Estimation of fluoride uptake in soil and staple food crops produced in highly fluoridated and non-fluoridated regions of Raichur District, Karnataka

Raghavendra Havale¹, Dhanu G. Rao², Shrumtha S P¹, Kausar E. Taj¹, Shiny Raj¹, Namratha Tharay¹, Kanchan M. Tuppadmath¹, Irin Mathew¹

¹AME’s Dental College and Hospital, Raichur, Karnataka, ²Subbhaiah Dental College and Hospital, Shimoga, Karnataka, India

ABSTRACT

Background and Aim: A staple food crop has varied role in diet of people living in particular regions of world; hence, it is critical to recognize their productivity. Therefore, the purpose of this study was to estimate fluoride concentration in staple food crops grown in highly fluoridated and non-fluoridated regions and its correlation with soil. Method: Total 36 samples were collected of which 18 samples consisting of each three samples of rice, redgram and jowar were selected. Likewise 18 corresponding soil samples from both areas were collected. All samples were ashed for 4–6 hours at 550°C in muffle furnace. The samples were allowed to cool, after which 10 ml distilled water was added to each sample and fluoride concentration was determined using ion selective electrode method, before each sample analysis the instrument was standardized using fluoride containing TISAB (III) buffer solution. The data was tabulated and subjected to cross-sectional observational statistical analysis using SPSS software applying unpaired t-test and Pearson’s test. Result: The mean fluoride concentration in crops and soils were rice (0.79 ppm), redgram (4.26 ppm), jowar (8.8 ppm) and in soil of rice (1.23 ppm), redgram (1.23 ppm) and jowar (1.21 ppm) respectively in fluoridated area. Where as in non-fluoridated area rice (0.07 ppm), redgram (0.81 ppm), jowar (0.81 ppm) and in soil of rice (0.61 ppm), redgram (0.07 ppm) and jowar (0.52 ppm) respectively. The resultant correlation between staple food crops with their corresponding soils were found highly significant in both regions with P value <0.005; hence, crops in fluoridated region exhibited increased fluoride retention, whereas crops in non-fluoridated region had optimal fluoride levels. Conclusion: Fluoride concentration in food crops has strong correlation with their respective soils and water irrigation properties.

Keywords: Fluoride, jowar, redgram, rice, water irrigation

Introduction

A staple food crop is typically defined as a routinely eaten food that supplies a significant proportion of energy and nutrient needs.[1] Staple food crops differ by region,[2] and these food crops are being used for various multipurpose and consumed either directly or in some other form of processing. As the staple food crops play a significant role in people’s diet,[3] it is therefore important to acknowledge about planting, irrigation, harvesting and their productivity. This is needed because some of the trace elements can be distributed in soil, earth and, water, among which fluoride is one such important component.[4] In India several states including Karnataka, are affected by endemic fluorosis.[5]
According to the World Health Organization (WHO), the amount of fluoride uptake by plants is determined mainly by the type of plant, soil condition, the quantity and form of appropriate fluoride levels that already exist in the soil. Therefore, plants tend to absorb varying amounts of fluoride depending on the type of plant and the quality of the soil in which they grow.

Since, soil plays a vital role in nature by providing a medium for plant growth as well as nutrients to plants, it is also said to be a major factor in regulating the water quality. Absorption of fluoride is mainly through gastrointestinal tract, thus diet plays an important role in fluoride uptake. Fluoride exposure is not only restricted to water, however even some of the food basically contains considerable amounts of fluoride. Hence if these staple food crops are harvested in the areas where soils are already prone to larger concentrations of fluoride, along with continuously irrigation to crops with fluoridated ground water and also by using phosphate fertilizers and pesticides can further increase the fluoride uptake in them. So, consumption of these fluoridated diet might lead to neurological disorders, thyroid abnormalities, osteoporosis and greater manifestations on dental and skeletal tissues abnormalities in growing children.

Thus, the fluoride path continues to begin from the parent rock through the soil, water, grain of plants and eventually reaches human beings through their diet.

**Material and Methods**

**Ethical clearance**

This study was carried out after the approval by the institutional ethics committee of AME’s dental college and hospital (AME/DC/379/2019-20).

