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GIS based fluoride contamination mapping of groundwater and its exposure risks to the hilly populace of the Chenab River Basin in Jammu province, North India

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Outline of the Presentation

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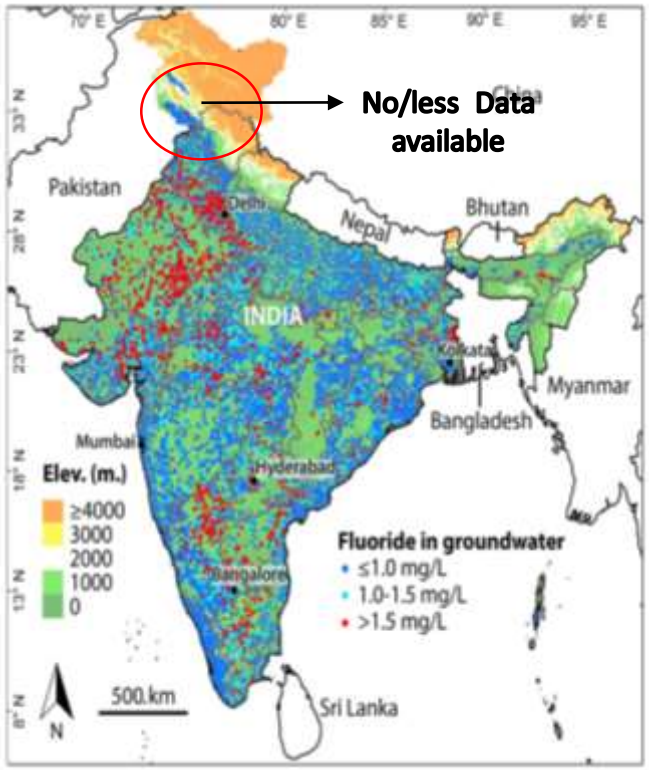
1. • Introduction: Need for the study
2. • Objectives and Study area
3. • Methodology adopted as per objectives
4. • Key Findings & Suggestions

Need for the study...

- More than 200 million people worldwide drink groundwater with fluoride concentrations > the WHO guideline value of 1.5 mg/L.
- In India, fluorosis problem has reached alarming proportions affecting at least 19 states (Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Gujarat, and Rajasthan where 50–100% districts are affected).
- 230 districts in India are endemic for dental and skeletal fluorosis and Doda district in UT of J&K is one of them.
- In J&K <30% districts are affected with fluorosis.
- Endemic fluorosis in India due to high levels of fluoride in drinking water sources and water supplies.



Source: Podgorski *et al.*(2018). Prediction Modeling and Mapping of Groundwater Fluoride Contamination throughout India **Environ. Sci. Technol., 52: 9889−9898.**

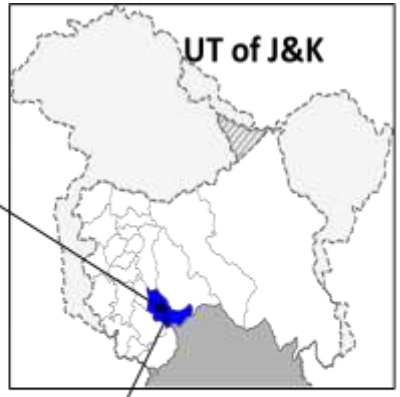
Objectives

Objective 1: To investigate the groundwater fluoride contamination level in the Chenab River Basin of Jammu Province of North India in order to identify the most vulnerable areas.

Objective 2: To prepare maps of the contamination zones using GIS.

Objective 3: To assess the health risks associated with fluoride contamination among the local populace and to establish its relationship with spatiotemporal distribution of fluoride in groundwater.

