International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 4 Issue 1 || January 2015 || PP.58-73

Fluoride Consumption in Endemic Villages of India and Its Remedial Measures

[1]Saxena K. L. (Dr.) and [2]Sewak R.
***Safe Water Network India**, The Centrum, Room 1, TB-3, 3rd Floor, 369-370,*
Main Mehrauli-Gurgaon Road, Sultanpur, New Delhi – 110030 INDIA

ABSTRACT: *In 2009, out of 639 districts in India, the fluoride-affected ones were 229 and 218, as per RGNDWM & CGWB respectively. Later in 2012, the number increased to 267 as per MoWR. The cereals, pulses and vegetables grown in fluoride-endemic areas have shown higher contents of fluoride when compared with those grown in the areas where fluoride level is 0.1 – 0.5 mg/L. Amongst other vegetables, Spinach has the highest fluoride content (29.15 mg/kg). The milk of cow, heifer and goat also have fluoride content ranging from 0.41 to 6.87 mg/L, whereas, in non-fluoride affected areas, the cow milk has 0.1 mg/L of fluoride in it. Drinking tea also contributes to fluoride ingestion between 0.3 and 1.9 mg/L per day. Toothpaste and dentifrice also substantially contribute to the daily intake of fluoride. RO plants of 1,000 liters capacity per hour installed in select 32 fluoride-affected villages of Warangal district of Telangana, where fluoride concentration in ground water varied from 0.9 mg – 1.8 mg/L. The treated water has 0.1 – 0.4 mg/L fluoride showing 90% removal efficiency. The pH is lowered in treated water and pH dosing is installed to correct pH. The water is disinfected with chlorine and residual chlorine of 0.2 mg/L is maintained. The storage container with a narrow mouth of 50 mm is being supplied to households to avoid recontamination of treated water due to dipping with dirty cups or unclean hands. The maximum contaminant ingress of fluoride based on 0.05 mg/kg/day is 2.5 mg/day for an average 50 kg adult in India and to achieve this level in hot climate of India where Maximum Mean Temperature of Region is over 32˚C, and fluoride ingestion through food, tea, milk and toothpaste leaves little, if any, to be provided with water. It is suggested that the fluoride level of 1 mg/L as requirement (acceptable) and 1.5 mg/L as permissible limits as per BIS 10500 be reviewed downwards considering the ever increasing fluoride-affected regions in India.*

KEYWORDS : *fluoride; food; tea; milk; aluminium; reverse osmosis; fluorosis; affected districts*

I. INTRODUCTION

Safe Water Network India works toward testing and creating solutions for providing affordable drinking water to communities that have health issues relating to water quality problems. It was observed during the interaction with the villagers in Warangal district that they were suffering from dental fluorosis, skeletal fluorosis, non-skeletal fluorosis and other associate diseases caused due to excessive fluoride ingestion. The water tests did not show the levels of fluoride higher than 2 mg/L. With the experience and literature survey, we have gained an understanding that the fluoride ingestion is caused not only through water but also through food, tea, toothpaste, milk, etc. The fluoride ingestion is roughly in the ratio of 30 to 40% from food and 60 to 70% from water as per prior literature surveys. Therefore, to control the overall intake of fluoride, the only controllable aspect was water. The permissible consumption of fluoride is recommended to be 0.05 mg/day/kg of body weight for maintaining good health. The average weight of rural Indian is about 50 to 60 kg. Thus per day permissible consumption of fluoride is about 2.5 to 3 mg. The scientific data about the fluoride contents in food indicates that about 2 to 3 mg fluoride is consumed from food, milk and tea alone leaving very little scope for the consumption through water. As it is very difficult to isolate the food having high fluoride content in the daily food chain, it was therefore decided to install reverse osmosis plants for water defluoridation. Within one year of installation of Reverse Osmosis (RO) plants, the interaction with the communities started giving positive signs of general improvement in health and wellbeing due to reduction in incidences of waterborne diseases and other health related problems of the villagers.

Fluoride Content in Groundwater: In India, the fluoride content of groundwater varies significantly and the factors that control such concentration include the presence of accessory minerals, fluorite and apatite in the rock mineral assemblage wherein the groundwater is stored, as well as the environmental factors such as precipitation and evaporation. The status of fluoride in India is given in Table 15, 30. Different states are arranged in descending order with the highest value of fluoride of 48 mg/L in Haryana and the lowest in Jammu and Kashmir of 4.21 mg/L. The problem has reached alarming proportion affecting at least 19 states of India.

Andhra Pradesh, Gujarat and Rajasthan have 50 to 100% districts affected by fluoride, whereas, Bihar, Jharkhand, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Punjab, Tamil Nadu and Uttar Pradesh have 30 to 50% districts affected. Chhattisgarh, Delhi, Jammu and Kashmir, Kerala and West Bengal have less than 30% of districts affected.[30] It is estimated that about 66.62 million people are at risk of consuming fluoride-contaminated water in 19 states of India including 6 million children below the age of 14 years (UNICEF, 1999).[37] It is further estimated that Indian population of 18,197,000 are affected with dental fluorosis and 7,889,000 with skeletal fluorosis. The study further indicates skeletal fluorosis has attributed Disability-Adjusted Life-Years (DALY) of 17 per 1000 population in India[7]. Safe Water Network commissioned a study with its partners that included national data collation on water quality, health, socio-economic indicators, Census as well as sanitation in one database called 'Jalstat'. Figure 1, derived from Jalstat, shows affected districts as per available data in RGNDWM[*] (2009) and CGWB[†] (2009). The names of the identified districts where fluoride in ground water was above 1.5 mg/L as per Jalstat and MoEF[‡] are listed in Table 2. The percent affected districts in every state are also given in Table 3. The names of affected districts with high fluoride concentration and the percentage of districts in each state (sorted on per cent affected districts as per CGWB) are listed in Table 2. The states or union territories not mentioned in the table did not either have representative data in RGNDWM or CGWB database in 2009 or were not affected by fluoride in groundwater samples. It can be seen from the data that out of 639 districts, 229 districts are affected by excessive fluoride as per RGNDWM and 218 districts are affected according to CGWB data. As per RGNDWM, Andhra Pradesh, Jharkhand, Karnataka, Maharashtra and Rajasthan are districts which have over 50 to 100% affected districts with high fluoride and as CGWB, Andhra Pradesh, Chhattisgarh, Delhi, Gujarat, Karnataka, Punjab, Rajasthan and Tamil Nadu have between 50 to 100% affected districts. As per 1999 UNICEF data, only three states were found to be in the 50 to 100% range whereas the affected states in 2009 have now increased to five as per RGNDWM and eight as per CGWB data. The MoWR[§] reported that 267 districts are affected by fluoride in 2012.[34] In the view of the widespread quality challenges, there is need for distributed off-grid solutions suited to local quality challenges.

Fluoride Content in Food: The fluoride content of food items is given in Table 4. The fluoride levels of food depend upon the nature of soil and quality of water used for irrigation and thus, varies from village to village and town to town. The data of Sengupta & Pal[33]and Lakdawala & Punekar[20] can be taken as control data as the irrigation water had fluoride levels of 0.4 mg/L and 0.15 to 0.48 mg/L at Kolkata and Mumbai respectively. Bhargava & Bhardwaj[6] and Gautam et al.[14] presented data from the villages of Tonk District and Nagaur District of Rajasthan respectively. The fluoride contents of cereals and vegetables vary from 0.45 to 5.98 mg/kg and 4.25 to 29.15 mg/kg respectively in Tonk district of Rajasthan where water used for irrigation has fluoride content from 1.5 to 11.82 mg/L. Similarly, the fluoride value in cereals, pulses and vegetables were found to vary from 1.88 to 18.9 mg/kg, 8.34 to 10.77 mg/kg and 8.34 to 24.88 mg/kg in Nagaur district where irrigation water has fluoride concentration of 1.57 to 13.83 mg/L. The fluoride values of all food items grown in endemic regions of fluoride has very high concentration of fluorides when compared with the control data where irrigation water has less than 1 mg/L fluoride content. Raghavachari et al.[26] presented data from Palamau district of Jharkhand, where food is grown with water having fluoride levels from 0.10 to 12.30 mg/L. The fluoride levels of cereals, pulses and vegetables varied from 1.5 to 1.78 mg/kg, 1.46 to 2.28 mg/kg and 0.14 to 0.23 mg/kg respectively and the intake of fluorides from food alone was between 0.97 to 1.30 mg per capita per day. Ramteke et al.[27] surveyed the fluoride levels in rice, corn, wheat and lentils (*dal*) to be in the ranges of 0.51 to 5.52 mg/kg, 10.2 to 40 mg/kg, 0.75 to 9.02 mg/kg and 1.1 to 13.42 mg/kg respectively data in Dhar and Jhabua districts of Madhya Pradesh. The fluoride level in water varied from 0.19 to 11.4 mg/L, while in soil in the range of 8.5 to 135.5 mg/kg. The total fluoride consumed varied from 10.72 to 21.21 mg/day according to the age group. While the average consumption was about 15.57 mg/day, the maximum consumption of fluoride was 21.21 mg/day in the age group of 31 to 45 years. Jolly et al.[18] reported that in Punjab, the fluoride intake in diet was in the range of 0.2 to 2.7 mg per day per capita depending upon the type of food consumed. Even with the above facts, the fluoride ingestion from food does not vary much from area to area but the total intake of fluoride depends mainly on fluoride concentration in water if the fluoride concentration in drinking water is high. Rao & Mahajan[28] reported that the combined daily intake of fluoride from food and drinking water in the local population of Ananthapur district of Andhra Pradesh was found to be in the range of 2.2 to 7.3 mg (0.05 to 0.32 mg/kg of body weight). They analyzed 98 food items out of which 32 locally grown Indian food items had

