GROUNDWATER FLUORIDE CONTAMINATION IN UNNAO DISTRICT (U.P.)

- A Research Report –

PEOPLES' SCIENCE INSTITUTE

252 VASANT VIHAR, PHASE-1

DEHRA DOON – 248006

June 2002

Groundwater Flouride Contamination in Unnao District (U.P.)

I. INTRODUCTION

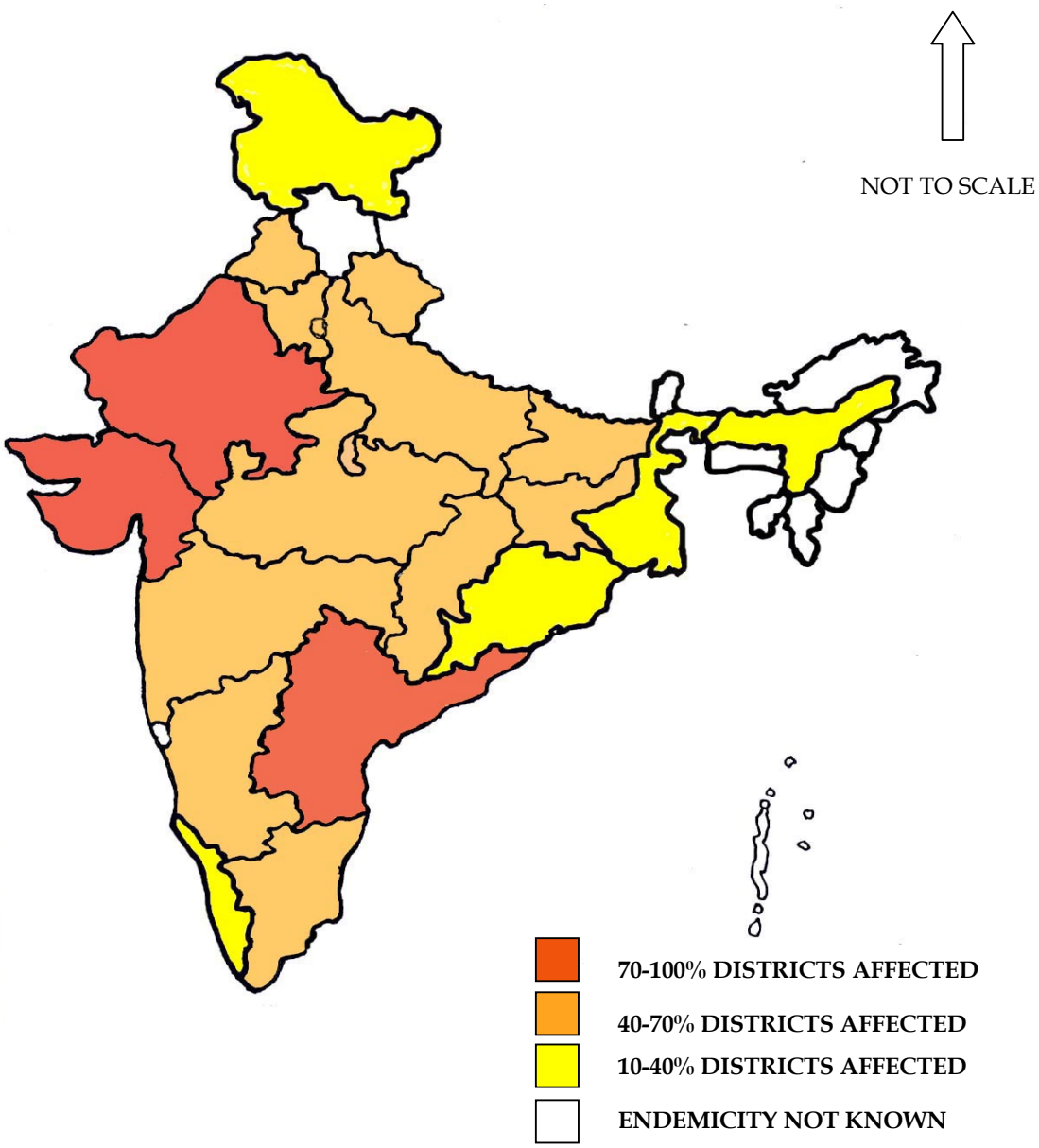
Flourosis is a crippling disease which is caused by the ingestion and accumulation of high amounts of fluorides in the body. An estimated 62 million people in India, of which 6 million are children below the age of 14 years, are affected with dental, skeletal and/or non-skeletal fluorosis.(1) Skeletal flourosis can lead to severe deformation of the bones. The damage caused by skeletal and dental fluorosis is irreversible.

