A STUDY ON INTEGRATED FLUOROSIS MITIGATION PLAN FOR ENDEMIC FLUOROSIS REGION – AN INDIAN PERSPECTIVE

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ABSTRACT
This paper presents the health based risk assessment of fluorosis 9 blocks of Gorakhpur Uttar Pradesh, Pradesh, India. The evaluation of fluoride concentration in 248 groundwater samples of Gorakhpur district, Uttar Pradesh, has provided useful insight into the extent of fluoride contamination in the study area. The most affected block is Piprauli where 88.9% samples were found to have fluoride more than 1.5 mg/L. To mitigate the effects of fluoride, an Integrated approach is needed as it is advantageous than the conventional defluoridation techniques. The Integrated Fluorosis Mitigation approach imparts better understanding of the adverse effects of fluoride consumption through Information, Education and Communication activities.

Key words: Fluorosis, Mitigation, Nutritional Supplementation, Quantitative Chemical Risk Assessment.


1. INTRODUCTION
As indicated by WHO (2016), 748 million individuals over the globe are still depended on unchanged drinking water sources. Fluoride in water is generally of land root. Very nearly 27 countries and 200 million individuals over the globe confront issues of abundance fluoride in drinking water, the force and seriousness of which changes with the ecological settings as far as their land and prudent status. The constant exposure to fluoride through food and drinking water results in dental, skeletal and non-skeletal fluorosis.
As per Mumtaz et al (2015) extreme fluorides in drinking water may bring about dental or skeletal fluorosis, which might be a state of profound worry to general wellbeing in the regions where event of fluoride more than 1 mg/L is accounted for in drinking water supplies. While dominant part of estimations of fluoride focus in drinking water having been found underneath 8 mg/L in the nations like Brazil, Canada, Finland, Czech Republic, Indonesia, Ghana, Japan, Kenya, India, Korea, Mexico, Nigeria, Pakistan, Poland, Saudi Arabia, Senegal, Spain, Sudan, Thailand, Uganda and U.S.A., a few values in the range 8-30 mg/L are accounted for in Germany, Norway, South Africa, Sri Lanka, Tanzania, Argentina, China, Turkey, Pakistan and U.S.A. alongside a couple especially high values in India (69.6 mg/L), Ethiopia (177 mg/L) and Kenya (2800 mg/L). This requires the expulsion of over the top fluoride from open water supplies or individual water supplies.

2. SCENARIO OF WATER RESOURCES IN INDIA

With 16% of world’s population, India has only 4% of global water resources. Over exploitation of finite groundwater resources has resulted in exploring deep aquifers which contain high level of minerals such as fluoride and arsenic which have leached from the deep basaltic rocks (NEERI, 2007). The high level of fluoride in the groundwater can result in dental, skeletal and non-skeletal fluorosis. Literature reveals that non-skeletal manifestations vary from reduced RBC count, reduced sperm count, nervousness, depression, tingling sensation in toes, abdominal pain and mouth sores. This is of great concern as 80% of domestic needs in rural India are met by groundwater (Ayoob and Gupta, 2006). The global burden of disease due to fluoride in drinking water was estimated by Fewtrell et al in 2006. It has been estimated in the study, that in India, about 1,81,97,000 are affected with dental fluorosis and 78,89,000 are affected with skeletal fluorosis. The study also estimated skeletal fluorosis attributed DALY (Disability Adjusted Life Years) as 17 per 1000. In India, the extent of fluoride in drinking water ranges from 1.0 to 48.0mg/L. World Health Organisation (WHO, 2011) has set the upper limit of fluoride in drinking water as 1.5mg/L. The Bureau of Indian Standards has 1.0mg/L as acceptable limit with remark as “the lesser the better.” (IS, 2012) Studies by Whyte et al. (2005) and Cao et al. (2006) identified food as a potential hazard and states that food consumption may increase the risk of fluorosis. Indeed, it is clear that establishment of water quality standard of 1.0 to 1.5mg/L for fluoride consumption through drinking water alone is not enough to mitigate the adverse health effects of fluoride. Literature provides convincing evidence to justify the important role of malnutrition and dietary habits on severity of fluorosis. Jolly et al. (1974) highlighted the role of nutritional factors relative to different clinical patterns of fluorosis seen in India.

