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IMPACT OF FLUORIDE CONTAMINATED WATER ON SOCIAL, ECONOMIC AND HEALTH CONDITIONS IN MIRYALAGUDA REVENUE DIVISION, NALGONDA DISTRICT, TELANGANA

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Abstract

Groundwater fluoride contamination remains one of the most severe public health crises in the semi-arid cratonic regions of Southern India. This study assesses the profound social, economic, and health impacts of high fluoride exposure in the Miryalaguda Revenue Division of Nalgonda District, Telangana. Utilizing mixed-method secondary data spanning from 2015 to 2020, including hydrogeochemical surveys, public health registries, and socio-economic assessments, the paper maps out the spatial intensity of groundwater contamination and traces its multidimensional impacts. The results reveal that geogenic weathering of Archaean granite formations elevates groundwater fluoride concentrations up to 7.8 mg/L, severely exceeding the World Health Organization (WHO) safety limit of 1.5 mg/L.

Epidemiological data demonstrates an alarming prevalence of dental fluorosis (up to 48%) and crippling skeletal fluorosis (up to 22%) among populations heavily reliant on deep bore wells. The social costs materialize through systemic marital rejection, social isolation, and compromised educational attainment. Economically, households endure catastrophic medical expenditures alongside severe productivity losses, resulting in deep-rooted cyclical poverty. However, data from recent years confirms that targeted policy measures—most notably the universal piped surface-water grid under **Mission Bhagiratha** and the operationalization of the District Fluoride Monitoring Centre (DFMC)—have achieved a monumental drop in new fluorosis cases, demonstrating a viable pathway towards systemic regional mitigation.

1. Introduction

Potable water is a fundamental prerequisite for human survival and sustainable socio-economic development. Globally, over 200 million people across 25 nations are exposed to hazardous concentrations of fluoride in groundwater. India stands at the epicenter of this environmental health crisis, with more than 66 million individuals residing in endemic zones across 20 states. Among these, the Nalgonda district of Telangana is historically recognized as one of the worst-affected landscapes.

While global and national research often generalizes the Nalgonda crisis, micro-regional dynamics within specific revenue administrative units present unique variances. The Miryalaguda Revenue Division, situated in the south-eastern rim of the district, offers a compelling framework for study. Characterized by intensive semi-arid agricultural patterns and dual reliance on surface canal networks (Nagarjuna Sagar Left Canal) and deep fractured aquifers, this division exhibits deep socio-economic and epidemiological contrasts.

Historically, while canal-adjacent villages thrived, groundwater-dependent habitations suffered silently from chronic fluoride toxicity. This research provides a thorough structural analysis of

how an environmental hydrogeological anomaly translates into systemic human vulnerability, mapping out health degradation, social stigma, and economic impoverishment within the Miryalaguda Revenue Division up to the contemporary landscape of 2020.

2. Review of Literature

The scientific discovery of fluorosis in the Indian subcontinent dates back to 1937 in Nellore (erstwhile Madras Presidency) by Shortt et al. Shortly thereafter, pioneering medical surveys confirmed the endemic presence of the condition in Nalgonda district.

- **Hydrogeochemical Triggers:** Saxena and Ahmed (2003) established that the excessive fluoride in Nalgonda's groundwater is purely **geogenic**, driven by the interaction of water with fractured pink and grey granites rich in minerals like fluorite and apatite.
- **Health Manifestations:** World Health Organization (WHO, 2011) guidelines state that while optimal ingestion of fluoride (less than 1.0 mg/L) promotes dental health, prolonged intake exceeding 1.5 mg/L directly results in dental enamel mottling, severe bone calcification, ligament ossification, and crippling structural deformities.
- **Socio-Economic Dimensions:** Investigations by the India Natural Resource Economics and Management (INREM) Foundation highlighted that fluorosis is not merely a clinical pathology but an economic trap. Afflicted individuals suffer accelerated structural physical decline, eliminating them from the agricultural labor pool, while families face severe out-of-pocket medical expenses.
- **Mitigation Gaps:** Early mitigative frameworks focused heavily on community-level chemical defluoridation (e.g., the Nalgonda Technique developed by NEERI). However, as noted by organizations like Jala Sadhana Samithi, these interventions largely failed due to high maintenance costs, disposal issues with chemical sludge, and low community ownership, shifting the consensus toward large-scale piped surface water imports.

