Practical Paper

Mitigation of naturally occurring fluoride in drinking water sources in rural areas in India: an overview

Brajesh K. Shrivastava

ABSTRACT

This paper provides updated status of fluoride affected rural habitations in all the States in India and explains the initiatives of Ministry of Drinking Water and Sanitation, Government of India, in tackling fluoride affected habitations since year 2000. It also analyses the impact of these initiatives and identifies challenges in tackling excess fluoride in drinking water in India. The paper is intended primarily for policy formulators and programme managers working in drinking water sector to tackle fluoride and fluorosis problem in rural areas.

Key words | coverage, fluoride, habitations, India

Brajesh K. Shrivastava
Consultant-Water Quality,
Ministry of Drinking Water & Sanitation,
9th Floor, Paryavaran Bhavan,
CGO Complex,
Lodhi Road,
New Delhi-03,
New Delhi
E-mail: *brajeshchem@gmail.com*;
brajesh979@rediffmail.com

INTRODUCTION

Excess fluoride intake causes a slow, progressive crippling scourge known as fluorosis. (Susheela 2001). Though drinking water is the major contributor (75–90% of daily intake), other sources of fluoride poisoning are food, industrial exposure, drugs, cosmetics *etc.* (Meenakshi & Maheshwari 2006).

The first formal WHO guideline for fluoride in drinking water was established in 1984 in the first edition of its guidelines for drinking water quality. The guideline value (permissible upper limit) for fluoride in drinking water was set at 1.5 mg/L, considered as the threshold where the benefit of resistance to tooth decay did not yet transit into a significant risk of dental fluorosis. WHO Guidelines are now under the 4th edition (WHO 2011) and all subsequent editions have retained 1.5 mg/L as the guideline value for fluoride. There could be minor variation from this value, country to country, as the WHO guidelines value is suggestive in nature. In setting national standards or local guidelines for fluoride, or in evaluating the possible health consequences of exposure to fluoride, it is essential to consider the intake of water by the population of interest and the intake of fluoride from other sources (e.g. from food and air). The Bureau of Indian Standards (BIS), which is the regulating agency for drinking water specifications in India, specifies that the acceptable value of fluoride in drinking water is 1.0 ppm (or 1.0 mg/L) but in the absence of alternatives, fluoride value in drinking water up to 1.5 ppm may be tolerated (BIS 2012).

The first report on endemic fluorosis in India was published by Shortt *et al.* from King's Institute of Preventive Medicine, Chennai (India) in 1937 (Susheela 1995; Arveti *et al.* 2011). At that time, the disease was noticed in four states; Andhra Pradesh, Tamil Nadu, Punjab, and Uttar Pradesh. During the period of 1960–1986, nine more states were identified as endemic for fluorosis. In 1990–1992, two more states, Kerala and Jammu and Kashmir were identified as endemic for the disease. The fluoride problem in India is primarily of hydro-geochemical origin (Meenakshi & Maheshwari 2006).

Rural drinking water supply is a State subject in India. It has been included in the Eleventh Schedule of the Constitution, among the subjects that may be entrusted to Panchayats (elected local village group for self governance) by the States. To accelerate the pace of drinking water coverage in villages, the Government of India (GoI) introduced the Accelerated Rural Water Supply Programme (ARWSP) in 1972–1973 to support States and UTs with financial and

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technical assistance to implement drinking water supply schemes. The entire programme was given a mission approach when the Technology Mission on Drinking Water Management, called the National Drinking Water Mission (NDWM), was introduced as one of the five missions in the social sector in 1986. NDWM was renamed as Rajiv Gandhi National Drinking Water Mission (RGNDWM) in 1991 and the Department of Drinking Water Supply (DDWS) was created under the Ministry of Rural Development in the year 1999. It was made a separate ministry – Ministry of Drinking Water and Sanitation – in 2011. The ministry prepares policies and guidelines on rural drinking water and sanitation at the national level and revises it from time to time as per need. It provides financial assistance and technical support to the States and monitors the programme. The ministry implements two major programmes, NRDWP (National Rural Drinking Water Programme) for drinking water and TSC (now renamed as NBA-Nirman Bharat Abhiyan) for sanitation, by providing financial assistance and technical support to the States/UTs.

National rural drinking water programme (NRDWP)

The NRDWP was launched in April 2009. NRDWP provides grants for construction of rural water supply schemes with special focus on water-stressed and water quality affected areas, rainwater harvesting and groundwater recharge measures, and for operation and maintenance including minor repairs.

METHODS

System of reporting data in the ministry

Physical and financial progress of NRDWP is reported by all the States on online IMIS (Integrated Management Information system) in the website of the ministry (www.ddws.gov.in) since year 2009. In each year, the ministry opens its online IMIS for entry on 1 March considering that 31 March is the last day of each financial year in India. All the States are required to enter their progress and also the targets for the next financial year. After that, entries on IMIS for number of water quality affected habitations are closed. States can update their progress on other aspects of the programme (like number of laboratories set up, field test kits (FTKs) distributed, details of schemes etc.) on online IMIS of the Ministry but not the number of water quality affected habitations. Hence, 1st April of each year is considered a base year for reporting water quality affected habitations by the Ministry.