Doda District Profile (Jammu and Kashmir, INDIA)



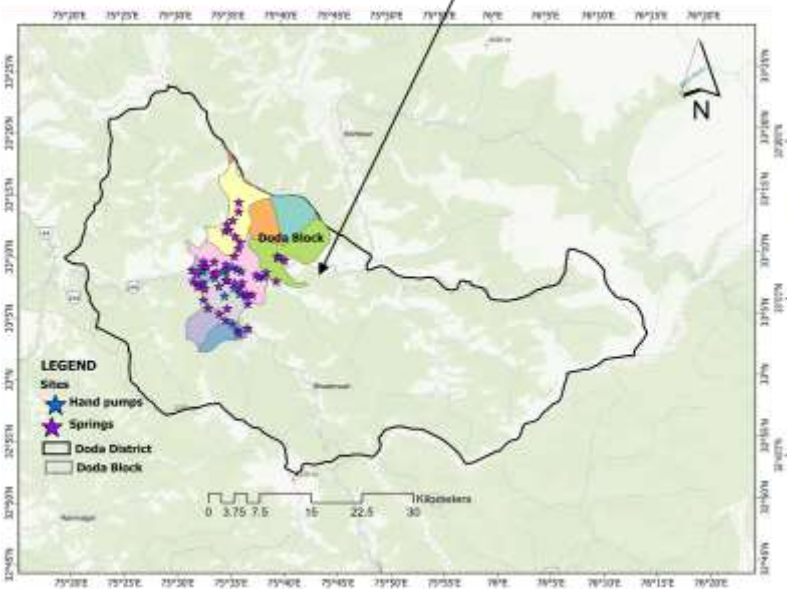
District Doda (32^0 53' and 34^0 21'N; 75^0 14' and 76^0 47' E)

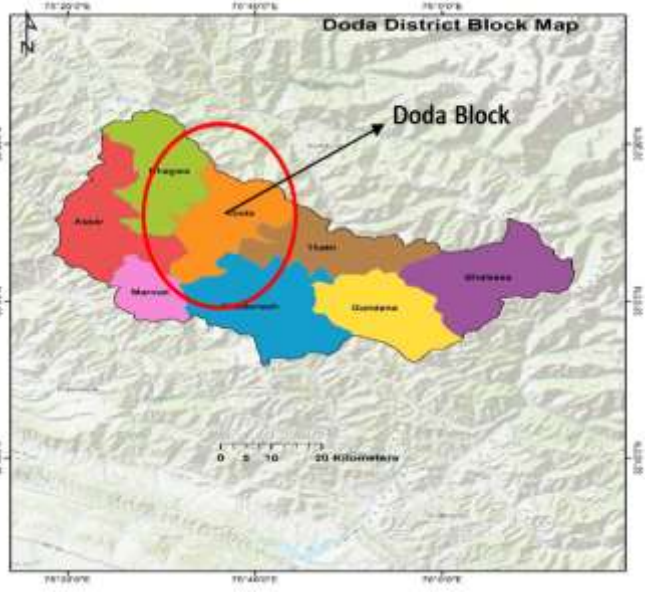
Area: 8912 Sq Km

Total Population: 409,936 (Male 213,641; Female 196,295)

Number of villages: 406(4 un-inhabited)

Elevation variation: 800 to 4400m above msl.





Methodology

Objective 1.

Sample collection

- Tested 66 drinking water samples from springs and hand pumps for water quality studies.

Sample Analysis

- Water quality analysis done during two seasons viz. pre-monsoon and post-monsoon.
- Physical parameters(pH, EC, TDS) determined in field using Horiba Water analyzer kit.
- Turbidity using Digital Turbidity meter(model331 E)
- Chemical parameters analyzed in the temporary lab using standard methods(APHA, 2005)
- Fluoride contamination recorded using Thermo-Orion pH/Ion Meter.





Descriptive statistics(N=66) and comparison with national and international standards for drinking water