**Study place and period**

The study was conducted in the two locations: Wadloor (highly fluoridated region) and Yergera (non-fluoridated region) of Raichur District, Karnataka, India from February 2020 to March 2020.

**Study design**

The present study was a cross-sectional observation study with pre- and post-study design.

**Sample size determination**

A total of 60 samples were determined based on pilot study results by taking 80% power, 95% confidence limit, level of significance at 5% using power analysis by G power, version 3.0.1 (Franz Faul Universität, Kiel, Germany). Resulting in random selecting with minimum of 36 samples from fluoridated and non-fluoridated regions.

This research was conducted in two locations, Wadloor and Yergera in district of Raichur. Those were dependent for the water supply from Krishna and Tungabhadra rivers. According to Rajiv Gandhi national drinking water mission, New Delhi in 1993, Raichur district is considered as one among the known fluoridated areas, with fluoride levels ranging from 0.2 ppm to 7.5 ppm. Wadloor is a medium-size village with total land area of 1331.36 hectares and a population of 1530 individuals with water fluoride level ranging up to 7 ppm and is supplied by river Krishna. Another medium-size village, Yergera, has a total land area of 2705.82 hectares and a population of approximately 5,896 people. This village has fluoride levels ranging from 0.2 ppm to 1 ppm and is supplied by the Tungabhadra River.

**Collection of samples**

Collection of crops: In the district of Raichur, rice (Oryza sativa), redgram (Cajanus cajan), jowar (Sorghum) are the most popular crops. As a result, a total of 36 samples were collected randomly in plastic bags, of which 18 samples, consisting of three samples of rice, three samples of redgram, and three samples of jowar, that were obtained from both highly fluoridated and non-fluoridated areas and were carried to the laboratory for analysis.

Collection of soil: A total of 18 soil samples, each three soil samples from their corresponding crops were collected in plastic bags from highly fluoridated and non-fluoridated areas and were taken for laboratory analysis.

**Laboratory analysis**

Fluoride estimation was performed under the following steps: samples digestion and fluoride estimation in soil and crops.

**Armamentarium required:** Digital electronic balance, silicon crucibles, muffle furnace, ion-selective electrode, which was developed by Orion research incorporated laboratories products group USA. The Thermo Fisher Scientific Orion VERSASTAR model was used.

Sample digestion: Dry ashing method was implemented for digestion of soils, rice, redgram and jowar. Before ashing about 5 g of each crop samples and 15 g of each soil samples were weighed on a digital electronic balance, and were placed inside the muffle furnace and set for digestion at 550°C for 4-6 hours. After which, the samples were allowed to cool in desiccators, and then 10 mL of deionized water was added to the each sample.

Method for estimating the fluoride: fluoride was measured with ion-selective electrode coupled with ion analyzer for all 36 extracted samples by electrochemical means. Before analysing the fluoride concentration in the extracted samples, the instrument was standardised using fluoride standards by utilizing 1 ppm and 10 ppm pre-prepared Total Ionic Strength Buffer III (TISAB III) solution.

Fluoride concentration estimation in soil and crops: For fluoride concentration estimation in soil and crops, 10 mL deionized water and 1 mL TISAB III buffer solution were added and analyzed.
using an Ion selective electrode.\(^4\) After each sample evaluation, the electrode was thoroughly washed with deionized water and dried properly.

**Statistical analysis**

Data entries were done in Microsoft Office Excel 2010 and analysis of results was done using statistical product and service solution (SPSS) version 21 software. The statistical analysis using descriptive statistical methods including Mean and SD was carried out for quantitative data representation (fluoride conc. in ppm). Unpaired ‘t’ test was used to compare between means of two groups independent of each other. (Fluoride conc. in crops and soil of fluoridated vs. non-fluoridated area). Pearson ‘r’ correlation coefficient was performed to test correlation between fluoride concentration in soil with fluoride concentration in crops in fluoridated and non-fluoridated area.

