Effect of Fluoride Contaminated Groundwater on Human Health in Fluorosis Endemic Areas

Abhyuday D Meghe[1], Deepak B. Malpe[2], Dhananjay C. Meshram[3]

[1]Chief Executive Officer, Acharya Vinoba Bhave Hospital, Datta Meghe Institute of Medical Sciences, [2]Professor, P.G. Department of Geology, R.T.M. Nagpur University, Nagpur, [3]Professor and Head, Department of Geology, Savitribai Fule Pune University, Pune

Abstract

Background: Fluorosis is an endemic health problem in twenty-five nations around the globe. **Objectives:** To correlate fluoride content of groundwater and health status of affected population and suggest remedial measures. **Methodology:** A cross-sectional research design is followed because people from different age groups were sampled, observations were made and skeletal examinations were conducted at a specified point of time. The study is conducted in Yavatmal and Chandrapur districts of Vidarbha region of Maharashtra State. Health related surveys were carried out in 54 villages from study area selected on the basis of high fluoride level in groundwater. **Result:** Out of these, 32 villages are selected from Yavatmal district having a population of 30320 and 22 villages from Chandrapur district with a population of 21581. Out of the total population of 51901 total 3268 subjects have been examined. Amongst these subjects 1760 were male (53.86%) and 1508 were female (46.14%). Out of the total 3268 subjects 2445 subjects included in the 'normal' grade, which does not show indications of skeletal fluorosis. It has been observed that as the concentration of fluoride increases the cases of 'normal' grade decreases. Out of the 360 subjects studied, about 102 (28.33%) subjects show radiological evidences of skeletal fluorosis. Mild radiological fluorosis was seen in 55, moderate in 21, severe in 17 and very severe radiological fluorosis in 9 subjects. **Conclusion:** Based on the outcome of the research work carried out in the study area, it is recommended that awareness among the people residing in the area about the protection & prevention of groundwater contamination from different sources, groundwater quality, its impacts on health, soil and plants should be created on priority basis.

Keywords: *Fluoride Contaminated Groundwater, Human Health, Fluorosis, Endemic Areas*

Background

Groundwater has become the major source of water supply for domestic, industrial and irrigation sectors of many countries. Fluorosis is an endemic health problem in twenty-five nations around the globe [1,2,3]. It is a conclusive fact that concentration of fluoride between 0.6 to 1.0 mg/L is essential in potable water to protect teeth decay and enhance bone development, while their higher concentration may lead to fluorosis [3]. Central Ground Water Board [4] and Groundwater Survey and Development Agency [5] carried out studies on occurrences of fluoride in groundwater in Maharashtra state which falls under second category, where 40 to 70 % of the districts are affected. The endemic districts are Bhandara, Chandrapur, Nanded, Aurangabad and Yavatmal, where up to 13.4 mg/L fluoride has been reported [4]. Though work pertaining to groundwater quality, hydrogeology, groundwater resource estimation, development and management have been carried out in parts of study area, detailed health related studies including effect of high concentration of fluoride in groundwater on human health have not so for been carried out in the present area. Therefore, objectives of

Corresponding Author:
Dr Abhyuday D Meghe
Chief Executive Officer
Acharya Vinoba Bhave Hospital
Datta Meghe Institute of Medical Sciences

the present investigations to correlate fluoride content of groundwater and health status of affected population and suggest remedial measures.

Methodology

In the present study, effect of fluoride on human health is studied and relationship with skeletal and radiological findings is explored. A cross-sectional research design is followed because people from different age groups were sampled, observations were made and skeletal examinations were conducted at a specified point of time.

Study Setting and Location: The study is conducted in Yavatmal and Chandrapur districts of Vidarbha region of Maharashtra State. The study includes Ghatanji, Kelapur, Maregaon, Wani talukas from Yavatmal District and Warora, Bhadrawati and Chandrapur talukas from Chandrapur district. Prior to the commencement of the study, permission to conduct the research investigations was sought from the Institutional Ethical Committee, Datta Meghe Institute of Medical Sciences (Deemed to be University). Following considerations were taken into account during the planning and execution of the study. The data of fluoride level in groundwater received from Groundwater Survey and Development Agency (GSDA) for study area have been used.