Liang et al. (1997) showed 43.8% prevalence of skeletal fluorosis with adequate nutrition and 69.2% in those with malnutrition. These studies outline that health and nutritional status play important role in fluorosis. Susheela A K. (2001) in early 1930s, fluorosis was reported only in 4 states in India, in 1986 it was 13, in 1992 it was 15 and currently it is 20 states, indicating that endemic fluorosis has emerged as one of the public health problems of the country.

3. EARLY INITIATIVES TAKEN BY THE INDIAN GOVERNMENT

According to A.K. Susheela 2009, due to lack of substantial data on the extent of fluorosis during the early 1980s, extensive research was encouraged. By 1986, The Technology Mission on Safe Drinking Water was launched in India by Prime Minister Sri Rajiv Gandhi and a submission named, “Control of Fluorosis” was also launched. A fluorosis control cell was supported by the Government of India at the All India Institute of Medical Sciences for coordinating the activities between the water supply and health departments of the state.
Governments where excess fluoride and fluorosis was known to be endemic. The conventional fluorosis mitigation approach mainly deals with defluoridation of water, however, it cannot be proposed as the most effective solution to mitigate fluorosis. Fluorosis mitigation approach needs to begin with better understanding of health impacts of excessive fluoride intake in relation with nutritional aspects and establishing tolerable levels of risk to human health. (NEERI, 2007). These aspects are fulfilled by Integrated Fluorosis Mitigation, introduced by NEERI and UNICEF in Madhya Pradesh in 2007.

4. INTEGRATED FLUOROSIS MITIGATION

Integrated Fluorosis Mitigation includes understanding health impacts of excessive fluoride intake through Information, education and Communication. Establish tolerable levels of risk to human health through Quantitative Chemical Risk Assessment (QCRA), followed by development of specific strategy for effective mitigation of fluorosis such as water management solutions, domestic level defluoridation of drinking water and nutritional supplementation. This approach addresses high levels of fluoride from various exposure routes and impact of nutritional behaviour and malnutrition towards fluorosis. (NEERI, UNICEF. 2007). Quantitative Chemical Risk Assessment, with data from health surveys, provides the basis for use based separation of water sources. Groundwater consumption can be reduced by creating alternative water resources such as rainwater harvesting, reuse of greywater for sanitation/gardening. Development of improved and simple process for defluoridation of drinking water at household level could be an effective way of defluoridation of drinking water (NEERI, UNICEF. 2007). Godfrey et al. (2009) studied about the case controlled cohort health indicator study of an integrated fluorosis mitigation programme in India. It focused on the health based targets and integrated fluorosis mitigation.

4.1. Quantitative Chemical Risk Assessment

Quantitative Chemical Risk Assessment tool is used to determine an acceptable level of risk and appropriate water quality. QCRA includes information available on exposure routes such as food and water and dose-response to produce estimates of the disease burden associated with exposure to chemical. The QCRA approach taken was based on WHO guidelines and comprised: hazard identification, dose-response assessment, exposure assessment and risk characterization (WHO 2011; NEERI 2007).

