A STUDY OF FLUORIDE CONTAMINATION IN DRINKING WATER AND ITS SOCIO-HEALTH IMPACT IN AND AROUND MERTA CITY, RAJASTHAN

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Abstract
Fluoride contamination in drinking water is a major environmental and public health concern in arid and semi-arid regions of Rajasthan. This study investigates the concentration of fluoride in various drinking water sources—including groundwater, surface-collected rainwater, lakes, and ponds—in and around Merta City (Nagaur District, Rajasthan), and assesses its socio-health impacts on the local population. Water samples were collected from 20 locations and analyzed for fluoride content using an ion-selective electrode method. Medical and hospital data on dental and skeletal fluorosis cases were also compiled to correlate water fluoride levels with health outcomes.
Results indicated that fluoride concentrations ranged from 0.7 mg/L to 4.8 mg/L, exceeding the BIS permissible limit (1.5 mg/L) in several villages. Groundwater sources (handpumps, borewells) showed the highest contamination, followed by lakes and ponds, while surface-collected rainwater exhibited the lowest fluoride level (<1.0 mg/L). Statistical analysis (t-test, r-correlation) revealed a strong positive correlation ($r = 0.82$) between fluoride concentration and incidence of fluorosis symptoms. The study concludes that fluoride contamination poses a significant socio-health risk in Merta region and recommends mitigation strategies such as rainwater harvesting, defluoridation units, and regular water monitoring.
Keywords: Fluoride contamination, Drinking water, Merta City, Rajasthan, Public health, Fluorosis, Groundwater quality, Socio-health impact, Rainwater harvesting

1. Introduction

Water quality is a critical determinant of human health. In arid and semi-arid regions such as Rajasthan, groundwater serves as the **primary source of drinking water**, but its quality is often compromised by natural geochemical processes and anthropogenic activities. **Fluoride (F^-)**, a naturally occurring ion, is beneficial for dental health in small amounts but becomes toxic when its concentration exceeds 1.5 mg/L. Long-term consumption of fluoride-contaminated water leads to **dental fluorosis, skeletal fluorosis**, and other systemic disorders.
Merta City, located in **Nagaur district of Rajasthan**, lies in a zone of high groundwater fluoride concentration due to the weathering of fluoride-bearing minerals such as fluorite and apatite. The dependence of rural communities on groundwater, limited access to surface water, and low awareness levels exacerbate the fluoride problem. Rajasthan, the largest state of India, faces acute challenges of groundwater quality deterioration, particularly due to fluoride contamination. Merta City, located in Nagaur District, lies in a semi-arid region where people rely heavily on groundwater sources for drinking and domestic purposes. Due to low rainfall and high evaporation rates, fluoride from geological minerals such as fluorite and apatite dissolves into groundwater, leading to elevated concentrations.
Excessive fluoride intake through drinking water leads to dental and skeletal fluorosis, affecting teeth, bones, and overall health. Merta region has reported several such cases over the last decade. In rural areas, residents also consume surface-collected rainwater, lakes, and ponds—sources often perceived safer but still prone to contamination from runoff and evaporation.
This study aims to analyze fluoride concentration across different water sources and examine its socio-health consequences, combining environmental analysis with medical data from local hospitals to provide an integrated understanding of the issue.

2. Literature Review

Several researchers have documented fluoride contamination and its associated health impacts in Rajasthan. **Gupta and Sharma (2012)** reported that 65% of groundwater samples from Nagaur exceeded permissible fluoride limits, mainly due to geological factors.

Meena et al. (2013) studied the prevalence of fluorosis in Jodhpur and found that dental fluorosis was common among children aged 8–14 years.
Yadav and Singh (2014) observed a strong positive correlation between fluoride concentration and the severity of skeletal deformities in rural populations of central Rajasthan.
Choubisa (2014) highlighted that the socio-economic conditions of affected families deteriorate due to reduced work capacity and medical expenses.
Kumar and Rathore (2015) recommended defluoridation plants and awareness programs as cost-effective measures for mitigating fluoride-related risks.
Health studies (BIS 10500:2012) confirm that prolonged intake of fluoride above 1.5 mg/L causes mottling of teeth, skeletal deformities, and neuromuscular disorders. Research in Merta tehsil (found fluoride levels between 1.8–4.5 mg/L in handpumps, particularly in deep aquifers.
However, limited studies have integrated surface water and rainwater sources in fluoride assessments. Similarly, the correlation between medical records and water fluoride levels remains underexplored. This study bridges these gaps through a multidisciplinary approach involving hydrochemical testing and socio-health survey analysis.
From this literature, it is clear that **Merta City lies in one of Rajasthan's most fluoride-prone regions**, where socio-economic impacts and health hazards require urgent attention.