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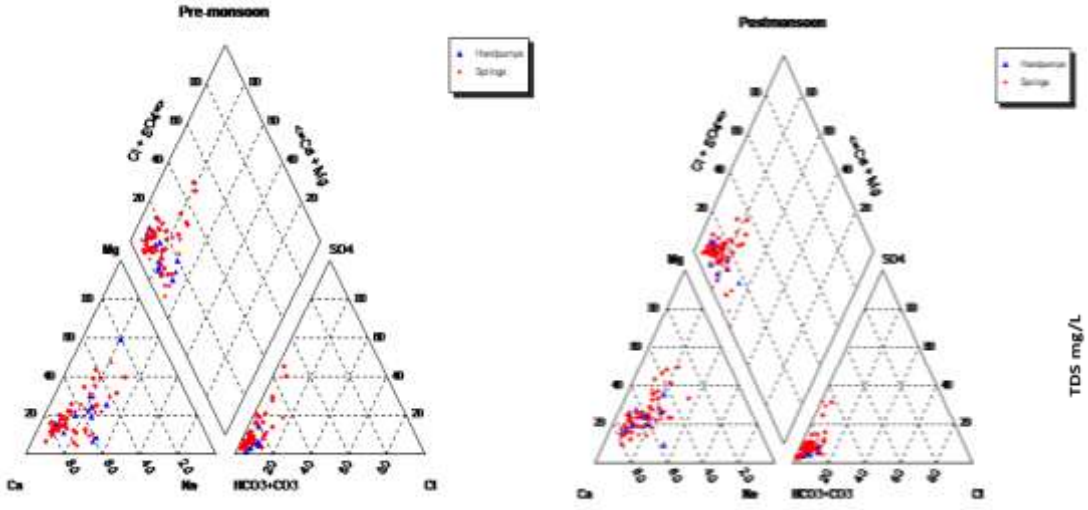
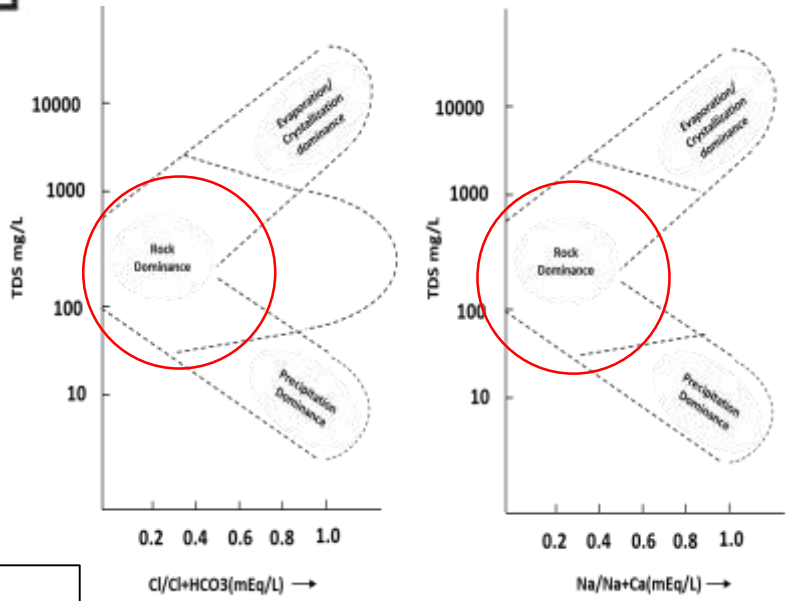
									WHO (2008)		BIS(2012)	
Parameter	Seasons	Mean	Median	Std. error	Variance	Coeff. var	Min	Max	Desirable	Permissible	Desirable	Permissible
pH	Pre-monsoon	7.34	7.34	0.08	0.40	8.57	5.94	8.80	6.5-8.5	NR	6.5-8.5	NR
	Post-monsoon	7.33	7.37	0.08	0.46	9.30	5.68	8.97				
EC(uS/cm)	Pre-monsoon	465.29	438.00	23.42	36187.25	40.88	100.00	1040	1500	-	-	3000
	Post-monsoon	443.70	399.00	25.34	42382.37	46.40	70.00	1120				
Turb.(NTU)	Pre-monsoon	8.11	1.50	1.83	220.18	183.04	0.00	64	-	-	1	5
	Post-monsoon	8.91	1.20	2.07	283.06	188.89	0.00	77.10				
TDS(ppm)	Pre-monsoon	343.71	306.50	20.96	29000.02	49.55	0.00	960	600	1000	500	2000
	Post-monsoon	314.91	277.50	21.34	30069.78	55.07	106.00	990				
DO(mg/L)	Pre-monsoon	5.21	5.49	0.25	4.12	38.93	0.78	9.44	5**	-	-	-
	Post-monsoon	5.54	6.23	0.29	5.60	42.68	0.00	10.74				
TA(mg/L)	Pre-monsoon	492.37	453.84	35.69	84053.83	58.88	98.74	1224.70	300*	600*	200	600
	Post-monsoon	523.39	516.85	31.86	66988.51	49.45	66.70	1220				
Ca^{2+}(mg/L)	Pre-monsoon	73.46	74.85	4.31	1225.78	47.66	8.72	174.30	100	300	75	200
	Post-monsoon	66.73	61.24	4.28	1209.27	52.11	11.45	168.75				
Mg^{2+}(mg/L)	Pre-monsoon	14.30	11.39	1.38	125.96	78.47	1.58	57.05	30*	150*	30	100
	Post-monsoon	16.48	14.27	1.22	98.53	60.24	3.17	54.41				
TH(mg/L)	Pre-monsoon	242.29	234.55	13.37	11801.83	44.84	52.10	524	100	500	200	600
	Post-monsoon	234.38	217.50	13.73	12444.18	47.59	58.80	534.8				
Na^{+}(mg/L)	Pre-monsoon	17.60	15.15	1.28	107.56	58.92	6.50	60	50	200	-	-
	Post-monsoon	15.36	12.75	1.27	106.37	67.14	5.20	62				
Cl^{-}(mg/L)	Pre-monsoon	16.84	13.25	1.54	155.63	74.08	1.45	60.40	250	600	250	1000
	Post-monsoon	18.10	16.00	1.50	148.23	67.26	0.66	67.50				
F^{-}(mg/L)	Pre-monsoon	1.96	0.33	1.00	66.33	416.57	0.00	62.20	1	1.5	1	1.5
	Post-monsoon	2.02	0.37	1.03	70.32	414.53	0.11	64				
NO_3^{-}(mg/L)	Pre-monsoon	25.06	22.84	2.49	409.25	80.73	0.58	82.72	50	-	45	NR
	Post-monsoon	28.49	25.39	2.87	543.39	81.81	1.67	98.32				