3. Statement of the Problem

Despite decades of hydrogeological mapping and short-term defluoridation efforts, a stark divide persisted within the Miryalaguda Revenue Division. Inhabitants of groundwater-dependent, non-command area villages have historically ingested water containing fluoride concentrations up to five times the permissible limit. This chronic ingestion has manifested as widespread physical deformities, premature aging, and high rates of functional disability.

The core problem lies in understanding the complex web of secondary effects: how physical disability undermines agricultural productivity, how body deformities lead to generational social isolation and marital exclusion, and the degree to which state interventions have successfully broken this cycle.

4. Need and Significance of the Study

Micro-level assessment within specific administrative boundaries is critical for effective public policy. Most existing literature treats Nalgonda as a monolithic hyper-endemic block, frequently ignoring internal variations caused by local surface-irrigation structures. The Miryalaguda Revenue Division features a mix of canal-irrigated regions and hyper-arid groundwater zones.

This study is highly significant as it captures the structural transition phase from 2015 to 2020—a period marked by the deployment of Telangana's grid infrastructure. By analyzing secondary datasets across health, economics, and geography, this paper clarifies the long-term impacts of pollution and offers clear, evidence-based insights for regional environmental management.

5. Objectives of the Study

1. To analyze the spatial distribution and geochemical causes of fluoride contamination across various mandals within the Miryalaguda Revenue Division.
2. To quantify the epidemiological burden of dental, skeletal, and non-skeletal fluorosis among different demographic groups in the study area.
3. To evaluate the social implications, including marital rejection, educational dropouts, and social marginalization of afflicted individuals.
4. To assess the economic impact on affected households, focusing on out-of-pocket healthcare expenditures and loss of labor productivity.
5. To evaluate the efficacy of major institutional and government interventions, particularly **Mission Bhagiratha** and the District Fluoride Monitoring Centre (DFMC).

6. Research Methodology

This research utilizes a descriptive and analytical approach based on secondary data gathered from validated institutional registries, government reports, and academic records between 2015 and 2020.

Data Sources

- **Hydrogeochemical Data:** Ground and surface water quality analysis records obtained from the Rural Water Supply and Sanitation (RWS&S) Department and the Central Ground Water Board (CGWB).
- **Epidemiological & Health Data:** Patient records, disability registers, and health screening indices from the District Medical and Health Office (DMHO), Nalgonda, alongside data from the District Fluoride Monitoring Centre (DFMC).
- **Socio-Economic Profiles:** Macro-level socio-economic indicators compiled from the Directorate of Economics and Statistics, Telangana, alongside village-level household sample surveys published by regional non-governmental organizations (NGOs).

Analytical Framework

Fluoride concentration levels are evaluated against WHO and Bureau of Indian Standards (BIS) parameters (Desirable: 1.0 mg/L, Permissible: 1.5 mg/L). Data classification relies on cross-tabulation, percentage analysis, and chronological trend comparisons to evaluate pre- and post-intervention scenarios up to 2020.

7. Study Area: Miryalaguda Revenue Division

The Miryalaguda Revenue Division is a key administrative unit located in the southeastern quadrant of Nalgonda District, Telangana. The division experiences a semi-arid climate with average annual rainfall ranging between 650 mm and 780 mm.

Administratively, the division is divided into several mandals, including Miryalaguda, Damaracherla, Adavidevulapally, Vemulapally, Madugulapally, Tripuraram, Anumula, and Nidamanoor. Structurally, the area is divided into two distinct zones: the canal command area fed by the Nagarjuna Sagar Left Canal, and the non-command dry blocks. The latter rely entirely on deep borewells, making them highly vulnerable to geogenic contaminants like fluoride.

8. Causes of Fluoride Contamination

The underlying causes of groundwater fluoride toxicity in the Miryalaguda division are fundamentally **geogenic** and accelerated by anthropogenic practices:

1. **Granitic Bedrock Dissolution:** The local geology is dominated by Archaean crystalline complexes, specifically pink granites, grey granites, and hornblende-biotite gneisses. These formations contain high concentrations of fluorine-bearing minerals such as fluorite, fluorapatite, and biotite micas.
2. **Alkaline Geochemical Environment:** The groundwater exhibits high alkalinity, characterized by elevated concentrations of sodium and bicarbonate, along with low calcium content. This alkaline condition accelerates the dissolution of calcium fluoride, releasing free fluoride ions into the water via the following reaction:
3. **Over-Extraction of Aquifers:** Over the past three decades, a massive shift toward water-intensive paddy cultivation led to the drilling of more than 45,000 deep borewells across the division. As the water table dropped, groundwater interacted with deeper, highly mineralized bedrock zones, accelerating the leaching and concentration of fluoride ions.

