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GIS based evaluation of contamination of fluoride in groundwater quality and occurrence of dental fluorosis in Coimbatore district, TamilNadu, India

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Abstract. Groundwater is the major source of drinking water in urban and rural India. Groundwater is primarily used for various purposes like drinking, washing, irrigation, etc. Groundwater can become contaminated in many ways. The study has been carried out to assess the fluoride in groundwater of Coimbatore district. The secondary data of groundwater has been collected from PWD, Chennai, Tamil Nadu for the years of 2014 to 2018. Geographic information system (GIS) approach is used to develop spatial information and knowledge about fluoride in groundwater quality. Fluoride plays an important role in human metabolism within the permissible limit. But it is exceeded by many activities mainly by the human activities. High level of fluoride cause major impact on human health. It can replace calcium ion in bones and teeth, which can lead to fluorosis. Therefore this study was aimed to identify the high and low risk of fluoride contamination in groundwater. The study revealed that high level of fluoride 2014 (2.83mg/l), 2015 (1.86mg/l), 2016 (3.6mg/l), 2017 (1.56mg/l), and 2018 (1.68mg/l). It provides an understanding into the problem of fluorosis among people in the study area, where fluorosis is a public health problem of significant impact. Ambrampalayam, Puliampatti, Puravaipalayam, Ettimadai, Sirumugai and Therampalayam where the places shows the high level fluoride and people experiences the symptoms of dental fluorosis. There is compulsory need for defluoridation of the groundwater before consumption.

Keywords: Groundwater; fluoride; GIS; Coimbatore, dental fluorosis.

1. Introduction

The world is in our hands. With the start of a new millennium, human race faces environmental challenges greater in magnitude than ever before because the scale of the problem is shifting from local to regional and even to global ones. Indeed, the footprint of human activity continues to expand to the point that it is exerting a major effect on nearly all of the Earth's systems. Global environmental problems such as global climate change, unsustainable development in many parts of the world are evolving as significant issues for the future of mankind and of the planet. At local and regional scales, change in land use, diminishing streams, loss of biotic integrity and habitat fragmentation constitute some of the examples of how human- induced changes have impacted the earth's systems. Water is an

essential element for sustaining life, touching all physical, chemical and biological features of our natural world [1, 2, 3]. Rivers, streams and lakes are the "lifeblood" of our environment. When waterways are polluted, it is known that the system is in need of repair. When waterways are healthy, it is known that the environment can support a diversity of plant and animal species. Adequate water supply and the biological diversity that the world's water supports is the key to a sustainable future for all forms of life, including humans. The main reason for over exploitation of ground water is absence of fresh surface water to meet various needs of human beings [4, 5, 6].

The majority of population from urban and rural India depends on ground water for drinking water [7, 8]. However unsustainable depletion of groundwater has been documented both regional and global level [9, 10]. Geological distribution and anthropogenic factors alter the spatial pattern variation in ground water quality factors [11]. Groundwater is used for various purposes like drinking, washing and irrigation etc. It can become contaminated in several approaches in various human and natural activities [12, 13]. Arsenic, Fluoride, Nitrate, Iron, Manganese and Boron were the majority of heavy metals and less number of radionuclide contaminants, which causes major impacts [14]. Among these contaminants fluoride has severe impacts on human health. The natural sources of fluoride are rocks, soil and water. Rock is the key source of fluoride, which causes contamination of ground water. Once the fluoride reaches in the human body through drinking water, it may reacts with calcium present in teeth and it results in dental fluorosis. Dental flourosis is affected by both children as well as adults [15].

Acceptable limit for fluoride in drinking water is 1.5 mg/l (WHO, 2010) as per World health organization (WHO). The level of fluoride in drinking water has to be within the range, higher or lower concentrations of fluoride are injurious to living organisms [16]. The extreme fluoride may affect the severity of damage in plants and animals determined by duration of exposure and concentration [17]. Global dumping rate of fluoride on ground is 85 million tons, among these 12 million tons are dumped by India [18]. In state of Tamil Nadu, 23 out of 32 districts have been affected by fluorosis in drinking water [19]. Several researchers from India as well as world reported the fluoride contamination in ground water [20]. Apart from natural sources, the other sources of fluoride are industrial effluents from glass and aluminum manufacturing, foods, beverages and tooth paste [21]. India and China countries are highly affected the fluorosis problem in due to over population. The high concentration of fluoride is caused by dental flourosis [22]. 17 states and 150,000 villages in India are endemic to ground water contamination by fluoride as well as dental flourosis. The severely affected Indian states are Punjab, Tamil Nadu, Andhra Pradesh, Rajasthan, Bihar and Uttar Pradesh [8, 23]. In Tamilnadu fluoride contamination is very high in Salem and Dharmapuri. Chidambaram, Madurai, Coimbatore, Erode, Trichy, and Dindugal also reported for dental fluorosis [24].