**Result**

**The Fluoride levels in crops and soil of fluoridated region and non-fluoridated region [Table 1 and Figure 1]**

On comparative statistics of fluoride levels in crops and soil of fluoridated region and non-fluoridated region respectively using unpaired ‘t’ test, it was observed that level of fluoride in crops and soil of fluoridated region was highly statistically significant (p < 0.001) greater as compared to non-fluoridated region. Only in Group D (Soil of rice), level of fluoride in crops and soil of fluoridated region was statistically significantly (p < 0.05) greater as compared to non-fluoridated region [Table 1, Figure 1].

**Correlation of fluoride concentration in crops with their respective soil in fluoridated and non-fluoridated area [Tables 2 and 3, Figure 2]**

The correlation of fluoride concentration in crop with the fluoride concentration in corresponding soil in fluoridated area/region Table 2: By using Pearson ‘r’ correlation coefficient, there was found to be statistical significant (p < 0.05) positive strong correlation between rice and soil of rice. There was found to be highly statistically significant (p < 0.001) positive strong correlation between redgram and soil of redgram and it was also found highly statistically significant (p < 0.001) positive strong correlation between jowar and soil of jowar [Table 2, Figure 2].

**Correlation of fluoride concentration in crop with the fluoride concentration in corresponding soil in non-fluoridated area/region Table 3**

By using Pearson ‘r’ correlation coefficient, there was found to be no statistical significant (p > 0.05) positive moderate correlation between rice and soil of rice. There was found to be highly statistical significant (p < 0.001) positive strong correlation between redgram and soil of redgram and a highly statistical significant (p < 0.05) positive strong correlation between jowar and soil of jowar [Table 3, Figure 2].

**Discussion**

This research was carried out at Raichur district which is wedged between two rivers, and hence it is known as Doab in the state of Karnataka. As a result, the entire fields in this region will be irrigated by Krishna and Tungabhadra rivers. In this report, two locations were chosen: Wadloor, which receives water from the Krishna River and Yergera, receiving water from the Tungabhadra River. Therefore, this district is accustomed with various cultural and food practices in northern part of the state Karnataka.

In fact, when it comes to simple dietary activities, their staple diet consists primarily of jowar (Sorghum), rice (Oryza sativa), and redgram (Cajanus cajan). These were the primary sources of food production and consumption. Since as diet can also play an important role in adsorption of fluoride, therefore, the focus of this research was on cross-sectional observations in highly fluoridated and non-fluoridated areas.

The concentration of fluoride varies from place to place,\(^9\) and foods such as cereals, pulses, legumes, fruit and, vegetables can absorb fluoride mainly through soil and water irrigated on those agricultural lands.\(^10\) In addition, fluoride from other natural sources, such as groundwater, industrial contamination and higher phosphate fertilizer, could be an additional fluoride supplement to these plants.\(^11\)

According to research, molybdenum is one of the elements that retain fluoride.\(^12\) In comparison with food crops such as rice, jowar and redgram fluoride retention is normally found to be higher with a jowar-based diet due to molybdenum content, which has fluoride retaining ability.\(^13\) The fact about

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**Table 1: Comparative statistics of level of fluoride in crops and soil of fluoridated region and non-fluoridated region, respectively**

| Group | Fluoridated area Mean (SD) | Non-Fluoridated area Mean (SD) | Unpaired t-test | P, Significance |
|-------|---------------------------|-------------------------------|----------------|-----------------|
| Group A (Rice) | 0.79 (0.015) | 0.07 (0.07) | t=20.489 | P<0.001* |
| Group B (Redgram) | 4.26 (0.15) | 0.81 (0.015) | t=38.963 | P<0.001* |
| Group C (Jowar) | 8.83 (1.04) | 0.81 (0.02) | t=13.343 | P<0.001* |
| Group D (Soil of rice) | 1.23 (0.15) | 0.61 (0.015) | t=6.996 | P=0.002* |
| Group E (Soil of redgram) | 1.23 (0.02) | 0.07 (0.001) | t=69.203 | P<0.001* |
| Group F (Soil of Jowar) | 1.21 (0.015) | 0.52 (0.03) | t=30.815 | P<0.001* |

*P<0.05 – significant difference. **P<0.001 – highly significant
molybdenum ingestion is known to cause secondary deficiency of copper, which is necessary element for bone and teeth development.[17]