Fluoride affected habitations in India

The first country-wide survey for assessment of the number of fluoride affected habitations was conducted by the DDWS, Ministry of Rural Development in year 2000. After 5 years of assessment, the number of fluoride affected habitations in the country was reported as 31,306 in 2005. It was again updated by the States in 2006 to 29,070 (Table 1). Five states with highest fluoride affected habitations as reported in 2006 were Rajasthan (6,992 habitations), Karnataka (5,000 habitations), Madhya Pradesh (3,282 habitations), Maharashtra (2,748 habitations) and Gujarat (2,563 habitations). In 2009, when all states started reporting through online IMIS on the website of the ministry, 18 states reported a total of 33,363 habitations affected with excess fluoride in drinking water (www.ddws.gov.in, NRDWP, Basic information, Format B-13). The number of rural people affected with fluoride affected habitations was reported to be 247 lakh (24.7 million). Five states with the highest fluoride affected habitations were Rajasthan (11,775 habitations), Bihar (5,957 habitations), Madhya Pradesh (4,720 habitations), Karnataka (4,152 habitations) and Uttar Pradesh (1,768 habitations) (Figure 1). A map of fluoride affected areas in different States of the country is shown in Figure 2.

Initiatives of Ministry of Drinking Water & Sanitation (GoI)

- Earmarking of fund for tackling water quality affected habitations
  - Under the NRDWP, there is a provision for states to utilize 20% of their allocation for providing safe water in the quality-affected habitations. In addition, 20% sustainability component can also be used on a 100% funding basis on sustainability measures in quality-affected habitations. If states want to utilize more

Table 1 | Fluoride affected habitations as on 1 April 2005 and 1 April 2006 (based on first survey, conducted from 2000 to 2005)

S.No.	States/Uts	2005	2006
1	Andaman and Nicobar	0	0
2	Andhra Pradesh	3,072	1,497
3	Arunachal Pradesh	0	0
4	Assam	0	660
5	Bihar	43	383
6	Chandigarh	0	0
7	Chattisgarh	17	17
8	Dadra and Nagar Haveli	0	0
9	Daman and Diu	0	0
10	Goa	0	0
11	Gujarat	4,341	2,563
12	Haryana	144	119
13	Himachal Pradesh	0	0
14	Jammu and Kashmir	0	0
15	Jharkhand	15	1159
16	Karnataka	5,838	5,000
17	Kerala	34	34
18	Lakshadweep	0	0
19	Madhya Pradesh	3,764	3,282
20	Maharashtra	800	2,748
21	Manipur	0	0
22	Meghalaya	0	0
23	Mizoram	0	0
24	Nagaland	0	0
25	Orissa	504	794
26	Puducherry	0	0
27	Punjab	613	588
28	Rajasthan	8,992	6,992
29	Sikkim	0	0
30	Tamil Nadu	737	452
31	Tripura	0	40
32	Uttar Pradesh	1,046	2,077
33	Uttarakhand	0	0
34	West Bengal	1,346	665
Total		31,306	29,070

funds for addressing water quality problems, they can also use funds available for coverage (45% of NRDWP State allocation), i.e. a total of 67% of the state allocation can be used to address water quality problems.

- Setting up district and sub-district water quality testing laboratories
  - States have been provided assistance via a 100% grant-in-aid basis under NRDWP-support funds to set up water quality testing laboratories at district and sub-district levels and for upgrading their existing laboratories. Further, states have also set up such laboratories from their own resources. As reported by the states (up to November 29 2012) on online IMIS of the ministry, 24 state laboratories, 749 district laboratories and 1,057 sub-district laboratories have been set up for analysis of drinking water which also includes a facility for testing fluoride.
- Decentralized water quality testing using FTKs
  - In order to develop the understanding and appreciation of safe and clean drinking water among rural communities and to enable them to determine the quality of drinking water, the National Rural Drinking Water Quality Monitoring and Surveillance Programme was launched in February 2006. The programme aimed at empowering rural communities by:

I. Bringing awareness through Information, Education and Communication (IEC) activities to address ownership of the systems, health hazards due to poor drinking water quality, hygiene, sanitary survey, importance of environmental sanitation, etc.;
II. Training five grassroot workers in each Gram Panchayat (GP; elected body at village level with a representative to take all initiatives), which may be an Accredited Social Health Activist (ASHA) worker, Anganwadi worker, science teacher, high school girl student, panchayat member, ex-servicemen, etc.;
III. In addition, two people at the state level, four people at the district and five people at the block level are also to be trained;
IV. Supply of FTKs and bacteriological vials to GPs for water quality testing.