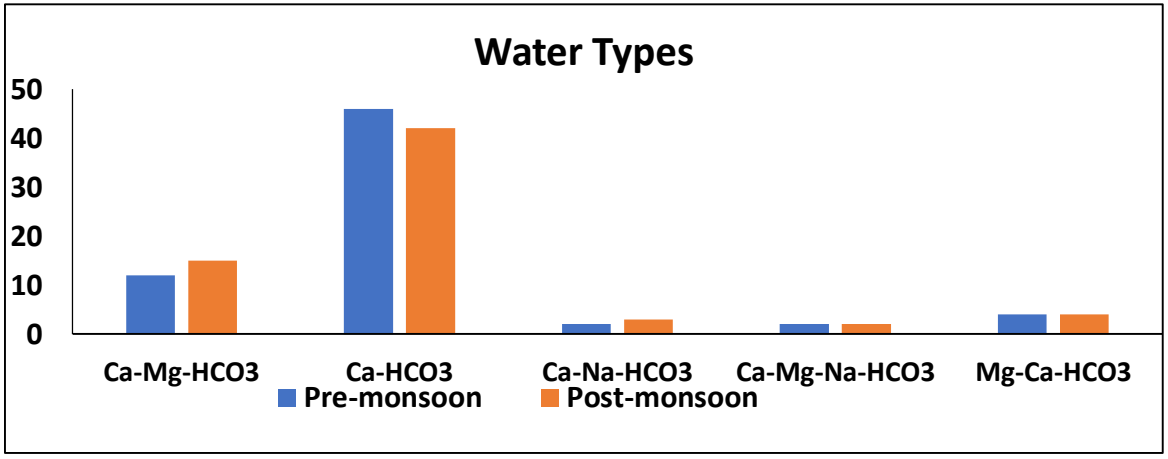
**World Health Organization(1997); **Bureau of Indian Standards (1991); NR No Relaxation*