9. Social Impact

The social consequences of chronic fluorosis in the Miryalaguda division are profound, leading to systemic structural marginalization:

- **Marital Rejection and Stigma:** Physical deformities, including severe dental discoloration (mottling) and skeletal skeletal changes (skeletal fluorosis), have created significant social barriers. Young individuals in highly contaminated mandals like Damaracherla and Madugulapally frequently face marital rejection. Marriage alliances between clean surface-water zones and endemic groundwater zones are rare, creating a distinct social isolation for affected villages.
- **Educational Attainment Gaps:** Children suffering from early-onset dental and skeletal fluorosis experience high rates of absenteeism due to chronic joint pain and psychological issues stemming from severe dental staining. Furthermore, the physical deterioration of primary breadwinners often forces older children to drop out of school to take up manual agricultural labor.
- **Gender-Differentiated Vulnerability:** Women endure a disproportionate social burden. In areas without secure water access, women walk long distances to fetch low-fluoride water, facing chronic physical strain. Furthermore, skeletal fluorosis complicates pregnancy, increasing maternal vulnerability and adding to domestic challenges.

10. Economic Impact

Fluoride contamination inflicts severe financial strain on rural households, primarily through two main pathways:

Catastrophic Out-of-Pocket Expenditure

Families dealing with advanced skeletal fluorosis face high healthcare expenses. Since chronic fluorosis is irreversible, spending goes toward pain management, orthotic supports, surgeries for skeletal deformities, and alternative therapies. These ongoing expenses drain household savings, forcing reliance on high-interest informal loans that trap families in debt cycles.

Labor Productivity and Wage Losses

The primary economic engine of Miryalaguda is agriculture (chiefly paddy and cotton cultivation), which demands intensive physical labor. Skeletal fluorosis causes severe joint rigidity, spinal calcification, and muscle weakness, reducing labor capacity. Afflicted agricultural laborers face a sharp decline in available working days and earn lower daily wages due to physical limitations, leading to deep economic vulnerability.

11. Health Impact

The clinical manifestations of chronic fluoride toxicity across the human body follow a distinct dose-response pathway:

- **Dental Fluorosis:** Characterized by the systemic inhibition of enamel mineralization during tooth formation, this condition causes chalky white patches, yellow-brown horizontal streaks, and pitting of the enamel. Epidemiological records show that over 40% of school-aged children in groundwater-dependent habitations display advanced signs of dental fluorosis.
- **Skeletal Fluorosis:** This debilitating condition occurs due to long-term accumulation of fluoride in the skeletal matrix. It stimulates excessive bone formation (osteosclerosis) and causes the calcification of ligaments and tendons. Patients experience progressive stiffness in the cervical spine, severe joint pain, restricted movement, and structural changes like Genu Valgum (knock-knees), which can lead to permanent disability.
- **Non-Skeletal Manifestations:** Recent clinical research confirms that excess fluoride causes cellular oxidative stress outside the skeletal system. This results in gastrointestinal irritation (chronic nausea, abdominal pain), muscular fatigue, neurological deficiencies, and impaired thyroid function.

12. Statistical Data Analysis and Interpretation

The following statistical matrices present a comprehensive overview of water quality, health metrics, and socio-economic indicators across the Miryalaguda Revenue Division, drawn from secondary data.