Fluorosis is a disease linked to environmental causes. Fluorides enter the human body mainly through water. In India, 20 states have been identified with the problem of excess fluorides in groundwater sources (See Fig.1).(2) Rural populations dependent mainly on groundwater for drinking purposes are the worst affected due to this problem. Metabolism and the capacity to excrete fluorides play a significant role in determining individual susceptibiliy to fluoride toxicity. Some sections of the population are more vulnerable to the poisonous effects of fluorides than others. These include:

- Pregnant women, lactating mothers and young children.
- Malnourished children.
- People with low intake of calcium, vitamins C and E and antioxidants (Poor nutrition and high fluoride intake aggravate the development of fluorosis).
- People with cardio-vascular and kidney problems.
- People who do hard manual labour in hot climates, as it necessitates a high intake of drinking water.

The maximum limit of fluoride ions in drinking water prescribed by the Bureau of Indian Standards (BIS) is 1.00 mg/l. (3) Groundwater surveys in Unnao district conducted by the U.P.

Fig. 1: FLUORIDE CONTAMINATION IN DRINKING WATER AND RESULTING ENDEMICITY IN INDIA



Source: " A TREATISE IN FLUORIDE " BY PROF. (DR.) A. K. SUSEELA (2001), FLUOROSIS RESEARCH AND RURAL DEVELOPMENT FOUNDATION, NEW DELHI

Jal Nigam (1992) and UNICEF (1997) reported fluorides contents well above the standard in over 500 villages. Thereafter, ameliorative measures were attempted in these villages to ensure supply of safe drinking water.

A recent survey done by Vikas Bharati, an Unnao-based voluntary organization, revealed that 35%, 47.8% and 60.3% of children were affected with dental fluorosis, in Junior High School, Thana, Janta Shiksha Niketan, Raukarna, and Junior High School, Makhi, respectively. At the request of Vikas Bharati, Peoples' Science Institute (PSI) undertook a study to determine fluoride concentrations in the groundwater in four villages. This report gives details of the research work.

II. OBJECTIVES

- To determine fluoride concentrations in the groundwater at Makhi, Patari, Shulkapur and Makhi Sarai villages of Unnao district (See Fig 2).
- To assess the drinking water quality of different sources, viz., wells, desi hand pumps, India Mark-II hand pumps and tubewells.

III. METHODOLOGY

In April 2001, researchers from Peoples' Science Institute (PSI) carried out rapid appraisals in seven villages of Unnao district. Finally four villages were selected for water quality testing. The selection of villages was done on the basis of – information from previous studies done by U.P. Jal Nigam and others, interest shown by the villagers towards the issue of fluoride, contamination, accessibility of the village and possible follow up activities. The details of the selected villages are presented in Table 1.

