Impact of Community Defluoridation on a Village Endemic for Hydric Fluorosis in Rural Karnataka, India

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Abstract

Introduction: Excessive intake of fluorides can lead to the development of fluorosis, a serious public health issue in India. The objective of this study was to assess the impact of community defluoridation in preventing fluorosis in Kaiwara village. **Methodology:** This community interventional trial was conducted in Kaiwara village, Karnataka, after obtaining ethical clearance. The study included 903 participants; preintervention data were collected by recording the required parameters. The postinterventional study was carried out 2 years after installing the reverse osmosis plant. Data from pre- and post-intervention study were compared. **Results:** Dean's index showed no significant change in the pre- and post-intervention period for its various categories ($P = 0.543$). However, the mean urine fluoride levels were found to be decreased significantly (Wilcoxon Signed-Rank test, $P < 0.001$). **Conclusion:** This study demonstrates the importance of providing defluorinated water to the village population as a potential solution for fluorosis.

Keywords: Community health services, fluorides, fluorosis, public health, reverse osmosis

INTRODUCTION

Fluorosis is an endemic disease that has affected 70 million individuals and is prevalent in 22 states of India, particularly in parched parts of the country.[1] The process of removal of harmful fluoride from water is called defluoridation.[2] The world's ground fluoride stores are estimated to be 85 million tons, of which almost 12 million tons are in India.[3] As Kaiwara, a part of Chikkaballapur district, Karnataka, has no alternate source of water, it is dependent solely on groundwater through bore wells for its water supply.[4]

Advanced defluoridation procedures have commenced in India. Nalgonda technique is one of them, which utilizes alum and lime combination in a two-step process. The process has disadvantages like the undesirable taste of treated water, high-cost maintenance, temperature, and the presence of silicate ions.[5] Reverse osmosis (RO) established by Jean-Antoine Nollet in 1748 is presently the most effective method in terms of fluoride removal.[6]

In a study conducted by Arvind *et al.* in Kaiwara and the villages under Kaiwara Primary Health Center, it was found that of the 1544 children examined, 42.1% and 8.4% had dental fluorosis and genu valgum, respectively,[4] which clearly proved increased consumption of fluoride. This study is aimed to assess the impact of community defluoridation in Kaiwara, a village endemic for hydric fluorosis.

METHODOLOGY

This was a community intervention trial carried out at Kaiwara village, Chikkaballapur district, Karnataka, from January 2011 to December 2014. After obtaining ethical clearance, a preliminary count and numbering of houses were done. A baseline study survey was performed in 3003 participants who aged ≥ 3 years and were permanent residents of Kaiwara village. The flow chart for subject enrollment and post-intervention analysis is presented in Figure 1. Demographic details such as age, education, and occupation were collected from the head of the family using the direct interview method and recorded in the pretested structured protocol. Signs of

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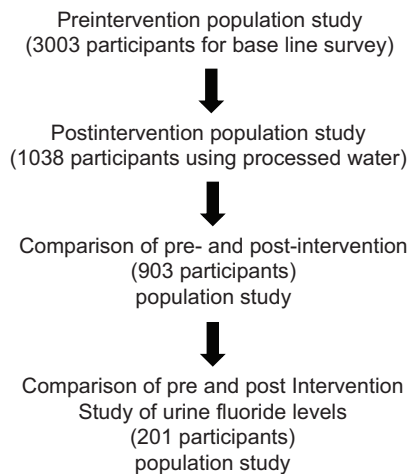**Access this article online**

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Preintervention population study
(3003 participants for base line survey)

↓

Postintervention population study
(1038 participants using processed water)

↓

Comparison of pre- and post-intervention
(903 participants)
population study

↓

Comparison of pre and post Intervention
Study of urine fluoride levels
(201 participants)
population study

Figure 1: Participants in various stages of the community intervention trial

fluorosis were collected by using the illustration chart published by Susheela.[7] Detection of dental fluorosis was done using the Dean's Index (Fluorosis Index). Genu valgum was measured with the help of a divider and a plastic scale by measuring the distance between the medial malleoli at the ankle when the subject stands or lies down with the knees touching each other, and was accordingly graded as mild (<5 cm), moderate (5–10 cm) and severe (>10 cm). Levels of fluoride in drinking water were recorded using ion chromatography. Iodine deficiency disorder was identified by clinical examination using the WHO criteria. One hundred participants were randomly enrolled for the preintervention study (urine analysis). These tests were piloted and used as a part of the protocol.