Piper trilinear Diagram for ground water samples



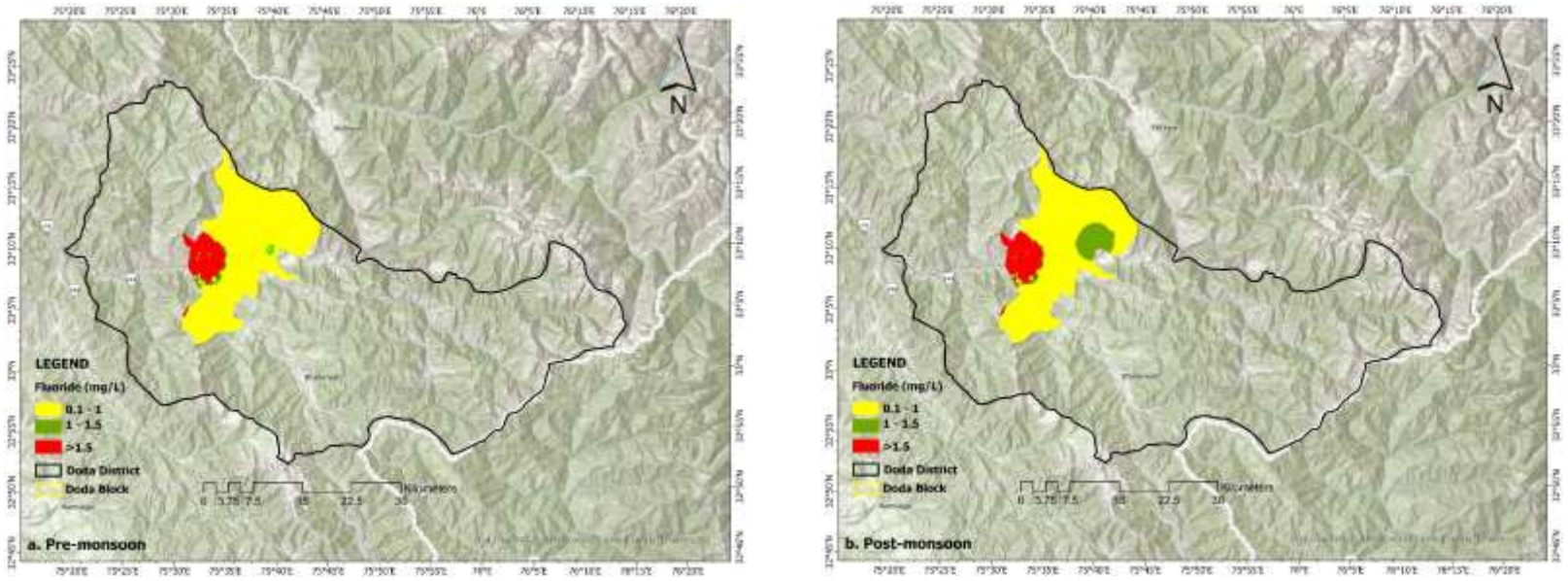
Mechanisms governing ground water chemistry (after Gibbs,1970)



Water types based on Piper diagrams

Objective 2. Arc-GIS 10.5.1 software has been used to obtain the spatial distribution of fluoride.

Inverse Distance Weighted (IDW) spatial analyst approach has been applied to delineate fluoride.



Fluoride distribution map of Doda block using IDW technique in ARCGIS 10.5.1 a. Pre-monsoon b. Post-monsoon

Fluoride conc.	Health Effects on humans
0.1 − 1ppm	Limited growth and fertility, dental caries
1 − 1.5ppm	Promotes dental health, prevents tooth decay
1.5 − 4ppm	Dental fluorosis (mottling of teeth)
4.0 − 10ppm	Dental fluorosis, skeletal fluorosis, bone fractures
> 10ppm	Crippling fluorosis , osteosarcoma & neurological effects

Objective 3. Prevalence and Severity of Dental Fluorosis

- 200 respondents called for visual evidence, only 125 agreed to get their teeth photographed.
- Respondents examined for the presence of dental fluorosis using Dean's classification system for dental fluorosis (1942).

Code	Pattern	Criteria(Dean's classification system, 1942).
0	**Normal**	The enamel is smooth, glossy, pale creamy-white translucent surface
1	**Questionable**	A few white flecks or white spots mainly on the edge of the incisors and cuspids
2	**Very Mild**	Small, opaque, paper-white areas covering less than 25% of the tooth surface
3	**Mild**	Opaque white areas covering less than 50%of the tooth surface
4	**Moderate**	All tooth surfaces are affected; marked wear on biting surfaces (attrition); brown stains may be present
5	**Severe**	All tooth surfaces are affected and have discrete or confluent pitting. Brown stains are present; teeth often show a corroded-like appearance