[*] Rajiv Gandhi National Drinking Water Mission
[†] Central Ground Water Board
[‡] Ministry of Environment and Forests
[§] Ministry of Water Resources

higher fluoride contents ranging from 0.2 to 11 mg/kg. Fluoride in irrigation water and drinking water was found to be 4.5 mg/L.

The fluoride levels of some fruits, nuts, oil seeds, mutton, beef, pork, fish, spices and condiments are given in Table 5[17,29,31]. The rock salt (*kala namak*), which is widely used in *chooran, dalmoth and golgappas* (regional food items) as a taste maker, contains 157 mg/kg fluoride. The betal leaf (*pan*), arcea nut (*supari*), tobacco and gutka (a preparation of arcea nut, tobacco, catchu (*kattha*), lime and sweet or savory flavoring agent) are consumed by millions of Indians, and are sold across India in small sized packets. About five million children under the age of 15 are addicted to Gutka. Intake of 2-4 sachets of Pan Masalas per person yield between 0.34 to 1.12 mg fluoride for absorption (Singh et al, 1993)[36]. This is generally a precursor of oral cancer and other diseases.

Fluoride Content in Beverages: The fluoride concentration of beverage, milk and other drinks is given in Table 6[19]. The average annual tea consumption in India was 718 gm/capita[38] in 2011. The tea from the top leaf of the plant, *Camellia Sinesis*, is one of the most widely used beverages, second only to water in the world. Wei et al.[41] reported that black tea leaf has fluoride from 30 to 340 mg/kg with an average of 141 ± 85 mg/kg. The infusion made from 15 Chinese, 11 Ceylon and Indian and six herbal tea with 1 gm of tea leaf per 100 ml deionized water at 85˚C reported mean fluoride levels of 173 mg/L in Chinese Tea and 124 mg/L in Indian/Ceylon teas. Herbal tea in contrast contained only 0.02 to 0.05mg/L. The fluoride content of Chinese tea varied from 30 to 400 mg/kg whereas Indian and Ceylon teas contained 38 and 90 mg/kg respectively.[29] Fung et al.[13] reported that tea is one of the most fluoride-enriched drinks with about two-thirds of the fluoride in leaf being soluble in the beverage. The fluoride concentration of Indian and Ceylon teas are more or less same and the tea grown in other parts of the world has higher concentration ranging from 3 to 300 mg/kg. The dry leaf of Indian tea has 39.8 to 68.59 mg/kg fluoride. Green tea has 72.62-89.02 mg/kg fluoride and mature leaf contains more fluoride than young buds.

One gram of Indian tea leaf, when boiled for five minutes in 125 ml of water, produces 18.13 to 56.10 mg/L fluoride and when 125 ml of hot water is poured on one gram of tea leaf, it has 11.13 to 37.34 mg/L fluoride. With average intake of just below 2 gm/capita/day tea leaf and two thirds absorption of fluoride in the infusion, the total daily intake through tea alone stands at 0.7 to 1.0 mg/day/capita. Gulati et al.[15] reported leaching of fluoride in tea infusions at contact time of two, four, six, eight and ten minutes and showed that the infusion of fluoride is the maximum at six minutes of boiling. They also showed that leaching of fluoride is least in case of leaf tea as compared to powdered tea. The ingestion of fluoride per cup of tea ranges from 1.55 mg/L to 3.21 mg/L amounting to fluoride intake between 0.3 and 1.9 mg/day. The addition of milk reduces the concentration of fluoride.

The aerated drink, coconut water and Lipton ice tea also have 0.77 to 1.44 mg/L, 0.43 to 0.60 mg/L and 0.56 mg/L fluoride respectively.[12, 19] The fluoride content of milk varies from 3.32 to 6.85 mg/L with an average value of 3.90 mg/L in buffalo's milk, 1.73 to 6.87 mg/L having average value of 3.87 mg/L in cow's milk and 0.41 to 2.06 mg/L with the average value of 0.85 mg/L in goat milk in the fluoride endemic areas where groundwater has 1.5 to 10.76 mg/L high fluoride concentration in the Tonk district of Rajasthan. The cow's milk has about 0.1 mg/L fluoride in the region where fluoride is normal in the water.

Fluoride Content in Toothpaste: The fluoride content of toothpaste varies from country to country as well as manufacturing company and their brands. Most toothpaste has about 1000 to 1500 mg/L of fluoride. The Bureau of Indian Standards has permitted up to 1000 mg/L of fluoride in toothpaste, whether a gel or a paste. Toothpastes contain surfactants, fluorides, abrasive or flavoring agents. The fluoride addition has a beneficial effect on the formation of dental enamel and bones. Sodium fluoride, stannous fluoride and sodium monofluorophosphate are commonly used compounds in toothpastes. The fluoride containing toothpaste can be toxic, if swallowed in large amounts. It has been reported in a number of studies[3,20, 21] that young children inappropriately swallow an average of 0.3 mg fluoride from fluoride toothpaste during each brushing cycle.[3,11,22] Children generally swallow about 50% of the toothpaste on their brush. More than half of fluoride intake of two year olds comes from the toothpaste. It is, therefore, recommended that children should not use fluoridated toothpastes. The potential fatal dose is 5 mg/kg of body weight that could cause toxic signs and symptoms including death. At the fluoride dose of 0.2 to 0.3 mg/kg of body weight, the ingestion could cause gastro-intestinal discomfort and therefore, children's toothpastes have about 250 to 500 mg/kg fluoride. In India, where separate toothpaste or fluoride-free toothpastes for children are rarely available, toothpaste tubes have declaration, such as "Children below 6 years of age should have adult supervision and use only pea sized amount" as well as "Do not swallow".

Treatment Technology: The Nalgonda process and Activated Alumina process are recommended for removal of fluoride from drinking water. These technology options use aluminum salts as coagulant/regenerate for removal of fluoride and a small amount of residual aluminum may remain in the treated water. Driscoll and Letterman[10] reported that approximately 11% of the aluminum dose remains in the finished water as residual aluminum and transported through the distribution system without any significant loss. This residual aluminum forms a very small part of the total daily intake. Selvapathy and Arjuman[32] reported that the treated water from Nalgonda technique has residual aluminum in the range of 2.1 to 6.8 mg/L under various operating conditions. Agarwal et al.[1] showed that while the raw water fluoride in activated alumina process was 24.1 mg/L, the treated water showed 1 to 1.5 mg/L fluoride and 0.18 to 0.45 mg/L of aluminum. The fluoride and aluminum have synergistic effect. Sharma[35] showed that the performance indicator among school children in two villages of Sanganer, Jaipur wherein the drinking water contained the same level of fluoride of 6 mg/L but different levels of aluminum of 0.03 mg/L and 0.11 mg/L were significantly different. The village with higher concentration of aluminum in drinking water showed a poor performance and much higher severity of skeletal fluorosis. The desirable and permissible limits of aluminum are 0.03 mg/L and 0.2 mg/L respectively in the IS 10500:2012. The most adverse effects of aluminum are neurotoxicity and bone toxicity, and it is also related to Alzheimer disease.

Fluoride selective ion-exchange resin is also offered by many manufacturers to remove fluoride in the raw water. However, this process is only effective if regeneration is closely monitored and executed regularly. In the absence of regeneration or timely change of resin, the treatment system with the presence of exhausted resin gives false sense of security to the users. Hence, community ownership in regeneration or change of resin and its close monitoring by authorities is critical to the use of this technology. Moreover, the volume of water that can be safely treated using a certain bed volume of resins can only be established by testing fluoride input and treated water in established laboratories – such facilities are not readily available with the village communities. In resin based technology, water continues to flow through the bed even when the treatment ability of the resin bed is exhausted and no automatic indicator or process shut down is possible.