After the preintervention study, details about infrastructure available (electricity, water supply, workforce) were collected, and considering the cost, the community was willing to afford, the RO plant was installed. The Council for Scientific and Industrial Research, Government of India, offered a 40,000 L capacity custom made RO unit for community defluoridation to pilot in the village. The Kaiwara Gram Panchayath granted land for the installation of the RO plant. The money collected by selling the processed water was used to run and maintain the RO plant. The cost of Rs 5/-per household was calculated considering Rs 3/-towards electricity and water charges for running of the RO Plant, maintenance charges for the RO plant (filter replacement, pump repair, etc.,) and salaries for the watchman, plant operator, and electrician. Rs 2/-was further collected towards payment for the water distribution vehicle maintenance and petrol for the running of the vehicle as well as salary for the water distributer. This processed water was supplied to all the subjects as drinking water and for cooking purpose.

Every 6 months, the fluoride level of the processed water was assessed by the ion analyzer. After 2 years, postintervention study was carried out on 250 households that included 1038 subjects who regularly used the processed water and were available for examination. The same parameters of the pre-intervention study were applied. Of the 1038

subjects available, 903 participants who matched by names, address, and age with the pre- and post-intervention analysis were considered for comparison. Out of 903 participants, 101 participants were randomly enrolled for the postintervention urine analysis and matched for age and sex with the pre-intervention study participants. Urine fluoride levels were estimated using an ELICO-LI-126 fluoride ion analyzer.

RESULTS

It was observed that among 903 participants compared, 60.5% of the study participants in the preintervention and 60.6% in the postintervention remained normal, whereas 17.9% of study participants in the preintervention and 18% of participants in the postintervention showed signs of fluorosis. The difference in age and gender in the pre- and post-intervention groups was noted to be insignificant ($P = 0.423$: Female and 0.287: Male), as presented in Table 1. The Deans Index showed no significant change in the pre- and post-intervention among its various categories ($P = 0.543$), as shown in Table 1.

During preintervention, 2.2% of total of 903 participants could not touch their toes, whereas, in the postintervention, only 0.2% of participants could not touch their toes. This difference was found to be statistically significant ($P < 0.001$), as shown in Table 1.

In the preintervention time, it was observed that 0% of subjects (males and females) were in the safety zone (<0.1 ppm); however, postintervention, 31.2% of females and 18.9% of male participants had entered the safety zone. Differences in urine fluoride levels in females between pre- and post-intervention were found to be statistically significant ($P < 0.01$). Urine fluoride levels were found to be high in the age group of 20–39 years, followed by 40–59 years [Table 2].

Before intervention, water samples were collected from four main tanks. The measures of all the components in each tank were noted, and the average was calculated, which was beyond the safety limit, 2.07 mg/l of fluoride. Postintervention, water samples were collected from the respective houses, and levels of fluoride were found to be within safety limits (<0.01), as shown in Table 3.

DISCUSSION

Fluorine is the 13th most abundant element that is naturally introduced into the environment through water and air.[8] Increased levels of fluorine intake will cause dental and skeletal fluorosis, and reducing the levels of fluoride in drinking water (de-fluoridation) will prevent fluorosis.[9] In a study by Kumar *et al*.,[10] the severity of dental fluorosis was assessed by Dean's index and was considered as a gold standard; accordingly, in the present study, Deans index was used for assessing fluorosis. It was observed that 17.9% of study participants in the pre-intervention and 18% of participants in the postintervention showed signs of fluorosis, included

Table 1: Characteristics of participants during pre- and post-intervention

Gender	Preintervention, *n* (%)		Postintervention, *n* (%)	
	Females	Males	Females	Males
Age (years)				
3-19	13 (28.3)	17 (31.5)	10 (15.6)	8 (21.6)
20-39	19 (41.3)	15 (27.8)	28 (43.8)	13 (35.1)
40-50	10 (21.7)	14 (25.9)	15 (23.4)	8 (21.6)
60 and above	4 (8.7)	8 (14.8)	11 (17.2)	8 (21.6)
Total	46 (100)	54 (100)	64 (100)	37 (100)
Deans Index				
Normal	546 (60.5)		547 (60.6)	
Questionable	195 (21.6)		193 (21.4)	
Very mild	86 (9.5)		87 (9.6)	
Mild	45 (5)		46 (5.1)	
Moderate	23 (2.5)		23 (2.5)	
Severe	8 (0.9)		7 (0.8)	
Total	903 (100)		903 (100)	

Genu valgum criteria	Capable	Not capable	Total	Capable	Not capable	Total
Toe touching	883 (97.8)	20 (2.2)	903 (100)	901 (99.8)	2 (0.2)	903 (100)
Chin to chest	898 (99.4)	5 (0.6)	903 (100)	903 (100)	0 (0.0)	903 (100)
Hands behind the head	890 (98.6)	13 (1.4)	903 (100)	903 (100)	0 (0.0)	903 (100)

