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Water Potential and Modeling Studies of Kollam and Adjoining Region of Kallada Basin, South India: Insights into Drinking and Irrigation Suitability

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Abstract

Groundwater resources within river basins are gaining global attention due to their critical role in sustaining human and agricultural needs. Preserving groundwater quality is essential for agricultural productivity and public health, as it serves as the primary source of drinking and irrigation water for billions of people worldwide. This study focuses on the hydrochemical characterisation and quality evaluation of groundwater in the lower urbanized regions of the Kallada River Basin (LKRB), covering Kollam town and its surrounding areas. This study aimed to assess water quality for drinking and irrigation purposes while also evaluating the underlying hydrogeochemical processes. The major cations and anions in groundwater follow the order: $Ca^{2+} > Na^{+} > Mg^{2+} > K^{+}$ and $HCO_3^{-} > Cl^{-} > SO_4^{2-}$. The dominant groundwater type is Ca-HCO_3, followed by Na-Cl. The Water Quality Index (WQI) was employed to evaluate groundwater suitability for drinking. WQI analysis revealed that 80% of samples fell within the 'good to excellent' range, indicating suitability for drinking and domestic use, while 20% were classified as poor quality. Several indices, such as the Magnesium Hazard (MH), Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Sodium Percentage (Na%), and Kelley's Ratio (KR), were used to assess the suitability of groundwater for irrigation. The findings indicate that although most samples are safe for irrigation, a few areas have problems with their water quality that render them harmful. This study helps with the sustainable management of groundwater resources in the LKRB by providing important insights for policymakers and urban planners.

Keywords: Groundwater Chemistry, Hydro-chemical Facies, Drinking Suitability, Irrigation Suitability, Water Quality Index, Lower Kallada River

Introduction

Water is the lifeblood of our planet, and groundwater, stored beneath the surface, plays a vital role in supporting human civilization (Loganathan and Sathiyamoorthy, 2024; Kumar *et al.,* 2024). It is an essential resource for drinking, irrigation, industrial uses and ecological balance (Khadri and Moharir, 2016; Pramoda *et al.,* 2022; Meghanad *et al.,* 2025). Groundwater quality assessment is particularly important in regions experiencing rapid urbanization and industrial growth, where contamination risks from industrial effluents, agricultural runoff, and urban wastewater continue to rise (Jain *et al.,* 2019). In many developing nations, water pollution and its management require urgent attention, as unsafe water is linked to nearly 80% of disease outbreaks and fatalities. According to Shayo *et al.* (2023), 2.2 million people die yearly from waterborne illnesses, and around 2.1 billion people worldwide lack access to clean drinking water. India has the highest groundwater extraction rate globally, surpassing China and the United States (NGWA, 2016). Groundwater hydrochemistry is influenced by geological formations, rock-water interactions, mineral dissolution, evaporation, precipitation, and anthropogenic activities such as industrialization and large-scale agriculture (Singh *et al.,* 2011; Rajesh *et al.,* 2012; Manjare and Pophare, 2020; Panigrahi and Das, 2022; Raheja *et al.,* 2024). Furthermore, hydrogeochemical processes such as weathering, ion exchange, and dissolution play a crucial role in determining the concentration of major and minor ions in groundwater. Approximately 15% of the world's groundwater is used for industrial purposes, 20% for irrigation, and 65% for drinking (Adimalla *et al.,* 2018; Gani *et al.,* 2023). Additionally, nearly one-third of the global population relies entirely on groundwater for their drinking water needs (Adimalla and Venkatayogi, 2018). However, excessive groundwater exploitation and recurring droughts have led to declining water tables and declining water quality (Hosseinifard and Mirzaei Aminiyan, 2015). Continuous monitoring is necessary for sustainable water resource management in the Kallada River Basin (KRB), as groundwater serves as a major source for irrigation and drinking. This study investigates groundwater quality in the Kallada River Basin's lower urbanized regions, focusing on Kollam town and nearby areas to evaluate its suitability for irrigation and drinking while assessing hydrochemical properties. Hydrogeochemical investigations help in formulating strategies to protect

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