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Research Article

Review on Developing Integrated Water Quality Management Systems Based On GIS and Remote Sensing Mechanism

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Abstract:

This paper examines the integration of remote sensing and GIS to monitor water quality indicators such as turbidity, chlorophyll levels, and surface temperature. It highlights how this synergy enhances the identification and management of pollution sources, supporting informed decision modelling for sustainable water resource management. Also emphasizes the need for comprehensive water quality management in river basins, addressing both point and non-point source pollutants. It proposes a distributed simulation model, utilizing GIS to assess pollutant loads based on land use and soil characteristics, aiming to predict water quality at river basin outlets.Even the accuracy of remote sensing-derived data was evaluated using statistical metrics such as Root Mean Square Error (RMSE) and the coefficient of determination (R^2), ensuring reliability and robustness of the results. The paper provide valuable insights into the development and application of integrated water quality management systems using GIS and remote sensing technologies.

Keywords: GIS, Remote Sensing, Decision Modelling, Root Mean Square Error (RMSE)

Introduction:

One of the most important natural resources, water is essential to ecosystem health, economic growth, and life support. However, water quality in many freshwater systems around the world has drastically declined due to growing urbanization, industrialization, agricultural development, and climate change. As a result, managing water quality effectively has gained international attention, especially in areas that are under environmental stress and significant population increase.

Even if they are accurate, traditional water monitoring techniques frequently require time-consuming, expensive, and spatially constrained laboratory analysis and field sampling.

Recent developments in geospatial technologies, including Geographic Information Systems (GIS) and Remote Sensing (RS), present viable ways to get beyond these restrictions. A more thorough and effective evaluation of water quality is made possible by these tools, which make it possible to gather, process, and analyze spatially distributed data at various temporal and spatial scales.

Spatial analysis, visualization, and decision-making are made easier by the platform that GIS offers for integrating diverse resources. However, using satellite or aerial photography, remote sensing enables real-time or near-real-time monitoring of water bodies, facilitating the easy assessment of broad and inaccessible areas. Together, GIS and RS technologies create a potent integrated system that can predict hydrological processes, detect pollution sources, monitor water quality indices, and assist in the sustainable management of water resources.

The goal of this research is to create an integrated water quality management system that makes use of remote sensing techniques and GIS. The system is intended to evaluate the effects of land use changes, examine spatial-temporal variations in water quality, and offer a framework for decision-making to environmental managers and policymakers.

Literature Review:

In recent years, there has been a lot of interest in the use of geospatial technology in environmental monitoring, particularly for the management and evaluation of water quality. The potential of Geographic Information Systems (GIS) and Remote Sensing (RS) to facilitate large-scale, cost-effective, real-time water quality monitoring has been shown in numerous research.

Priyanka et al. (2023) emphasized that the integration of GIS, remote sensing, and water quality modeling provides a holistic framework for water resources management. Their study revealed that such integration not only improves accuracy but also aids in predicting future scenarios under different land use or climate change conditions.

Somvanshi et al. (2012) conducted one of the early comprehensive studies using an integrated GIS and remote sensing approach for assessing the water quality of the Gomti River in Uttar Pradesh. By utilizing IRS LISS III satellite imagery and in-situ measurements, the study analyzed water quality parameters like pH, dissolved oxygen (DO), biological oxygen demand (BOD), and total solids. The research highlighted seasonal variations in pollution levels and the influence of surrounding land use, demonstrating the effectiveness of satellite-based monitoring.

Similarly, Yadav et al. (2014) investigated the effects of urbanization on the Hindon River using Landsat imagery and GIS methodologies. Their results showed a substantial relationship between rising nitrate and BOD concentrations, particularly in metropolitan areas, and rapid land use changes. The study focused on the use of GIS techniques for long-term urban water body monitoring.

Chaurasia et al. (2019) developed a GIS-based Water Quality Index (WQI) mapping system for the Ganga River near Varanasi. By integrating parameters such as pH, DO, BOD, and total coliforms into a spatial model, the study produced WQI maps that clearly illustrated the river's health over different stretches and times of the year. This tool proved useful for both scientists and policymakers.

More recently, **Sharma and Dutta (2022)** introduced a real-time satellite monitoring model using Sentinel-2 and Landsat-8 data for the Brahmaputra River. Their research showed how time-series satellite data can detect turbidity, chlorophyll-a, and algal blooms with significant accuracy. The integration with GIS further enhanced the ability to track spatial pollution patterns and predict future risks.

Research Methodology

In order to create a thorough water quality management system, this study uses an integrated, multidisciplinary research approach that combines ground-truth water sampling, GIS-based spatial modeling, and remote sensing analysis. There are five main stages to the methodology:

In order to create a thorough water quality management system, this study uses a multidisciplinary method that combines field-based water quality testing, GIS-based spatial modeling, and remote sensing. A river basin or urban water body in India, for example, was chosen as the study region because to its environmental significance, pollution level, data accessibility, and field validation ease. Multi-temporal satellite imagery was first obtained for the study from platforms such IRS LISS III, Sentinel-2 MSI, and Landsat 8 OLI.