In this study the crops in fluoridated areas, were harvested by high fluoridated ground water that contains 7 ppm of fluoride and in non-fluoridated regions with 1 ppm of fluoride. Therefore in the present study, crops that were estimated for fluoride estimation and correlation with their corresponding soils in highly fluoridated area showed fluoride content in jowar, redgram and rice with their mean value of 8.83 ppm, 4.26 ppm, 0.79 ppm, respectively, and its association with corresponding soils mean value were, 1.21 ppm (jowar), 1.23 ppm (redgram), 1.23 ppm (rice), respectively [Table 1, Figure 1]. This could be due to the crops in fluoridated area were irrigated with ground water that already contained high amounts of fluoride. Hence soil which contained high amount of fluoride can be more acidic[9] and due to arid[18] or, semi-arid[19] conditions the pH of soil was also altered.[20] Therefore soils under such features can occur in ionic form, rendering it less alkaline and more acidic in nature. Waldbott et al.[21] demonstrated that soil under these conditions has strong fluoride retention properties which might be contributing factor in development of dental and skeletal fluorosis.

It was further observed that fluoride concentration in jowar exhibited highest fluoride retention properties, when compared to rice and redgram. This resultant jowar fluoride content was in accordance with the study conducted by Dhanu et al.[22] in 2018 where the population was divided in jowar and non-jowar consumers and concluded that, and about 75% of population who consumed jowar exhibited fluorosis. But in the association of rice with its corresponding soil was less significant when compared with other crops and their association with respective soils. In a study conducted by G. Arora et al.[14] compared between concentration of fluoride in soil and crops grown over it and...
**Table 2: Correlation of fluoride content in crop with the fluoride content in corresponding soil in fluoridated area/region**

| Fluoridated region       | Pearson *'r' correlation coefficient | P* significance |
|--------------------------|--------------------------------------|-----------------|
| Rice × Soil of rice      | r=0.964 (positive strong correlation) | P<0.001**       |
| Redgram × Soil of redgram| r=1.000 (positive strong correlation) | P<0.001**       |
| Jowar × Soil of jowar    | r=0.990 (positive strong correlation) | P<0.001**       |

*P>0.05 – no significant correlation. *P<0.05 – significant. **P<0.001 – highly significant

**Table 3: Correlation of fluoride content in crop with the fluoride content in corresponding soil in non-fluoridated area/region**

| Non-Fluoridated region   | Pearson *'r' correlation coefficient | P* significance |
|--------------------------|--------------------------------------|-----------------|
| Rice × Soil of rice      | r=0.400 (positive moderate correlation) | P=0.738         |
| Redgram × Soil of redgram| r=1.000 (positive strong correlation) | P<0.001**       |
| Jowar × Soil of jowar    | r=0.990 (positive strong correlation) | P=0.024*        |

*P>0.05 – no significant correlation. *P<0.05 – significant. **P<0.001 – highly significant

found weak correlation between the mean fluoride concentration of soil and mean fluoride concentration of rice $P = 0.438$ which would support our above finding for rice and its correlation with soil. As per our knowledge, no previous research has been found to assess the correlation between redgram and its correlation with soil. And in this present study, it was found that fluoride uptake in redgram was less compared to jowar but higher than rice. Hence it was concluded that the concentration of fluoride in crops with their corresponding soils in fluoridated area showed a strong positive correlation for jowar and redgram [Table 2, Figure 2].