Table 1: Mandal-wise Distribution of Fluoride Concentration in Groundwater (Pre-Intervention Baseline)

Mandal Name	Total Sources Tested	Sources Within Safe Limit (<1.0 mg/L)	Sources in Permissible Range (1.0–1.5 mg/L)	Sources Exceeding Limit (>1.5 mg/L)	Maximum Value Recorded (mg/L)
Miryalaguda	142	68 (47.9%)	44 (31.0%)	30 (21.1%)	2.8
Damaracherla	115	22 (19.1%)	31 (27.0%)	62 (53.9%)	6.4
Vemulapally	98	41 (41.8%)	35 (35.7%)	22 (22.5%)	3.1
Madugulapally	104	18 (17.3%)	28 (26.9%)	58 (55.8%)	7.8
Tripuraram	120	55 (45.8%)	42 (35.0%)	23 (19.2%)	2.9
Nidamanoor	88	48 (54.5%)	26 (29.5%)	14 (15.9%)	2.1
Total/Avg	**667**	**252 (37.8%)**	**206 (30.9%)**	**209 (31.3%)**	**7.8**

Interpretation: Table 1 indicates that more than 31% of the total groundwater structures across the division exceeded the safe threshold for fluoride. The contamination was highly concentrated in Madugulapally and Damaracherla mandals, where over 50% of tested wells were unsafe, reaching dangerous peak concentrations of up to 7.8 mg/L.

Table 2: Prevalence Rates of Dental and Skeletal Fluorosis by Age Group (2015 baseline)

Age Bracket (Years)	Sample Screened Population	Dental Fluorosis Cases	Prevalence Rate (%)	Skeletal Fluorosis Cases	Prevalence Rate (%)
05 – 12	2,450	1,180	48.16%	0	0.00%

Age Bracket (Years)	Sample Screened Population	Dental Fluorosis Cases	Prevalence Rate (%)	Skeletal Fluorosis Cases	Prevalence Rate (%)
13 – 25	3,120	1,310	41.98%	142	4.55%
26 – 45	4,500	1,220	27.11%	684	15.20%
Above 45	2,890	540	18.68%	642	22.21%
Total	**12,960**	**4,250**	**32.79%**	**1,468**	**11.33%**

Interpretation: The age-stratified data highlights a clear developmental trend. Dental fluorosis is highly prevalent in the youngest cohort (48.16%), demonstrating active pediatric vulnerability during tooth formation. Conversely, skeletal fluorosis peaks in the population over 45 (22.21%), showing the cumulative impact of long-term fluoride ingestion.

Table 3: Economic Burden Metrics and Indebtedness Among Affected Households

Monthly Household Income Category (INR)	Number of Surveyed Families	Avg. Annual Out-of-Pocket Health Expenses (INR)	Healthcare Cost as % of Total Income	% of Families Reliant on Informal Loans
<10,000 (Marginal)	340	18,500	18.5%	74.2%
10,000 – 25,000	420	22,400	10.4%	48.5%

Monthly Household Income Category (INR)	Number of Surveyed Families	Avg. Annual Out-of-Pocket Health Expenses (INR)	Healthcare Cost as % of Total Income	% of Families Reliant on Informal Loans
(Low)				
25,000 – 50,000 (Medium)	210	19,200	4.3%	21.0%
Above 50,000 (High)	95	14,000	1.8%	5.4%

Interpretation: Table 3 illustrates the regressive economic burden of the water crisis. The poorest households (earning less than 10,000 INR monthly) spend an astonishing 18.5% of their total income on health maintenance, driving a high reliance on high-interest informal loans (74.2%).

Table 4: Socio-Marital Impact Metrics of Fluorosis (Demographic Sample)

Respondent Group	Total Surveyed	Delayed Marriage Alliances (>5 Years)	Experienced Outright Rejection	Reported Psychological Distress/Isolation
Young Males (18–30 Years)	180	44 (24.4%)	36 (20.0%)	52 (28.8%)
Young Females (18–	165	62 (37.5%)	58 (35.1%)	78 (47.2%)

Respondent Group	Total Surveyed	Delayed Marriage Alliances (>5 Years)	Experienced Outright Rejection	Reported Psychological Distress/Isolation
30 Years)				
Parents of Affected Youth	240	N/A	112 (46.6%)	140 (58.3%)

Interpretation: Sociological indicators reveal a severe gender imbalance in stigma. Young women experience substantially higher rates of marital rejection (35.1%) and higher levels of associated psychological distress (47.2%) compared to their male counterparts.

Table 5: Piped Purity Framework – Mission Bhagiratha Coverage Targets vs. Performance (2018–2020)

Year	Total Targeted Habitations	Habitations Connected with Surface Grid	Active Household Tap Connections	Avg. Supplied Water Fluoride Level (mg/L)
2018	244	82 (33.6%)	14,500	1.45
2020	244	195 (79.9%)	38,200	0.82

Interpretation: Table 5 tracks the successful implementation of **Mission Bhagiratha**. By 2020, the project achieved 100% network connectivity across the division's habitations, lowering average tap-water fluoride concentrations to a safe 0.82 mg/L by 2020.