States were provided adequate funds to procure and distribute one chemical FTK to each GP for on-the-spot testing of some of the basic drinking water quality parameters (fluoride, hardness, alkalinity, nitrate, iron etc). Bacteriological vials/powder were procured by the States for testing bacteriological contamination of drinking water. The purpose

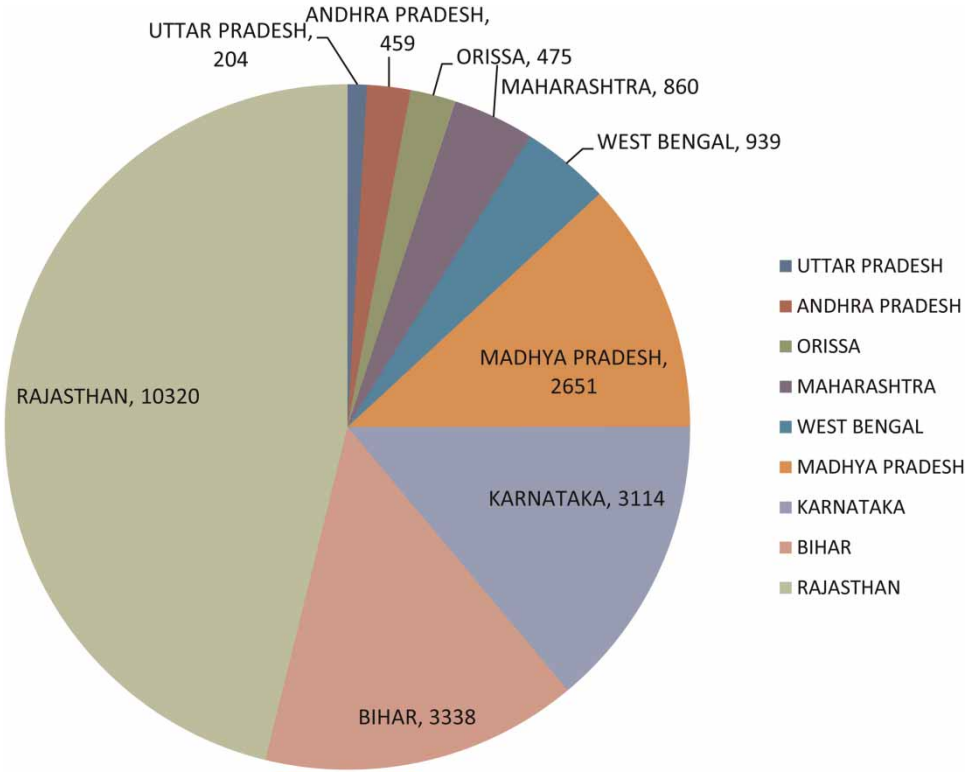

Figure 1 | Distribution of fluoride affected habitations as reported by States on IMIS of the ministry in 2009 (states which reported number of fluoride affected habitations higher than 200).

of providing FTKs and bacteriological vials to the GPs was to ensure that all GPs receive a drinking water testing facility at their village and do not depend upon the laboratories, which were also inadequate in number, considering the need to test higher number of drinking water sources. At least five villagers were trained from each village on the use of chemical FTKs and on sanitary survey.

The system of distributing chemical FTKs and bacteriological vials/powder to GPs is still continuing in all states. This system is in practice along with setting up of new water testing laboratories (or strengthening the existing facilities) at block and district laboratories. Drinking water sources, which are found indicating excess fluoride (or excess hardness, alkalinity, nitrate, iron etc) are referred to laboratories for further analysis. The laboratories, apart from testing 'positively' referred water samples by chemical FTKs/bacteriological vials, also undertake analysis of some of the randomly selected samples from drinking water sources.

The following are the cumulative achievements as reported by the states till November 29, 2012 on online IMIS of the ministry (www.ddws.gov.in, NRDWP, Basic information, Format E-20):

- 14.94 lakh (1.49 million) rural people have been imparted training on use of chemical FTKs, testing for *Escherichia coli* and on sanitary surveys;
- 3.62 lakh (0.362 million) chemical kits and 870 lakh (87.0 million) bacteriological vials have been distributed to GPs in different states;
- 16.69 lakh (1.669 million) drinking water sources were screened using FTKs and bacteriological vials in rural areas;
- 4.44 lakh (0.444 million) sanitary surveys have been carried out.

Research and development (R&D) activities and technologies suggested India has been a leader in developing and deploying technologies for fluoride mitigation in drinking water. Nalgonda technology, developed by NEERI-Nagpur, is an example of technology development at the beginning of the fluoride mitigation programme in the country. This