Table 2: Study population distribution analysis in pre- and post-intervention

Age (years)	Grade prevalence	Preintervention (%)	Postintervention (%)	Total (%)
3-19	<0.1 ppm	0 (0.0)	5 (27.8)	5 (10.4)
	0.1-0.5 ppm	1 (3.3)	12 (66.7)	13 (27.1)
	0.5-2.00 ppm	18 (60.0)	0 (0.0)	18 (37.5)
	>2.00 ppm	11 (36.7)	1 (5.6)	12 (25.0)
	Total	30 (100)	18 (100)	48 (100.0)
	Mean urine fluoride levels	1.65±0.87	0.19±0.13	*P*<0.001
20-39	<0.1	0 (0.0)	12 (29.3)	12 (16)
	0.1-0.5	4 (11.8)	18 (43.9)	22 (29.3)
	0.6-2.00	24 (70.6)	6 (14.6)	30 (40)
	>2.00	6 (17.6)	5 (12.2)	11 (14.6)
	Total	34 (100)	41 (100)	75 (100)
	Mean urine fluoride levels	0.99±0.43	0.26±0.31	*P*<0.001
40-59	<0.1ppm	0 (0.0)	7 (30.4)	7 (14.9)
	0.1-0.5ppm	1 (4.2)	12 (52.2)	13 (27.7)
	0.5-2.00ppm	17 (70.8)	3 (13.0)	20 (42.6)
	>2.00ppm	6 (25.0)	1 (4.3)	7 (14.9)
	Total	24 (100)	23 (100)	47 (100.0)
	Mean urine fluoride levels	1.47±0.94	0.45±0.89	*P*<0.001
60 and above	<0.1 ppm	0 (0.0)	3 (15.8)	3 (9.7)
	0.1-0.5 ppm	1 (8.3)	10 (52.6)	11 (35.5)
	0.5-2.00 ppm	8 (66.7)	5 (26.3)	13 (41.9)
	>2.00 ppm	3 (25.0)	1 (5.3)	4 (12.9)
	Total	12 (100)	19 (100)	31 (100.0)
	Mean urine fluoride levels	1.31±0.91	0.55±0.73	*P*<0.001

in the very mild, mild, moderate, and severe forms of dental fluorosis. Dean's Index showed no significant change pre- and post-intervention among its various categories (*P* = 0.543). There was a statistically significant difference (*P* < 0.01) in the population that could not touch their toes pre- and post-intervention. Similar findings were seen with chin-to-chest

and hands-behind-the-head test, but the results were not statistically significant. Susheela[7] in her book revealed that with sustained use of defluoridated water, rigidity, stiffness, and restricted movement in the backbone, knee, neck, and shoulder reduced gradually in fluorosis patients. Fluorosis was observed more in the age group of 20–39 years. It was noted

Table 3: Complete chemical analysis of baseline water available at Kaiwara village before and after intervention

Tests performed	Results	
	Before intervention (mg/l)	After intervention (mg/l)
Turbidity as (NTU)	0.0	0.0
pH value	25.15	7.40
Dissolved solids	1711.2	70
Total hardness	958	10
Calcium	220.4	4.8
Sodium	196.6	-
Potassium	17.605	-
Sulfate	314.15	0.01
Alkalinity	819	48
Chlorides	264.5	10.70
Iron	0.26	0.01
Fluoride	2.07	0.01
Nitrate	19.6	0.60
Physical appearance	Clear	Clear

NTU: Nephelometric Turbidity Units

that the majority of participants studied during preintervention had urine fluoride levels >0.5 ppm while the majority of participants studied in the postintervention had urine fluoride levels below 0.5 ppm.[11-13] Adult urinary fluoride levels determined by Toth *et al.* showed increased signs of fluorosis after the consumption of fluoridated milk.[14] A study done by Das and Mondal in West Bengal found a strong positive correlation between water fluoride levels and urinary fluoride levels ($r = 0.513$, $P < 0.01$) and similar results were seen in this study.[15] It was observed that in all age groups and in both genders, there was a statistically significant reduction in the urine fluoride levels before and after the intervention, similar to Chen *et al.*[16]

This study has a few limitations. First, one-to-one pre- and post-intervention comparison of urine fluoride levels was not done due to the unavailability of the same subjects in both the pre- and post-intervention stages. Second, pregnant women and babies may be included for future follow-up studies as change in DF can be expected only among children conceived and born in the postdefluoridation phase.

CONCLUSION

This study demonstrates the importance of providing processed or de-fluoridated water to the population in endemic areas by setting up a sustainable community de-fluoridation RO plant, a potential solution for preventing hydric fluorosis.

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