In view of the possibility of aluminum toxicity and resulting ill effects and false sense of security in the resin technology, use of RO technology to treat fluoride and high Total Dissolved Solids (TDS) in raw water provides a more secure alternative. If the operation and maintenance of RO plant is improper, it reduces the flows and finally stops rather than give contaminated water thereby indicating need to take corrective measures. Thus the risk of ingesting poorer quality water is controlled. The resin based technology does not have similar warning signal when the functioning of the plant is not proper.

Safe Water Network India installed many RO plants in India in the states of Telangana and Uttar Pradesh. The performance summary of Safe Water Station RO plants (*as shown in Image 1*) installed in 32 fluoride-affected villages for the villages of Nizampally, Pochampally, Katrapalle, Wadlakonda, Gangirenigudem, Pathipaka, Gorikothapally, Rangapuram, Jookal, Rajavaram, Mannegudem, Mahabubabad, Thodellagudem, Shayampet, Rajole, Mulkalapally, Hasanparthi, Madikonda, Chowlapally, Kuravi, Apprajpally, Chilkodu, Enumamula, Katapuram, Issipet, Peddakodepaka, Gudur, Pocharam, Bhupalpally, Namiligonda, Gundalasingaram and Parkal II in the Warangal district of Telangana, given in Table 7.

Image 1: iJal Station, District Warangal, Telangana

Image 2: Reverse Osmosis Water Treatment Plant installed by Safe Water Network India

The pH of raw water and treated water in these stations vary from 6.6 to 8.6 and 6.5 to 8.2 indicating a fall in pH levels after RO treatment. The dosing pump has been installed in every RO Plant for pH correction which is used in case of pH less than 6.5. The performance of the RO plant for the removal of turbidity and color could not be ascertained as the raw water had below detection limit concentration. TDS, total alkalinity, total hardness, chloride, and sulphate in raw water and treated water averaged at 1792 and 106 mg/L; 425 and 23 mg/L; 852 and 16 mg/L, 470 and 21 mg/L, and 140 and 2 mg/L respectively. All these values show removal efficiency of 95% or above. The fluoride and nitrate in the raw and treated water averaged at 1.3 and 0.1 mg/L, and 181 and 29 mg/L respectively showing percentage reduction above 90% and 84% respectively. The iron and arsenic removal by RO system could not be concluded as concentration of both these ions was very low in the Telangana raw water tests. The raw water used in villages is from bore wells protected by well protection protocol with suitable apron to prevent contamination ingress in raw water even during the rainy season, owing to increased height of the apron above ground. The treated water is free from total coliforms, faecal coliforms and E. coli. As a precautionary measure, disinfection is done with chlorine and residual chlorine of 0.2 mg/L is maintained in the treated water reservoir. This reduces the chances of recontamination, if any.

II. REDUCTION OF RECONTAMINATION RISK

Recent meta-analysis commissioned by World Bank indicated a reduction in diarrheal disease incidences on (a) hygiene education (by 42%) and water quality improvements (by 39%), and hence regarded them as two effective tools when compared with control groups. Further, multiple randomized, controlled studies were conducted by several authors to validate these findings, who then highlighted the role of drinking water contamination during collection, transport and storage, and that of the health value of effective HWTS[**] interventions (Clasen et al. 2003)[8]. They concluded that community-based programs yielded lesser health benefits owing to possible recontamination.

Factors known to affect recontamination of water at household level include the size of the storage vessel mouth (Mintz et al. 1995)[24], transfer of water between containers from collection to storage (Lindskog and Lindskog 1988)[23] and hand-to-water contact and dipping of utensils (Hammad and Dirar 1982)[16].

In order to minimize the risk of recontamination through dipping of hands or unhygienic vessels in the water container by its users, Safe Water Network India has selected a 20 L container with a narrow mouth, the proprietary design adapted with permission from PepsiCo, such that the users cannot dip their hands while extracting water for drinking or other purposes. People at homes generally store water in the containers with large opening and approximately 90% of them take water out by dipping their hands inside with smaller vessels. The entire process emanates high chances of recontamination. Normally containers have hollow handle providing for dead pockets for microbial growth which are difficult to remove. The container being offered by Safe Water Network India has a solid handle that avoids occurrence of such dead pockets inside. In addition, 0.2 ppm residual chlorine is added to prevent any chance of recontamination during transportation, storage and subsequent use.

Image 3: iJal 20-liter Water Container with narrow mouth, designed to avoid dipping of hands

Image 4: Pouring water from iJal container in cooking vessel

Guideline Values of Fluoride Standards in Drinking Water: The World Health Organization (WHO) recommends 1.0 mg/L of fluoride concentration in drinking water (WHO, 1984) and the Bureau of Indian Standards IS 10500:2012 recommends requirement (acceptable) limit of 1 mg/L and permissible limit of 1.5 mg/L in drinking water sources. The adaption of lower drinking water standards of fluoride is desirable because of the hot climate with a mean temperature as high as 38˚C (100.4˚F) and correspondingly, high water consumption in rural India. The fluoride permissible limit are progressively reduced in European Standards of drinking water depending on annual average of maximum daily air temperature from 10˚C to 26.2 ˚C (50 – 79 ˚F) with lower and upper limits of fluorides from 0.9 to 0.7 mg/L and 1.7 to 1 mg/L respectively. Similarly,

[**] Household Water Treatment and Safe Storage

WHO has also recommended the sliding scale of temperature with respect to fluoride levels in drinking water; the data is shown in Table 9.[35]
In January 2011, the U.S. Department of Health and Human Services (HHS) and the U.S. Environmental Protection Agency (EPA, or USEPA) announced a reduction in the permissible fluoride levels in the U.S. drinking water. HHS recommended 0.7 milligrams of fluoride per liter of water, as against the earlier recommended range of 0.7 to 1.2 milligrams, to balance the benefits of preventing tooth decay while limiting any unwanted health effects[40].

The effect of fluoride on human health depends on the amount of water consumed per capita per day along with fluoride intake in food. Therefore, its level in drinking water should be based on average maximum temperature in the area. Raghavachari et al.[26] reported that the occupation of majority of people living in rural Palamau areas of Jharkhand is farming where many of the working adults consume an average of 7 liters of water per day including water used for cooking. Cooking requires approximately two liters of water per day with a staple Indian diet, consisting mostly of cereals, pulses and vegetables. The rural diet is semi-solid and starchy with substantial amount of water. Bhasin et al.[7] reported a high intake of fluoride through drinking water which is about 70% and through food it is 30%, while others have also stated that drinking water contributes to about 60% of fluoride intake and the remaining intake comes from other sources.

The Acceptable Daily Intake (ADI): Rose and Marier[31] stated that "Fluoride is a persistent bio accumulator, and is entering into human food-and-beverage chains in increasing amounts. Careful consideration of all available data indicates that the amount of fluoride ingested daily in foods and beverages by adult humans living in fluoridated communities currently ranges between 3.5 and 5.5 mg. For an adult weighing 70 kg, this range is close to 0.03 to 0.07 mg/kg/day estimated for 'an Acceptable Daily Intake'. In addition to the food chain, dentifrices and pharmaceuticals can contribute significantly to the fluoride intake of some individuals."

An average Indian adult male height is 5'5" and that of female is 5', and the average weight is about 54 kg and 50 kg respectively. Thus, the average weight of an adult is about 50 kg, as considered by Raghavachari et al[26]. For ADI of 0.05 mg per day per kg of bodyweight[17] and assuming an average bodyweight of 50 kg adult in rural India, the total guideline intake should be 2.5 mg/person/day. Considering fluoride intake through food of over 1 mg / day / capita[22] in the fluoride endemic areas and 0.3 – 1.9 mg / day / capita[14] from tea, it leaves little, if any, of dosage needed from drinking water in such areas. Table 8 shows WHO recommendation of fluoride concentration in drinking water and its effect on human health. In view of the above, the fluoride concentration in drinking water may be reviewed and adjusted as per human needs, especially for endemic areas in light of the fluoride intake from foods, beverages (especially tea) and absorption through toothpaste. Municipalities in India do not add fluoride in the water supplies, as practiced in developed countries, despite low levels of fluoride in the surface water source.

