Fluoride Enriched Groundwater in Patan District, Gujarat, Western India: Inverse Modeling

NOAH STROM

NDSU GEOCHEMISTRY 2018

Study Area

- Patan District, Gujurat, Western India
- Climate: warm, arid to semi-arid
- Bank of the Saraswati River
- Mean Annual Rainfall: 765mm
- 95% of rainfall from monsoon season (June – September)
- Min. Temp: 5°C – 10°C , Max. Temp: 40°C – 48°C
- Elevation Gradient: 10m – 190m above mean annual sea level

Study Area

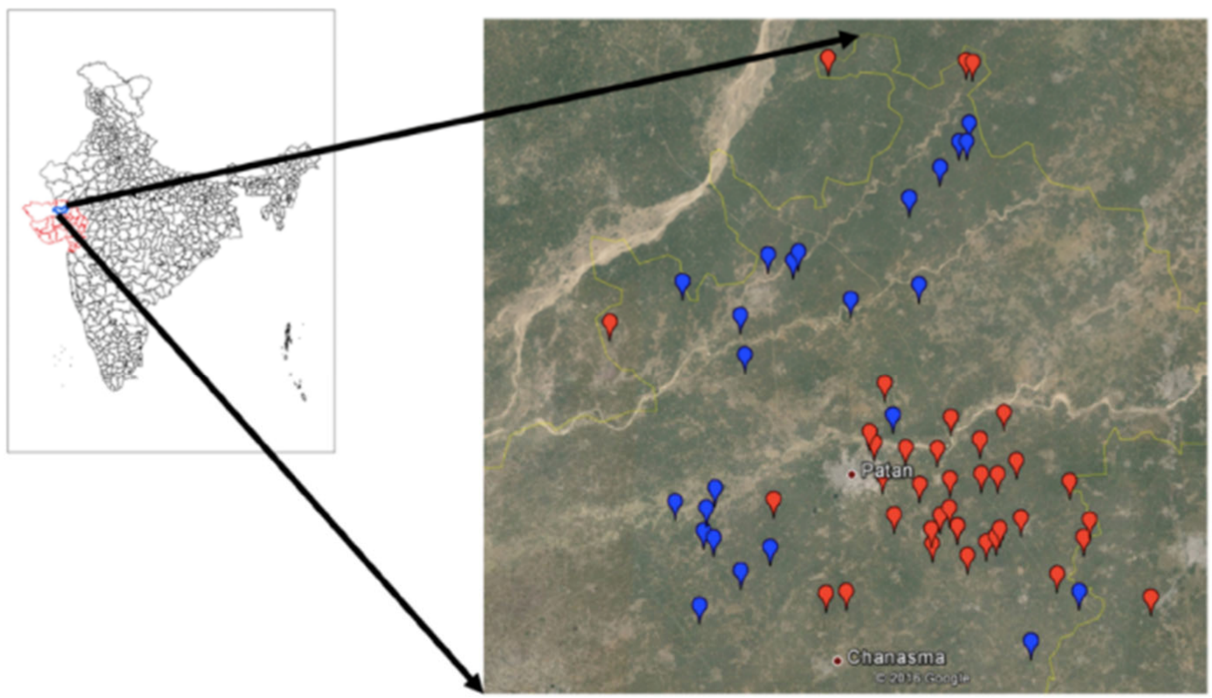
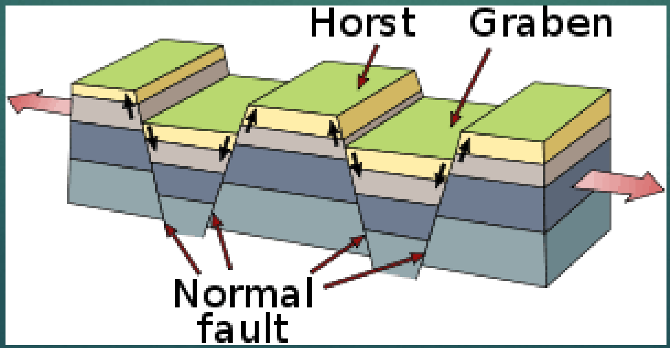


Fig. 1. Study area map showing (a) groundwater sampling location, and fluoride safe (blue) and unsafe water (red).

