patterns and geomorphological features, (2) examine temporal variations in gamma radiation and correlate them with eruption events, and (3) evaluate the use of gamma radiation to predict volcanic activity. To achieve these objectives, gamma radiation data were collected at 40 locations over a 23-month period using a Geiger-Muller counter. The measurements were taken at five intervals (0, 4, 11, 17, and 23 months), both 1 meter above and 0.5 meters below ground level (GL). The results indicate that the highest gamma radiation levels above GL occur in the southern and eastern areas of the main crater, while the northern and western sections show the highest gamma radiation levels below GL. This spatial pattern aligns with the presence of syngenetic fractures and smaller subsidiary craters, which are more common in the active northern and western areas. Gamma radiation also fluctuates with time, with levels above GL rising steadily from month 0, then peaking at month 11, before declining through months 17 to 23. In contrast, radiation levels below GL follow the opposite trend. Notably, these shifts coincide with an eruption between months 11 and 17, suggesting a link between radiation fluctuations and volcanic activity. This study demonstrates that gamma radiation offers a promising method for monitoring mud volcanic activity. By correlating radiation shifts with eruption timing, this technique could enable early detection, enhancing volcano monitoring systems and risk management strategies.