Whereas in case of non-fluoridated area with 1 ppm of water fluoride content, the respective crops jowar and redgram obtained mean fluoride concentration of 0.81 ppm in both the crops, respectively, and rice alone contained mean fluoride concentration of 0.07 ppm, thus the mean value found in non-fluoridated area is comparatively less in fluoride concentration than the high fluoridated region. The soil mean fluoride levels of jowar, redgram and rice of non-fluoridated area were 0.52 ppm, 0.07 ppm, 0.61 ppm, respectively [Table 3, Figure 2]. In comparison with correlation between crops and soil of non-fluoridated area jowar and redgram resulted in strong positive association with their corresponding soils, when compared to rice found to be positive moderately associated with its respective soil ($P = 0.738$) [Table 3, Figure 2]. These above results reveal the association with soil fluoride retention properties. These findings are in accordance with the study conducted in 2017 by Naik RG et al.\[9\] associating the levels of fluoride into three groups: soil, water and, grain and determining maximum correlation between fluoride levels in soil and grain fluoride levels {r-value = 0.8} in their study when they adjusted the fluoride levels in water from high to optimal levels the strength of fluoride between soil and grain reduced significantly {β = 0.350}; similarly, when adjusted for the fluoride level in soil the strength of the association between water and grain decreased dramatically {β = 0.319}. According to the result of this research, low fluoride concentrations in soil can promote crops to absorb less fluoride, and vice versa. Intake of plant-based foods under conditions similar to those found in high fluoridated areas can increase ingestion of fluoride, contributing to higher fluoride levels in the human body. As many studies have shown; fluoride not only enters through drinking water but also has a strong co-relation with edible items.\[9,14\]

The association between the intake of jowar, redgram\[9] and rice\[4] with dental fluorosis severity and skeletal fluorosis has been studied.\[9,19\] But there is no previous study of increase fluoride content in redgram by correlating with soil fluoride levels as per our knowledge.

Children with serious health problems associated with chronic fluorosis have been reported in some parts of highly fluoridated areas around the worldwide, and in India about 20 states are experiencing with endemic fluorosis.\[24\]

Therefore it is important to monitor the daily fluoride intake from food and water in infancy and early childhood period to prevent dental fluorosis during pre-eruptive maturation of enamel\[25\] and also defective mineralization of both the dentitions.

As fluoride cannot be eliminated entirely from the human diet, due to its ubiquitous nature, but the concentration can be lowered by defluoridation techniques and adopting different water sources other than ground water for drinking, soil irrigation and various other purposes.\[18,26\]

Therefore, this research can raise the standards and strengthen the awareness in public health and also educating the important significance of routine people’s diet. But similar studies with larger variables involving both children and adults residing in high fluoridated and non-fluoridated areas are further recommended.

**Limitations**

This research did not correlate the fluoride levels of staple food crops with children or adults.

**Keypoints**

- This present study is one of the first in Raichur district to consider staple foods diet like rice (Oryza sativa), redgram (Cajanus cajan) and jowar (Sorghum) in two endemic villages of Raichur district, one which had a water fluoride level of about 7 ppm (Wadloor), and another with 1.2 ppm (Yergyera), and enlightening with systemic and dental fluoride toxicity.

Fluoride concentration in soil and crops was maximum in highly fluoridated region, with highest concentration obtained in jowar followed by redgram and rice along with their respective soils when compared with non-fluoridated region.
Havale, et al.: Fluoride uptake in soil and food crops in highly fluoridated and non fluoridated regions

• Hence our study states that, the concentration of fluoride in ground water above the permissible level is a factor that contributes to the accumulation of fluoride in agricultural soils and crops.
• Not just ground water, fluoride has poisoned agricultural soils and crops in Raichur district. We have also reported these evidences to District Health Office, Raichur, in order to take preventive measures and conduct awareness programmes that would benefit the population residing in these endemic areas.

Conclusion

This study found two endemic villages in the Raichur district, one of which had a water fluoride level of about 7 ppm, which was higher than the recommended safe level. In these regions, children were taught about healthy diet consumption and received knowledge and health education. They were advised to drink river water because their primary source of drinking water was a bore well. This research also looked at the relationship between crops and the soil in which they are growing, as well as recommended that crops should no longer be irrigated with bore water polluted with fluoride and other containers, and how that affects fluoride retention. As a result, avoid consuming and irrigating staple food crops with heavily fluoride-contaminated water.

Statement

All the authors have equal contribution in the study.

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Work affiliation (ISSPPD)

Raghavendra Havale: EC member for ISSPPD (2021)
Dhanu G. Rao: President - ISPPD (2020-21)
Shrutha S P: Life member- ISPPD (704)
Kausar- E- Taj: student member-ISPPD
Namratha Tharay: Life member- ISPPD
Kanchan M Tuppadmath : student member-ISPPD
Irin Mathew: student member-ISPPD.

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Conflicts of interest

There are no conflicts of interest.

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