IV. CONCLUSION

The data derived by Jalstat on fluoride-affected areas in India revealed that out of 639 districts in India, 229 districts and 218 districts suffered with endemic fluorosis in 2009 as per RGNDWM & CGWB respectively. In 1991, UNICEF estimated about 66.62 million to be at risk due to community fluoride contaminated water in 19 states of India including 6 million children below the age of 14. The MoWR has enumerated that out of these 639 districts, the salinity, fluoride, nitrate, arsenic and toxic metal affected districts are 158, 267, 385, 53 and 69 respectively in the year 2012. In 1999, the most affected states where 50% to 100% districts are affected with fluoride were three, viz. Andhra Pradesh, Karnataka and Rajasthan, whereas Jalstat data as per RGNDWM 2009 showed Jharkhand and Maharashtra in this list, and five states viz. Chhattisgarh, Delhi, Gujarat, Punjab and Tamil Nadu as per CGWB 2009. According to MoEF data of 2009, the fluoride-affected districts were between 50-100% viz. Andhra Pradesh, Delhi, Gujarat, Haryana, Punjab, Rajasthan and Karnataka. Fluoride-affected districts in various states of India are given in Table 2. The fluoride content of cereals, pulses and vegetables grown at Tonk & Nagaur districts of Rajasthan where fluoride content in ground water varies from 1.5 to 13.85 mg/L are 0.45-18.90 mg/kg, 8.34-10.77 mg/kg and 3.91-24.88 mg/kg respectively. The fluoride contents of cereals, pulses and vegetable varies from 1.7-14.03 mg/kg, 2.34-6.2 mg/kg and 1.79-7.33 mg/kg respectively, where fluoride content of water varies from 0.15 to 0.48 mg in Mumbai and Kolkata. The fluoride content of milk from cow, heifers (buffalo) and goat varies from 0.41 – 6.87 mg/L whereas cow's milk from control area is about 0.1 mg/L. Human milk has lowest fluoride concentration of 0.004 mg/L. Hence, babies must be fed by mothers for as long as possible. The quick absorption of fluorides into the blood streams through use of toothpaste and evidences that millions in the country are affected by fluorosis, there is need to limit the use of toothpaste to a restricted amount in fluoride endemic regions.

The RO technology has been selected and installed for the treatment of fluoride and high TDS from existing drinking water sources in the villages of Warangal district in Telangana. The plant has the capacity of 1,000 LPH. There is fall in pH of the treated water and a dosing pump is installed in every RO Plant to adjust pH in the range of 6.5 to 8.5. TDS, total alkalinity, total hardness, chloride, and sulphate in raw water and treated water averaged at 1792 and 106 mg/L; 425 and 23 mg/L; 852 and 16 mg/L, 470 and 21 mg/L, and 140 and 2 mg/L respectively. All these values show removal efficiency of 95% or above. The fluoride and nitrate in the raw and treated water averaged at 1.3 and 0.1 mg/L, and 181 and 29 mg/L respectively showing percentage reduction above 90% and 84% respectively. The treated water is disinfected with chlorine and residual chlorine is dosed at 0.2 mg/L. Safe Water Network India has designed a plastic container of 20 L capacity with narrow opening of 50 mm so that unhygienic hands and vessels cannot be dipped while taking water. A solid handle has also been designed for ease of pouring. The total ingestion of fluoride is over 1 mg/capita/day from food and tea leaving very little to be ingested from drinking water. The food and water contribute 30-40% and 60-70% of fluoride respectively. It leaves little, if any, of dosage needed from drinking water in endemic areas as ADI is 0.05 mg per kg per day. It is suggested that the permissible limits of fluoride in drinking water be reviewed downwards for fluoride endemic areas.

Table 1: Status of Fluoride and Area Affected as Percentage in the States of India and the Range of Fluoride in Groundwater as mg/L

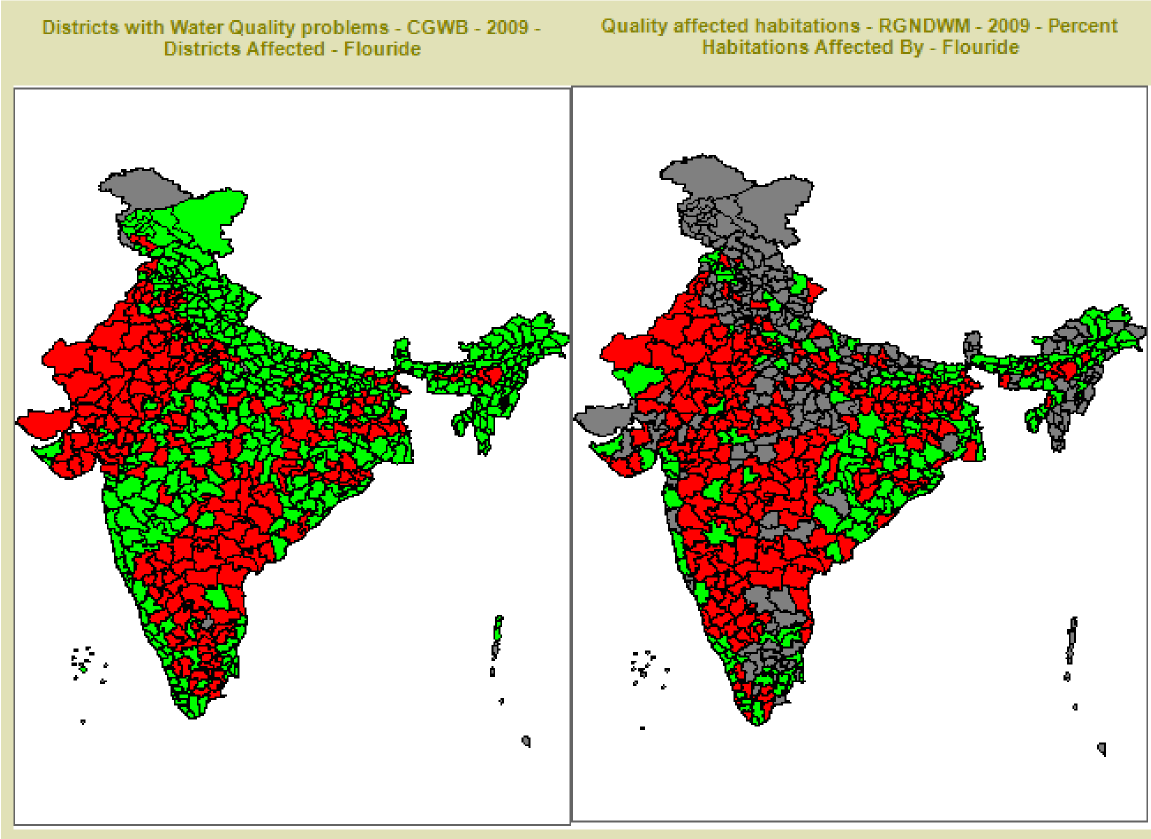
S. No.	State	Affected Area (%) [Min – Max Range]	Range of Fluoride in Groundwater in mg/L [Min – Max Range]
1	Andhra Pradesh	50 – 100%	0.4 to 29
2	Gujarat	50 – 100%	0.15 to 13
3	Rajasthan	50 – 100%	0.1 to 14
4	Bihar	30 – 50%	0.2 to 8.12
5	Chhattisgarh	30 – 50%	0.9 to 8.8
6	Delhi	30 – 50%	0.2 to 32.46
7	Haryana	30 – 50%	0.23 to 48
8	Jharkhand	30 – 50%	0.5 to 14
9	Karnataka	30 – 50%	0.2 to 7.79
10	Madhya Pradesh	30 – 50%	1.5 to 11.4
11	Maharashtra	30 – 50%	0.11 to 10
12	Punjab	30 – 50%	0.4 to 42.5
13	Tamil Nadu	30 – 50%	0.1 to 7.0
14	Uttar Pradesh	30 – 50%	0.2 to 25
15	Assam	< 30%	1.6 to 23.4
16	Jammu & Kashmir	< 30%	0.5 to 4.21
17	Kerala	< 30%	0.2 to 5.40
18	Orissa	< 30%	0.6 to 9.20
19	West Bengal	< 30%	1.1 to 14.47

Table 2: Fluoride-affected Regions in India, for CGWB and RGNDWM (from JalStat Database) **and MoEF** (All sorted by % affected districts in 2009)