In the present study, 37 locations of Coimbatore were assessed for fluoride contamination in groundwater for five years 2014 -2018. Fluoride concentration in groundwater was identified with the help of Geographical information system (GIS) [8, 25]. To represent the spatial pattern of fluoride in groundwater into different classes Inverse distance weighted (IDW) method comes under spatial interpolation technique was used. The collected data were analyzed descriptive statistics and Pearson Correlation bivariate two tailed analysis by using SPSS software's method. The key objective of the present study is to assess the fluoride pollution in groundwater of Coimbatore with the help of GIS and to check the incidence of dental fluorosis in the population. The attempt was made to analyze the groundwater for fluoride contaminated prone areas in Coimbatore district, state of Tamilnadu, India.

2. Study Area

The study area was chosen Coimbatore district, it is surrounded by the western part of TamilNadu State, nearby border of Kerala. It is covered the eastern part of Tiruppur district, Western Ghats extended by western and northern part, stretches in Nilgiris biosphere. Southern region has bounded

by Anaimali and Munnar stretches. The geographic area of the region is around 4,723 square kilometres (sq.km). It lies between 10°10′08″ and 11°30′12″ northern latitude, 76°40′28″ and 77°30′42″ eastern longitude. The elevation of the region is 411 m (1,348 ft) and total area of district is covered 4732 sq km. The overall population of the area is 19, 93,920. The maximum temperature of plains is 37.5°C and minimum temperature is 19.5°Celsius. The average yearly precipitation contributing in the areas is around 700 mm with the northeast (47%), and southwest monsoon (28%) was respectively. The district has net cultivated area of about 1, 65,260 Hectares. The study area has more than 25,000 industries in and around in rural and urban areas. The main soil types of study area are black cotton soil, reddish brown/brown loamy soil, alluvium and colluvium [26]. The overall study area map is presented in figure1.
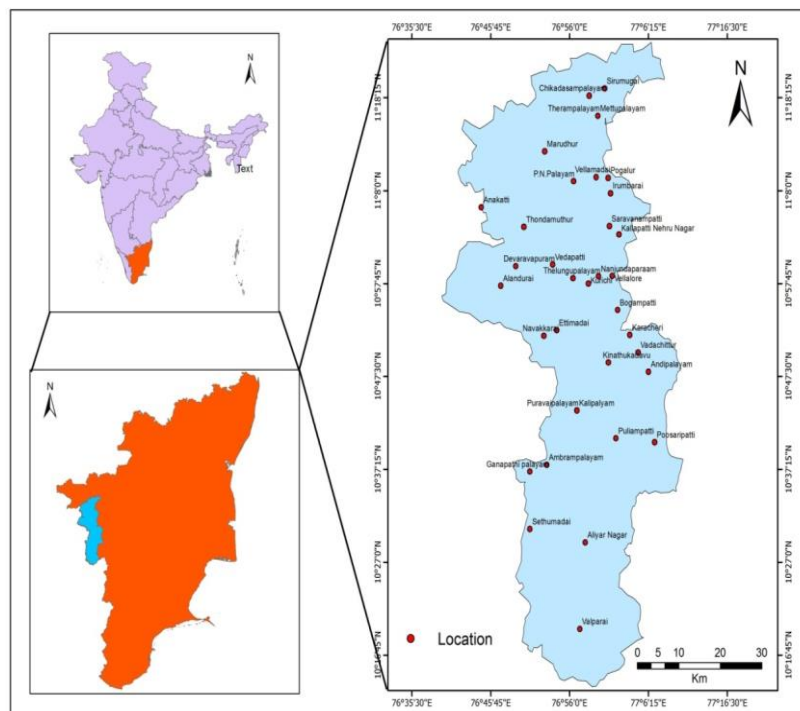

Figure 1: Study area map of Coimbatore district

3. Methodology

3.1. Data sources and collection
The groundwater quality data of 37 locations, 12 blocks of Coimbatore such as Anamalai, Annur, Karamadai, Kinathukadavu, Madukarai, Periyanayakkanpalayam, North Pollachi, South Pollachi, Sarkarsamakulam, Sultanpet, Sulur, and Thondamuthur were collected from State ground and surface water resources data centre (Public Works Department, Tharamani) for the years of January 2014 to December 2018.

3.2. Data collection
The ground water samples were collected in 1 litre new plastic container and get analyse in laboratory the samples were analysed as per the standard method (APHA, 2005) [27]. The fluoride analysis was used to estimate the calorimetric method with the help of UV-Visible spectrophotometer. All the sampling sites where located using global position system (GPS). The quality of the groundwater differs from area to area with the depth of water table. The each parameter values along with observations on the groundwater quality presented in results.

3.3. Sample Analysis

The fluoride analysis was used to estimate the calorimetric method in UV visible spectrophotometer. Colorimetric method (SPADNS) and Ion selective electrode methods were proposed the fluoride ion determination.