Fig. 2: MAP OF THE STUDY

NOT TO SCALE

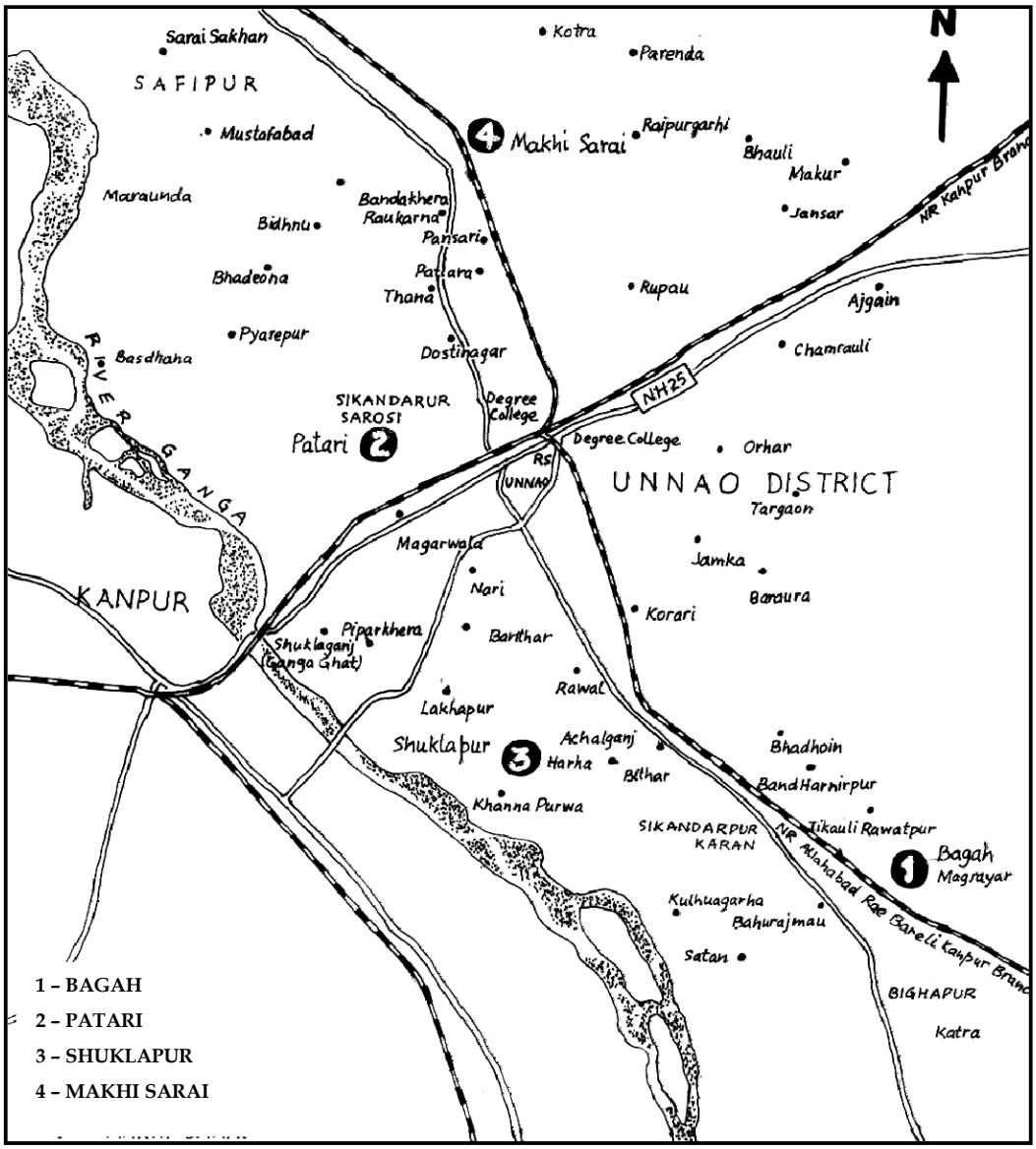


Table – 1 Description of the villages selected for water quality monitoring.

Village Name →	**Bagah**	**Patari**	**Shuklapur**	**Makhi Sarai**
Gram Panchayat	Kulah Bagah	Patari	Shuklapur	Makhi
Block	Sikandarpur Karan	Sikandarpur Sarosi	Sikandarpur Sarosi	Miyanganj
Population (Approx.)	2000	2000	1100	2500
No. of Open Dug Wells	5	20	3	20
No. of Desi Hand Pumps	50	--	--	~50
No. of India Mark-II Hand pumps	8	22	5	7
No. of Tubewells	1	1	3	--

Village locations are given in Fig. 2.

Selection of Parameters

Fluoride contamination in groundwater was the main concern of the present study. A literature review on defluoridation techniques revealed that defluoridation mechanisms are associated with pH, total dissolved solids (TDS), total alkalinity and total hardness.[2] Therefore the samples collected were also analyzed for these parameters. Coliform bacteria counts (MPN/100ml) of water samples from dug wells were also conducted. Water quality analysis was done in accordance with the standard methods.[4]

Parameters Monitored

i) Colour, ii) Odour, iii) Depth,* iv) pH, v) Total alkalinity,
vi) Total hardness, vii) Fluoride and viii) Coliform count (MPN/ 100ml)**

* Depth obtained from the local people using the source.
** Analysed only for 10-dug wells.