Affected States in India	CGWB 2009	RGNDWM 2009	MoEF 2009
Rajasthan	Ajmer, Alwar, Banswara, Barmer, Bharatpur, Bhilwara, Bikaner, Bundi, Chittaurgarh, Churu, Dausa, Dhaulpur, Dungarpur, Ganganagar, Hanumangarh, Jaipur, Jaisalmer, Jalor, Jhunjhunun, Jodhpur, Karoli, Kota, Nagaur, Pali, Rajsamand, Sawai Madhopur, Sikar, Sirohi, Tonk, Udaipur	Ajmer, Alwar, Baran, Bharatpur, Bhilwara, Bikaner, Bundi, Chittaurgarh, Churu, Dausa, Dungarpur, Ganganagar, Hanumangarh, Jaipur, Jaisalmer, Jalor, Jhalawar, Jhunjhunun, Jodhpur, Karauli, Kota, Nagaur, Pali, Rajsamand, Sawai Madhopur, Sikar, Tonk, Udaipur	Ajmer, Alwar, Banswara, Baran, Barmer, Bharatpur, Bhilwara, Bikaner, Bundi, Chittorgarh, Churu, Dausa, Dholpur, Dungarpur, Ganganagar, Hanumangarh, Jaipur, Jaisalmer, Jalor, Jhalawar, Jhunjhunun, Jodhpur, Karauli, Kota, Nagaur, Pali, Rajsamand, Sawai Madhopur, Sikar, Sirohi, Tonk and Udaipur
Andhra Pradesh	Adilabad, Anantapur, Chittoor, Guntur, Hyderabad, Karimnagar, Khammam, Krishna, Kurnool, Mahbubnagar, Medak, Nalgonda, Nellore, Prakasam, Rangareddi, Visakhapatnam, Vizianagaram, Warangal, West Godavari	Adilabad, East Godavari, Guntur, Hyderabad, Karimnagar, Khammam, Krishna, Kurnool, Mahbubnagar, Nalgonda, Nellore, Prakasam, Rangareddi, Srikakulam	Ananthapur, Chittoor, Cuddapah, Guntur, Hyderabad, Karimnagar, Khammam, Krishna, Kurnool , Mahaboobnagar, Medak , Nalgonda, Nellore, Prakasam, Rangareddy and Warangal
Gujarat	Ahmedabad, Amreli, Anand, Bans Kantha, Bharuch, Bhavnagar, Dahod, Junagadh, Kachchh, Mehsana, Narmada, Panch mahal, Patan, Rajkot, Sabar Kantha, Surat, Surendranagar, Vadodara	Amreli, Anand, Banas Kantha, Dahod, Junagadh, Kheda, Narmada, Porbander, Sabar Kantha, Surendranagar, Tapi, Vadodara	Ahmedabad, Amreli, Anand, Banaskantha, Bharuch, Bhavnagar, Dahod, Gandhinagar, Godhara, Jamnagar, Junagadh, Kutch, Mehsana, Narmada, Navsari, Panchmahals, Patan, Porbandar, Rajkot, Sabarkantha, Surat, Surendranagar, Vadodara and Valsad
Chattisgarh	Baster, Bilaspur, Dantewada, Janjgir-champa, Jashpur, Kanker, Korba, Koriya, Mahasamund, Raipur, Rajnandgaon, Surguja	Durg, Koriya, Raigarh	Dhandewala and Durg
Karnataka	Bagalkot, Bangalore, Belgaum, Bellary, Bidar, Bijapur, Chamarajnagar, Chikmagalur, Chitradurga, Davanagere, Dharwad, Gadag, Gulbarga, Haveri, Kolar, Koppal, Mandya, Mysore, Raichur, Tumkur	Bagalkot, Bangalore, Belgaum, Bellary, Bidar, Bijapur, Chikmagalur, Chitradurga, Dakshin Kannada, Davanagere, Dharwad, Gadag, Gulbarga, Hassan, Haveri, Kolar, Koppal, Mandya, Mysore, Raichur, Ramanagara, Shimoga, Tumkur, Udupi	Bangalore Rural, Bijapur, Belgaum, Bellary, Chikmagalur, Chitradurga, Dharwad, Gadag, Gulbarga, Kolar, Mandya, Mangalore, Mysore, Raichur, Shimoga and Tumkur
Delhi	East Zone, North West Zone, South Zone, South West Zone, West Zone		Central Zone, North East Zone, North West Zone, East Zone, South West Zone, South Zone and West Zone
Punjab	Amritsar, Bhatinda, Faridkot, Fatehgarh Sahib, Firozpur, Gurdaspur, Mansa, Moga, Muktasar, Patiala, Sangarur	Faridkot, Firozpur, Hoshiarpur, Muktsar, Sangrur	Amritsar, Bhatinda, Faridkot, Fategarh, Ferozpur, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Mansa, Moga, Muktsar, Nawanshahar, Patiala, Ropar, Sahib and Sangrur
Tamil Nadu	Coimbatore, Dharmapuri, Dindigul, Karur, Krishnagiri, Namakkal, Perambalur, Pudukkottai, Ramnathapuram, Salem, Sivaganga, Theni, Tiruchirappalli, Tiruvanamalai, Vellore, Virudhunagar	Kancheepuram, Madurai, Thiruvallur, Toothukudi, Virudhunagar	Coimbatore, Dharmapuri, Erode, Krishnagir, Madurai, Salem, Thiruchirapally, Vellore and Virudunagar

Haryana	Bhiwani, Faridabad, Gurgaon, Hissar, Jhajjar, Jind, Kaithal, Kurukshetra, Mahedragarh, Sonipat	Gurgaon, Kaithal, Mewat	Bhaiwani, Faridabad, Gurgaon, Jhind, Kaithal, Karnal, Kurukshetra, Mohindragarh, Rewari, Rohtak, Sirsa and Sonipat
West Bengal	Bankura, Barddhaman, Birbhum, Dakshin Dinajpur, Medinipur, Nadia, Puruliya, Uttar Dinajpur	Bankura, Birbhum, Dakshin Dinajpur, Maldah, Puruliya, South 24-Parganas, Uttar Dinajpur	24 South Parganas, Bankura, Birbaum, Dakshin Dinajpur, Malda, Purulia and Uttar Dinajpur
Madhya Pradesh	Bhind, Chhatarpur, Chhindwara, Datia, Dewas, Dhar, Guna, Gwalior, Harda, Jabalpur, Jhabua, Mandsaur, Rajgarh, Satna, Seoni, Shajapur, Sheopur, Sidhi, W. Nimar(Khargoan)	Alirajpur, Balaghat, Barwani, Chhindwara, Dhar, Dindori, Jhabua, Mandla, Neemuch, Raisen, Rajgarh, Ratlam, Sagar, Sehore, Seoni, Shajapur, Sheopur, Ujjain, Vidisha, W. Nimar (Khargoan)	Chhindwara, Dhar, Dindori, Gwalior, Jubua, Vidhisha, Seoni, Sehore, Shivpuri, Raisen, Mandla, Mandsour, Neemuch and Ujjain
Orissa	Anugul, Bargarh, Baudh, Bhadrak, Cuttack, Debagarh, Dhenkanal, Jajapur, Kendujhar, Sonapur	Anugul, Balangir, Baleshwar, Bargarh, Baudh, Cuttack, Kalahandi, Khordha, Nayagarh, Nuapada	Angul, Balasore, Bhadrak, Bolangir, Boudh, Dhankanal, Ganjam, Jagatsinghpur, Jajpur, Kalahandi, Keonjhar, Khurda, Koraput, Mayurbhanj, Nayagarh, Pulbani, Puri and Rayagada
Jharkhand	Bokaro, Giridih, Godda, Gumla, Palamau, Ranchi	Bokaro, Chatra, Deoghar, Dumka, Garhwa, Giridih, Godda, Gumla, Hazaribagh, Kodarma, Latehar, Lohardaga, Pakaur, Palamau, Sahibganj, Seraikela Kharsawan, Simdega, Singhbhum (E), Singhbhum(W)	Deoghar, Girdh, Pakur, Palamu and Sahabganj
Bihar	Aurangabad, Banka, Buxar, Jamui, Kaimur (Bhabua), Munger, Nawada, Purnia, Supaul	Aurangabad, Banka, Bhagalpur, Gaya, Jamui, Kaimur (Bhabua), Munger, Nalanda, Nawada, Rohtas, Samastipur, Shekhpura	Bhagalpur, Gaya, Jamual, Munger, Nawada and Rohtas
Maharashtra	Amravati, Chandrapur, Dhule, Gadchiroli, Gondiya, Jalna, Nagpur, Nanded	Ahmadnagar, Amravati, Bhandara, Bid, Buldana, Chandrapur, Dhule, Gadchiroli, Gondiya, Hingoli, Jalgaon, Jalna, Kolhapur, Latur, Nagpur, Nanded, Nandurbar, Nashik, Osmanabad, Parbhani, Pune, Sangli, Satara, Wardha, Washim, Yavatmal	Akola, Amravati, Bhandara, Buldhana, Chanderpur, Jalgaoun, Nagpur, Nanded, Sholapur and Yavatmal
Assam	Goalpara, Kamrup, Karbi Anglong, Nagaon	Jorhat, Kamrup, Karbi Anglong, Karimganj, Nagaon	Karbi Anglong and Nagaon
Uttar Pradesh	Agra, Aligarh, Etah, Firozabad, Jaunpur, Kannauj, Maharajganj, Mainpuri, Mathura, Mau	Agra, Allahabad, Auraiya, Banda, Basti, Bulandshahar, Deoria, Etawah, Farrukhabad, Fatehpur, Firozabad, Ghaziabad, Gorakhpur, Hamirpur, Hathras, Jhansi, Kannauj, Kanpur Nagar, Kheri, Kushi Nagar, Lalitpur, Lucknow, Mathura, Mirzapur, Muzaffarnagar, Pratapgarh, Rai Bareli, Shonbhadra, Unnao	Kaunauj, Farukhabad, Hardoi, Raebareily, Pratapgarh, Unnao andVaranasi
Jammu & Kashmir	Rajaori, Udhampur	Nil	Doda
Kerala	Palakkad	Alappuzha, Ernakulam, Idukki, Palakkad, Triruvananthapuram	Alleppy , Palghat and Vamanapuram
Uttarakhand		Pithoragarh	
Meghalaya		West Garo Hills	

