**Advancing environmental management in mining: a GIS-based approach to acid mine drainage tracking and quantification**

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**Abstract**

A thorough grasp of the “mining landscape” is critical to address mining-related environmental challenges effectively. Managing and mitigating environmental impacts hinge on the ability to visualize and interpret affected areas - including evaluating the pollution extent and the effectiveness of mitigation strategies. Comprehensive mapping and quantification of mining areas are necessary, going beyond mere location plotting to detailing and quantifying the pollution extent. This extends beyond demarcating boundaries to understanding how much land and water are directly affected, and to what degree. Such quantification is crucial for resolving land-use conflicts, assessing pollution risks, and planning reclamation activities.

This study employs a novel geographic information system (GIS)-based approach, integrating remote sensing technologies, and on-site sampling to map, quantify, and analyse the extent of AMD within coal mining properties in the Nkangala District of South Africa. Utilizing an array of data sources, including ESRI databases, Sentinel 2 imagery, and Shuttle Radar Topography Mission (SRTM) data, this research geolocates 265 coal mining properties and identifies the primary and secondary sources of AMD. The analytical process included supervised image classification, automated mapping via Landsat 8 imagery, and detailed volume calculations for water bodies at the sites.

Findings reveal a substantial concentration of AMD issues within 116 mining locations (which encompasses 459.69 km² of the study area) -815 potential AMD bodies (including tailings dams and pit lakes). The bodies within the properties have a combined surface area of 10.78km², and field verification further substantiates the varying effects of AMD on water quality, with pH levels and sulphate concentrations demonstrating the adverse effects of mining operations. The average depth of water body was found to be 4,48 m (much lower than regulations prescribe). In addition, of the most common depth of water body was 2 m, a shallow measurement which might indicate that evaporation is being implemented as treatment methods. A total of 97 136,8 million litres stored in containment dams, pit lakes and other water storage facilities was calculated. Moreover, the economic valuation of REEs in the AMD-influenced waters of the sampled sites suggests a potential worth of over 1 billion South African Rands, offering an economically viable incentive for AMD treatment beyond environmental remediation.

This work could inform the design and implementation of site-specific AMD management strategies that are economically sustainable. The integration of modern geospatial technologies enables a more nuanced understanding of AMD effects, facilitating informed decision-making in environmental management.

**Keywords:** Geographic Information System (GIS), Environmental Remediation, Mining Effect Quantification