In the present work, BIS recommendations have been used for the desirable level of fluoride in groundwater (1mg/L) as the study area comes under semi-arid climate and surveys have been carried out in rural and tribal part of Yavatmal and Chandrapur districts where most of the population is farm laborers or working laborers in quarries or mines and their per day consumption of water is 3 to 4 liters/day/person. In view of this fluoride level in groundwater has been divided into four groups namely ≤1mg/L, 1.01-2.00mg/L, 2.01-4.00mg/L, >4.01 mg/L. Safe level of fluoride in the potable drinking water has been considered as 0.5mg/L desirable and 1.0 mg/L as maximum allowable concentration [6].

Health related surveys were carried out in 54 villages from study area selected on the basis of high fluoride level in groundwater. Out of these 32 villages are selected from Yavatmal district having a population of 30320 and 22 villages from Chandrapur district with a population of 21581. Out of the total population of 51901 total 3268 subjects have been examined. These

54 villages are selected Primary Health Centre (PHC) wise and total 2 villages are selected from 26 PHC, while from Durgapur and Guggus PHC of Chandrapur taluka, one village each is selected. From each taluka two villages are selected having fluoride level ≤1mg/L, 1.01 - 2.00mg/L, 2.01 - 4.00mg/L, >4.01 mg/L. In Chandrapur taluka >4 mg/L fluoride level is not present in the groundwater and therefore two villages from this category have not been selected.

RECRUITMENT AND SAMPLING PROCEDURE

A nonprobability convenience sampling technique was used in the study, as the samples were restricted to a part of the population that was readily available and true random sampling would have been difficult to achieve due to time, cost, and transportation limitations. To start with, 3602 potentially eligible subjects were identified which were examined for eligibility. Out of this, 3268 subjects were confirmed eligible and were included in the study. All these 3268 subjects gave consent to participate in the study and so were investigated and their data was analysed. 334 subjects were excluded from the study because they either met exclusion criteria or were not willing to participate in the study because of social reasons or lack of availability of time.

Data Collection Procedures

The participants were evaluated according to pre-designed protocol. They were explained the purpose of the study and were requested to participate in it. Each participant was interviewed and examined. The purpose of the questions was to extract a brief medical history and to identify pre-existing risk factors for skeletal deformity. The formulation of the questions was same for all the participants to ensure reliability.

SKELETAL INVESTIGATIONS

In the present work, during the clinical examination, base line data was collected using the proforma, while incidence of skeletal fluorosis has been assessed on the basis of physical tests designed for assessing the pain in the joints [2]. Classification of skeletal fluorosis based on the clinical and radiological examinations given by Teotia, M. and Singh, K.P. [6] has been used. Out of the total 3268 subjects studied, 360 subjects were subjected to radiological investigations. In the present case, sample size was calculated by taking confidence level of 99%, confidence interval of ± 2.58 and population 51901. The sample size was calculated as 2532.

Results and Discussion

In the present work health related surveys were carried out in 54 villages selected on the basis of fluoride level in groundwater. The villages surveyed are 32 from Yavatmal district and 22 from Chandrapur district. Out of the total population of 51901 from these 54 villages, total 3268 subjects have been finally selected and examined. Amongst these subjects 1760 were male (53.86%) and 1508 were female (46.14%).

The fluoride level in groundwater has been divided into four groups namely first ≤1mg/L, second 1.01-2.00mg/L, third 2.01-4.00mg/L and fourth >4.0 mg/L. The participants are also distributed into three age groups. In the first group (≤18years) the subjects included are 1099 (33.63%). In the second age group (19 - 60 years) 1075 (32.89%) subjects and in the third age group (>60 years) total subjects included are 1094 (33.48%) (Table 1.1).