Figure 1: Schematic Representation of India's Fluoride-affected Districts from Jalstat, a National Database commissioned by Safe Water Network with its partners



Legend

	Fluoride Affected Districts		Non Fluoride Affected Districts		Data Not Reported

Table 3: Fluoride-affected Districts in India for CGWB and RGNDWM (from JalStat Database) **and MoEF** (Sorted by % affected districts in 2009)

Affected States in India	CGWB 2009	% Districts	RGNDWM 2009	% Districts	MoEF 2009	% Districts	Total Districts
	218	**34%**	**229**	**36%**	**207**	**32%**	**639**
Rajasthan	30	91%	28	85%	32	97%	33
Andhra Pradesh	19	83%	14	61%	16	70%	23
Gujarat	18	69%	12	46%	24	92%	26
Chhattisgarh	12	67%	3	17%	2	11%	18
Karnataka	20	67%	24	80%	16	53%	30
Delhi	5	56%	No data	No data	7	78%	9
Punjab	11	50%	5	23%	17	77%	22
Tamil Nadu	16	50%	5	16%	9	28%	32
Haryana	10	48%	3	14%	11	52%	21
West Bengal	8	42%	7	37%	7	37%	19
Madhya Pradesh	19	38%	20	40%	14	28%	50
Orissa	10	33%	10	33%	18	60%	30
Jharkhand	6	25%	19	79%	5	21%	24
Bihar	9	24%	12	32%	6	16%	38
Maharashtra	8	23%	26	74%	10	29%	35
Assam	4	15%	5	19%	2	7%	27
Uttar Pradesh	10	14%	29	41%	7	10%	71
Jammu & Kashmir	2	9%	0	0%	1	5%	22
Kerala	1	7%	5	36%	3	21%	14
Uttarakhand	0	0%	1	8%	No data	No data	13
Meghalaya	0	0%	1	14%	No data	No data	7

Figure 2: Graphic Representation (of Table 3) of Percentage Distribution of Fluoride-affected Districts in States of India in 2009 as per CGWB, RGNWN, MoEF

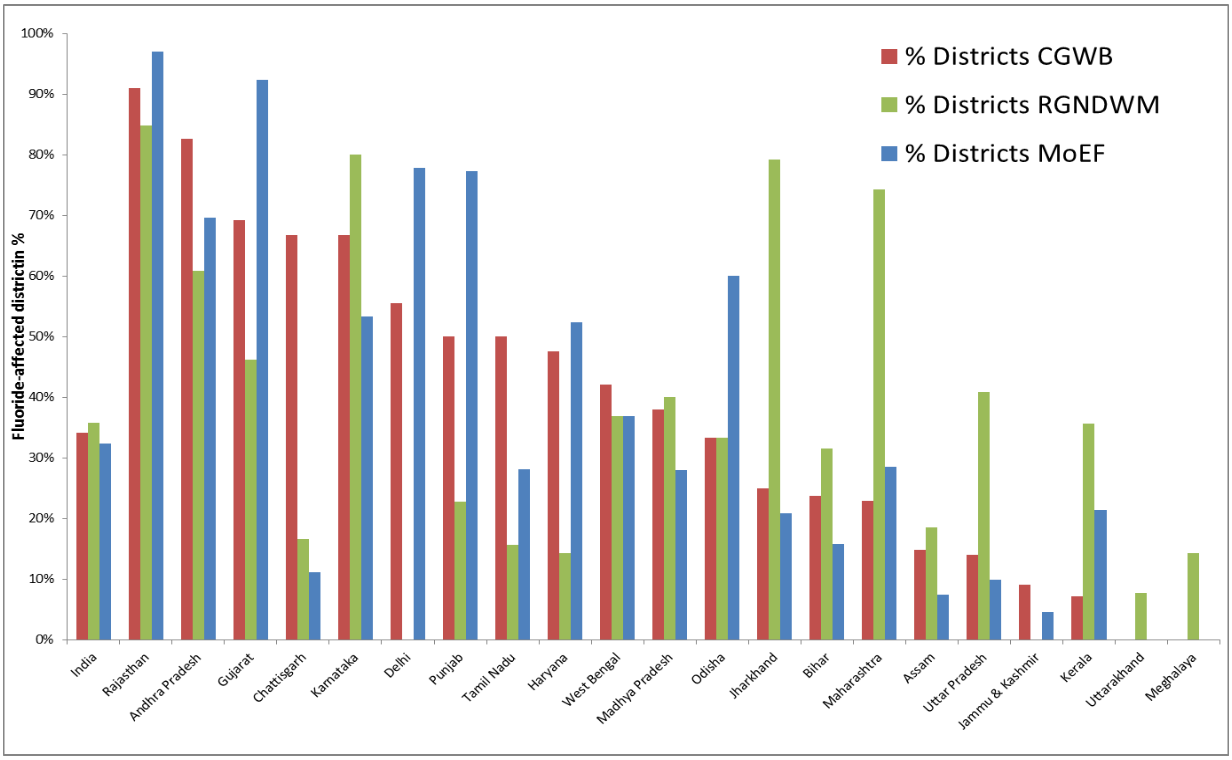


Table 4: Fluoride Levels in Indian Food

S. No.	Items of Food	Sengupta & Pal[33]	Lakdawala & Punekar[20]	Bhargava & Bhardwaj[5]	Gautam et al. [14]	Raghavachari et al. [26]	Ramteke et al. [27]
		Kolkata	Mumbai	Tonk	Nagaur	Palamau	Dhar & Jhabua
1.	**Cereals**	4.6	2.59 – 3.3			1.50 – 1.78	
A	Wheat	5.9	3.27 – 14.03	0.51 – 5.98	2.76 – 6.96		0.75 – 9.02
B	Rice	-	1.72 – 2.23				0.51 – 5.52
C	Maze	5.6	-				
D	Chana			3.26	7.80 – 11.74		
E	Barley			0.45 – 3.65			
F	Bajra				1.88 – 6.18		
G	Moth				10.46 – 13.6		
H	Chawla				14.44 – 18.98		
I	Corn						10.2 – 40
2.	**Pulses and Legumes**						
A	Bengal gram	6.2	3.84 – 4.84				
B	Green gram dal	2.5	2.34 – 4.84				
C	Red gram dal	3.7	2.34 – 4.84				
D	Soyabeen	4	-				
E	Moong						
F	Peas				10.77		
G	Pulses				8.34	1.46 – 2.28	
3.	**Leafy Vegetables**					0.14 – 0.23	1.1 – 13.42
A	Spinach	2	0.77 – 4.14	9.87 – 29.15	15.98 – 23.12		
B	Cabbage	3.3	1.28 – 2.29	4.25 – 11.30			

C	Amaranth leaf	5.8	4.91 – 7.14				
D	Lettuce	5.7	-				
E	Bathua leaf	6.3	-		13.24 – 13.54		
F	Cholai leaf	-	1.79 – 7.33				
G	Mint	4.8	-				
H	Mustard leaf			12.66 – 14.59	24.00 – 24.88		
I	Radish leaf			9.16 – 14.96	10.46 – 20.56		
J	Sarson				10.10		
K	Methi				18.24		
L	Mustard				14.44		
4.	**Vegetables**						
A	Cucumber	4.1	2.57 – 3.58				
B	French Beans	-	1.07 – 1.96				
C	Tomato	3.4	1.00 – 2.08	13.48			
D	Brinjal	1.2	1.62 – 2.48				
E	Lady's finger	4.0	2.2 – 3.62	22.09			
F	Snake Gourd	2.3	2.16 – 3.44				
G	Cauliflower			12.09	8.34		
5.	**Roots and Tubers**						
A	Beetroot	4.2	-				
B	Carrot	4.2	1.9 – 4.9	10.75 – 15.88			
C	Potato*	2.8	1.27 – 2.92	11.95			
D	Onion	3.7	1.00 – 3.00	5.67 – 10.50	8.08 – 23.92		
E	Sweet Potato	3.2					
F	Radish				14.58 – 22.20		
6.	**Groundwater** fluoride levels mg/L	0.4	0.15 – 0.48	1.5 – 11.82	1.57 – 13.83	0.10 – 12.30	0.19 – 11.4