3.3.1. Colorimetric method (SPADNS)

When fluoride reacts with Zirconium dyes a clorless complex anion and a dye are formed. The formed complex is propositional to the concentration of fluoride. This is the main principle of SPADNS speactrophotometric method. The resulted colour complex formed by the reaction of fluoride with Zr-SPADNS (Na_2 parasulphophenylazo) - (1, 8-dihydroxy-3, 6-napthalene disulphonate) was measured in a speactrophotometer at 570 nm. Fluoride versus absorbance calibration curve was used to measeures fluoride level in samples. The overall methodology of the present study is shown in figure 2.
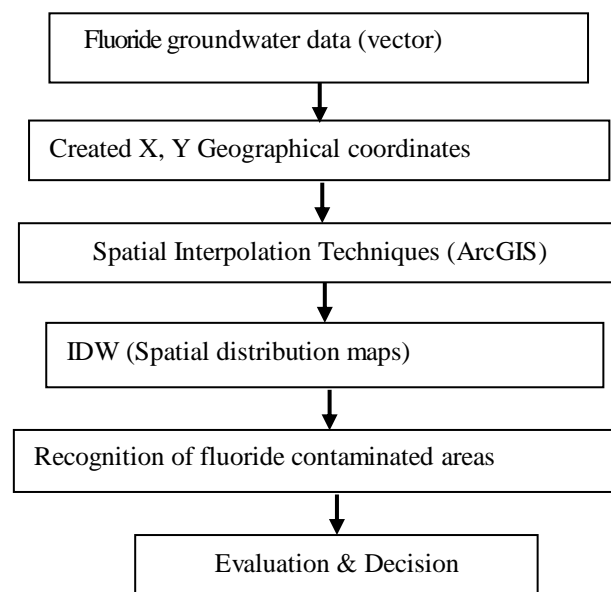

Figure 2: Methodology of the distribution and identification of fluoride

3.4. Descriptive statistics, Pearson Correlation bivariate two tailed analysis and GIS analysis

In statistical analysis fluoride is performed the groundwater quality of 25 sample locations for the period of 2014 and 2018. The descriptive statistics containing the range, minimum, maximum, mean standard variation, variance, skewness and kurtosis of the values to have a general idea about the distribution of the samples. Pearson correlation is used to examine the relationship between two variables which gives the indication that the changes in one variable are associated with those in another variable. Once correlation do exist, then by measuring a very few important parameters one can easily calculate, rest of the other parameters can be easily and quickly assessed. The Statistical Package for the Social Sciences (SPSS) software were produced for the management and statistical analysis of social science studies. Based on the study, geographical information system (GIS) is an important tool. The functional area of computer mapping, spatial database management and cartographic modelling were used to process the spatial information and analysis [26, 28].

3.5. IDW interpolation method

The spatial interpolation method is used to predict the unknown values of geographical parameters [29, 30]. Choice interpolation based on the number of samples and their spatial distribution, IDW is better in performance [31]. The general equation of the IDW is,

$$Z_0 = \frac{\sum_{i=1}^{s} Z_i \frac{1}{d_i^k}}{\sum_{i=1} \frac{1}{d_i^k}}$$

Where,

Z_0 is estimated value at point 0; Z_i is the Z value at control point i ; d_i is the distance between control point i and control point 0; S is the number of control point used in estimation; k the specified power.

4. Result and discussion

4.1 Descriptive Statistics of fluoride contamination analysis
The statistical analysis assists to assess the correlation between the set of data. The descriptive statistics were used to expressed or summarize data in different manner that are significant and useful. Statistical interference of the study describes the difference in the fluoride content in study region. Cross validation of the data can be done by statistical package for social science (SPSS). The result of this statistical analysis shows positive correlation. The overall statistics of the fluoride levels were presented in Table 1.

Table 1: Mean fluoride concentration in study area with descriptive statistics for the years of 2014 to 2018 (n = 37)

Year	N	Range	Min	Max	Mean	Std. Dev	Variance	Skewness	Kurtosis
2014	37	2.78	0.05	2.83	1.0219	0.64502	0.416	0.911	0.967
2015	37	2.08	0.02	2.1	0.9219	0.57516	0.331	0.323	-0.771
2016	37	3.55	0.05	3.6	0.7905	0.65589	0.43	2.267	8.478
2017	37	1.5	0	1.6	0.628	0.4649	0.216	0.555	-0.769
2018	37	1.6	0.08	1.68	0.5901	0.39864	0.159	1.049	0.681

The total numbers of samples are 37, where the minimum and maximum statistical value was found to be 0.05mg/l and 2.83mg/l respectively. The mean value and standard deviation were observed 1.021mg/l and 0.645mg/l respectively in the year 2014. In 2015, minimum and maximum statistical values were 0.02mg/l and 2.10mg/l respectively. The mean value is 0.9219 mg/l and standard deviation is 0.57516mg/l. The minimum and maximum values were found in 2016 with respective of 0.05mg/l and 3.60mg/l. Mean and standard deviation were presented in 0.7905 mg/l and 0.65589mg/l. In 2017, maximum statistical 1.6mg/l, mean 0.628mg/l and standard deviation 0.4649mg/l values were presented respectively. The minimum and maximum statistical values were obtained in 0.08mg/l and 1.68mg/l of 2018. The mean value 0.5901mg/l and standard deviation 0.39864 mg/l were presented in same. The mean value of 2014 is higher than other four years (2015, 2016, 2017, and 2018). The different organizations were given the rating of the permissible limits of fluoride in drinking water. The World Health Organization (WHO) permissible limit (1.5 mg/l); Bureau of Indian Standards (BIS), Public Health Engineering (PHE) and Indian Council of Medical Research (ICMR) were allowed the permissible limit in 1.0 mg/l [9].