Geology

- Tertiary graben causing large scale alluvial deposition from large river systems
- Whole area covered in thick alluvium
- Granitic bedrock overlain by sandstone, conglomerate, and shale
- Highly weathered
- Dominated by pegmatites, amphibolites, quartz, feldspars, and clays



Background

- F^- is important for formation of bones and tooth enamel
- Healthy amount is 1.5 mg/L
- Low F^- = deficiency (<0.5 mg/L)
- High F^- = dental (1.5-2.0 mg/L) and skeletal fluorosis (>3.0 mg/L)
- F^- in groundwater: weathering and leaching of rocks
  - Fluorite, Fluorapatite, Cryolite, Amphibole, Muscovite, Biotite
- 62 samples taken
- F- concentration range: 0.4 - 4.8 mg/L; 2.9 mg/L average
- ~80% of samples were in low risk range but over the limit

Background

- SI values calculated using PHREEQC to determine processes responsible for F- enrichment
- Most water samples were oversaturated with calcite and under-saturated with fluorite

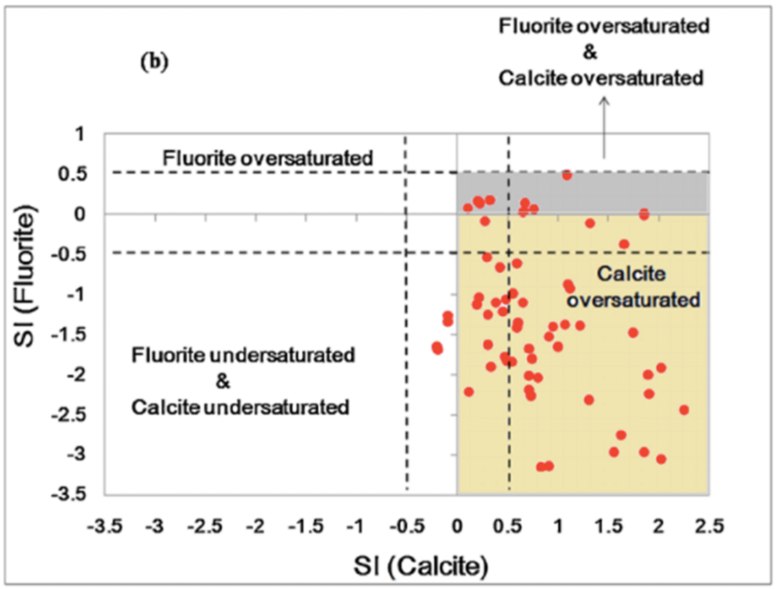


Fig. 4. Plot showing saturation indexes (a) minerals that relate to fluoride enrichment (b) SI (Fluorite) versus SI (Calcite) to elucidate the process responsible for fluoride enrichment.

Focus

- Semi – Arid Region
- According to Kumar et al, high rate of evaporation influences F^- concentrations in groundwater
- High rate of evaporation: high salt concentration
  - Enrichment of Cl^-
- High rate of evaporation: calcite precipitation
  - Ca^{2+} removed allowing more Fluorite (CaF_2) to dissolve

PHREEQC: Inverse Modeling

- Calculates change in chemical composition of water
- Sampled water is first solution
- Initial water is second solution
- Making solution 1 from solution 2 through precipitation of reactants
- These reactants include: calcite, carbon dioxide, gypsum, halite, water

```
#must use DATABASE pitzer.dat
TITLE Example 17.--Inverse modeling of India Groundwater
SOLUTION 1  India Groundwater
        units   mg/L
        pH      7.3     # estimated
        Ca      34.0
        Mg      42.0
        Na      133.16
        K       2.19
        Cl      72.0
        C       1       CO2(g) -4.20
SOLUTION 2  Composition during halite precipitation
        units   mg/L
        pH      5.0     # estimated
        Ca      0.0
        Mg      50500
        Na      55200
        K       15800
        Cl      187900
        C       1       CO2(g) -4.20
INVERSE_MODELING
        -solution 1 2
        -uncertainties 2.5
        -range
        -balances
                K
                Mg
```

Results

- Calcite precipitation is dependent on dissolved CO_2
- USGS paper on sources of contaminants in groundwater
- Median value was 52 mg/L of dissolved CO_2
- 52 ppm to 0.000052 out of 1; then take the log
- This value is plugged into PHREEQC for CO_2 contamination
- Inverse modeling: increased CO_2 until calcite precipitated
- Calcite started to precipitate when $pCO_2 = 10^{-4.2}$, increased to 63 mg/L

$$CaCO_3 + H_2CO_3 \leftrightarrow Ca^{2+} + 2HCO_3^-$$

$$CO_2 + H_20$$

Summary

- Evaporation enhances calcite precipitation using inverse modeling
- Allows more fluorite to dissolve
- Higher amounts of F^- in solution leads to negative health risks

- Inverse modeling in PHREEQC shows how evaporation leads to calcite precipitation
- Increasing the CO_2 is an influence what is precipitating

References

Kumar, P., Singh, C.K., Saraswat, C., Mishra, B., and Sharma, T., 2017, Evaluation of aqueous geochemistry of fluoride enriched groundwater: A case study of the Patan district, Gujarat, Western India: Water Science, v. 31, p. 215–229.

USGS Groundwater Contaminants Analysis

Questions?