Selection of sampling points

Four types of drinking water sources were observed in the area, viz., open dug wells, desi hand pumps, India Mark-II hand pumps and tubewells installed by individual families for their personal use. These sources draw water from different depths, in increasing order, respectively. Before starting the sampling, a discussion was organised in each village to inform the villagers about PSI's study and its objectives. In order to seek participation from the community, PRA exercises like social and resource mapping were done with the villagers.

Villagers were asked to locate the drinking water sources, School, Temple, Panchayat Ghar, in their villages on the map. They were also asked to rank the drinking water sources on the basis of their usage. From the maps drawn by villagers and the ensuing discussion, the final selection of the sampling sites was done on the basis of – the location of the sources, the number of users, types of sources and distribution of source types. The study tried to cover the entire village and all types of drinking water sources.

IV. RESULTS AND DISCUSSION

Water quality testing was done in June 2001. A total of 60 water samples from different water sources were collected from the affected area for analysis. Sampling information and the tests results are presented in Tables 2 to 5.

Fluorides Concentration

In **Bagah** village, maximum fluoride concentration (3.75 mg/L) was observed in water lifted by desi hand pumps, and minimum concentration (2.1 mg/L) in India Mark- II hand pump water. A large number of people consume water from desi hand pumps, which they have installed on their own. Some cases of skeletal fluorosis were noticed in this village.

In **Patari** village the fluoride content varied between 1.9 mg/L to 2.45 mg/L for India Mark –II hand pumps and between 3.05 mg/L to 3.45 mg/L in water from dug wells. The latter are the predominant source of drinking water in the village. Dental fluorosis complaints were common among the children.

Most of the residents in **Shuklapur** use drinking water from India Mark-II hand pumps, which lift water containing comparatively low fluoride content (1.45 mg/L to 1.90 mg/L). The study conducted by U.P. Jal Nigam during 1992, however, recorded the highest fluoride concentration (9.4 mg/L) in Shuklapur village. Subsequently, the Jal Nigam, installed India Mark - II hand pumps there.

Table - 2

Village name: **BAGAH**
Date of sampling: 16/6/2001

Sample No.	Source	Identification feature of a sampling point	Depth Ft	Colour	Odour	*pH	TDS mg/L	*Total Alkalinity mg/L	*Total Hardness mg/L as $CaCO_3$	*Fluoride mg/L	TC MPN/ 100ml	FC MPN/ 100ml
Indian Standard for Drinking water. IS 10500:1991, (BIS)					**Unobjectionable**	**6.5 -8.5**	**500**	**200**	**300**	**1.0**	**10**	**0**
1	IMHP	Near Kalika mandir	120	Colourless	Muddy	7.2	520	490	420	2.65		
2	IMHP	Near Ganga Charan's house	125	Colourless	Muddy	7.1	500	220	356	2.65		
3	DHP	Near Sushil kumar's hosue	50	Colourless	Metallic	7.1	1880	360	388	2.4		
4	DW	Tiwari ji's house	60	Milky	Odourless	7.2	940	360	332	2.75	43	<3
5	DHP	Amrit Lal's house	100	Turbid	Muddy	7	1820	310	368	2.1		
6	DW	Chaudhary ji's house, near Shiv mandir	33	Muddy	Muddy	7.1	560	330	288	3.5	38	7
7	IMHP	Primary school campus	100	Colourless	Odourless	7.1	440	210	308	2.1		
8	DW	Near Mathura Das's house	40-42	Muddy	Muddy	7.3	580	340	524	3.5		
9	IMHP	Ganga Ram Kori's house	100	Colourless	Odourless	7.2	500	250	324	2.5		
10	DW	Namberdari's well	40-45	Colourless	Odourless	7.3	1380	440	572	2.85		
11	DW	Kumharo Ka Kuan	40	Muddy	Muddy	7.3	640	370	260	2.95		
12	IMHP	Master Surya prasad’s house	100	Colourless	Odourless	7.5	420	250	284	3.15		
13	TW	Sarvesh Bhai 's Tube well	100	Colourless	Odourless	7.2	980	320	472	2.6		
14	DHP	Ganga Ram's house	50	Colourless	Odourless	7.3	1400	420	320	3.75		
15	DHP	Laloo Ram's house	40	Colourless	Odourless	7.1	780	560	612	3.1	2400	43

	IMHP	DHP	DW	TW
No. of each type of drinking water source existing within a village	7	--	6	3
No. of each type of sources covered during pre-monsoon monitoring	5	4	5	1

Abbreviation used:

DW : Dug Well
DHP : Desi Hand Pump
IMHP : India Mark - II Hand Pump
TW : Tube Well

* Values are mean of three observations each.

