Groundwater Fluoride Contamination and Dental Fluorosis in Rajasthan: A Geo-Medical Study

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Abstract: ***Rajasthan, one of India's most arid states, has been globally recognized for widespread groundwater fluoride contamination leading to severe health outcomes, particularly dental and skeletal fluorosis. The present study investigates the spatial distribution of fluoride concentration in groundwater across selected districts—Nagaur, Jodhpur, Ajmer, and Jaipur—and assesses the prevalence of dental fluorosis among local populations. The research employs a medical-geographical framework integrating field surveys, GIS-based spatial mapping, water sampling, clinical assessment, and secondary datasets from PHED, CGWB, and health reports. Results reveal that over 60% of sampled locations exceed the WHO permissible limit of 1.5 mg/L. The highest concentrations are recorded in Nagaur–Deedwana belt, followed by western Jodhpur, where dental fluorosis prevalence among children (10–18 years) ranges between 40–72%. Socio-economic factors, inadequate water purification, and dependence on deep aquifers intensify disease risk. The study concludes that targeted interventions such as Nalgonda technique units, rooftop rainwater harvesting, awareness programs, and fluoride-safe groundwater identification are crucial.***

Keywords: Fluoride Contamination; Dental Fluorosis; Medical Geography; Groundwater; Rajasthan; Spatial Distribution; Public Health; Arid Region; Water Quality.

1.1 Introduction

Groundwater quality is a critical determinant of public health, especially in arid and semi-arid regions such as Rajasthan, where surface water availability is extremely low. Fluoride (F^{-}) is an essential micro-element required in trace amounts; however, its elevated concentration in drinking water results in a significant health hazard. Rajasthan is recognized as a fluorosis hotspot in India, accounting for nearly one-sixth of the nation's fluoride-affected population (CGWB, 2015). Geological formations dominated by granites, gneisses, and fluorspar deposits release fluoride through natural leaching processes, aggravated by overexploitation of groundwater.

Dental fluorosis, the earliest visible sign of fluoride toxicity, manifests as discoloration, pitting, and mottling of teeth. In advanced stages, fluoride exposure causes skeletal fluorosis, leading to joint pain, restricted mobility, and deformities. While several studies have analyzed fluoride in isolated districts, there is limited comprehensive medical geographical documentation integrating spatial, environmental, and epidemiological perspectives.

This research aims to explore fluoride distribution patterns, identify high-risk zones, examine the prevalence of dental fluorosis, and propose spatially appropriate mitigation strategies.

1.2 Objectives

1. To analyze the spatial distribution of fluoride concentration in groundwater across selected districts of Rajasthan.
2. To map fluorosis-affected zones using GIS and field-level data.
3. To assess dental fluorosis prevalence in rural and semi-urban populations.
4. To examine socio-environmental factors contributing to high fluoride levels.
5. To provide medical-geographical recommendations for fluoride mitigation and safe drinking water planning.

1.3 Methodology

I. Study Design

Descriptive and analytical research integrating environmental sampling, clinical assessment, and spatial mapping.

II. Data Collection

1. Groundwater sampling: 120 water samples collected from borewells, tube wells, and handpumps across Nagaur, Jodhpur, Ajmer, and Jaipur.
2. Fluoride testing: SPADNS spectrophotometric method.
3. Health data: Dental fluorosis assessment using Dean's Index.

III. Secondary data:

1. PHED Rajasthan water quality reports (2008–2017)
2. CGWB (Central Ground Water Board) reports
3. National Rural Drinking Water Programme datasets
4. Census 2011 demographic data

IV. Survey and Interviews

1. 480 households surveyed across villages

2. Semi-structured interviews with health workers, school teachers, and villagers

1.4 Study Area

Rajasthan, the largest state of India situated in the north-western part of the Indian union is largely and arid state for most of its part. The Tropic of Cancer passes through south of Banswara town. Presenting an irregular rhomboid shape, the state has a maximum length of 869 km. from west to east and 826 km. from north to south. The western boundary of the state is part of the Indo-Pak international boundary, running to an extent of 1,070 km. It touches four main districts of the region, namely, Barmer, Jaisalmer, Bikaner and Ganganagar. The state is girdled by Punjab and Haryana states in the north, Uttar Pradesh in the east, Madhya Pradesh in south east and Gujarat in the south west.

Rajasthan which consisted of 19 princely states, the centrally administered province of Ajmer-Merwara, and 3 principalities in the times of the British rule, was formerly known as Rajputana-the land of Rajputs, whose chivalry and heroism has been celebrated in the legendary tales from times immemorial. The. formation of Rajasthan state in its present form started in 1948 when the states Reorganization Commission reconstited the various provinces.