4.1.1 Pearson Correlation bivariate two tailed analysis
 The positive ($p < 0.01$) and significant correlation ($p < 0.05$) were monitored in the groundwater samples. The correlation analysis from the Pearson correlation output, fluoride shows that 2014 (r = 0.016), 2015 (r = 0.352), 2016 (r = 0.087), 2017 (r = 0.118), and 2018 (r=0.103). This means changes in fluoride of ground water are associated with the 2014 - 2018 years. The low positive correlation years are 2014 and 2016; moderate positive years are 20117 and 2018. The high positive fluoride range is presented in the year 2015. It means No negative correlation was found between 2014 -2018

fluoride data and fluoride levels in either drinking water or water for domestic use. It infers that as water becomes more fluoride are dissolved from the water minerals into it. The fluoride shows that high positive correlation 2015 (r^2 = 0.125), moderate year is obtained in 2018 (r^2 =0.009), low positive years were observed in 2014 (r^2 =0.002), 2016   (r^2 =0.007) and 2017 (r^2 =0.244) respectively.

4.2 Groundwater contaminated by fluoride

The fluoride accessibility in ground water in mg/l has been used for generation of fluoride contamination map. For this study, 5 years groundwater samples of fluoride data from 2014 to 2018 were used.   GIS, Inverse distance weighted (IDW) method comes under spatial interpolation techniques were used to prepare 37 sampling site distribution maps in smooth ways.   IDW method is very easy and very effective for generating the spatial distribution maps.

4.2.1. Spatial analysis of fluoride in groundwater in 2014

 The year 2014, fluoride were highly concentrated the areas of southern part of Coimbatore areas Puliampatti, Poosaripatti, Sethumadai and Sirumugai ranged between 1.717- 2.821mg/l.   The low concentration of fluoride is mostly occurred in northern and few southern areas such as Vedapatti, Valparai, Thondamuthur, Saravanampatti, Kallapatti Nehru nagar, Ganapathipalayam and Alandurai. The spatial distribution of fluoride (2014) is presented in figure 3. For this study, in the year of 2014 high level of fluoride is ranges from1.58 to 2.82 mg/l and low concentration is ranges from 0.05 to 0.16 mg/l. According to WHO [32] fluoride concentration level i.e. high and low concentration was shown in figure 4.
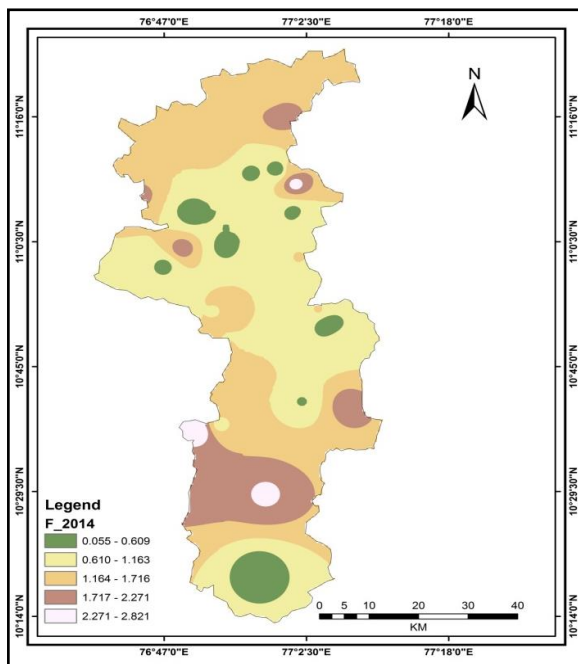

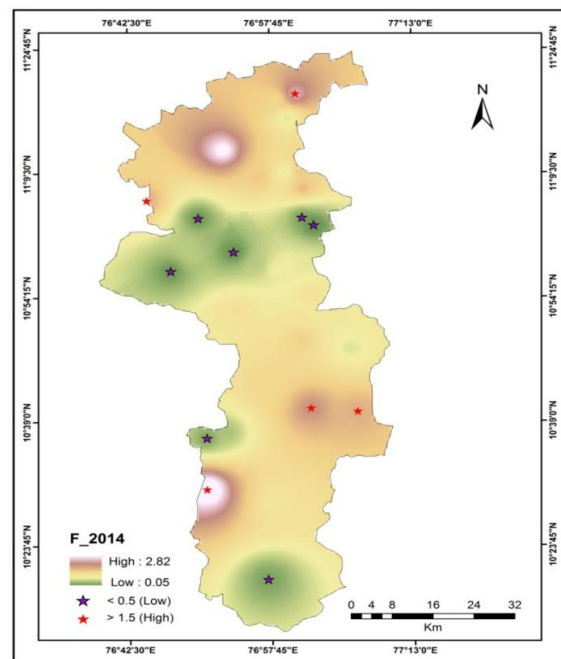**Figure 3**: IDW method for fluoride contamination groundwater (2014)

Figure 4: Fluoride contamination of groundwater as per WHO limit (2014)