Table - 3

Village name : **PATARI**
Date of sampling : 17/6/2001

Sample No.	Source	Identification feature of a sampling point	Depth Ft	Colour	Odour	*pH	TDS mg/L	*Total Alkalinity mg/L	*Total Hardness mg/L as $CaCO_3$	*Fluoride mg/L	TC MPN/ 100ml	FC MPN/ 100ml
Indian Standard for Drinking water. IS 10500:1991, (BIS)					**Unobjectionable**	**6.5-8.5**	**500**	**200**	**300**	**1.0**		
16	IMHP	Near Pradhan Bhagwan Singh's house	85	Colourless	Mettalic	6.5	280	200	316	2.3		
17	IMHP	Near Gokaran 's house	110	Colourless	Odourless	7.1	2660	210	300	2.3		
18	IMHP	Near Hardya Nath Bajpai's house	100	Colourless	Odourless	7.2	2620	250	256	2.3		
19	IMHP	Near Bhagwahn Shanker Mishra's house	115	Colourless	Odourless	7.0	2900	230	196	2.45		
20	DW	Lallan's well	45	Muddy	Rotten	7.1	2000	310	204	2.3		
21	IMHP	Near Ram Ghulam's House	125	Colourless	Odourless	7.1	1420	210	164	2.0		
22	IMHP	Near Amar Nath Singhs House	85	Colourless	Odourless	7.0	2600	160	306	2.4		
23	IMHP	Near Kali Charan's House	150	Colourless	Odourless	7.2	1940	210	164	2.0		
24	IMHP	Primary school campus	150	Muddy	Muddy	7.1	940	290	102	1.9		
25	DW	Yakoob's well	45	Muddy	Rotten	7.2	900	280	36	3.45	140	<3
26	DW	Masjid's well	45	Muddy	Rotten	7.2	1140	330	430	3.05		
27	DW	Kalika Mandir’s well	60	Colourless	Odourless	7.4	1320	370	430	3.6	43	4

	IMHP	DHP	DW	TW
No. of each type of drinking water sourceexisting within a village	21	--	5	1
No. of each type of sources covered during pre-monsoon monitoring	8	--	4	--

* Values are mean of three observations each.

Table - 4

Village name: **SHUKLA PUR**
Date of sampling: 18/6/2001

Sample No.	Source	Identification feature of a sampling point	Depth Ft	Colour	dour	*pH	TDS mg/L	*Total Alkalinity mg/L	*Total Hardness mg/L as $CaCO_3$	*Fluoride mg/L	TC MPN/ 100ml	FC MPN / 100ml
Indian Standard for Drinking water. IS 10500:1991 (BIS)					**Unobjectionable**	**6.5 -8.5**	**500**	**200**	**300**	**1.0**	**10**	**0**
28	TW	Gainda Lal's Tube well	60	Colourless	Odourless	7.4	840	260	320	1.65		
29	IMHP	Near Rameshwer's home	90	Colourless	Odourless	7.1	260	213	350	1.65		
30	IMHP	Near Chadi Lal's House	90	Colourless	Odourless	6.9	740	320	149	1.6		
31	DW	Nankuo's well	45	Colourless	Odourless	7	940	1530	230	2		
32	DW	Near Puran Lal's house	42	Colourless	Odourless	7.2	1600	280	732	1.9	210	150
33	IMHP	Inside Panchayat Ghar premise	100	Colourless	Odourless	7.2	440	240	320	1.75		
34	IMHP	Near Sheetla Prasad's house	103	Colourless	Odourless	7.2	460	220	296	1.75		
35	TW	Shri Ram's Tube well	90	Colourless	Odourless	7.2	560	230	328	1.6		
36	IMHP	Near Shankar Mandir	100	Colourless	Odourless	7.2	400	220	296	1.9		
37	IMHP	In front of Jodhan's house	100	Colourless	Odourless	7.1	460	160	328	1.45		
38	DW	In front of Pratap Lodhi's house	50	Colourless	Odourless	7.3	740	250	194	1.7	460	240
39	DW	Near Devi Dayal's house	60	Yellowish	Odourless	7.2	1540	240	272	1.75	460	240