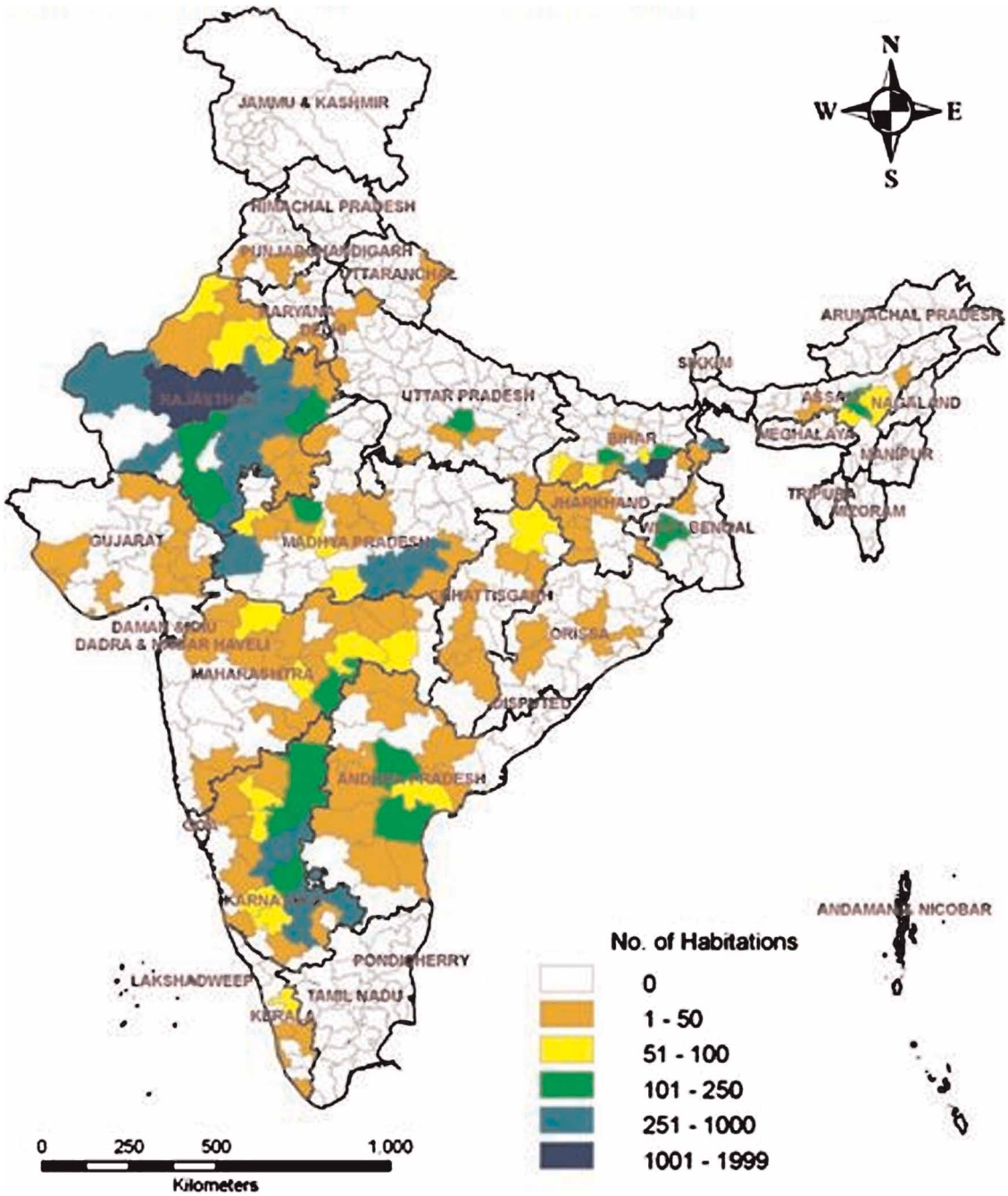

Figure 2 | Map of India: fluoride affected habitations in different states. *Source:* Ministry of Drinking Water & Sanitation (2012).

technology, which is now known worldwide, was developed for the rural people suffering from severe fluorosis in the Nalgonda district of Andhra Pradesh state. Later on, many technologies were also developed by other institutions.

The Ministry of Drinking Water and Sanitation has provided funds for many R&D projects to premier research institutions and universities in the country for developing technologies for fluoride mitigation. So far, 167 R&D

projects worth Rs 15.37 crore (approx. 31 million US$) have been approved, of which 132 projects have been completed. The Ministry of Science and Technology has also provided funds in the past to many research institutes and universities for developing technologies and for case studies on various types of water contaminants which includes fluoride mitigation as well.

Some of the technological options suggested for fluoride removal in drinking water are: the Nalgonda technique (co-precipitation), Prashanti technique (activated alumina), electro-coagulation, reverse osmosis, ion exchange, roof-top rainwater harvesting and *in situ* dilution through artificial ground-water recharge. R&D projects on the use of herbal extracts, drumsticks seeds, amla seeds, nirmal seeds, charcoal, burnt bricks and burnt paddy husk filters for defluoridation of drinking water have also been approved. Tapping alternate safe water, if available, has also been recommended subject to the condition that *E. coli* or thermo-tolerant bacteria should not be present in the supplied water from alternate surface sources. While considering *in situ* treatment plants as a short term solution to provide safe water, state governments are suggested to adopt a dual-water policy to supply safe treated drinking water for drinking and cooking purposes.

Recent initiatives

The ministry has also taken some other initiatives to improve the quality of drinking water supplied in the rural areas of the country such as:

- Support for setting up of 'International Institute of Water Quality' in Kolkata with focus on geogenic contamination in drinking water;
- Support for setting up two Regional Fluoride Mitigation Centres; one at Gandhinagar in Gujarat state and the other one at Hyderabad in Andhra Pradesh State;
- Phased procurement of 'Fluoride ion meters' in district laboratories to speed up testing of fluoride in drinking water;
- Introduction of 'groundwater quality layer' into the Hydro-Geo-Morphological Maps (groundwater prospect maps) to delineate water quality hotspots occurring geogenically;
- Developing a Uniform Drinking Water Quality Monitoring Protocol to devise minimum standards for setting up of laboratories and water quality testing procedures. Sanitary survey, an integral part of Water safety Plan, for different types of water supply schemes, has been included;
- Preparation of a 'Technology Manual' which indicates all available technologies for various geogenic and anthropogenic pollutants in drinking water with comparison of cost of the treated water for some of the important parameters including fluoride.

