

Evaluation of Groundwater Contamination for Fluoride in Pullamapatti Watershed, Northern Tamil Nadu, India: An Emphasis on Human Health Risk Assessment

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Abstract

The high fluoride concentration in groundwater, exceeding 1.5 mg/L in parts of Dharmapuri, Krishnagiri, Salem, and Vellore districts, poses significant public health concern. Notably, Dharmapuri district exhibits the highest fluoride levels in Tamil Nadu. Recent studies revealed that many groundwater samples from Dharmapuri district of Tamil Nadu are affected by fluoride contamination. To investigate the spatial distribution of fluoride in groundwater, hydrogeochemistry and the effect on human health, 66 water samples collected from Pullamapatti Watershed (PW) were analyzed. The samples collected from different groundwater extraction structures were analyzed for pH, EC, TDS, total hardness, alkalinity and major ions utilizing standard methods. In the case of cations, Na^+ is the most prevalent, followed by Mg^{2+} , Ca^{2+} , and K^+ and the major anions in the groundwater are ordered by proportional abundance as follows: Chloride > Bicarbonate > Sulfate > Nitrate > Fluoride. The investigation using Gibbs analysis revealed that the chief cause of groundwater contamination is rock-water interaction. Furthermore, Fluoride human health risk assessment for various age groups was performed by estimating the total hazard Index for all the collected samples. It is found that 75.7% of infants, 50% of children, and 34.28% of adults are affected by fluoride contaminated water.

Keywords: Hazard Quotient, Fluorosis, Groundwater contamination, Aquifer, Hydrochemistry

Introduction

Groundwater is a necessary natural material for mankind as it is renewable, low-cost cost and less polluted (Awadh *et al.*, 2021). Nevertheless, widespread withdrawal of groundwater is leading to over-exploitation of the resources in several areas of the globe, particularly in nations like India, where the demand for freshwater resources is rapidly increasing (Ashraf *et al.*, 2017). India is the largest global consumer of groundwater, utilizing approximately 250 billion cubic meters annually, which constitutes nearly a quarter of the worldwide groundwater consumption. Groundwater holds immense importance in India, as it supplies over 60% of the irrigation water for farmlands and supplies over 85% of the drinking water, making it an indispensable and essential resource for these regions (Saha and Ray, 2018). In India, injudicious management of water resources and environmental deterioration have sparked concerns regarding water scarcity and quality (Saha *et al.*, 2017). The thresholds for various chemical constituents in groundwater to ensure its suitability for potable use are followed after WHO, 2022 and BIS, 2022. Contamination of groundwater has direct

implications for human health, particularly in arid and semi-arid terrains of India (Tiwari *et al.*, 2020).

Fluoride is the thirteenth most prevalent element in the lithosphere. Despite the vital role as a micronutrient essential for human well-being, fluoride has the capacity to pollute groundwater on a significant scale, considering it a global concern (Ghosh *et al.*, 2013). Naturally raised levels of F^- found in groundwater present a worldwide health hazard, potentially affecting vast populations, especially in the developing countries (Sane *et al.*, 2025). The existence of fluoride in small concentrations ($< 1.0 \text{ mg/L}$) in potable water generally contributes positively in reducing tooth decay, particularly among youngsters (Shomar *et al.*, 2004). Nonetheless, data from WHO (2022) highlights that the prolonged and excessive influence of fluoride ($> 1.5 \text{ mg/L}$) can cause various harmful consequences. These include dental and skeletal fluorosis, an elevated likelihood of bone injury, diminished birth rates, enhanced susceptibility to kidney stones, compromised thyroid function, and a decline in children's cognitive development. Due to a variety of factors, like elevated pH, increased presence of Na^+ and HCO_3^- concentrations, and decreased Ca^{2+} ions, groundwater often contains elevated levels of fluoride (Jaunalkar and Murkute, 2023). Human influence on fluoride mainly happens through the consumption of groundwater for drinking.

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