4.2.2. Spatial analysis of fluoride contamination in 2015

In 2015, the south and southwest part of the areas were observed Aliyar Nagar, Devarayapuram, Ganapathipalayam, Irumbarai, Poosaripatti, Puravaipalayam, Sethumadai and Therampalayam areas higher fluoride concentration which ranges from 1.289 to 2.095mg/l. The low concentration has been occurred in northeast and northwest as well as in some southern part of Coimbatore (i.e. Vellamadai, Vedapatti, Valparai, Vadachitthur, Thondamuthur, Saravanampatti, Puliampatti, P.N. palayam, Alandurai), ranges from 0.027 to 0.441mg/l. The fluoride contamination of groundwater as presented in figure 5. For this study, in the year of 2015 high level of fluoride is ranges from 1.54 to 2.1mg/l and

low concentration is ranges from 0.02 to 0.41mg/l. According to WHO fluoride concentration level i.e. high and low concentration for 2015 is shown in figure 6.
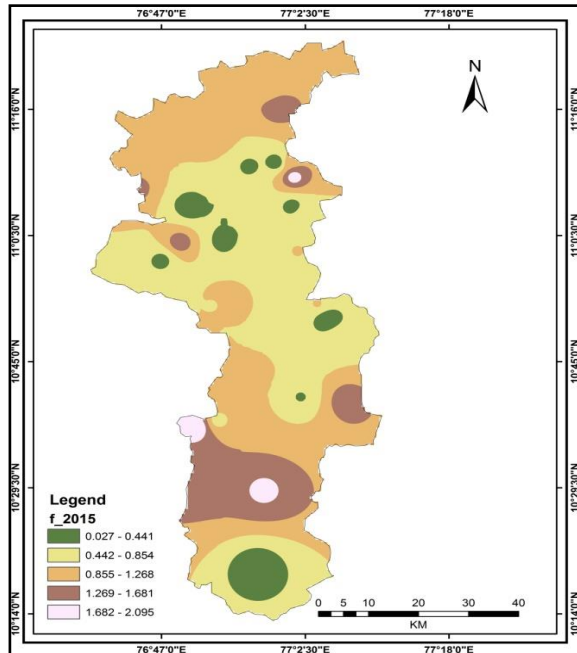

Figure 5: IDW method for fluoride contamination groundwater (2015)
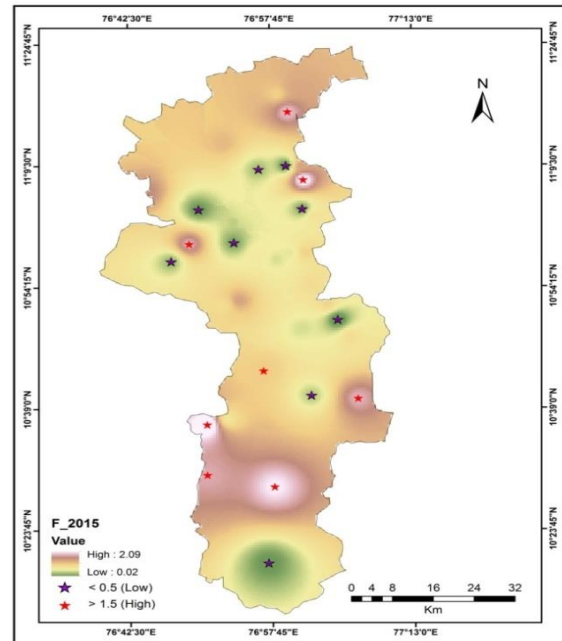

Figure 6: Fluoride contamination of groundwater as per WHO limit (2015)

4.2.3 Spatial analysis of fluoride contamination in 2016
 In year 2016, high concentration is ranges from 2.175 to 3.591mg/l, it has occurred in Southwest part (i.e. Ambrampalayam, Ettimadai, Sirumugai, and Vellamadai) of Coimbatore. Low concentration of fluoride was occurred in South, Southeast, northeast and northwest part of Coimbatore (i.e. Alandurai, Aliyar Nagar, Anakatti, Irumbarai, Kurichi, Marudhur, Nanjundapuram, Puliampatti, Saravampatti, Vadachittur, Valparai and Vedapatti) which is ranges from 0.051 to 0.758mg/l. The fluoride distribution for 2016 is shown in figure 7. Fluoride concentration were investigated the correlation, regression analysis of the data points of groundwater at Pennagaram block of Dharmapuri district, Tamilnadu. The study concludes that 45% of the groundwater samples were found to be higher in fluoride levels and posing a major problem for water resources. Dental and skeletal fluorosis is very common in people those who lives in the study area [14]. For this study, in the year of 2016 high level of fluoride is ranges from 1.52 to 3.6mg/l and low concentration is ranges from 0.08 to 0.41mg/l. According to WHO fluoride concentration level i.e. high and low concentration for 2016 is shown in figure 8.