Table 1.1 Distribution of studied subjects as per age group and F^- level in groundwater

Age Group	F^- level in groundwater												Total	%
	≤1.00 mg/L			1.01 - 2.00 mg/L			2.01 – 4.00 mg/L			> 4.00 mg/L				
	M	F	Total	M	F	Total	M	F	Total	M	F	Total		
≤18	139	129	268	158	123	281	149	110	259	158	133	291	1099	33.63
19-60	137	119	256	146	123	269	135	136	271	151	128	279	1075	32.89
>60	135	128	263	145	132	277	148	119	267	159	128	287	1094	33.48
Total	411	376	787	449	378	827	432	365	797	468	389	857	3268	100.0

Relationship of Skeletal Fluorosis with fluoride Level in Groundwater

Relationship of skeletal fluorosis with fluoride level in groundwater used for drinking purpose has also been studied and their details are given in table 1.2. The concentration of F in drinking water has been divided into 4 groups namely first (≤1 mg/L), second (1.01-2.00 mg/L); third (2.01-4.00 mg/L) and fourth (>4.0 mg/L).

As discussed earlier, out of the total 3268 subjects 2445 subjects included in the 'normal' grade, which does not show indications of skeletal fluorosis. It has been observed that as the concentration of fluoride increases the cases of 'normal' grade decreases. The remaining 823 subjects show symptoms of skeletal fluorosis. Present study showed that out of the total 823 subjects, 431 show the symptoms of 'mild' grade, where 60 subjects are from ≤1mg/L group. This could be due to long time of exposure to F- intoxication and change in source of drinking water. Earlier they were using the drinking water with high concentration of fluoride and now shifted to the drinking water source having low concentration of fluoride.

Table 2: Relation of skeletal fluorosis with F- level in drinking water

Grade of Fluorosis	F. Level In Groundwater Used for drinking Purpose(mg/L)									
	<=1.0	%	1.01 – 2.00	%	2.01-4.00	%	>4.0	%	Total	%
Normal	727	29.73	688	28.14	592	24.21	438	17.92	2445	74.8
Mild	60	13.9	71	16.47	98	22.7	202	46.87	431	13.2
Moderate	-	-	36	18.46	49	25.13	110	56.41	195	6.0
Severe	-	-	21	15.55	42	31.11	72	53.34	135	4.1
Very Severe	-	-	11	17.74	16	25.81	35	56.45	62	1.9
Total	787		827		797		857		3268	100.0

Study by Teotia, M. and Singh, K.P.[6] has shown that the clinical recovery of skeletal fluorosis is partially possible with supplementation of vitamin D and calcium. But in the present case as the subjects are from the rural and backward area where the food is habitually deficient in vitamin D and calcium no clinical recovery has been observed. Perusal of table 1.2 shows that as the fluoride concentration in the drinking water source increases, the cases of skeletal fluorosis increases. In the present case in all the grades (mild, moderate, severe and very severe) there is an increase in the number of cases of skeletal fluorosis from 'mild' to 'very severe' as the fluoride concentration in drinking water source increases. This has also been observed by Nirgude et al[7] during their studies in Gadag and Bagalkot districts of Karnataka, Punjab, Nalgonda and Rajasthan areas respectively.

Surprisingly, in the areas where fluoride levels of drinking water is not very high and is in the range of 1-2 mg/L, the cases of skeletal fluorosis have been observed. The proposed possible mechanisms for such severe manifestations may be: (a) high atmospheric temperatures (115-116°F) during summer months, (b) hard physical labor activity, (c) poor nutrition, deficient in calories and vitamin C. Similarly, it is now established that diseased kidneys cannot handle fluoride excretion leading to F- toxicity and development of skeletal fluorosis even while consuming low levels of F- in drinking water supplies [8].

Radiological Studies

In the present work, classification of skeletal fluorosis based on the radiological examinations given by Teotia, M. and Singh, K.P. [6] has been used (Table 6.5). On the basis of radiological studies they suggested mild, moderate, severe and very severe grades depending on the basis of intensity of the fluorosis.

Out of the total 3268 subjects studied, 360 subjects are subjected to radiological investigations at Acharya Vinoba Bhave Rural Hospital, Sawangi Meghe, Wardha. Out of the 360 subjects studied, about 102 (28.33%) subjects show radiological evidences of skeletal fluorosis. Mild radiological fluorosis was seen in 55, moderate in 21, severe in 17 and very severe radiological fluorosis in 9 subjects. In general, in male the radiological fluorosis is more as compared to female. In 'moderate' and 'very severe' grades the radiological fluorosis in female is marginally more as compared to the male subjects (Table 1.3).