	IMHP	DHP	DW	TW
No. of each type of drinking water source existing within a village	7	--	5	3
No. of each type of sources covered during pre-monsoon monitoring	6	--	4	2

* Values are mean of three observations each.

Table – 5

Village name: **MAKHI SARAI**
Date of sampling: 19/6/2001

Sample No.	Source	Identification feature of a sampling point	Depth Ft	Colour	Odour	*pH	TDS mg/L	*Total Alkalinity mg/L	*Total Hardness mg/L as $CaCo_3$	*Fluoride mg/L	TC MPN/ 100ml	FC MPN/ 100ml
Indian Standard for Drinking water. IS 10500:1991, (BIS)					**Unobjectionable**	**6.5 -8.5**	**500**	**200**	**300**	**1.0**	**10**	**0**
40	DW	J.K. Pandey's well	45	Turbid	Odourless	7.5	820	260	60	3.15	2400	2400
41	DW	Near Kalika devi's mandir	20	Muddy	Rotten	7.4	960	320	116	2.85		
42	DW	Santosh Singh's well	30	Turbid	Odourless	7.4	1260	290	54	4.7		
43	DW	Thakur Sukhbir Singh's well	20	Turbid	Odourless	7.4	1240	320	62	3.05		
44	DHP	Pootni Singh's house	45	Turbid	Odourless	7.2	1640	330	880	2.65		
45	DW	Near Kaushal Singh's house	42	Muddy	Muddy	7.5	1220	270	74	2.45		
46	IMHP	Near PDS shops	90	Colourless	Odourless	7.3	400	270	146	1.95		
47	DW	Guljari Badai's well	21	Muddy	Odourless	7.3	660	230	148	2.5		
48	DHP	Gopal Mishra's House	30	Colourless	Odourless	7.6	2020	290	24	3.15		
49	DW	Gokul Singh's well	20	Muddy	Muddy	7.5	2140	450	106	2.7		
50	DHP	Krishan Pal Singh's house	40	Muddy	Odourless	7.2	840	260	154	1.8		
51	DHP	Jaganath Singh's House	40	Muddy	Muddy	7.2	780	320	166	2.5		
52	DW	Suneel Bhojwa's well	23	Muddy	Odourless	7.3	1340	370	126	2.85		
53	DW	Near Guri Charan Koril's house	50	Muddy	Odourless	7.3	840	270	30	2.85	2400	2400
54	IMHP	Near Haneef's House	75	Colourless	Odourless	7.1	460	160	162	1.9		
55	DW	Shaed Sunab Suhag Ali's house	35	Colourless	Odourless	7.5	2420	340	92	2.85		
56	DW	Ram Shanker's well	25	Muddy	Odourless	7.5	2580	420	144	3.05		
57	IMHP	Near Pradhan Chunni Devi's house	100	Colourless	Odourless	7.3	440	200	166	1.6		
58	DHP	Ashok Kumar Mishra's house	30	Colourless	Muddy	7.5	1380	310	72	3.45		
59	DW	Surya Pal Singh's house	30	Colourless	Odourless	7.4	1300	280	70	3.15	2400	2400
60	IMHP	Primary School campus	90	Colourless	Odourless	7.3	540	160	164	1.9		

	IMHP	DHP	DW	TW
No. of each type of drinking water source existing within a village	7		20	--
No. of each type of sources covered during pre-monsoon monitoring	4	5	12	--

* Values are mean of three observations each.

A majority of the households in **Makhi Sarai** village get their drinking water from open dug wells, which are contaminated with high fluoride content (upto 4.7 mg/L). The Jal Nigam, has installed some India Mark-II hand pumps in this village. The concentration of fluoride in the water samples collected from these hand pumps was comparatively low (1.6 – 1.95 mg/L).