4.2.4. Spatial analysis of fluoride contamination in 2017
 In year 2017, Coimbatore north and Southwest Coimbatore (i.e. Ettimadai and Sethumadai) has higher concentration. South and Southwest part of Coimbatore (i.e.Alandurai, Aliyar Nagar, Ambrampalayam, Anakatti, Devaravapuram, Ganapathipalayam, Kalipalayam, Kurichi, Nanjundapuram, Navakkarai, and Puliampatti) has lower concentration of fluoride. According to WHO limit fluoride IDW method 2017 shown in figure 9. For this study, in the year of 2017 high level of fluoride is ranges from 1.53 and 1.56mg/l and low concentration is ranges from 0.02 to 0.48mg/l. According to the WHO fluoride concentration level i.e. high and low concentration for 2018 shown in figure 10.
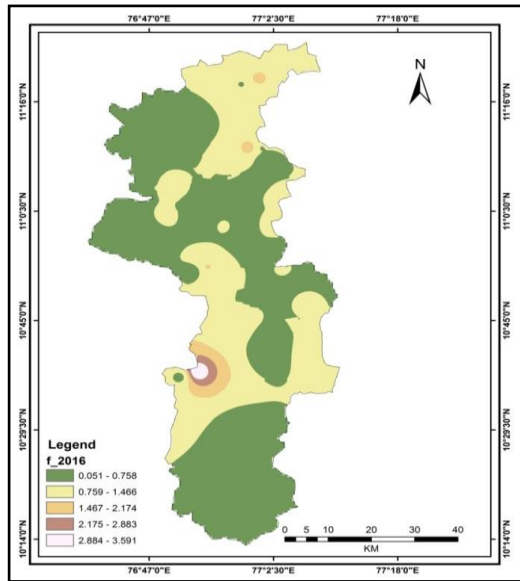
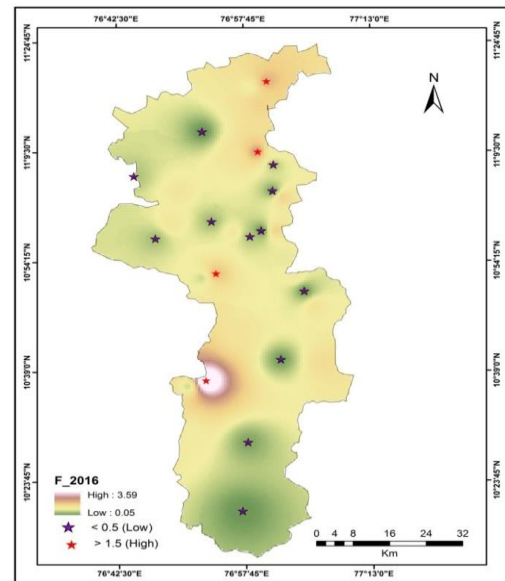**Figure 7:** IDW method for fluoride contamination groundwater (2016)

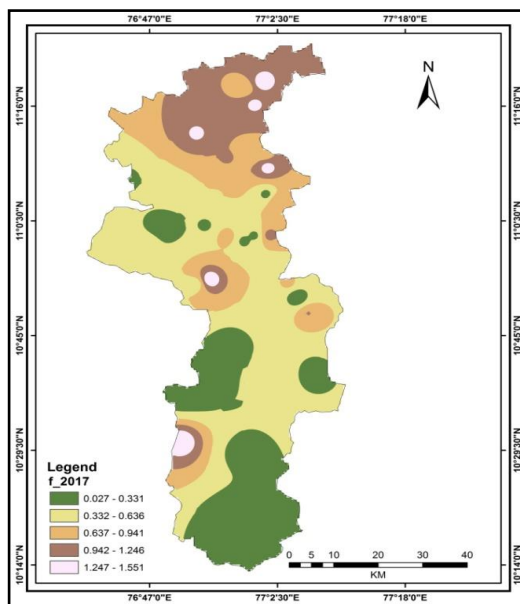**Figure 8:** Fluoride contamination of groundwater as per WHO limit (2016)

Figure 9: IDW method for fluoride contamination groundwater (2017)
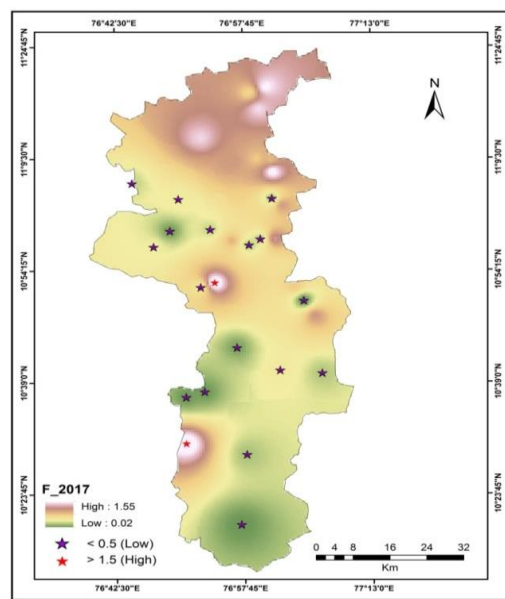

Figure 10: Fluoride contamination of groundwater as per WHO limit (2017)

4.2.5 Spatial analysis of fluoride contamination in 2017

In year 2017, Coimbatore north and Southwest Coimbatore (i.e. Ettimadai, Sethumadai) has higher concentration. South and Southwest part of Coimbatore (i.e. Alandurai, Aliyar Nagar, Ambrampalayam, Anakatti, Devaravapuram, Ganapathipalayam, Kalipalayam, Kurichi, Nanjundapuram, Navakkarai, and Puliampatti) has lower concentration of fluoride IDW method 2017 shown in figure 9. For this study, in the year of 2017 high level of fluoride is ranges from 1.53 and 1.56mg/l and low concentration is ranges from 0.02 to 0.48mg/l. According to WHO fluoride concentration level i.e. high and low concentration for 2018 shown in figure 10.