Table -3: Relation of radiological fluorosis with sex in studied subjects

Grade of Fluorosis	Male	%	Female	%	Total	%
Normal	147	71.02	111	72.55	258	71.67
Mild	34	16.42	21	13.72	55	15.28
Moderate	11	5.31	10	6.54	21	5.83
Severe	10	4.83	7	4.58	17	4.72
Very Severe	5	2.42	4	2.61	9	2.50
Total	207	100	153	100	360	100

Conclusion

Based on the outcome of the research work carried out in the study area, it is recommended that awareness among the people residing in the area about the protection & prevention of groundwater contamination from different sources, groundwater quality, its impacts on health, soil and plants should be created on priority basis.

Creating environmental awareness among the people about the habit of safe drinking water, side effects of drinking high fluoride rich groundwater, improving oral hygiene conditions and handling of defluoridation instruments is essential in effective mitigation of fluorosis.

Regular health surveys and Periodic monitoring should be conducted in the affected areas to assess the health impacts of high concentration of fluoride and NO_3- present in groundwater, especially in infants and children residing in the area.

More emphasis may be given to intake of calcium and phosphorous rich food as it helps in reducing the absorption of fluoride by intestine and also reduces the rate of accumulation of fluoride in human body.

As abundance of fluoride is more in deep aquifers (bore wells) compared to shallow aquifers (dug wells), the groundwater from shallow aquifers are safer and should be preferred for drinking purpose, if nitrate and other contaminants are within the safe limits.

Water quality management in the area should be carried out considering the hydro-geochemical conditions existing in the area and influence of geogenic and anthropogenic factors on physico-chemical characteristics of groundwater.

Defluoridation technique like Nalgonda, reverse osmosis, activated alumina and other techniques may be adopted in areas where no alternative source is available with the involvement of community in operation and maintenance. Recharging centres for the household activated alumina filters for defluoridation of groundwater shall be set up at each affected village.

The planners, policy-makers and public should become more aware of programme concerned with the sustainable management of groundwater quality.

Integrated fluorosis mitigation approach in the form of dilution of groundwater through artificial recharge, nutritional supplement through food intake and use of cost-effective and environmentally friendly adsorption based defluoridation techniques should be adopted in dealing with fluorosis problems existing in the area.

Conflict of Interest: None

Funding: Datta Meghe Institute of Medical Sciences

Ethical Approval: Obtained from Institutional Ethical Committee of DMIMS, Wardha.

References

1. Vaish AK, Gyani KC. Management of fluoride contaminated drinking water–A successful approach of defluoridated at domestic level in Dungarpur District of Rajasthan''Proceeding of Int. workshop on. Fluoride in drinking water''organized by Govt. of Madhya Pradesh at Bhopal. 2001 Jan:22-4.
2. Susheela A.K. A treatise on fluorosis. Revised 3rd edition 2007. Fluorosis Research and Rural Development Foundation. Delhi – India
3. Rao NS. High-fluoride groundwater. Environmental monitoring and assessment. 2011 May 1;176(1-4):637-45.
4. CGWB (2013) Groundwater information Yavatmal district, Maharashtra. Central Ground Water Board, Ministry of Water Resources, Government of India, 23p.
5. GSDA and CGWB (2005) Dynamic groundwater resources of Maharashtra as on March 2004. Groundwater Surveys and Development Agency, Govt. of Maharashtra and Central Ground Water Board, Ministry of Water Resources, Govt. of India, 332p.
6. Teotia SP, Teotia M, Singh KP. Highlights of forty years of research on endemic skeletal fluorosis in India. In4th International workshop on fluorosis Prevention and Defluoridation of water 2004 Mar 2 (pp. 107-125).
7. Nirgude AS, Saiprasad GS, Naik PR, Mohanty S. An epidemiological study on fluorosis in an urban slum area of Nalgonda, Andhra Pradesh, India. Indian journal of public health. 2010 Oct 1;54(4):194.
8. Reddy DR. Neurology of endemic skeletal fluorosis. Neurology India. 2009 Jan 1;57(1):7.