RESULTS AND DISCUSSION

The financial and technical assistance provided by the GoI, has enabled the states to reduce fluoride affected habitations significantly. As per information provided by the states on the online IMIS on the website of the ministry, the total number of fluoride affected habitations has reduced from 33,363 in 2009 to 17,986 in 2012, which indicates that so far 15,377 fluoride affected habitations have been covered with safe drinking water during the last 3 years (Table 2). The leading states tackling fluoride affected habitations as per the IMIS data are Rajasthan, which addressed 4,645 fluoride affected habitations during the last 3 years, followed by Bihar, Madhya Pradesh, Uttar Pradesh and Karnataka which addressed 3,259, 2,235, 1,624 and 1,346 habitations, respectively (Figure 3). States which have performed moderately in tackling fluoride affected habitations as per the IMIS report are Maharashtra which addressed 932 habitations during the last 3 years, followed by Andhra Pradesh, Assam, Gujarat and Odisha which addressed 459, 437, 393 and 302 habitations, respectively, since 2009. Increased fluoride monitoring in drinking water sources and surveillance has also led to the addition of more fluoride affected habitations in some States such as West Bengal, Jharkhand, Chhattisgarh and Jammu and Kashmir during the period between 2009 and 2012, though these states have not been completely tackled the comparatively lower number of fluoride affected habitations. Fluoride affected habitations in Tamil Nadu state were none in 2009, but in 2012, the State reported two new fluoride affected habitations, affecting 1969 of the rural population in the areas. The emergence of new fluoride affected habitations

Table 2 | Fluoride affected rural habitations – statewise

S.No.	State/Uts	Fluoride affected habitations from 2005 to 2012						Reduction (since 2009)
		2005	2006	2009	2010	2011	2012	
1	Andaman and Nicobar	0	0	0	0	0	0	0
2	Andhra Pradesh	3,072	1,497	791	611	459	332	– 459
3	Arunachal Pradesh	0	0	0	0	0	0	0
4	Assam	0	660	517	248	192	80	– 437
5	Bihar	43	383	5,957	4,157	3,338	2,698	– 3,259
6	Chandigarh	0	0	0	0	0	0	0
7	Chattisgarh	17	17	51	18	188	313	262
8	Dadra and Nagar Haveli	0	0	0	0	0	0	0
9	Daman and Diu	0	0	0	0	0	0	0
10	Goa	0	0	0	0	0	0	0
11	Gujarat	4,341	2,563	450	186	111	57	– 393
12	Haryana	144	119	173	32	27	12	– 161
13	Himachal Pradesh	0	0	0	0	0	0	0
14	Jammu and Kashmir	0	0	0	0	2	2	2
15	Jharkhand	15	1,159	83	409	93	41	– 42
16	Karnataka	5,838	5,000	4,152	3,084	3,114	2,806	– 1,346
17	Kerala	34	34	172	109	109	106	– 66
18	Lakshadweep	0	0	0	0	0	0	0
19	Madhya Pradesh	3,764	3,282	4,720	2,906	2,651	2,485	– 2,235
20	Maharashtra	800	2,748	1,415	1,426	860	483	– 932
21	Manipur	0	0	0	0	0	0	0
22	Meghalaya	0	0	1	1	0	0	– 1
23	Mizoram	0	0	0	0	0	0	0
24	Nagaland	0	0	0	0	0	0	0
25	Orissa	504	794	700	639	475	398	– 302
26	Puducherry	0	0	0	0	0	0	0
27	Punjab	613	588	54	7	22	19	– 35
28	Rajasthan	8,992	6,992	11,775	10,788	10,724	7,130	– 4,645
29	Sikkim	0	0	0	0	0	0	0
30	Tamil Nadu	737	452	0	69	3	5	5
31	Tripura	0	40	0	0	0	0	0
32	Uttar Pradesh	1,046	2,077	1,768	530	204	144	– 1,624
33	Uttarakhand	0	0	2	1	1	2	0
34	West bengal	1,346	665	582	959	939	873	291
Total		31,306	29,070	33,363	26,180	23,512	17,986	– 15,377

are, though not greater in general, also linked to increased surveillance and improved reporting.

Based upon field experiences in rural areas on dealing with fluoride problems in drinking water and cases of fluorosis, constraints have also been identified and steps have been taken accordingly (Tables 3 and 4). Of all the constraints identified, states are still required to deal with the following three major issues, which despite efforts of the

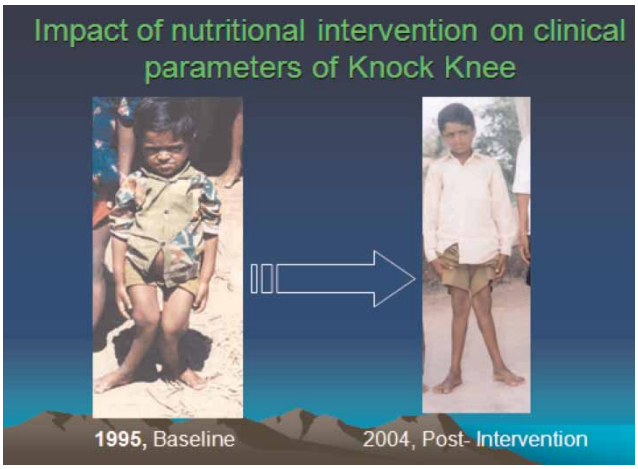

Figure 3 | Impact of nutritional intervention on clinical parameters of knock knee. *Source:* Presentation in International Workshop on Mitigating Effects on Geogenic Contamination, NEERI-Nagpur, 2012.