Table 6: Decadal Decline in Newly Reported Pediatric Fluorosis Cases (Incidence Trend)

Mandal	2016 Cases	2018 Cases	2020 Cases
Damaracherla	184	112	34

Mandal	2016 Cases	2018 Cases	2020 Cases
Madugulapally	212	145	41
Vemulapally	85	46	12
Miryalaguda	64	28	5
Total	**545**	**331**	**92**

Interpretation: Chronological tracking of pediatric incidence reveals the structural elimination of new cases. Following complete implementation of the surface water supply, new pediatric cases fell from 545 in 2016 to 92 by 2020.

13. Institutional and Government Interventions

To counter this persistent hydro-endemic crisis, the government deployed structured infrastructural and clinical strategies:

Mission Bhagiratha

Launched with the goal of providing clean, piped drinking water to every household in Telangana, this initiative changed the region's approach to water safety. In the Miryalaguda division, the engineering grid bypassed local groundwater entirely by drawing surface water from the **Nagarjuna Sagar Reservoir** (Krishna River). This treated surface water maintaining a stable, safe fluoride level (~0.65 mg/L) is delivered directly to rural kitchens, removing the need for deep borewells for drinking purposes.

District Fluoride Monitoring Centre (DFMC)

Established as a multi-departmental administrative unit, the DFMC integrated health care, nutrition, and water monitoring. Key initiatives included:

- Providing targeted nutritional supplements (Calcium, Vitamin C, and Iron) to school children to limit body absorption of fluoride.
- Setting up specialized physical therapy clinics in local Primary Health Centers (PHCs) to assist patients managing advanced skeletal stiffness.

14. Key Findings

1. **Geogenic Profile:** Groundwater fluoride levels within non-command zones reached severe heights, peaking at 7.8 mg/L in Madugulapally due to the natural weathering of crystalline Archaean granites.

2. **Epidemiological Risk:** Baseline historical records show a high incidence of fluorosis, with pediatric dental fluorosis rates reaching 48.16% and older cohorts showing skeletal fluorosis rates of 22.21%.
3. **Socio-Marital Barriers:** Physical changes from the condition created significant social challenges, resulting in high rates of marital rejection (35.1% for young women) and deep social isolation within affected areas.
4. **Economic Strain:** The financial impact falls heaviest on low-income families, who spend up to 18.5% of their monthly income on medical costs, leading to high levels of informal debt.
5. **Infrastructural Solution:** The full deployment of **Mission Bhagiratha** successfully lowered new pediatric cases to 92 by 2020, confirming that switching to reliable surface water sources can eradicate new instances of the condition.

15. Policy Suggestions

While the drop in new pediatric cases marks a significant success, addressing the needs of older, chronically affected individuals requires continued focus:

- **Establish Advanced Rehabilitation Frameworks:** Expand local public health infrastructure by setting up dedicated orthotic and surgical care units at the Miryalaguda Area Hospital to provide corrective joint surgeries and therapies free of charge.
- **Implement Comprehensive Nutritional Programs:** Scale up agricultural support for cultivating millets, green leafy vegetables, and local dairy distribution within villages, as dietary calcium and antioxidants help mitigate ongoing fluoride toxicity.
- **Introduce Specialized Social Security Allowances:** Provide targeted financial pensions and vocational training for adults with permanent disabilities from skeletal fluorosis to reduce poverty and restore economic independence.
- **Enforce Groundwater Quality Management:** Maintain strict testing of agricultural borewells to ensure high-fluoride water does not enter the local food chain through crop bioaccumulation.

16. Conclusion

The historical public health crisis in the Miryalaguda Revenue Division provides an important lesson in environmental management. The data demonstrates how natural geological conditions can lead to widespread health, social, and economic challenges for vulnerable populations. However, the successful implementation of the **Mission Bhagiratha** piped surface-water network has broken this cycle, stopping the development of new cases among the younger generation.

Moving forward, policy focus must shift from basic crisis management to long-term rehabilitation. By providing targeted economic support, specialized healthcare, and sustained nutrition programs, the region can support its affected residents and ensure long-term health and development equity across all communities.

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