4.2.6 Spatial analysis of fluoride contamination in 2018

In year 2018, Southwest (i.e. Ettimadai) Coimbatore has high fluoride concentration. South and some part of north (i.e. Alandurai, Aliyar Nagar, Amabrampalayam, Anakatti, Bogampatti, Devaravapuram, Kalipalayam, Kinathukadavu, Kurichi, Marudhur, Nanjundapuram, P.N.palayam, and Puliampatti) have low concentration of fluoride. Fluoride distribution of 2018 is shown in figure 11. Assessment of the fluoride concentration in kundadam block in Tiruppur District, they were stated that out of 64 different locations the ground water samples analysed for fluoride, merely 16 locations of the ground water were highly observed the permissible limits of fluoride (1.5 mg/l) [6]. For this study, in the year of 2018 high level of fluoride is 1.68mg/l and low concentration is ranges from 0.08 to 0.49mg/l. High and low level of fluoride according to the WHO limit can be shown in figure 12. According to WHO limit, the above maps were differentiate the vulnerable areas and low level concentration of fluoride. Compared to all the five years, Southwest Coimbatore was vulnerable than other part of Coimbatore. The variation of fluoride distribution of groundwater maps are clearly indicates the ranges between 0.02 to 3.59mg/l. The variation of fluoride value and the location for the five years is shown in the following figure 13. In 2014, Anakatti, Maruthur, Puliampatti, Poosaripatti, Sethumadai, Sirumugai has the higher concentration of fluoride. Aliyar nagar, Ganapathipalayam, Irumbarai, Puravaipalayam, Therampalayam has high concentration in 2015. In 2016, Ambrampalayam has the highest concentration of fluoride. In 2017, Ettimadai and Sethumadai have high concentration and in 2018, Ettimadai shows high concentration.
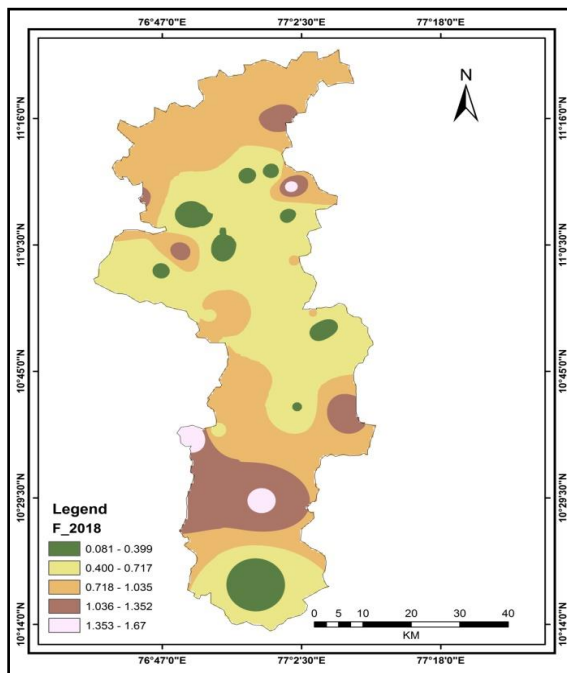

Figure 11: IDW method for fluoride contamination groundwater (2018)
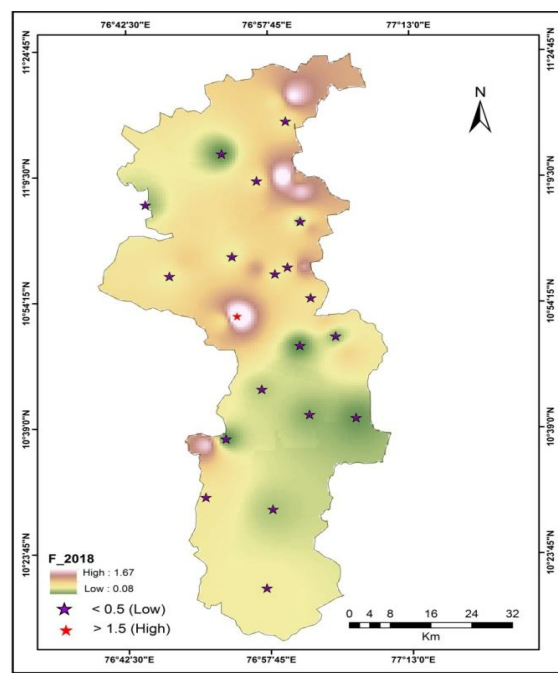

Figure 12: Fluoride contamination of groundwater as per WHO limit (2018)