ministry, are still concerns to deal with the fluoride problem of drinking water and in checking cases of the emerging fluorosis problem:

1. Accurate and timely reporting of drinking water quality information on IMIS of the ministry;
2. Strengthening of the drinking water quality testing laboratories; and,
3. Reluctance to undertake innovative R&D projects/case studies in fluoride affected habitations by the concerned department of the states and lack of inter-departmental coordination.

States have primarily adopted treatment technologies such as the Nalgonda technique (co-precipitation), Prashanti

Table 3 | Constraints documented based on field experiences and remedial measures suggested

S.No.	Constraints	Remedial measures taken/suggested
I	Lack of awareness in villages about sources of fluoride, its adverse effect and the remedial measures. Poverty is also a prime reason as many rural peoples are not able to take nutritional diet to buffer the effect of fluorosis to some extent	IEC (Information, Education and Communication) activities to make rural people aware on adverse impact of excess fluoride and remedial measures are being undertaken by ministry (and also by external agency like UNICEF) by preparing audio/video spots and telecasting it on radio and TV channels
II	Inability of GPs to take up the problem timely with concerned department of the state and sometime apathy of the state officials dealing with fluoride problem in the states	Constitution of Village Water and Sanitation Committee (VWSC) in each village in all the States
III	Not reporting/under reporting/higher reporting of the data on online IMIS: It has also been observed that sometime the figures provided on IMIS does not reflect the ground reality	Each state has nominated one IMIS coordinator who is responsible for reporting the data on IMIS of the ministry and to update it appropriately. However, the fact still remains that entry made on IMIS of the ministry still does not reflect the ground realities and some of the entry is incorrect or not updated timely
IV	Non-functionality of the laboratories is one of the major problems to appropriately identify the problem and address it. Many laboratories in the states are not equipped with qualified manpower and appropriate instruments/equipments though funding is provided by GoI	Adequate funding has been provided to all the states under NRDWP for laboratory strengthening at state, district and sub-district level. Meeting of State Chief Chemists is taken at National level to review the status.
V	Overdependence of groundwater puts lot of stress on groundwater and it has been observed that sometimes even though surface water is available in nearby area, the same is not used by concerned state department due to availability of ground water based hand pumps. Artificial recharge/*in situ* dilution of fluoride, which is the best option in long run for addressing fluoride contamination in drinking water is not experimented extensively. Fluoride problem is tried to address only by installing fluoride removal plants.	Technology manual with specific reference to geogenic pollutants such as fluoride, arsenic etc. have been prepared and distributed to all the states. Compendium of R&D projects are also uploaded from time to time on website of the ministry to benefit the states

(*continued*)

Table 3 | continued

S.No.	Constraints	Remedial measures taken/suggested
VI	Industrial effluents/municipal and household waste discharge in surface water resources. The Environmental standards on discharge of industrial effluents, specified by Ministry of Environment and Forest (MoEF), Government of India, are not followed properly.	Villagers are educated on household discharge through various IEC (Information, Education and Communication) activities
VII	Long gestation period of water supply schemes: Sometime, even a single village drinking water supply scheme takes many years to complete and it aggravates the fluorosis problem in rural people	Status of new and old water supply schemes is reviewed by the ministry at Annual Action Plan (AAP) meetings and in State Secretary meetings at regular intervals
VIII	Chemical Field Test Kits (FTKs), which is provided to Gram Panchayats for testing drinking water quality, is not distributed appropriately or not used properly	Status is reviewed from time to time by officials from the ministry by conducting field visits
IX	Inadequate capacity of PRIs and local communities to manage water supply in a sustainable and professional manner	Financial incentive to states for handing over water supply schemes to Gram Panchayats has been provided
X	Lack of professional human resources in water quality, hydrology, geophysics, IEC in many states to assist in addressing water quality problems including fluoride	All states have been provided fund to set up WSSO (Water Sanitation and Support Organisation), District Water and Sanitation Mission (DWSM) and Block Resource Centre (BRC) and hire professionals (on contract) under NRDWP
XI	Fluoride ion meters which is one of the most reliable methods of fluoride testing is not available in many laboratory	States have been suggested to use fluoride ion meters for monitoring fluoride in drinking water but still fluoride ion meters are not used extensively, even in fluoride affected habitations
XIII	Operation & Maintenance of fluoride treatment units which are installed in hand pumps, is not included during installation resulting in non functionality of the fluoride treatment plant.	States have been suggested to install defluoridation plants with appropriate O&M
XIII	Lack of understanding of the symptoms of identify fluorosis by doctors in district hospitals due to the apparent similarity of skeletal fluorosis with arthritis.	Inter-Ministerial coordination and organising National and State level Workshops/Conferences etc.
XIV	States do not undertake innovative Research & Development projects on study of fluoride from different sources and on fluorosis mitigation.	States have been provided adequate fund under NRDWP. However, innovative R&D projects/case studies are not being undertaken by many States.
XV	[a]Many fluoride affected habitations are in 'critical' and 'over-exploited' blocks. However, some states are slow on recommending the blocks as 'over-exploited' and 'critical' fearing that this will hamper their growth. To avoid declaring as over-exploited blocks, states sometime restructure their already declared over-exploited blocks with safe or semi-critical block which bring the already over-exploited declared blocks into critical or in semi-critical blocks.	States have been requested to frame legal provisions to restrict ground water withdrawal in 'Critical' and 'Over-exploited' blocks and encourage recharging of groundwater in these blocks.