It was on 18th March 1948, that the feudal states of Alwar, Bharatpur, Dhaulpur and Karauli were merged to form the "Matsya Union", the confederation having its capital at Alwar. Only about a week later, on 25th March 1948, other ten states viz. Banswara, Bundi, Dungarpur, Kishangarh, Kushalgarh, Kota, Jhalawar, Pratapgarh, Shahpura and Tonk formed another union of states called "Eastern Rajasthan" with its separate capital at Kota. On the April 18th 1948, Udaipur state also joined this federation which was renamed as Union of Rajasthan. About a year later, on March 30th 1949, the other major states of Rajputana viz. Bikaner, Jaipur, Jodhpur and Jaisalmer also joined the federation. The Matsya Union was also merged with the larger federation and the combined political complex, under the name of Greater Rajasthan, came into existence with Jaipur as the capital. On January 26th 1950, Sirohi state too joined this federation which was thereafter named as Rajasthan. The centrally administefred area of Ajmer Merwara was merged with Rajasthan on November 1 th 1956, when the recommendations of the State Reorganization Commission were accepted, and the new state of India came into existence.

The rich wealth of non-renewable resources is yet to be explored and exploited. Their judicious exploitation can make the state economically self-sufficient. At the same time, renewable resources like solar power, wind and water can also be harnessed effectively to serve man's needs.

1.5 Observations

1. Groundwater Fluoride Levels (mg/L)

District	Minimum	Maximum	Mean
Nagaur	1.2	6.8	3.9
Jodhpur	0.9	5.1	2.7
Ajmer	0.8	4.3	2.1
Jaipur	0.5	3.2	1.6

1. WHO permissible limit = 1.5 mg/L
2. 60% of samples exceed safe limit
3. Nagaur worst affected (Deedwana, Jayal, Makrana belts)

II. Dental Fluorosis Prevalence (Dean's Index)

1. Nagaur: 72% (moderate to severe)
2. Jodhpur rural: 55%
3. Ajmer: 43%
4. Jaipur rural: 28%

III. Socio-environmental Findings

1. High dependence on deep borewells (>200 ft)
2. Low adoption of RO units
3. Cattle and livestock show visible fluorosis
4. Lack of awareness in remote villages
5. Women and children show higher susceptibility

1.6 Discussion

The findings highlight a direct correlation between geological formations and fluoride levels. High floride belts overlap with:

1. Granitic and gneissic terrain
2. High groundwater extraction points
3. Low rainfall zones (<300 mm)
4. Dental fluorosis prevalence strongly aligns with contaminated water sources rather than dietary factors. Villages using RO-treated or PHED piped water show substantially lower prevalence, confirming water as the primary vector.
5. Socio-economic vulnerability enhances disease risk. Poor households lack adequate water purification systems. Cultural habits—such as early morning well water consumption—also increase exposure.

Gendered exposure patterns show higher fluorosis among women due to longer household water-use involvement.

1.7 Results

I. Strong spatial clustering

1. Hotspot mapping confirms concentrated fluoride belts in:
2. Nagaur–Deedwana–Jayal
3. Western Jodhpur
4. Parts of Ajmer (Kekri, Srinagar)

II. High disease association

1. Areas with >3 mg/L fluoride show >50% dental fluorosis prevalence.

III. Environmental determinants significant

1. Lower rainfall and high evaporation increase fluoride concentration

2. Agriculture borewell intensification deepens aquifer extraction

1.8 Conclusion

Rajasthan's fluoride crisis is a serious medical-geographical problem. The study confirms that groundwater in major parts of Nagaur, Jodhpur, Ajmer, and Jaipur exceeds the safe limit, directly contributing to high dental fluorosis prevalence. Geological conditions, groundwater overexploitation, and socio-economic vulnerability intensify health impacts. Spatial mapping indicates identifiable high-risk zones where interventions must be prioritized.

Public health response must integrate geospatial planning, safe water infrastructure, and community education.

1.9 Recommendations

1. Install decentralized defluoridation units (Nalgonda technique) at village level.
2. Promote rooftop rainwater harvesting in fluoride hotspots.
3. Regular PHED groundwater monitoring and public display of fluoride levels at water points.
4. NGO-led awareness drives on fluorosis symptoms and safe water practices.
5. Shift to shallow aquifer sources where fluoride is naturally lower.
6. Mobile dental screening camps for early diagnosis in schools.
7. GIS-based fluoride atlas for district-level planning.
8. Promote alternative drinking water sources such as RO community plants.

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