4.3 Occurrence of dental fluorosis in Coimbatore

High concentration of fluoride can cause dental fluorosis. The most important symptoms of dental fluorosis are white spots on teeth, black spots on teeth, white streaks on teeth, discoloured teeth, mottled teeth and pitted teeth.
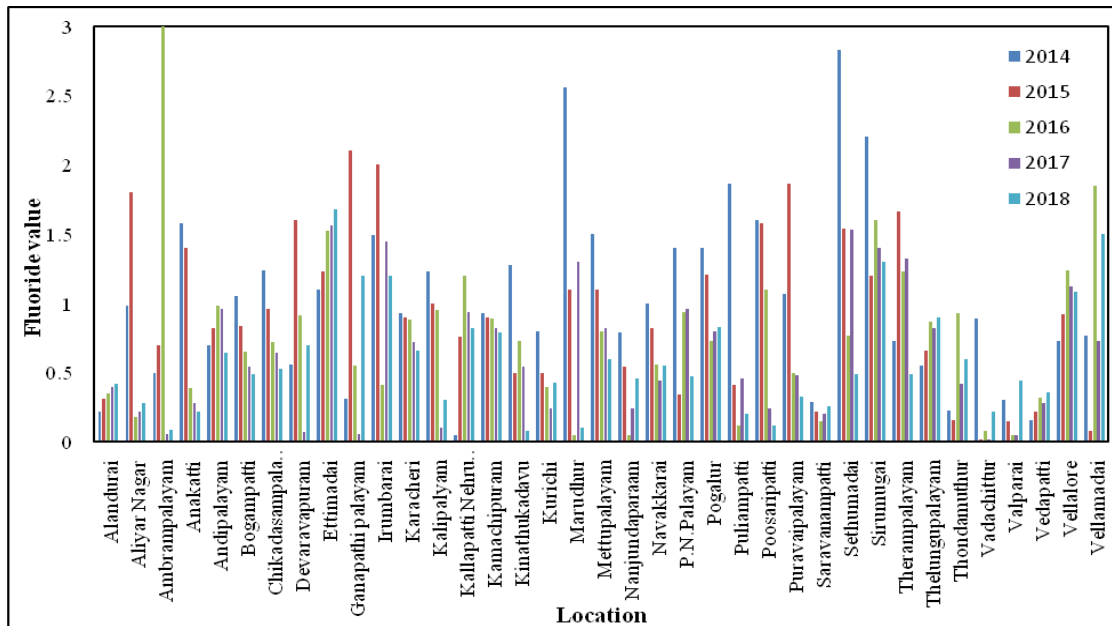
Figure 13: Fluoride contamination variation chart for 2014-2018

4.3.1. Investigation of the dental fluorosis

The sample locations fluoride concentration greater than 1.5 mg/l was consider for dental fluorosis survey. Ambrampalayam, Puliampatti, Puravipalayam, Ettimadai, Sirumugai and Therampalayam areas shows higher values of fluoride in groundwater. The diagnosis of dental fluorosis is a confusing and tideous process because tobacco chewing and smoking also causes stains on teeth. So appropoiate precaution was taken during field survey. The following figure (14) clearly shows that different types of dental fluorosis from different villages which consumes high fluoride containing groundwater.

Figure 14: Indicate the evidence of dental fluorosis from the selected areas

Ambrampalayam-Pollachi taluk, Puliampatti-Pollachi taluk, Puravaipalayam-Pollachi taluk, Ettimadai-Coimbatore south taluk, Sirumugai-Mettupalayam taluk, Therampalayam-Mettupalayam taluk people experiences the symptoms of dental fluorosis. The important souuce of fluoride intake of this population is from tap water provided by fluoride contaminated groundwater. Most of the people experiencing symptoms of dental fluorosis have the age above 36 years. The main symptoms of dental fluoris are white spots on teeth, black spots on teeth, white streaks on teeth, discoloured teeth, mottled teeth and pitted teeth. In this study, almost all the groundwater smaples fluoride level (0.1- 2.5 mg/l) is above the prescribed limit. The main water sources in the study area were highly contaminated by effluents from aluminium and glass manufacturing industries. The key aluminium and glass manufacturing industries were located in Puliampatti-Pollachi taluk, Puravaipalayam-Pollachi taluk and Ettimadai-Coimbatore south taluk. The tap water of the study area has to treat before supplying to the population. Ion exahnage, reverse osmosis and electro dialysis etc can be used to treat the groundwater before discharge.

5. Conclusion

The study was conducted to evaluate the groundwater fluoride contamination in study area. The secondary data of groundwater has been collected from PWD, Tharamani for the years of 2014 to 2018. GIS is used to create spatial information and understand the fluoride in groundwater. Fluoride plays an important role in human metabolism within the permissible limit. But it is exceeded by many activities mainly by the human activities. High level of fluoride cause major impact in human health. It can replace calcium ion in bones and teeth, which can lead to fluorosis. The highest and lowest areas of fluoride contamination of groundwater were identified. The study states that in 2014 high level of fluoride estimated as 2.83mg/l, in 2015 high fluoride can be estimated as 1.86mg/l, in 2016 high fluoride can be estimated as 3.6mg/l, in 2017 high fluoride can be estimated as 1.56mg/l, in 2018 high fluoride can be estimated as 1.68mg/l. It provides an understanding into the problem of fluorosis among people in the study area, where fluorosis is a public health problem of significant impact. There is compulsory need for defluoridation of the groundwater before consumption.

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