Note: *Potato skin (potato waste) has very high level of fluoride of 22 mg/kg on the outside whereas inside pulp has up to 2 mg/kg (as per Federal Register: March 12, 1997; Volume 62, # 48, 11437-11441).*
All values are expressed as mg/kg

Table 5: Fluoride Concentration in Fruits, Nuts, Oil Seeds, Mutton, Beef, Pork, Fish, Spices and Condiments

S No.	Items	Lakdawala & Punekar[20]	Sengupta & Pal[33]	Susheela A.K.[38]	Devotta S. et al.[9]
		Mumbai	**Kolkata**		
1.	**Fruits**				
A	Banana	0.84 – 1.58	2.9		
B	Dates		4.5		
C	Grapes	0.84 – 1.74	-		
D	Figs		4.2		
E	Mango	0.8 – 1.80	3.7		
F	Apple	1.05 – 2.20	5.7		
D	Guava	0.24 – 0.52	5.1		
2.	**Nuts and Oilseeds**				
A	Almonds		4.0		
B	Cashew nut		4.1		
C	Coconut		4.4		
D	Mustard Seeds		5.7		
E	Ground Nut		5.1		
F	Arcea Nut (*Supari*)			3.8 – 12.0	
G	Betal Leaf			7.8 – 12.0	
H	Tobacco			3.1 – 38.0	
3.	**Spices and Condiments**				
A	Coriander		2.3		
B	Cumin Seeds		1.8		
C	Garlic		5.0		
E	Ginger		2.0		
F	Tamarind Pulp		3.8		
G	Turmeric		3.3		
H	Rock Salt (*Kala Namak*)			157	
I	Cardamom (*Ilaichi*)				14.4
4.	**Food from Animal Sources**				
A	Mutton	3.0 – 3.5			
B	Beef	4.0 – 5.0			
C	Pork	3.0 – 4.5			
D	Fish	1.0 – 6.5			

All values are expressed as mg/kg.

Table 6: Fluoride Concentration of Beverage, Milk and Other Drinks

S No.	Items of Beverage	Lakdawala & Punekar[20]	Poisonfluoride.com[11]	Bhargava & Bhardwaj	Becker & Bruce[4]	Oeleschlaeger[25]	Koparal E. et al.[19]
		Mumbai		Tonk			
1.	**Tea**						
A	Dry Leaf	39.80 – 68.50			3.2 – 178.8	100.8 – 143.6	
B	Tea Infusion (1 gm boiled for 5 min. in 125 ml. water)	18.13 – 56.10					
C	Tea Infusion (1 gm 125 ml of hot water)	11.13 – 37.34					
D	Lipton Ice Tea		0.56				
2.	**Green Tea**						
A	Leaf		72.62-89.02				
B							
3.	**Milk**						
A	Heifer (Buffalo)			3.32 – 6.85			
B	Cow			1.73 – 6.87			
C	Goat			0.41 – 2.06			
D	Human						0.004
4.	**Aerated Drinks**	0.77 – 1.44					
5.	**Coconut Water**	0.43 – 0.60					

All values are expressed as mg/kg or mg/L in liquids

Table 7: Performance Summary of Reverse Osmosis Plants installed by Safe Water Network India in 32 fluoride-affected villages in Warangal District of Telangana [Tests conducted by Bhagavathi Ana Labs, NABL/FSSAI Accredited]

S.No.	Test Parameters	Unit	Test Method	Equipment	Requirement (Acceptable Limit) as per IS 10500:2012	Permissible Limit in the absence of alternate source	Raw Water		Treated Water		Average		% Reduction
							Max	Min	Max	Min	Raw Water	Treated Water	
						Date of Sample Collection							
						Date of Test Completion							
1	Colour	Hazen Unit	IS 3025 (Pt 4): 2012	Nessler Tube	5 Max.	Max 15	5.0	5.0	5.0	5.0	5.0	5.0	0%
2	Turbidity	NTU	IS 3025 (Pt 10): 2012	Nephelometer	5 Max.	5 Max.	36.0	1.0	3.0	1.0	2.4	1.1	56%
3	pH	--	IS 3025 (Pt 11): 2012	pH Meter	6.5 to 8.5	No Relaxation	8.6	6.6	8.2	6.5	7.7	6.8	
4	Electrical Conductivity	µS/cm	IS 3025 (Pt 14): 1984	Conductivity Meter		--	5350.0	910.0	296.0	43.0	2794.7	158.4	94%
5	Total Dissolved Solids	mg/L	IS 3025 (Pt 16): 2012	Gravimetry	500 Max.	2000 Max.	3478.0	590.0	215.0	27.0	1791.7	106.0	94%
6	Total Hardness	mg/L	IS 3025 (Pt 21): 1983	By Titration	300 Max.	600 Max.	1891.5	200.0	130.0	0.0	851.6	15.6	98%
7	Non Carbonate Hardness	mg/L	By Calculation	-	--	--	1611.0	57.0	42.0	0.0	544.1	8.0	99%
8	Calcium Hardness	mg/L	By Calculation	-	--	--	1518.0	20.0	30.0	0.0	366.5	10.6	97%
9	Alkalinity to Phenolphthalein	mg/L	IS 3025 (Pt 23): 1986	By Titration	--	--	142.8	16.0	1.0	0.0	60.9	0.5	99%
10	Total Alkalinity to Methyl Orange	mg/L	IS 3025 (Pt 23): 1986	By Titration	300 Max.	600 Max.	772.0	176.0	88.0	5.0	424.7	23.0	95%
11	Calcium	mg/L	IS 3025 (Pt 40): 1991	By Titration	75 Max.	200 Max.	609.0	8.0	24.7	0.0	146.8	3.6	98%
12	Magnesium	mg/L	IS 3025 (Pt 46): 1994	By Titration	30 Max.	100 Max.	341.0	12.0	24.0	0.0	122.2	2.2	98%
13	Sodium	mg/L	IS 3025 (Pt 45): 1993	Flame Photometer	--	--	805.0	16.1	52.0	5.6	232.3	27.1	88%
14	Potassium	mg/L	IS 3025 (Pt 45): 1993	Flame Photometer	--	--	158.0	0.2	27.1	0.1	30.2	4.0	87%
15	Chloride	mg/L	IS 3025 (Pt 32): 1988	By Titration	250 Max.	1000 Max.	1162.9	9.6	44.0	2.0	470.3	20.5	96%
16	Sulphates	mg/L	IS 3025 (Pt 24): 1986	Spectrophotometer	200 Max.	400 Max.	411.0	23.3	10.0	0.0	139.5	2.1	99%
17	Nitrates	mg/L	SM 4500 NO3- B	Spectrophotometer	45 Max.	No Relaxation	765.0	5.0	116.0	0.1	181.3	29.0	84%
18	Nitrites	mg/L	IS 3025 (Pt 34): 1988	Spectrophotometer	0.02 Max.	--	14.0	0.0	0.4	0.0	0.4	0.0	93%
19	Fluoride	mg/L	SM 4500 F^- D	Spectrophotometer	1.0 Max.	1.5 Max.	**1.8**	**0.9**	**0.4**	**0.1**	**1.3**	**0.1**	90%
20	Iron	mg/L	SM 3125	ICPMS	0.3 Max.	No Relaxation	0.1	0.0	0.0	0.0	0.0	0.0	59%
21	Silica	mg/L	IS 3025 (Pt 35): 1988	Spectrophotometer	--	--	53.0	0.1	53.0	0.1	16.2	2.3	85%
22	Arsenic	mg/L	SM 3125	ICPMS	0.05 Max.	0.05 Max.	0.0	0.0	0.0	0.0	0.0	0.0	NA
23	E. Coli	per 100 ml	IS 1622: 1981	-	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	
24	Faecal Coliforms	per 100 ml	IS 1622: 1981	-	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	
25	Total Coliforms	per 100 ml	IS 1622: 1981	-	Absent	10 Max	Absent	Absent	Absent	Absent	Absent	Absent	

Table 8: Concentration of Fluoride in Drinking Water and Its Effect on Human Health[41]

Fluoride Concentration (mg/L) [Min – Max Range]	Effect
Nil	Limited growth and fertility
<0.5	Dental carries
0.5 – 1.5	Promotes dental health and prevents tooth decay and cavities
1.5 – 4.0	Dental fluorosis, mottling and pitting of teeth
4.0 – 10.0	Dental and skeletal fluorosis, pain in the back and all joints

Table 9: Code of Practice for Fluoridation of Drinking Water Supplies[2]