4.2. Water Management Solutions

According to the report from NEERI in 2007; water management solutions are based on the concentration of fluoride in drinking water. The dilution method can be used which involves collection of rainwater from individual households and schools in storage tanks. The collected rainwater and fluoride contaminated groundwater are allowed to mix and drawn through hand pump or pipes ensuring safe water for cooking and drinking purposes. Promotion of greywater reuse reduces demand on groundwater by 60% thereby resulting in decreased levels of fluoride. Common defluoridation techniques used can be categorised into precipitation based techniques and adsorption and ion exchange based techniques (Piddennavar R, Pushpanjali K. 2013). Other techniques such as reverse osmosis, membrane based techniques, electrodialysis, donnan dialysis and lime reactor have been efficient. However, Integrated Fluorosis Mitigation approach directed attention towards development of cost effective and simple adsorbent materials such as alumina, bauxite and bone char. Domestic level defluoridation techniques like Bamboo column, stacked mutka and Nalgonda Technique were promoted for use in ruralmareas (Liang et al.1997). According to Mumtaz et al. (2015) it is also revealed that electrolytic defluoridation process produces the treated water
with 90–99% reduction efficiency of excess fluoride. Simultaneously the hardness, nitrate, total coliform, and fecal coliform counts are also reduced in raw water. This process requires less space and is very cost-effective. It is found highly effective in dechlorination of drinking water supply. Electrolytic defluoridation requires simple equipment and is easy to operate with sufficient operational latitude to handle most problems encountered on running (Mumtaz et al. 2014, 2012a, 2012b).

4.3. Nutritional Supplementation

Chinoy et al (2005), reported that nutrient supplementation is necessary to reduce fluoride induced liver toxicity and for recovery. Community based studies by Krishnamachari et al (1986) reported that calcium supplementation reverses bone changes seen in fluorosis. Cassia tora (Chakoda Bhaji) a vegetable grown commonly in rural areas has very high calcium content (3200mg/100g of dry leaves) (NEERI,. 2007). Chakma et al (2000) reported that consumption of Chakoda Bhaji resulted in reversal of skeletal fluorosis. Hence consumption of Chakoda Bhaji is promoted as a part of Integrated Fluorosis Mitigation.

Table 1 List of Various Fluorosis Mitigation Projects Launched and Evaluated in Different Indian States/Regions

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Year</th>
<th>Investigator</th>
<th>Place</th>
<th>Project</th>
<th>Initiating authority</th>
<th>Strategy used</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2000</td>
<td>Vaish AK and Vaish P.</td>
<td>Dungarpur, Rajasthan</td>
<td>Project SARITA.</td>
<td>UNICEF</td>
<td>Nalgonda based drum sets and Activated alumina filters.</td>
<td>800 households of five villages opted both the techniques. Significant relief from non-skeletal symptoms. Households owned Activated Alumina filters and Nalgonda drum sets.</td>
</tr>
<tr>
<td>2</td>
<td>2004</td>
<td>Gautam A and Tripathi RC.</td>
<td>Sonbhadra, Uttar Pradesh.</td>
<td>Fluorosis Mitigation Project</td>
<td>People’s Science Institute, Banwasi Seva Ashram.</td>
<td>Health assessment, water quality management, Public awareness programmes, nutritional intervention.</td>
<td>2146 household and 970 children were benefited from this project.</td>
</tr>
<tr>
<td>3</td>
<td>2004</td>
<td>Narayana AS, Khandare AL, Krishnamurthi MVRS.</td>
<td>Nalgonda district, Andhra Pradesh.</td>
<td>Fluorosis Mitigation</td>
<td>Sai Oral Health Foundation and Government of Andhra Pradesh</td>
<td>Rainwater harvesting system and bone char based defluoridation techniques.</td>
<td>38 % of decrease of urinary fluoride, 6 % increase of serum calcium, 5 % increase of serum phosphorus and 8 % increase in serum alkaline phosphatase.</td>
</tr>
<tr>
<td>4</td>
<td>2005</td>
<td>Peoples Science Institute</td>
<td>Naupada District, Orissa.</td>
<td>Fluorosis Mitigation</td>
<td>People’s Science Institute and Sahbhagi Vikash Abhiyan.</td>
<td>Conversion of dug wells into safe sanitary wells, construction of sand wells</td>
<td>6995 beneficiaries</td>
</tr>
</tbody>
</table>
Combating fluorosis on a large scale has remained a dream till now because of absence of massive communication programs, absence of awareness with respect to individuals and so forth. Mass communications or web-based social networking can assume a key part in anticipating and restricting issue of fluorosis. It is apparent from studies by a few specialists worldwide that fluoride in groundwater and sustenance has been a potential issue to human culture. To remediate the menace caused by fluoride, an integrated approach is needed. But ultimate solution for this fluoride menace remains to be the principal of “Prevention is better than cure”.

