

ESCALATION OF GROUNDWATER FLUORIDE IN THE GANGA ALLUVIAL PLAIN OF INDIA

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SUMMARY: Fluoride contamination of groundwater reserves occurs in many places globally. A critical area for such contamination in India is the Ganga alluvial plain comprising Saidabad Tahsil of Mathura district. Analyses conducted in April 2001, 2002, and 2004, indicate that the shallow aquifers which supply water to dugwells generally have higher concentrations of fluoride (F) than those of borewells supplied by deep aquifers. During these years the F concentration continuously escalated in both dugwells and borewells. In shallow and deep aquifers the F content ranges from 0.6 to 2.5 mg/L and from 0.1 to 1.5 mg/L, respectively. Over the three-year period the average F level increased by 0.1 to 0.6 mg/L. The most probable factors for variation and escalation of F concentrations between the two aquifers in the alluvial plain are discussed.

Keywords: Borewells; Dugwells; Fluoride content increase; Ganga alluvial plain, India; Groundwater fluoride; Hydraulic conductivity.

INTRODUCTION

In many places, especially in India, the quality of groundwater is generally superior to surface water since the soil column purifies the contaminants in water by anaerobic decomposition, filtration, ion exchange etc. Generally, in hard rock terrain, water quality variations and changes are common, especially for fluoride in shallow, intermediate, and deep aquifers. In alluvial plain groundwater, however, such variation and changes in fluoride levels are usually rare.

In the Ganga alluvial plain, fluoride (F) contamination has been reported by Indian state and central groundwater departments in a few districts like Unnao, Kanpur, and Agra. The Saidabad Tahsil area with its three blocks, i.e., Baldeo, Saidabad, and Shahpur, is situated in the easternmost part of Mathura district. Saidabad block was recognized as a critical (dark) block, and Baldeo and Shahpur blocks were marked as semi-critical (grey) blocks in 1998 by the state groundwater department.

The area of the present study is situated between 27° 27' N latitude and 78° 02' E longitude at 178 m above the sea level in the Ganga alluvial plain. It has a semi-arid to arid climate with an average monthly temperature varying between 38 and 46°C in summer and 25 and 32°C in winter. The average annual rainfall is between 600 and 650 mm. The study area is characterized by Vindhyan Group of rocks (sandstone, shale and limestone), which are overlaid by thick unconsolidated sediments of the Ganga alluvial plain. The groundwater is mostly saline and exhibits variation and escalation of F concentration in shallow and deep aquifers. Because of the uncertainty of these variations and changes in F levels of the two aquifers, the present study was undertaken to investigate factors that might be responsible for them and thereby evaluate the potential risk of fluorosis to people drinking and using these waters for irrigational purposes.

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MATERIALS AND METHODS

Because of the growing intensity of the F contamination in recent years, it was decided to carry out a comparative study and monitoring in the region. Sixty samples, 30 each from the shallow dugwells and nearby deeper borewells were collected in April 2001, 2002, and 2004 (Figure). The dugwells range in depth from 8 to 20 m and the borewells from 50 to 100 m.

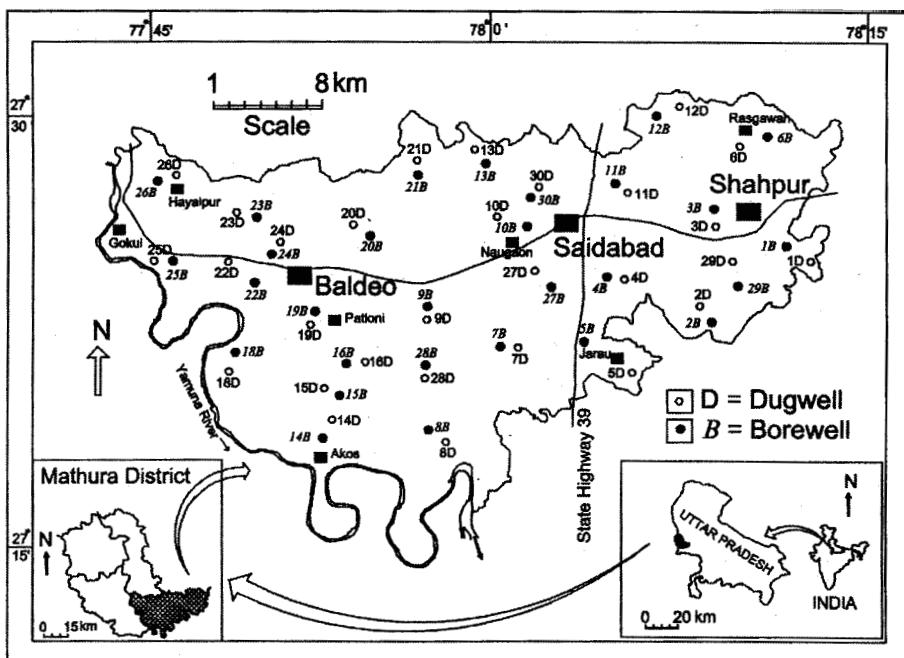


Figure. Locations of dugwells and borewells in the Saidabad Tahsil area 2001–2004.

Water samples were analyzed by using the SPADNS colorimetric method. A calibration standard ranging from 0 to 1.4 mg F⁻/L was prepared by diluting an appropriate volume of standard F⁻ solution. To 50 mL of standard solution, 10.0 mL the SPADNS reagent was added and mixed well. The spectrophotometer (Perkin Elmer model LAMBDA 40) was set at wavelength of 570 nm, and a calibration graph was prepared from different standard F⁻ concentrations. When the graph gave a straight line, the instrument was considered ready for measurement of F in the samples.