Results of the fluoride concentrations for all the villages and the different types of sources are summarized in Table 6 below.

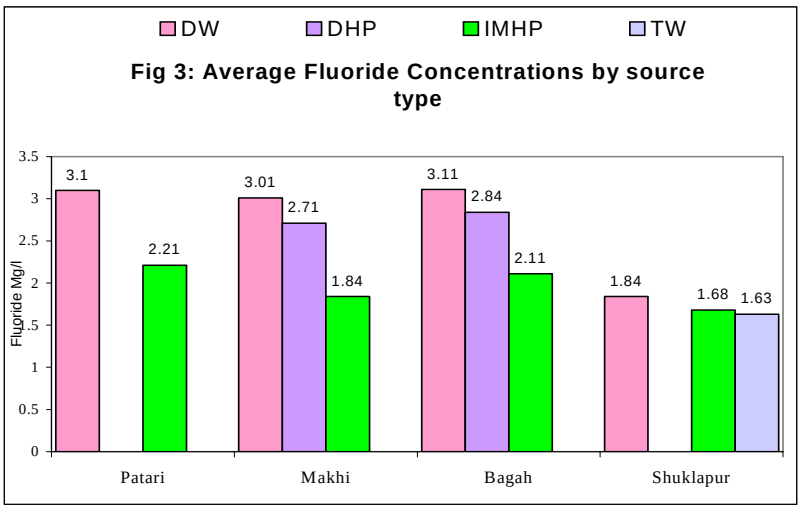
Table 6: Fluoride concentrations (mg/L).

Village	**Bagah**				**Patari**			
Type of source	DW	DHP	IMHP	TW	DW	DHP	IMHP	TW
Depth in ft (range)	33-60	40-100	100-125	--	45-60	--	85-150	--
Fluoride (range in mg/L)	2.75-3.5	2.1-3.75	2.1-3.15	2.6-2.6	3.05-3.45	--	1.9-2.45	--

Village	**Shuklapur**				**Makhi Sarai**			
Type of source	DW	DHP	IMHP	TW	DW	DHP	IMHP	TW
Depth in ft (range)	42-60	--	90-100	60-90	20-50	30-45	75-100	--
Fluoride (range in mg/L)	1.7-2.0	--	1.45-1.9	1.6-1.65	2.5-4.7	1.8-3.45	1.6-1.95	--

DW – Dug well, DHP – Desi hand pump, IMPH – India Mark –II hand pump, TW – Tube well.

It is interesting to note that the average concentration of fluorides in water decreases with the depth of the source (Fig 3). Deeper water sources, e.g., India Mark –II hand pumps (75 – 150 ft) and tubewells (60-90 ft), yielded low fluoride concentrations as compared to shallow water sources, viz., dug wells and desi hand pumps. This observation suggests the possibility of the



presence of high fluoride bearing minerals in the shallower strata. Similar observations were also reported by Rao et al. in 1994.[5]

Physical Characteristics

Colour and odour of drinking water are due to the presence of organic substances. Ideally, potable water should be colourless and odourless. Some particular odours are indicative of increased biological activities.[6] In the present study muddy and turbid water with typical odour was recorded in the water of dug wells, desi hand pumps and India Mark-II hand pumps.

TDS

TDS (total dissolved solids) is an important parameter of drinking water quality testing that denotes the presence (or absence) of various kinds of minerals, like chlorides, sulphates, phosphates and ions like calcium, magnesium, potassium and iron etc., in water. Its value varied from 420 –1880 mg/L in Bagah, 280 – 2900 mg/L in Patari, 260 – 1600 mg/L in Shuklapur and 400 – 2580 mg/L in Makhi Sarai village. High amounts of dissolved solids (above 500 mg/L) impart a particular taste to water and reduce its palatability.[7]

pH

For drinking water, the pH value must be within the range of 6.5 – 8.5, as per the BIS standard. [3] Although pH has no direct adverse health effect, it is an important factor in drinking water treatment particularly in defluoridation.[8] In the present study, pH values of all samples were within the permissible range.