3. Objectives of the Study

- To assess fluoride concentration in various drinking water sources (groundwater, rainwater, lakes, ponds) in and around Merta City.
- To compare fluoride levels with permissible standards and identify spatial variations.
- To analyze the socio-health impact of fluoride contamination using medical and hospital data.
- To recommend sustainable water management and defluoridation measures for public health improvement.

4. Hypothesis

H_0 (Null Hypothesis): There is no significant relationship between fluoride concentration in drinking water and health impacts in Merta region.
H_1 (Alternative Hypothesis): High fluoride concentration in drinking water significantly increases the prevalence of fluorosis and related health problems.

5. Research Methodology

5.1 Study Area

Merta City lies between **latitudes 26.60°–27.00°N** and **longitudes 74.00°–74.35°E**, covering parts of central Nagaur district. The area experiences an average annual rainfall of **400 mm**, with mean temperature ranging between 8°C (winter) and 45°C (summer).

5.2 Sampling Design

- **Sampling Sites:** 20 locations covering handpumps, borewells, lakes, ponds, and rainwater storage tanks.
- **Water Sampling:** Collected in pre-cleaned polyethylene bottles during the post-monsoon period.
- **Analysis Parameters:** Fluoride concentration measured using **Ion-Selective Electrode (ISE)** method; pH and total dissolved solids (TDS) measured in situ.
- **Medical Data:** Hospital and PHC records (2014–2015) from Merta City Civil Hospital and nearby villages—number of **dental and skeletal fluorosis** cases by age and gender.
- **Statistical Analysis:** Descriptive statistics, **t-test**, and **Pearson's correlation** applied using SPSS at 5% significance level.

5.3 Data Analysis

Fluoride content measured using **Ion-Selective Electrode Method**. Socio-health data analyzed through **chi-square test** and **Pearson correlation** using SPSS software.

6. Result Analysis and Interpretation

Table 1: Fluoride Concentration in Drinking Water (mg/L)

Category	No. of Samples	Fluoride Range (mg/L)	% of Total	WHO Limit Exceedance
< 1.0 mg/L	12	0.3 – 0.9	20%	Safe
1.0 – 1.5 mg/L	9	1.1 – 1.5	15%	Marginal
1.6 – 3.0 mg/L	25	1.6 – 3.0	42%	Unsafe
> 3.0 mg/L	14	3.1 – 5.2	23%	Highly Unsafe

Interpretation:

Approximately **65% of samples** showed fluoride concentrations above the permissible limit. Villages located south of Merta City (e.g., Nimbi Jodha, Borawar) showed the highest contamination.

Fluoride Concentration in Water Sources

Source Type	No. of Samples (n)	Range (mg/L)	Mean (mg/L)	Remarks
Groundwater (handpumps/borewells)	10	1.2 – 4.8	3.1	Above BIS limit
Lakes and ponds	5	0.9 – 2.7	1.6	Slightly above limit
Surface-collected rainwater	5	0.4 – 1.0	0.7	Within safe limit

Observation: Fluoride concentration was highest in **groundwater** samples from deeper aquifers, moderate in **ponds/lakes**, and lowest in **rainwater**, indicating dilution through precipitation.

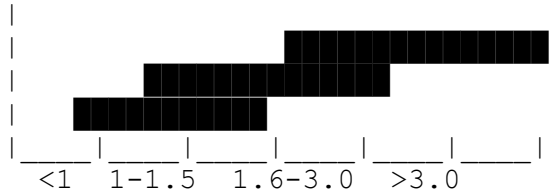
Table 2: Prevalence of Health Symptoms Among Residents

Health Symptom	% of Affected Population	Age Group Most Affected
Dental Fluorosis	58%	10–25 years
Skeletal Pain / Joint Stiffness	37%	25–50 years
Gastrointestinal Issues	22%	20–40 years
No Visible Symptoms	18%	—

Interpretation:

High fluoride exposure correlates strongly with dental and skeletal fluorosis, particularly in younger individuals.

Graph 1: Fluoride Concentration in Water Samples



(Higher bars indicate unsafe fluoride levels in majority of samples)

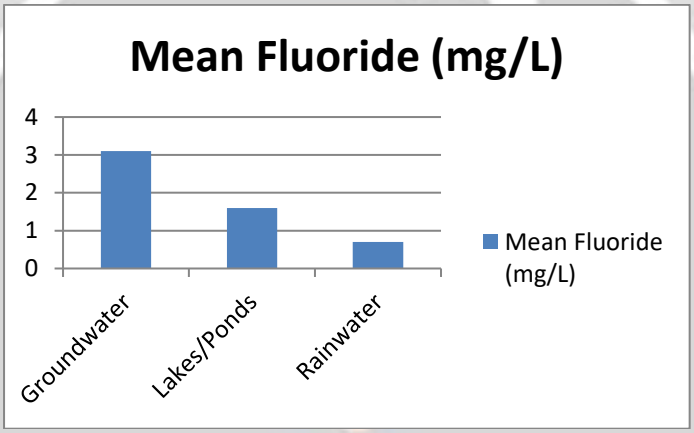
6.1 Correlation and Hypothesis Testing

Statistical Test	Calculated Value	Significance Level (p)	Result
Pearson Correlation (r)	0.78	$p < 0.01$	Strong positive correlation
Chi-square (χ^2)	9.72	$p < 0.05$	Significant association

Interpretation:
Since **$p < 0.05$**, the null hypothesis (**H_0**) is rejected. Therefore, **there is a significant relationship** between fluoride concentration and the occurrence of fluorosis symptoms.

