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# A report on Fluoride distribution in drinking Water

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**ABSTRACT**

High fluoride groundwater leads a health threat to millions of people around the world. This paper analyzes the most extensive database on fluoride and other chemical constituent distribution in arid tract of Ottapidaram block, Tamilnadu, India where it is the only source of drinking water. The study was conducted in the summer season (May – June, 2010). The water samples of 61 village panchayats were tested; 81.97% had injurious fluoride level above than 1.5 mg/L. The fluoride concentration in drinking waters varied from 0.936 to 4.34 mg/L in the study area. Due to the high concentration of fluoride, dental fluorosis was also identified. Majority of the samples do not comply with Indian as well as WHO standards for most of the water quality parameter. In addition, Fluoride concentration was not correlated with other physicochemical parameters significantly in ground water. Overall water quality was found as unsatisfactory for drinking purposes without any prior treatment except at eleven locations out of 61.

**Keywords:** Ottapidaram, Fluoride, Ground water, Wilcox, Piper Diagram

## 1. Introduction

Fluoride is a key aspect of water quality in rural water supply system, which potentially affects the sustainability of water if it exceeds its prescribed limit. At first in 1937, the excessive fluoride in groundwater reported in India in the state of Andhra Pradesh. Approximately 62 million people including 6 million children suffer from fluorosis because of consumption of water with high fluoride concentrations (Susheela, 1999). Seventeen states in India have been identified as endemic for fluorosis and Tamilnadu is one of them. The amount of fluoride occurring naturally in groundwater is governed by climate, composition of the host rock, and hydrogeology (Gupta et al., 2006).The major sources of fluoride in groundwater are due to fluoride-bearing rocks such as fluorspar, cryolite, fluorapatite and hydroxylapatite. The fluoride content is a function of many factors such as availability and solubility of fluoride minerals, velocity of flowing water, temperature, pH, concentration of calcium and bicarbonate ions in water, etc. (Meenakshi et al., 2004). In Indian continent, the higher concentration of fluoride in groundwater is associated with igneous and metamorphic rocks.

An inventory of fluoride concentration in drinking groundwater is important to curb spread of the disease fluorosis. This study was carried out to assess the quality of underground water of sixty-one village panchayats in Ottapidaram block in the state of Tamilnadu, India. The fluoride concentration along with various chemical parameters in ground water samples was determined in these regions. Moreover, an attempt has been made to statistically correlate the concentrations of fluoride with the other measured parameters and the conditions affecting the ground water quality.

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## 2. Materials and Methods

### 2.1 Profile of the study site

The study area Ottapidaram block, Tuticorin district of Tamilnadu, India is located between 8°49′19″ and 9°3′14″ N latitude and 77°46′55″ and 78°13′29″ E longitude (Figure 1) covering an area of 1,149 $km^2$ with 1,15,254 population (2001 census). This block has Way of Bengal on its eastern border, Tirunelveli district on its western border, Kovilpatti block and Virudunagar district on its northern border and Tuticorin block on its southern border. There are 61 village panchayats and every panchayat having 3-5 villages (approximately 200 villages in total). This area is semi-arid with scanty to normal rainfall. Groundwater is the only source for both drinking and irrigation purpose. Commercial crops grown in the area are doll verities, vegetables, ragi, groundnut etc. Cotton is one of the major principal crops in this area. The water is extracted by using hand pumps, electrical compressor pumps and from wells.

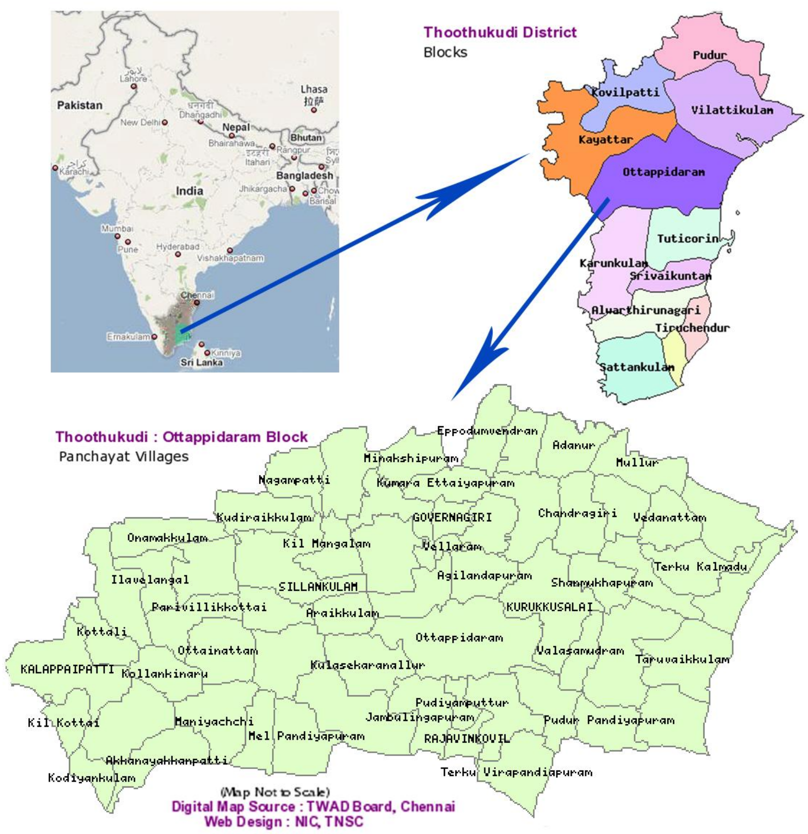


**Figure 1**: Location of Ottapidaram Block in Tuticorin district, India.

### 2.2 Sample collection

A total of 260 samples of groundwater used for drinking purpose were collected from either hand pumps or open wells at different villages spread over the 61 panchayats (in each