Calculations

- **Prevalence of Dental Fluorosis(DF)**

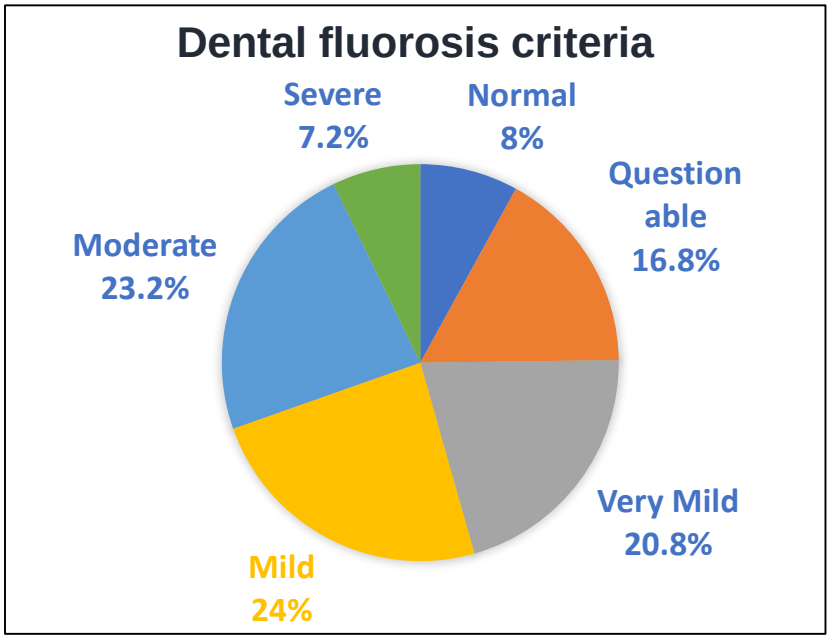
  Prevalence of DF= $\frac{No.of\ persons\ affected}{Total\ Number\ of\ respondents} \times 100$

- **Community Fluorosis Index (CFI)**

  CFI calculated by multiplying Questionable respondents with 0.5, very mild with 1, mild with 2, moderate with 3 and severe with 4.

  Products obtained for various categories are added up & sum divided by the total sample size.

  CFI= $\frac{\Sigma(\text{No.of respondents with Fluorosis} \times \text{Deans Numerical weight})}{\text{Total respondents studied}}$



Deans Criteria for fluorosis

(a.) Normal (b.) Questionable (c.) Very Mild (d.) Mild (e.-g.) Moderate (h.-i.) Severe

CFI	Public Health significance
1.76	Medium

Public health significance based on CFI

Risk Assessment of fluoride

Fluoride risk assessment was done by calculating the daily exposure to fluoride using Eq. 1

$$EDI = \frac{Cf \times Cd}{Bw} \quad \text{Eq. 1}$$

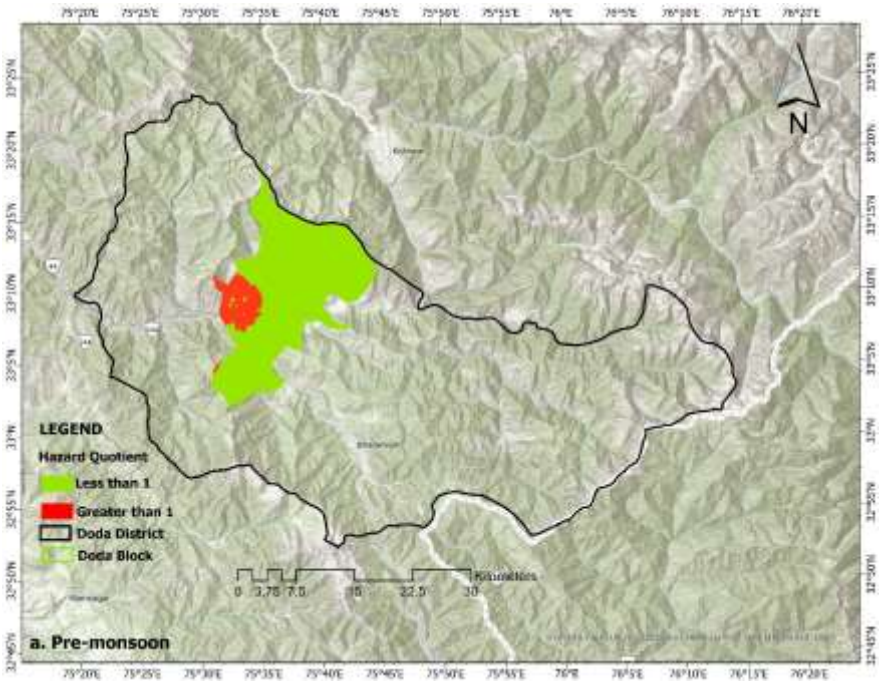
EDI: Estimation of daily fluoride consumption
C_f: Fluoride concentration in drinking water (mg/L)
C_d: Average daily drinking water intake
B_w: body weight (Kg)