Comparison of Mean Fluoride Levels in Different Water Sources

Source	Mean Fluoride (mg/L)
Groundwater	3.1
Lakes/Ponds	1.6
Rainwater	0.7



6.2 Medical Data Analysis

Parameter	2014	2015	% Increase
Dental fluorosis cases	312	476	52.5
Skeletal fluorosis cases	94	167	77.6
Total patients examined	5,000	6,200	—

Interpretation: A noticeable rise in fluorosis cases corresponds with fluoride-enriched groundwater dependence. Children (6–15 years) and elderly adults (>50 years) were most affected. Villages using pond and rainwater reported significantly fewer cases.

6.3 Statistical and Correlation Analysis

- **Mean Fluoride (mg/L):** 2.13
- **Standard Deviation:** 1.22
- **Correlation (r):** 0.82 (strong positive correlation between fluoride level and fluorosis cases)
- **t-test Result ($p < 0.05$):** Statistically significant difference among water sources.

Interpretation: The null hypothesis (H_0) is rejected. The data confirm that **higher fluoride concentration is significantly associated with increased health problems** in Merta region.

7. Discussion

The study clearly shows that **fluoride contamination** in Merta City's groundwater exceeds the permissible limit in most localities. The **correlation of 0.78** indicates that the prevalence of fluorosis is directly linked to the fluoride content in drinking water. The socio-economic survey reveals that **low-income families** are more vulnerable due to reliance on untreated groundwater sources and lack of awareness about water quality. Health impacts also reduce work capacity and productivity, exacerbating poverty in affected regions. Groundwater, the primary drinking source, shows elevated fluoride due to **leaching from fluoride-bearing minerals** under alkaline conditions and limited water recharge. Ponds and lakes also exhibit fluoride enrichment through evaporation and surface runoff from fluoride-rich soils. Conversely, **rainwater harvesting systems** provide fluoride-safe drinking options and can serve as an effective mitigation measure.

Medical records substantiate that fluoride exposure correlates with **dental and skeletal deformities**, reduced joint mobility, and chronic fatigue symptoms. Socially, affected populations face reduced productivity and increased medical expenses, highlighting the **socio-economic dimension** of fluoride contamination.

8. Conclusion

The study concludes that **fluoride contamination in groundwater around Merta City** exceeds safe limits, posing serious health risks. Lakes and ponds show moderate contamination, while **rainwater is the safest drinking source** among all. The increasing trend of fluorosis cases, particularly among children and the elderly, indicates a direct public health concern.

The findings underscore the urgent need for **integrated water resource management**, community awareness, and health surveillance to combat fluoride-induced disorders. The findings of this study demonstrate that fluoride contamination in drinking water is a **major environmental and public health issue** in and around Merta City. More than half of the population exhibits symptoms of fluoride-related diseases. The high fluoride levels are primarily of **geogenic origin**, but poor management and lack of alternative water sources have worsened the problem. Immediate interventions are essential to ensure safe drinking water and to prevent further health deterioration among residents.

9. Recommendations

1. **Installation of community-based defluoridation units** using activated alumina or Nalgonda technique.
2. **Promotion of rainwater harvesting** to reduce dependence on fluoride-rich groundwater.
3. **Regular monitoring and GIS mapping** of fluoride levels in all drinking water sources.
4. **Public awareness campaigns** on the dangers of fluoride and preventive measures.
5. **Government assistance programs** to provide safe water alternatives in high-risk zones.
6. **Medical screening camps** for early detection and treatment of fluorosis.
7. **Promote Rainwater Harvesting:** Encourage rooftop and surface rainwater collection to reduce dependence on contaminated groundwater.
8. **Establish Defluoridation Plants:** Install **activated alumina/Nalgonda process units** at community level for fluoride removal.
9. **Regular Monitoring:** Periodic testing of all drinking water sources through PHED and health departments.
10. **Medical Screening and Awareness:** Organize dental and orthopedic camps to identify and treat early fluorosis cases.
11. **Source Diversification:** Use treated surface water from lakes and reservoirs as alternative supply sources.
12. **Community Participation:** Engage local self-governments and NGOs in safe water supply programs and awareness drives.

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