RESULTS AND DISCUSSION

The Table shows the F concentration in groundwater of dugwells and borewells determined in April 2001, 2002, and 2004. As the F levels in the table indicates, the groundwater of the shallow aquifers has a higher concentration of fluoride than the deep aquifers, which is continuously escalating in both the aquifers. These variations and escalation of fluoride content between the two-aquifer waters of the Ganga alluvial plain are believed to result from the interplay of the following factors.

Nearly 75 percent of sodic soils in the Ganga alluvial plain occur as Entisols and Inceptisols. According to previous studies, the sodic soils of the Indo-Ganggetic

plain derive their sodicity from in-situ weathering of alkali aluminosilicates.^{1,2} It is also postulated that salt-rich geological formations have contributed to the alluvial deposits of the Ganga plain.^{3–5} In addition, the study area shows a frequent alteration of mud and clay layers in the subsurface lithology and which have very low hydrologic conductivity.⁶ All these factors together constitute a favorable condition for the maximum absorption of F[–] by the clay minerals in the soil. Moreover, the weathering of alkaline sedimentary rocks (especially shales), releases F into soil and groundwater.⁷

Table. Fluoride concentration in dugwell (D) and borewell (B) water samples of Saidabad Tahsil

| Dugwell sample No. | Dugwell water samples | | | Borewell water samples | | |
|--------------------|----------------------------------|------------|------------|------------------------|----------------------------------|------------|
| | Concentration of fluoride (mg/L) | | | Borewell sample No. | Concentration of fluoride (mg/L) | |
| | April 2001 | April 2002 | April 2004 | | April 2001 | April 2002 |
| 1D | 1.2 | 1.4 | 1.6 | 1B | 0.8 | 0.9 |
| 2D | 0.6 | 0.9 | 1.1 | 2B | 0.2 | 0.5 |
| 3D | 0.9 | 1.3 | 1.8 | 3B | 1.0 | 1.0 |
| 4D | 1.1 | 1.4 | 1.9 | 4B | 1.0 | 1.1 |
| 5D | 1.6 | 1.8 | 2.1 | 5B | 1.1 | 1.2 |
| 6D | 0.8 | 1.2 | 1.4 | 6B | 0.3 | 0.8 |
| 7D | 0.9 | 1.2 | 1.6 | 7B | 0.1 | 0.3 |
| 8D | 1.2 | 1.5 | 1.7 | 8B | 0.5 | 0.9 |
| 9D | 1.1 | 1.6 | 1.8 | 9B | 0.3 | 0.7 |
| 10D | 0.9 | 1.1 | 1.3 | 10B | 0.4 | 0.6 |
| 11D | 1.5 | 1.7 | 1.9 | 11B | 0.7 | 0.9 |
| 12D | 1.6 | 1.9 | 2.0 | 12B | 1.1 | 1.2 |
| 13D | 0.8 | 0.9 | 1.3 | 13B | 0.1 | 0.1 |
| 14D | 0.9 | 1.3 | 1.6 | 14B | 0.5 | 0.9 |
| 15D | 1.2 | 1.6 | 1.6 | 15B | 1.0 | 1.2 |
| 16D | 1.4 | 1.6 | 1.8 | 16B | 0.8 | 0.9 |
| 17D | 1.1 | 1.3 | 1.5 | 17B | 0.5 | 0.8 |
| 18D | 1.0 | 1.4 | 1.6 | 18B | 0.2 | 0.6 |
| 19D | 1.6 | 1.9 | 2.1 | 19B | 0.9 | 1.2 |
| 20D | 0.6 | 1.0 | 1.5 | 20B | 0.5 | 0.5 |
| 21D | 1.2 | 1.4 | 1.7 | 21B | 1.0 | 1.2 |
| 22D | 1.5 | 1.7 | 1.9 | 22B | 1.2 | 1.4 |
| 23D | 0.9 | 1.2 | 1.4 | 23B | 0.9 | 0.8 |
| 24D | 1.2 | 1.3 | 1.6 | 24B | 1.0 | 1.0 |
| 25D | 1.2 | 1.6 | 1.9 | 25B | 1.1 | 1.0 |
| 26D | 0.7 | 1.5 | 2.5 | 26B | 0.4 | 0.8 |
| 27D | 0.9 | 1.4 | 1.8 | 27B | 0.3 | 0.8 |
| 28D | 1.4 | 1.6 | 1.8 | 28B | 0.6 | 0.9 |
| 29D | 1.0 | 1.2 | 1.4 | 29B | 0.5 | 0.8 |
| 30D | 1.3 | 1.6 | 1.7 | 30B | 0.8 | 0.9 |

As mentioned above, the study area is underlain by Vindhyan formations (sandstone, shale, and limestone), and therefore weathering of these formations would be one of the major reasons for the continuous escalation of F content in the shallow and deep aquifers. In addition, the extremely low hydrologic conductivity between the shallow and deep zones also suggests that the recharge sources for both deep and shallow zones are different; otherwise both the aquifers would have similar fluoride content.

It is also reported that the leachable F in soils is of greater significance in contributing F to groundwater than its absolute content in the rocks.⁸ Leaching of fluoride in deep zones is minimal due to the frequent alteration of clay and mud layers (impermeable nature), but since the subsurface lithology of the region is not homogeneous, leaching of F in deep zones continuously occurs leading to variation and escalation of F levels in both the shallow and deep aquifers.

For the most part, F levels in the present study are all fairly low, and for the majority of the sites the risk of fluorosis from them is therefore minimal. But the continuous escalation of F in groundwater can pose a potential health hazard in the future if such water is used for domestic and irrigational purposes.

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