[a]Central Ground Water Board (CGWB), Ministry of Water Resources, has categorized availability of ground water in the country in four categories : 'Safe', 'Semi-critical', 'Critical' and 'Over-exploited'. The assessment units are categorized based on two criteria: (1) stage of ground water development, and (2) long-term trend of pre- and post-monsoon water levels. The criteria for categorization of assessment units, i.e. block is at Table 6. After notification from CGWB and its recommendation, concerned states may regulate groundwater withdrawal in 'critical' and 'over-exploited' blocks. The power to regulate ground water withdrawal rests with states as water is a state subject.

technique (Activated Alumina) and reverse osmosis for defluoridation. Other technologies have also been adopted, though to a lesser extent. The installation of solar energy-based electrolytical defluoridation plants by: (1) Maharashtra Government in Dongargaon, Chandrapur district; (2) Chhattisgarh Government in Usaravara village in Durg district; and (3) Madhya Pradesh in Sargapur village in Seoni District, using funds provided by Ministry of Drinking Water and

Table 4 | Criteria for categorization of assessment units

	Significant long term water level decline trend		
Stage of ground water development	**Pre-monsoon**	**Post-monsoon**	**Category**
< =90%	No	No	Safe
> 70% and <= 100%	No	Yes	Semi-critical
> 70% and <= 100%	Yes	No	Semi-critical
> 90% and <= 100%	Yes	Yes	Critical
> 100%	No	Yes	Over-exploited
> 100%	Yes	No	Over-exploited
> 100%	Yes	Yes	Over-exploited

Sanitation (GoI), has made it possible to address very high concentrations of fluoride in drinking water (up to 48 mg/L) in these remote villages where piped water supply is yet to be provided due to the unavailability of electricity. UNICEF has also provided funds for the installation of 16 such electrolytic defluoridation plants in Madhya Pradesh State. Wherever there is a problem of power shortage in remote fluoride affected areas, solar energy based electrolytical defluoridation plants are being installed. Such type of plants are installed primarily in some Left Wing Extremism (LWE)-affected districts in the country.

There are also examples whereby natural dilution of groundwater and fluoride concentration in groundwater has been reduced to safe limits. In Surendra Nagar district in Gujarat, 41 recharging structures (injection wells) of borewells have resulted in the dilution of fluoride levels to less than 1 mg/L in 21 villages. The Intervention of National Geophysical Research Institute (NGRI), Hyderabad during 2002–2005, in mitigating fluoride from 10 mg/L to less than 1.0 mg/L in Gurkhanipalle village in Chittor District, is worth mentioning. During the period between 2002 and 2005, NGRI carried out detailed geo-physical studies of the area and diverted the rainwater by constructing small checkdams/sub-surface dykes to rechargeable areas. This initiative allowed the rising of groundwater tables substantially and, in the process, fluoride was diluted naturally. Sustained recharging of ground-water has made it possible to keep the fluoride concentration in Gurkhanipalle village in safe limits even after expiry of the project duration.

Pro-activeness of GPs is an important aspect in dealing with the fluoride problem in rural areas in the Indian context. In some of the fluoride affected rural habitations in Andhra Pradesh State in the country, GPs themselves took steps to obtain RO plants installed in their respective Panchayats with technical assistance from private companies and financial assistance from donors. Under this arrangement, 70% of the cost was taken on loan from different donors (which was paid in instalments later on) and the remaining 30% cost was provided by Panchayats themselves at the beginning of installation of RO plants.

The successful model of fluorosis mitigation, in the Tilaipani and Hirapur villages in Mandla district in Madhya Pradesh State in the country, has helped not only to check further fluorosis cases in the villagers but has also helped to reduce the effect of fluorosis to a large extent (Figures 4 and 5). Measures adopted to reduce fluoride concentration in

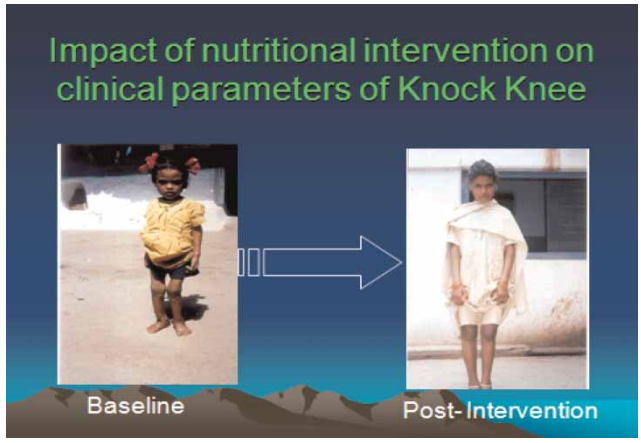

Figure 4 | Impact of nutritional intervention on clinical parameters of knock knee. *Source:* Presentation in International Workshop on Mitigating Effects on Geogenic Contamination, NEERI-Nagpur, 2012.

