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Spatio-temporal patterns of river water quality in the klang river basin, malaysia: a functional data analysis approach to detect pre- and post-pandemic shifts

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Abstract

Understanding spatial and temporal patterns of river water quality over a multi-year period is crucial for effective basin management and pollution control. This study applies functional data analysis (FDA) to evaluate monthly water quality index (WQI) data from 16 monitoring stations across the Klang River Basin, Malaysia, covering the period from 2020 to 2023, which spans both pre- and post-pandemic conditions. By treating water quality index (WQI) measurements as smooth functions over time, FDA captures underlying trends and variations that are not readily detected using classical statistical techniques. Functional principal component analysis (FPCA) reveals that

the first component accounts for 97% of the total variation, reflecting the dominant pattern in water quality over time, which is characterized by relatively stable upstream conditions and gradual deterioration downstream. The second and third components capture seasonal fluctuations and short-term disturbances, potentially linked to monsoonal cycles and shifts in human activities during the pandemic. Functional clustering based on FPCA scores groups stations according to their temporal behavior, distinguishing upstream areas with stable conditions from downstream areas experiencing greater variability. Spatial interpretation of these clusters offers additional insight into localized pollution sources and environmental stressors. Compared to classical PCA, FDA provides a more detailed, curve-based understanding of time-dependent and location-specific changes in water quality. The result underscore the value of FDA in environmental monitoring, particularly for detecting pre- and post-pandemic shifts, and support its application in guiding adaptive and spatially targeted management strategies for river basins. © The Author(s) 2025.

Author keywords

Functional principal component analysis; Monsoonal influence; River basin monitoring; Spatio-temporal clustering; Water quality trends

Indexed keywords

MeSH

COVID-19; Data Analysis; Environmental Monitoring; Humans; Malaysia; Pandemics; Rivers; Spatio-Temporal Analysis; Water Pollutants, Chemical; Water Pollution; Water Quality

Regional Index

Klang Basin; Malaysia; Selangor; West Malaysia

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Engineering controlled terms

Data quality; Data reduction; Environmental monitoring; Information analysis; Pollution control; Principal component analysis; Quality control; River control; River pollution; Water conservation; Water management; Watersheds

Engineering uncontrolled terms

Functional data analysis; Functional principal component analysis; Malaysia; Monsoonal influence; River basin monitoring; River basins; River water quality; Spatio-temporal clustering; Water quality indexes; Water quality trends

GEOBASE Subject Index

data set; detection method; pollution control; principal component analysis; river water; spatiotemporal analysis; water quality

EMTREE medical terms

Article; controlled study; data analysis; human; Malaysia; river basin; spatiotemporal analysis; water quality; chemistry; coronavirus disease 2019; data analysis; environmental monitoring; epidemiology; Malaysia; pandemic; procedures; river; spatiotemporal analysis; water pollutant; water pollution; water quality

Engineering main heading

Water quality

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Unique identifiers assigned by the Chemical Abstracts Service (CAS) to ensure accurate identification and tracking of chemicals across scientific literature.

Water Pollutants, Chemical

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Abstract

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