Evaluating Geothermal Energy Potential in Tattapani Springs, Azad Jammu and Kashmir, Pakistan: Integrated Geophysical and Geochemical Analysis Amid Environmental and Resource Challenges

Mehboob ur Rashid[1,2,3], Waqas Ahmed[2*], Said Muhammad[2], Muhammad Kamran[1], and Muhammad Jawad Zeb[1]

[1]*Geoscience Advance Research Labs, Geological Survey of Pakistan Islamabad;*

[2]*National Centre of Excellence in Geology, University of Peshawar;*

[3]*Graduate School of Science and Engineering Kagoshima University, Japan*

**Email: waqas.nce@gmail.com*

The Tattapani Thermal Spring in Azad Kashmir's NW-Himalaya region boasts a steady surface temperature of 60°C, attracting attention for its potential in geothermal energy. This integrated study combines geology, geophysics, and geochemistry to unravel its subsurface dynamics and assess its suitability for power generation. A thorough resistivity survey revealed four lithological units based on resistivity contrasts. High resistivity (>300 ohm-meters) indicated weathered dolomite/limestone, while low to moderate resistivity (80-200 ohm- meters) suggested clay and sandstone layers, possibly holding meteoric water. A low resistivity zone (20-80 ohm-meters) hinted at moderate hydrothermal alteration, and a very low resistivity zone (5-20 ohm-meters) pinpointed the geothermal spring. Thermal plumes (10-70 ohm-meters) detected at depths of 30-60 m indicated hot plume migration north-eastward, affecting fresher water (100-200 ohm-meters). Longitudinal conductance (0.95-15 mhos) and transverse resistance (20-300 ohm-m^2) peaked in the northeastern and northwestern regions. Fresh groundwater, mainly in sandstone (150-200 ohm-meters) and dolomite (≥400 ohm-meters), lay above the thermal plumes, vulnerable to contamination. Magnetic and gravity surveys revealed the spring's depth range of 30m to 60m, linked to deep-seated thermal convection cells tied to the Tattapani fault and Riasi thrust at greater depths. Recharge sources included surface runoff and the perennial Poonch River, with the heat source originating from Precambrian shield rocks sourced from the mantle. The spring emerges along a fault zone, bridging Cambrian

Abbottabad and Paleocene Patala Formations, serving as a conduit for thermal convection. This fault zone may interconnect with the Riasi thrust at deeper levels, suggesting a link to the mantle heat source. Vapor from the spring condenses upon mixing with groundwater at depths of 20-40 m, causing a temperature drop. Given the promising geothermal potential at deeper levels, the study advocates pilot drilling to 500 m for thermal assessments and geotechnical studies. This exploration, paired with gravity-based basin analysis, promises insights into Tattapani's thermal dynamics, paving the way for sustainable geothermal energy initiatives.