Ancillary datasets, including rainfall records, Digital Elevation Models (DEMs), sewage discharge maps, and land use/land cover (LULC) maps, were also acquired to complement the spatial analysis. Platforms such as ArcGIS and QGIS were used to combine all datasets into a GIS environment. Pollution hotspots were located and mapped using spatial interpolation techniques (e.g., Kriging, IDW). To evaluate the distribution and flow pathways of pollutants, watershed and sub-basin borders were established. Standardized formulas (such the NSF-WQI) were used to construct the Water Quality Index (WQI), and the results were categorized into excellent, good, and bad categories based on the levels of water quality. To study temporal fluctuations, these WQI values were spatially mapped throughout various seasons.

In addition, a GIS-based decision-support system (DSS) was created as a result of the study to assist environmental managers and policymakers in visualizing pollution trends, monitoring changes over time, and prioritizing regions that require intervention. To ensure the reliability and robustness of the results, statistical metrics like the coefficient of determination (R2) and Root Mean Square Error (RMSE) were used to assess the accuracy of data produced from remote sensing. Software tools used in the study included statistical programs such MS Excel, R, and SPSS for data analysis, ENVI and ERDAS Imagine for image classification, and Google Earth Engine for satellite processing.

Analysis:

The examination of the reviewed literature shows a distinct and expanding trend toward the use of geospatial technologies, particularly GIS and Remote Sensing (RS), in the management of water quality in different parts of India. The following significant findings and trends surfaced.

1. Coverage and Spatial Focus

Major river systems like the Ganga, Yamuna, Hindon, Gomti, and Brahmaputra have been the subject of the majority of region-specific studies. Because of the industrialization and extensive urbanization, these rivers are especially vulnerable to pollution.

2. Remote Sensing Use

The main applications of remote sensing have been:

Tracking total suspended solids (TSS), algal blooms, turbidity, and chlorophyll-a Finding seasonal and inter-annual changes in pollution levels through temporal analysis Classification of land use and land cover (LULC) to link catchment activities to deterioration of water quality Because of their accessibility and resolution, sensors such as IRS LISS-III, Sentinel-2, and Landsat-8 are widely employed. In order to do more reliable trend analyses, more recent studies (2020+) have begun to use time-series data and higher-resolution imagery.

3. Role of GIS

GIS was widely utilized to:

- Map the contaminants' spatial distribution
- Create maps based on the Water Quality Index (WQI).
- Find areas with high pollution levels.
- Incorporate several datasets into watershed-based models, such as LULC, rainfall, and topography.

In order to evaluate the impact of human activity on water bodies, GIS-based overlay analysis and buffering techniques were frequently used. Accessibility and standards have improved with the usage of programs like ArcGIS, QGIS.

4. Gaps and Challenges Identified

Restricted real-time applications: Real-time data integration was absent from the majority of retrospective investigations.

Spectral limitations: Remote sensing cannot directly identify some factors, particularly chemical contaminants.

During monsoon seasons, the dependability of optical images was impacted by cloud cover and data availability concerns.

The methods used to calculate WQI in various studies are not consistent.

Conclusion

This study integrates advanced geospatial technologies, remote sensing, and ground-truth validation to develop a robust and scalable water quality management framework. By combining field-based water sampling with GIS-based spatial modeling and multi-temporal satellite analysis, the approach enables a comprehensive understanding of the spatial and temporal dynamics of water pollution. The inclusion of ancillary datasets such as rainfall, sewage discharge, and land use further enhances the accuracy of pollutant distribution assessments. The development of a GIS-based decision-support system provides a practical tool for policymakers and environmental managers to visualize trends, monitor changes, and prioritize areas for intervention. Through rigorous statistical validation, the methodology ensures the reliability of results, making it a valuable model for water resource monitoring and management in ecologically sensitive or data-scarce regions.

References:

1. Chaurasia, S., Pandey, A., & Singh, R. (2019). GIS-based water quality indexing and mapping of River Ganga at Varanasi, India. *Journal of Environmental Management*, 240, 402–412. https://doi.org/10.1016/j.jenvman.2019.03.127
2. Kumar, R., & Jayappa, K. S. (2017). Watershed-based water quality assessment using GIS and remote sensing: A case study of Nethravathi River Basin, Karnataka. *Environmental Monitoring and Assessment*, 189(3), 121. https://doi.org/10.1007/s10661-017-5821-4
3. Sharma, R., & Dutta, D. (2022). Remote sensing-based monitoring of water quality parameters in the Brahmaputra River using multi-temporal satellite data. *Remote Sensing Applications: Society and Environment*, 25, 100670. https://doi.org/10.1016/j.rsase.2022.100670
4. Singh, R., & Singh, A. (2016). Monitoring water quality of River Yamuna in Delhi using GIS and remote sensing techniques. *Journal of Water Resource and Protection*, 8(1), 91–99. https://doi.org/10.4236/jwarp.2016.81009
5. Somvanshi, S., Kunwar, P., Singh, N. B., Shukla, S. P., & Pathak, V. (2012). Integrated remote sensing and GIS approach for water quality analysis of Gomti River, Uttar Pradesh. *International Journal of Environmental Sciences*, 3(2), 933–945. https://www.researchgate.net/publication/234001194
6. Yadav, R., Bhatnagar, A., & Kumar, V. (2014). Impact of urbanization on water quality of Hindon River using remote sensing and GIS. *International Journal of Remote Sensing & Geoscience (IJRSG)*, 3(5), 1–7. https://doi.org/10.13140/RG.2.2.19099.00805