Maximum Mean Temperature of Region (°C)	Maximum Recommended Fluoride Concentration (mg/L)
0	2.1
10	1.3
20	0.9
30	0.7
40	0.6
50	0.5
60	0.4

REFERENCES

[1]. Agarwal, K. C., Gupta, S. K. and Gupta A. B. (1999) *"Development of New Low Cost De-fluoridation Technology (KRASS)."* Water Science & Technology, UK, **40**(2): 167-173.
[2]. Bårdsen, K. B. a. A. (1995). *"1st International Workshop on Fluorosis Prevention and Defluoridation of Water, Ngurdoto, Tanzania, The International Society for Fluoride Research."* October 18-21.
[3]. Barnhart, W. E., Hiller, L. K., Leonard G. J. & Michaels, S. E. (1974) *"Dentifrice Usage and Ingestion among Four Age Groups."* J Dent Res; **53(6)**:1317-22.
[4]. Becker, W. and Bruce, A. (1981). "*Fluoride Intake from Food."* Var Foda: **33 (Suppl 3)**: 198-261.
[5]. Beg M. K. (2009). "*High Fluoride Incidence in Groundwater and its Potential Health Effects In Parts of Raigarh District of Chattisgarh."* Current Science.
[6]. Bhargava, D. & Bhardwaj, N. (2009) "*Study of Fluoride Contribution through Water & Food in Human Population in Fluoride Endemic Villages of North – Eastern Rajasthan."* African Journal of Basic & Applied Science. **1(3-4)**:55-58.
[7]. Bhasin, J. K., Jain, A., Bansiwal, A. K. and Gupta S. K. (2004) "*Nutritional Value of Food Consumed by Villagers in Rajasthan; Relevance of Fluoride and its Control."* National Workshop on Control and Mitigation of Fluoride in Drinking Water: February 5-7.
[8]. Clasen, Thomas F. & Bastable, Andrew (2003). "*Faecal contamination of drinking water during collection and household storage: The need to extend protection to the point of use." Journal of Water and Health* **1(3)**, 109–115.
[9]. Devotta, S., et. al. (2007) *"Guidance Manual: Integrated Fluorosis Mitigation"* issued by NEERI, UNICEF, RMRC & PHED, MP.
[10]. Driscoll, C. T. and Letterman, D. N. (1988) *"Chemistry and Fate of Al (III) in Treated Drinking Water."* J. Environmental Engg. Division, ASCE; **114(1)**:21.
[11]. Ericsson Y, Forsman B. (1969) "Fluoride retained from mouth rinses and dentifrices in preschool children." Caries Res; **3**: 290-9.
[12]. Fluoride in Food. (2009). Retrieved April 19, 2012, from http:// poisonfluoride.com/pfpc/html/f-_in_food.html
[13]. Fung, K. F., Zhang, Z. Q., Wong, J. W. C. and Wong, M.H. (1999) *"Fluoride Contents in Tea and Soil from Tea Plantations and Release of Fluoride with Tea Liquor during Infusions"* Environ. Pollut; **104**:197-205.
[14]. Gautam, R., Bhardwaj, N. and Saini, V. (2010) *"Fluoride Accumulation by Vegetables and Crops Grown*." in Nawa Tehsil of Nagaur District, Rajasthan, India Jour. of Physio; **(2)2**:80-85.
[15]. Gulati, P., Singh, V., Gupta, M. K., Vaidya, V., Das, P. and Prakash, S. (1993) *"Studies on the Leaching of Fluoride in Tea Infusions"* Sci. Total Environ; **138(1-3)**:213-221.
[16]. Hammad ZH and Dirar HA (1982). *"Microbiological examination of sebeel water."* Appl Environ Microbiol*;* **43(6)**:1238-43.
[17]. Institute of Medicine (IOM). (1997) *"Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride.*" Washington DC: National Academy Press.
[18]. Jolly, S. D., Oberoi, R., Sharma, R. S. and Ralhan, S. (1974) *"Fluoride Balance Studies in Cases of Endemic Fluorosis."* Proceedings of the Symposium on Fluorosis, Hyderabad, India.
[19]. Koparal E, Ertugrul F, Oztekin K. (2000) *"Fluoride levels in breast milk and infant foods."* J Clin Pediatr Dent; **24(4)**:299-302.
[20]. Lakdawala, D. R. & Punekar, B. D. (1973). *"Fluoride Contents of Water and Community Consumed Foods in Bombay and a Study of Dietary Intake."* Ind. J. Me. Res; **16**:1679-1687.
[21]. Levy, S. M. (1993). *"A Review of Fluoride Intake from Fluoride Dentifrice"* J Dent Child; **60(2)**: 115-24.
[22]. Levy, S. M. (1994). *"Review of Fluoride Exposures and Ingestion"* Community Dent Oral Epidemiol; **22**: 173-80.
[23]. Lindskog RU and Lindskog PA (1988). Department of Pediatrics, Linköping University, Sweden. "*Bacteriological contamination of water in rural areas: an intervention study from Malawi."* J Trop Med Hyg; **91(1)**:1-7.

[24]. Mintz ED, Reiff FM, Tauxe RV (1995). "Safe water treatment and storage in the home. A practical new strategy to prevent waterborne disease." *JAMA. Mar 22-29; 273 (12): 948-53.*

[25]. Oeleschlaeger, W. (1970) "Fluoride in Food" Fluoride; **3**:6-11.

[26]. Raghavachari, S., Tripathi, R. C. and Bhupathi R. K. (2008). *"Endemic Fluorosis in Five Villages of the Palamau District, Jharkhand, India."* Fluoride; **41(3)**:206-211.

[27]. Ramteke, D. S., Onkar, R., Pakhide, D. and Sahasrabudhe, S. (2007). *"Assessment of Fluoride in Groundwater, Food and Soil and its Association with Risk to Health."* Proceedings of the 10th International Conference on Environmental Science & Technology, Kos Island, Greece.

[28]. Rao, K. V. and Mahajan, C. L. (1990). "Fluoride content of some common South Indian foods and their contribution to fluorosis" J. of Science of Food and Agriculture; **51**: Issue 2:275-279

[29]. Reid, E. (1936). *"The fluorine content of some Chinese food materials."* Chinese J. Physiol; **10**: 259.

[30]. RGNDWM. (1993). "*Prevention & Control of fluorosis in India."* Water Quality and Defluoridation Techniques, Volume II, Published by Rajiv Gandhi National Drinking Water Mission, Ministry of Rural Development, New Delhi.

[31]. Rose D and Marier Jr (1977). *"Environmental Fluoride."* NRCC Number 16081, Ottawa: National Research Council of Canada; 108-110.

[32]. Selvapathy, P. and Arjuman, N. K. (1995) *"Aluminum Residue in Water."* 3rd International Appropriate Waste Management Technology for Developing Countries" NEERI, Nagpur: Feb 25-28.

[33]. Sengupta, S. R. & Pal, B. (1937). "Iodine and Fluoride Contents of Food Stuffs" Ind. J. Nutrition Dieter; **8**:66-71.

[34]. Sethi, N. (2012, May 2). Poison in India's Groundwater posing national health crisis. *The Times of India*, p. 1.

[35]. Sharma, S. P. (1998). *"The Role of Aluminum in Fluorosis and Defluoridation"* M. E. Dissertation, University of Rajasthan, Jaipur.

[36]. Singh, V., Gupta, M.K., Rajwanshi, P., and Dass, S. (1993). "*Studies on ingestion of fluoride through tobacco, pan masala and toothpaste*". Indian J. Environ. Health. **35**: 215-220.

[37]. State of Art Report on the extent of fluoride in drinking water and the resulting endemicity in India (1999). UNICEF, New Delhi.

[38]. Susheela A. K. (2009). *"Handbook of Planning and Implementation of Water Supply Programme in Fluorosis Endemic Areas in India."* 21.

[39]. Tea Board. (2012) "*Estimates of (Internal) Consumption and Per capita consumption of Tea in India*." Retrieved April 22, 2012 from http://www.teaboard.gov.in/pdf/stat/Consumption.pdf

[40]. Washington's Blog. (2012) *Government To Reduce Fluoride Levels in Drinking Water Because Too Much Fluoride Can Cause Health Problems.* Retrieved May 14, 2012, from http://georgewashington2.blogspot.in/2011/01/government-to-reduce-fluoride-levels-in.html

[41]. Wei SH, Hattab FN and Mellberg JR. (1989) *"Concentration of fluoride and selected other elements in teas."* Department of Children's Dentistry and Orthodontics, University of Hong Kong. Nutrition. Jul-Aug; **5(4)**:237-40.

[42]. WHO. (1971) *International Standards for Drinking Water.* World Health Organization, Geneva.