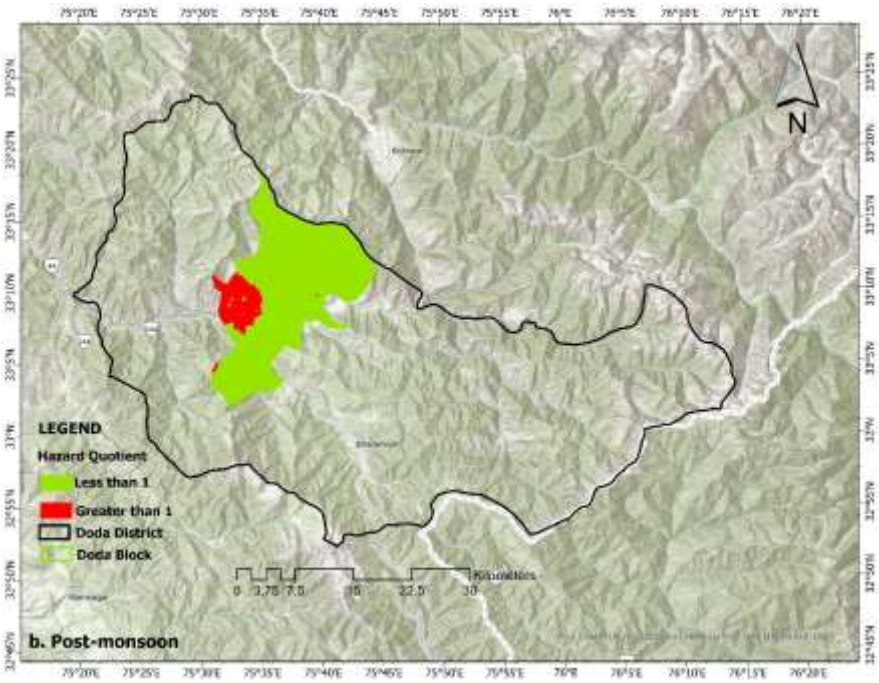
Hazard Quotient is the non-carcinogenic risk of fluoride to human health and was calculated using Eq. 2.

$$HQ = \frac{EDI}{RFD} \quad \text{Eq. 2}$$

EDI: Estimated Daily intake (mg/kg/day)
RFD: Reference dose of fluoride (mg/Kg/day)

Hazard Quotient based on ingestion pathway in rural populace of Doda block a. Pre-monsoon b. Post-monsoon





Hazard Quotient	Health Effects on humans
Less than 1	Negligible non-carcinogenic risk
Greater than 1	Significant non-carcinogenic risk

Key Findings & Suggestions

- Doda block in Chenab River Basin has been found to be endemic for fluoride contamination during both the pre-monsoon and post-monsoon seasons.
- Comparison of calculated parameters with drinking water quality standards have confirmed elevated concentrations of parameters like pH, turbidity, TDS, TA, DO, fluoride and nitrate at several sites.
- Piper trilinear diagram has shown variable hydrochemical facies. Gibbs diagram has confirmed fluoride contamination due to geogenic sources.
- Granite formations in the study area most likely to deliver fluoride to the groundwater.
- Doda block has high prevalence of Dental fluorosis and falls under medium health significance category based on CFI.
- There is a potential non-carcinogenic health risk for the people getting their drinking water from springs and handpumps in the studied area.
- Study suggests use of alternative surface water resources/dilution of spring waters and defluoridation of supply water in the contaminated areas.

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Thanks....