<table>
<thead>
<tr>
<th>Year</th>
<th>Year</th>
<th>Authors</th>
<th>Location</th>
<th>Institution</th>
<th>Activities</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2006</td>
<td>Mythri H and Dinesh, Bennadi D.</td>
<td>Tumkur district, Karnataka</td>
<td>BAIF Institute for Rural Development, Karnataka. Rural Development and Panchayati Raj Department.</td>
<td>Rooftop rainwater harvesting, recharge of borewells, direct aquifer recharge.</td>
<td>5600 rain water harvesting structures were constructed. Creation of artificial catchment and recharge of borewells.</td>
</tr>
<tr>
<td>7</td>
<td>2008</td>
<td>People’s Science Institute, Dehradun. Vasudha Vikas Sansthan (Dhar), Water Aid, India.</td>
<td>Dhar district, Madhya Pradesh</td>
<td>A Pilot study</td>
<td>People’s science institute, Vasudha Vikas Sansthan and Water Aid, India.</td>
<td>Assess prevalence of fluorosis, water quality testing of all water sources, Fluorosis mitigation interventions. The intervention has been implemented in 24 clusters identified from 8 panchayats.</td>
</tr>
</tbody>
</table>
5. HEALTH BASED RISK ASSESSMENT

The evaluation of fluoride concentration in 248 groundwater samples from 9 blocks of Gorakhpur district, Uttar Pradesh, have provided useful insight into the extent of fluoride contamination in the study area (Figure 1). This district is highly affected by both Japanese Encephalitis, Acute Encephalitis syndrome and the dietary surveys also indicated that there is severe malnutrition in this area.

![Fluoride Concentration Scenario in terms of Percentage](image)

**Figure 1** Fluoride Concentration in Ground water samples, Gorakhpur, Uttar Pradesh

It was found that fluoride concentration in 67 samples taken from India Mark-II hand pumps was higher than 1 mg/L. About 73% of the groundwater samples have fluoride concentration of 1.0 mg/L and 14.1% of the samples are within the range of 1-1.5 mg/L. Whereas 12.9% are beyond the maximum limit of 1.5 mg/L. The most affected block is Piprauli where 88.9% samples were found to have fluoride more than 1.5 mg/L (APHA, 2005). In view of the fact that the problem particularly lies in rural areas, the defluoridation techniques involving simplicity of operation and low cost need to be adopted.

6. CONCLUSION

Considering the availability of excess fluoride in drinking water it is necessary to perform a Quantitative Chemical Risk Assessment of the affected area. Using data from dental survey and Quantitative Chemical Risk Assessment tool, the hazard is identified and risk is characterised. Based on these data, mitigation strategies are planned. This tool can be used to determine an acceptable level of risk and appropriate water quality. It includes information available on exposure routes such as food and water and dose-response to produce estimates of the disease burden associated with exposure to chemical. Based on exposure to chemicals and dose response, the risk is characterised and management options can be prioritized. It is also realized that for integrated fluorosis mitigation, defluoridation of water, and other ways of lowering fluoride intake would be necessary. There is a need to create awareness in the areas endemic to fluorosis toward suggesting the use of foodstuffs having low fluoride content and minimizing the use of edible items having high contents of fluorides. It is realized that, for effective fluorosis mitigation, a holistic approach should be adopted and adoption of an adequate strategy for water defluoridation, minimization of fluoride intake through foodstuffs, edible items, and nutrient supplementation may be required. The application of integrated fluorosis mitigation using electrolytic defluoridation system in fluorosis endemic areas can prove to be beneficial in long term.
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A Study on Integrated Fluorosis Mitigation Plan for Endemic Fluorosis Region – An Indian Perspective


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