Assessment of Groundwater Quality with Special Emphasis on Fluoride Contamination: A Case Study in Thar Desert, Pakistan

Haider A. Khwaja[1]*, Thoin Begum[1], Akhtar Shareef [2], Tahir Rafique[2]
[1]Department of Environmental Health Sciences, College of Integrated Health Sciences, University at Albany, Albany, New York, USA.
[2]Pakistan Council of Scientific and Industrial Research (PCSIR) Laboratories Complex, Karachi, Pakistan.
*E-mail: hkhwaja@albany.edu

ABSTRACT

Safe drinking water is inaccessible for about 1.1 billion people globally. This study scrutinizes the physicochemical characteristics, pollution sources, suitability for drinking and agricultural purposes, and associated health risks of groundwater in the Thar Desert of Pakistan. Groundwater collected from 15 villages was analyzed for physical and chemical contaminants. We found that a significant number of samples exceeded the World Health Organization's (WHO) guidelines for various contaminants: F^- in 9 wells, Cl^- in 12 villages, SO_4^{2-} in 10 villages, and NO_3^- in 11 wells. Factor analysis identified both geogenic and anthropogenic activities as significant contributors to the observed groundwater chemistry. Based on the water quality index, 87% of samples were unsuitable for drinking, and a non-carcinogenic risk assessment deemed groundwater from 80% of the sites unacceptable for adults and entirely unsuitable for infants. Our findings indicate a high risk of F^- and NO_3^- exposure for Thar Desert inhabitants.

Keywords: Fluoride and Nitrate, Groundwater Quality, Health Risk Assessment, Thar Desert, Water Quality Index.

INTRODUCTION

Access to safe drinking water remains a pressing global concern, affecting 1.1 billion people worldwide (Bain *et al*., 2012). Only a small portion of the Earth's water supply can be utilized as freshwater, and groundwater sources are particularly crucial for drinking water in many regions, including the Thar Desert in Pakistan. Anthropogenic activities, such as cattle farming and improper well lining, contribute to high nitrate (NO_3^-) concentrations in the study area. On the other hand, fluoride (F^-), calcium (Ca^{2+}), and potassium (K^+) concentrations in the Thar Desert are primarily geogenic in origin. Both F^- and NO_3^- contaminants disrupt the local ecosystem and pose risks to human health (Schullehner *et al*., 2018). Given the serious adverse health outcomes associated with excessive F^- and NO_3^- contaminants exposure, it is important to assess F^- and NO_3^- concentrations in the drinking water supply of Thar Desert communities. These findings underscore the urgent need for a comprehensive evaluation of groundwater quality and associated health risks in this region.

OBJECTIVE

The aim of this study is to assess the groundwater quality of villages in the Thar Desert. The suitability of groundwater for drinking and irrigation purposes will be evaluated using the Water Quality Index (WQI), Sodium Absorption Ratio (SAR), Percent Sodium (%Na), Magnesium Hazard (MH), Kelly's ratio (KR), and Potential Salinity (PS) (Yu *et al*., 2019). Additionally, a health risk assessment will be conducted to estimate the potential health risks associated with F^- and NO_3^- exposure using Hazard Quotients (HQ) (both oral and dermal), Total hazard index (THI), and Carcinogenic Risk (CR) (USEPA 2004, 2005).

METHODOLOGY

Fifteen groundwater samples were randomly collected from the shallow- and deep-dug wells. for analyses. Temperature, pH, conductivity (EC), total dissolved solids (TDS) and dissolved oxygen (DO) were measured at the sampling site. Standard methods were used for the determination of the chemical characteristics of the water samples.

CONCLUSION/RESULT

- This study, examining F^- and NO_3^- contamination within the groundwater of the Thar Desert, has revealed alarming levels exceeding the WHO's permissible limit for safe consumption. Concentrations of F^- and NO_3^- ranged 0.24 - 29.9 mg/L (Figure **1**) and 2.73 -196 mg/L (Figure **2**), respectively, signifcantly surpassing the WHO threshold of 1.5 mg/L and 10 mg/L.
- High F^- concentrations in groundwater can be attributed to factors such as regional and local geological settings, hydrological conditions, and weathering and leaching of rocks and minerals. NO_3^- originates from decaying plant or animal material, agricultural fertilizers, and domestic sewage.
- According to WQI values, 87% of samples were deemed unsuitable for drinking, and hence, harmful for consumption.
- Results of HQ and THI demonstrated that infants are more susceptible to non-cancer risk related to F^- and NO_3^- toxicity in the Thar Desert region. Overall, F^- seems to contribute more to the non-cancer risk than NO_3^- toxicity in the study area.
- The CR posed by NO_3^- exceeded the safety limit in most of the villages, highlighting a greater risk of developing a carcinogenic disease among residents of the Thar desert region.
- The problem of F^- and NO_3^- contamination in the groundwater of the Thar desert region presents a signifcant public health challenge requiring urgent attention. Our study emphasizes the need for a comprehensive, multi-pronged approach that includes the implementation of efective remediation techniques, continuous monitoring of water quality, and extensive public education campaigns to raise awareness about the dangers of F^- and NO_3^- contamination.