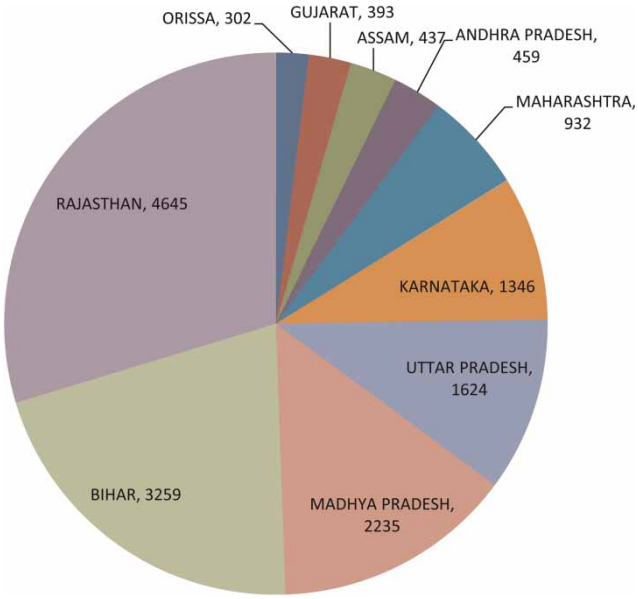

Figure 5 | Reduction of fluoride affected habitations in different states in India.

groundwater-based drinking water and tackle fluorosis problem in the Mandla district includes several initiatives such as:

- Providing an alternative water source for drinking water;
- Closing all hand pumps where fluoride concentration in ground water is higher than 1.5 mg/L;
- Providing surgical shoes for children under the age of 10 affected with fluorosis;
- Supplementing diet with calcium, vitamin C, D_3, iron etc.;
- Dietary counselling and health education;
- The use of Cassia Tora (Chakod Bhaji), which is naturally available in the affected villages and very rich in calcium (Chakma 2012).

While recovery of fluorosis is still debated, it offers the opportunity of intensive research on fluorosis mitigation.

There are also examples of highlighting the plight of the rural people suffering due to excess fluoride in drinking water in some remotely located and backward areas such as Garhwa in Jharkhand State by prominent newspapers such as the Hindustan Times in 2011. Following reports in the newspaper, experts working in the area of fluorosis prevention approached the ministry which resulted in constitution of an inter-disciplinary central team by the Ministry of Drinking Water and Sanitation. The central team visited the affected areas, assessed the extent of the problem and suggested remedial measures in coordination with the concerned officers of the state government. Such a coordinated initiative helped not only in accelerating the pace of tackling the fluoride problem in remote areas, but also motivated doctors and grassroot workers working in rural areas in raising awareness about fluoride mitigation.

It is also worth mentioning that private sector Indian companies as well as companies from other countries working in India (such as Merc, Hack, Orion, etc.) have contributed immensely to different state governments by either providing scientific assistance for water quality analysis or by taking up installation of fluoride removal plants and their operation and maintenance. NGOs (non-government organizations), as well as print media, have also both provided vital support in working and highlighting problem of excess fluoride in drinking water and in bringing up cases of fluorosis. Availability of adequate funds, the use of fluoride ion meters for accurate determination of fluoride, selection of the appropriate technology and community participation in operation and management of fluoride removal plants have proved major contributing factors in mitigating fluoride problems in affected habitations in India.

CONCLUSION

There are still 17,986 rural habitations in the country (as of 1 April 2012), which are affected with excess fluoride in drinking water and 111 lakh (11.1 million) people living in these habitations are affected by moderate to severe fluorosis. Though financial assistance to all the states by the GoI was started way back in 1973, the focus of the programme was to provide access to drinking water and increase the coverage of all rural habitations to at least 40 lpcd (litre per capita per day) of drinking water. Water quality issues started being taken up only after 2006 when the National Rural Drinking Water Quality Monitoring and Surveillance Programme was launched. However, with the initiatives taken by the GoI since 2006 onwards and the progress observed in many fluoride affected states in the country, it appears that India would be able to tackle all fluoride affected rural habitations in the next 4–5 years. The present status shows that all fluoride affected major states, such as

Rajasthan, Bihar, Madhya Pradesh, Uttar Pradesh and Karnataka, have shown remarkable progress in tackling fluoride affected habitations and in checking new cases of fluorosis. On the other hand, some of the states where the number of fluoride affected habitations remained very low in 2009, 2010 and 2011 (such as Jharkhand, Jammu and Kashmir, Uttarakhand etc.), have still not managed to address the fluoride problem completely due to lack of focus in the past. The overall review shows that sustained efforts on part of all concerned stakeholders, i.e. GPs, officials from the states and central government, scientific institutions, NGOs and international organizations are necessary to ensure that the remaining 17,986 fluoride affected rural habitations in the states are tackled for the fluoride and fluorosis problem completely in the coming 4–5 years.

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