Advancing Water Quality Monitoring through the Integration of Machine Learning and Remote Sensing: Challenges, Innovations, and Future Prospects

Shashank Mohan *
PhD Researcher, Department of Biosystems and Agricultural Engineering, Michigan State University, East Lansing, MI 48824, USA

Brajesh Kumar
Department of Computer Science and Information Technology, Mahatma Jyotiba Phule Rohilkhand University, Bareilly 243006, India

A. Pouyan Nejadhashemi
Department of Biosystems and Agricultural Engineering, Michigan State University, East Lansing, MI 48824, USA

Abstract

Water quality degradation threatens ecosystems, public health, and economic stability, necessitating efficient monitoring solutions. Traditional field-based methods are limited by cost and spatial-temporal constraints. This study explores the integration of remote sensing (RS) and machine learning (ML) to enhance large-scale water quality monitoring. ML models estimate key indicators such as chlorophyll-a, turbidity, and total suspended solids by leveraging multispectral/hyperspectral satellite data (e.g., Sentinel-2, Landsat-8) and UAV-based observations. The research employs regression models, deep learning architectures (CNNs, LSTMs), and hybrid approaches incorporating meteorological and land-use data. Case studies in Lake Taihu, the Mississippi River Basin, and Florida's coastal regions demonstrate improved accuracy and cost-efficiency over traditional methods. However, challenges remain, including data limitations, model interpretability, and computational scalability. Future directions include advanced hyperspectral sensors, IoT-integrated monitoring, and explainable AI for regulatory applications. The RS-ML paradigm presents a transformative pathway toward proactive water resource management, aligning with global sustainability goals.

Keywords

Remote Sensing, Machine Learning, Water Quality Monitoring, Algal Blooms, Sustainable Development.