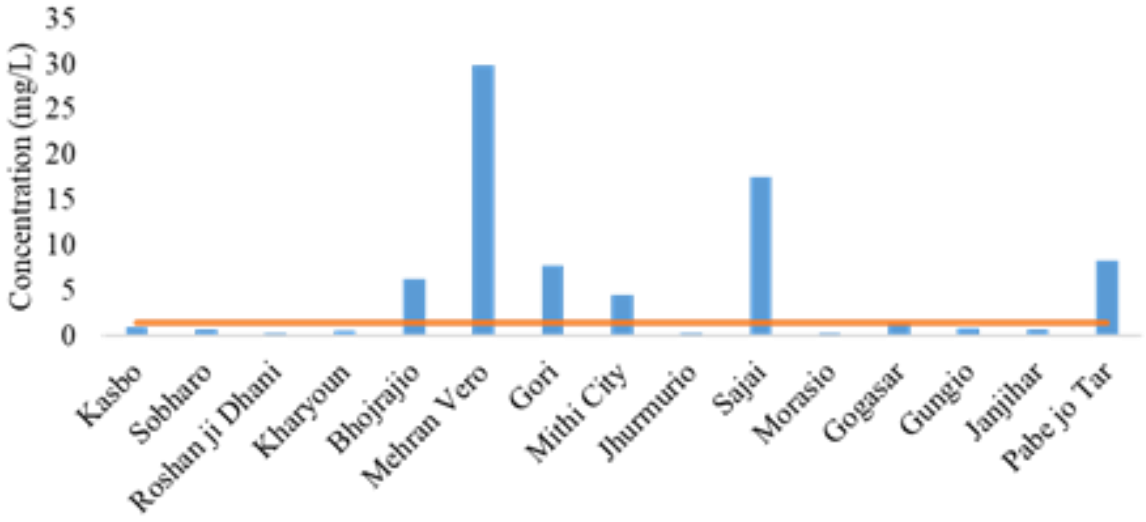

Figure 1. F- concentrations (mg/L) in groundwater of Thar desert, Pakistan. Solid line indicates the WHO standard of 1.5 mg/L of F-.

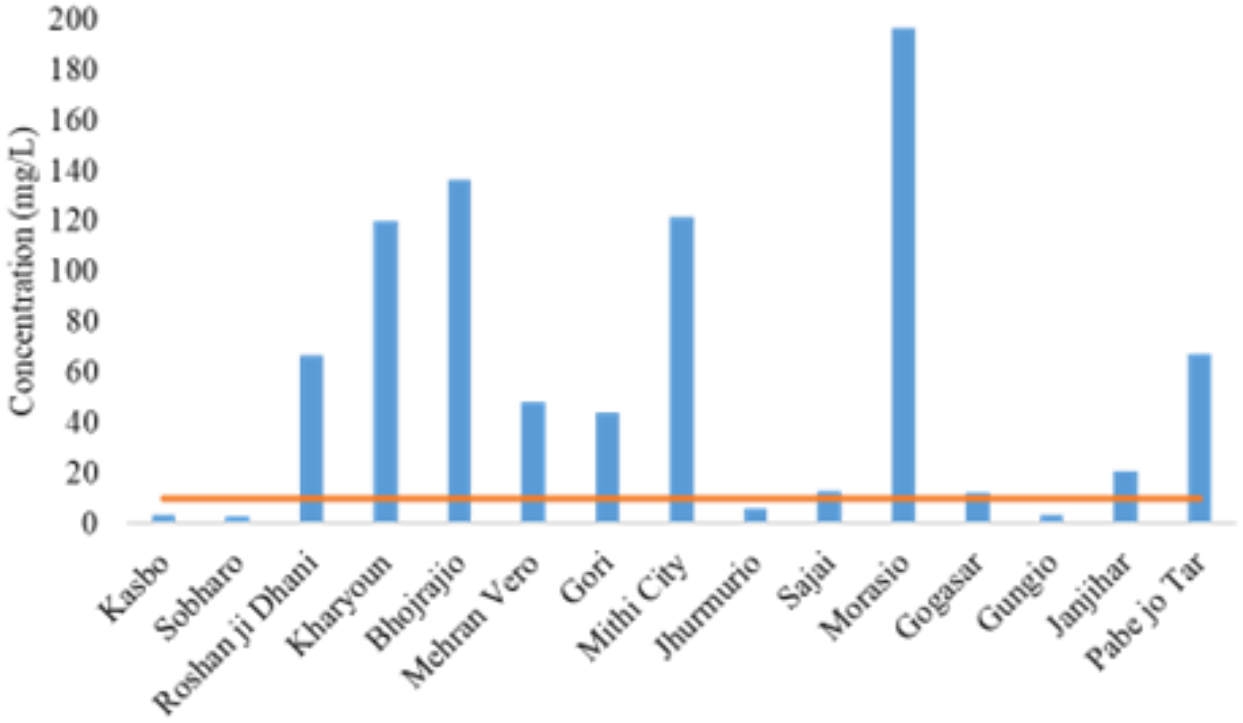

Figure 2. NO3- concentrations (mg/L) in groundwater of Thar desert, Pakistan. Solid line indicates the WHO standard of 10 mg/L of NO3--N/L.

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