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Research Article

ISSN : 2455-1953
JGSR
Journal of Geosciences Research
Vol. 11, No.2, July, 2026, pp. 126-133

Soil Geochemistry and Health Assessment Based on Heavy Metal Indexing in Kanyakumari District, Tamil Nadu, India

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Abstract

Understanding soil characteristics in river basins is crucial, as they directly influence agricultural productivity, ecological health, and the transport of contaminants within watersheds. This study investigates the Tamiraparani River Basin, where 39 soil samples were systematically collected across the region to evaluate physicochemical properties and selected metal concentrations, aiming to assess soil quality and contamination levels. Standard methods were employed to analyse parameters such as pH, electrical conductivity, and elemental concentrations. The degree of contamination ranged from 6.47 to 14.54, with four sites exhibiting low contamination and the remaining sites showing moderate levels. Pollution Load Index values varied between 0.73 and 1.26, with sixteen sites indicating progressive deterioration of soil quality, reflecting increasing anthropogenic pressures. The findings indicate generally low contamination levels, with only marginal enrichment at certain sites, suggesting that precautionary monitoring is needed. Given the critical role of soils in achieving several United Nations Sustainable Development Goals, including Zero Hunger, Climate Action, and Life on Land, the study underscores the importance of sustainable soil management in the context of global environmental changes, climate variability, and accelerating soil degradation. The results not only enhance understanding of regional soil health but also provide a foundation for future research, policy formulation, and sustainable land-use planning.

Keywords: Anthropogenic, Pollution Load Index, Soil Contamination Indices, XRF geochemistry

Introduction

Soil is an essential natural resource that greatly contributes to food security, as it determines the quality and composition of crops and animal feed forming the foundation of the food chain. Soils serve as the basis of all terrestrial ecosystems and play a crucial role in supporting biodiversity and the provision of ecosystem services (Neuenkamp *et al.,* 2024). It also plays an important role in maintaining ecological balance across the planet (Tóth *et al.*, 2016). However, every year, soil is polluted by various harmful substances from industries, agriculture, mining, and household waste (Franco-Uría *et al.*, 2009).

Toxic elements present in soils are particularly concerning. This is because they do not break down naturally, stay in the environment for a long time, and can persist in living organisms (Gowd *et al.*, 2010; Romic and Romic, 2003). These elements accumulate in soil through human activities and can eventually enter crops, leading to contamination of the food chain and posing serious health risks to humans (Antoniadis *et al.*, 2017a, b, 2019; Cheng, 2003; Kelepertzis, 2014). Over time, long-term exposure to high levels of toxic elements—beyond safe limits—can cause harmful effects on human health (Beckers and Rinklebe, 2017; Bolan *et al.*, 2014; Rinklebe *et al.*, 2019). Recent studies have emphasized the importance of geochemical characterization of soils for understanding elemental distribution, contamination levels, and their implications for sustainable land management (Moreno *et al.,* 2026; Wu *et al.,* 2026). Soil geochemistry plays a critical role in identifying both natural and anthropogenic influences on elemental concentrations and helps in establishing baseline values for environmental assessment (Berdie *et al.,* 2026). Health issues such as skin diseases, asthma, cancer, and reproductive problems are commonly reported in the highland regions and may be linked to the heavy use of these agrochemicals (Misra, 2011). Recent research in the southern Western Ghats has highlighted the importance of soil geochemistry in assessing both environmental quality and human health risks. Studies from the Kabini Basin have demonstrated heavy metalloid enrichment and its potential health implications in agricultural soils (Gupta *et al.*, 2025; Gupta *et al.,* 2023). Investigations in the Idukki agroforestry-dominated HRML regions further emphasize how land-use practices influence soil geochemistry and associated health status (Krishnakumar *et al.*, 2024). Complementary work in the Periyar Basin has established baseline reference geochemical values for tropical soils, providing a framework for evaluating contaminant accumulation in the Western Ghats (Krishnakumar *et al.,* 2023). Together, these studies underscore the geochemical variability across river basins and the

(Received : 16 September 2025 ; Revised Form Accepted : 21 April 2026)
https://doi.org/10.56153/g19088-025-0283-105