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Spatial and Temporal Trends of Mining-Associated Water Quality in the Vaal River System, South Africa

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South Africa faces increasing water stress driven by growing demand and deteriorating water quality, intensified by climate change, population growth, inadequate water services management, and the impacts of mining, agricultural, and industrial activities. Addressing these pressures requires robust, long-term water quality monitoring. This study draws on a harmonized dataset of inorganic surface water chemistry derived from the National Chemical Monitoring Programme, spanning five decades. This spatiotemporal dataset includes parameters such as electrical conductivity, pH, alkalinity, and major inorganic ions. Although openly accessible, the raw data required extensive preprocessing to correct inconsistencies. After harmonization and charge balance validation, over 500000 records were retained, providing a foundation for spatiotemporal trend assessment.

The Vaal River is heavily regulated and overutilized, supporting extensive industrial and mining activities across the catchment, hosting coal and gold deposits. Since 1886, approximately 40000 tons of gold have been extracted from the Witwatersrand basin alone, contributing to regional development but also introducing persistent water quality pressures associated with acid mine drainage and elevated salinity [1-3].

Long-term trends in key mining-associated parameters were analyzed at six monitoring stations distributed longitudinally along the Vaal River, evaluating spatiotemporal changes in pH, sulphate, calcium, magnesium, and total dissolved solids (TDS) content over approximately 40 years. Trend screening revealed that upstream stations experienced the strongest relative increases, with sulphate rising to over 200% of 1985-1988 baseline levels by the 2010s and TDS increasing up to 160%. Despite more stable relative trends at downstream stations, absolute concentrations below the Vaal Barrage Dam are approximately double upstream values, indicating possible persistent legacy contamination rather than active deterioration.

Geochemical diagrams, statistical trend analyses using generalized additive models, and geospatial tools were used to illustrate patterns and assess how they reflect cumulative mining-related pressures. This study demonstrates the value of long-term monitoring data for detecting impacts of mining over space and time.

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