Alkalinity

Alkalinity in natural waters is a results of dissolution of CO_2 in water. Carbonates and bicarbonates thus formed are dissociated to yield hydroxyl ions.[7]

$$CO_2 + H_2O \text{ ==== } H_2CO_3 \text{ ===== } HCO3^- + H^+$$

$$HCO_3 \text{ ===== } H^+ + CO_3^-$$

$$CO_3^{-2} + 2HOH \text{ ===== } H_2CO_3^- + OH^-$$

In the samples analyzed, total alkalinity ranged from 210 – 560 mg/L, 160 – 370 mg/L, 160 – 1530 mg/L and 160-450 mg/L in Bagah, Patari, Shuklapur and Makhi Sarai villages,

respectively. Alkalinity of the drinking water has little public health significance.[6] Still drinking water having alkalinity less than 200 mg/L is desirable for domestic purposes. The alkalinity value is essential to evaluate the dose of disinfection in water treatment practices and defluoridation processes.

Hardness

Water hardness is the traditional measure of the capacity of water to lather with soap. Hard water requires considerably more soap to produce lather.[7] Hardness is mostly expressed in terms of mg/L as $CaCO_3$. The principal natural sources of hardness in water are dissolved polyvalent metallic cations from sedimentary rocks, seepage, and runoff from the soil. Hardness values ranged from 332 – 612 mg/L in Bagah, 36 – 430 mg/L in Patari, 149 – 732 mg/L in Shuklapur and 24 – 880 mg/L in Makhi Sarai village. There is no report, which relates health effects in humans directly with hardness of water.[9]

Bacteriological Contamination

Bacteriological analyses were conducted only for samples from dug wells, as they are more susceptible to bacterial contamination. Dug wells are the most contaminated sources with respect to fecal coliforms.[6] Bacterial contamination was recorded in all the samples tested. The most serious source of bacterial pollution, including pathogenic bacteria, is human and animal wastes from latrines and farm manure. [9] People wash and bathe near the wells. Dug wells, therefore, require routine disinfection. But this is not done on a regular basis making them sources of bacterial contamination. Under such a situation, installation of India Mark-II hand pumps and fitting of sanitary covers on open dug wells should improve their water quality.

VI. CONCLUSIONS

Unnao district is known for the incidence of fluorosis due to high levels of fluoride ions in the groundwater. **PSI's** water quality testing indicated that all the selected water sources in the four villages contained fluoride in excess of the BIS limit (1.0 mg/L). The extent of fluoride contamination fluctuated from 1.45 to 4.7 mg/L.

Open dug wells, which draw water from shallow aquifers, generally contain more fluoride than India Mark-II hand pumps, which draw water from deeper aquifers. It must be noted, however, that the fluoride concentrations even in the deeper aquifers are above the permissible limit. Therefore it is preferable to supply drinking water from deeper sources. People should be motivated to avoid dug wells as sources of domestic water supply. Awareness campaigns on preventive measures, such as eating proper foods, rainwater harvesting and the use of defluoridation kits should also be undertaken. U.P.Jal Nigam, other water supply agencies and voluntary organizations should regularly monitor the fluoride content of the water supplied, and release the data to the public.

VII. REFERENCES

1. Susheela, A.K. (2001). A Treatise On Fluorosis. Fluorosis Research and Rural Development Foundation, New Delhi.
2. Susheela, A.K. (1999). Fluorosis management Program in India. *Current Science*, vol. 77.
3. ------- (1991). Drinking water specification IS 10500 : 1991. Bureau of Indian Standards, Manak Bhawan, New Delhi.
4. -------- (1998). Standard Methods for the examination of water and wastewater. American Public Health Association,
5. Rama Rao, M. Sahaji, C.S. Leela Iyengar and Venkobchar, C. (1994). Fluoride in groundwater of Unnao (U.P.) and Shivpuri (M.P.) districts. *Journal of Indian Water Works Association.* July – September.
6. ------- (1997). Guidelines for drinking water quality. Second edition. Vol. 3, Surveillance and control of community supplies, WHO, Geneva
7. Trivedy, P.K. and Goel, R.K. (1997).
8. Raju Ramchandra, D.V. (2001). Relation between pH and fluoride removal bio-fod use of defluoridation in rural areas. Journal of the IPHE, India, No. 4
9. ------ (1997). Guidelines for drinking water quality. Second edition. Vol. 2, Health criteria and other supporting information, WHO Geneva.