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panchayat 3-5 samples) of the block during the summer season month of May and June, 2010. This season was selected because in this season often contamination increases due to low dilution and this tends to the accumulation of ions. Before sampling, the water left to run from the source for few minutes. Then water samples collected in pre-cleaned, sterilized polyethylene bottles of 1 L capacity.

### 2.3 Methodology

The samples were analyzed to assess various physicochemical parameters according to APHA (2007). The fluoride concentration in the samples were measured by using an Orion, model 2100 expandable ion analyzer EA 940 and the fluoride ion selective electrode BN 9609 (Orion, USA). Sodium fluoride was used to prepare the standard solutions. The parameters pH and electrical conductivity of the water samples were measured by using a portable pH meter (Model-Cyberscan Eutech pH 510) and EC meter (Systronic, Model 306), respectively. Total alkalinity and total hardness were measured by titrimetric method using standard sulfuric acid and standard EDTA solutions, respectively. The cations sodium and potassium were determined by using flame photometer; calcium was assessed using titrimetric method, whereas anions like chloride and nitrate were determined using argentometric method and spectrophotometric methods respectively. Analytical grade chemicals were used throughout the study without further purification. To prepare all reagents and calibration standards, double distilled water was used. All the experiments were carried out in triplicate. After the analysis, the results of all parameters were discussed, correlated and plotted using AquaChem software.

## 3. Results and Discussion

### 3.1 General Parameters

Various physicochemical parameters pH, electrical conductivity, total alkalinity, total hardness as well as calcium, magnesium, sodium, potassium, chloride, nitrate, carbonate, and bicarbonate were analyzed with the determination of fluoride concentrations. In general, the ground water had no colour, odour and turbidity except few samples. Many of the water samples had slightly salty in nature.

The findings and their comparison with WHO health based drinking water guide lines (2008) are presented in Table 1. The data revealed a considerable variation in the water samples with respect to their chemical composition. Except seven village panchayats all other having the pH values greater than 7.5, indicates that the nature of ground water in that region is alkaline. Many samples having electrical conductivity closure to the value of 500µS/cm.

The WHO acceptable limit for alkalinity in drinking water is 200 mg/l. Except 15 places, the total alkalinity was higher than the acceptable limit. According to Durfor and Becker's (1964) classification of total hardness, water was very hard at all the locations except at twelve sites (Table 2) (cited in Meenakshi et al., 2004). Carbonate was either absent or present upto the higher amount of 87.28 mg/L, but the bicarbonate ranged from 56.05 to 456.33 mg/l in these panchayats. Except eleven panchayats, the calcium content in water samples was present in acceptable limit. Also the magnesium amount lower than the calcium levels in water samples and having the lower and higher values 2.56 and 33.25 mg/L respectively. There are nineteen

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records found as the sodium levels lower than 20 mg/L and they meet the WHO limits. However, in the case of panchayat Kothali, sodium amount was found as 214.59 mg/L. The entire villages having potassium value less than 84 mg/L.

**Table 1**: Chemical characteristics of Ground water in Ottapidaram block, India and their comparison with WHO guidelines

| No | Parameter | Unit | WHO | Min | Max | Mean | SD |
|---|---|---|---|---|---|---|---|
| 1. | pH | | 6.5 – 9.5 | 7.1 | 8.2 | 7.7016 | 0.03 |
| 2. | Total Hardness | mg/L | 200 – 500 | 42.11 | 494.74 | 212.32 | 0.56 |
| 3. | Total Alkalinity | mg/L $CaCO_3$ | 200 – 500 | 62.34 | 467.55 | 252.17 | 0.42 |
| 4. | EC | µS/cm | - | 250 | 2110 | 741.8 | 0.52 |
| 5. | $F^-$ | mg/L | 1.5 | 0.936 | 4.34 | 2.1532 | 0.34 |
| 6. | $Cl^-$ | mg/L | 250 | 22.27 | 267.74 | 74.666 | 0.57 |
| 7. | $HCO_3^-$ | mg/L | - | 56.05 | 456.33 | 166.1 | 0.49 |
| 8. | $CO_3^{2-}$ | mg/L | - | 0 | 87.28 | 41.677 | 4.87 |
| 9. | $NO_3^-$ | mg/L | 50 | 0.006 | 1.913 | 0.934 | 1.54 |
| 10. | $Na^+$ | mg/L | 200 | 3.58 | 214.59 | 48.878 | 0.92 |
| 11. | $K^+$ | mg/L | - | 1.58 | 83.56 | 21.534 | 0.99 |
| 12. | $Ca^{2+}$ | mg/L | 100 – 300 | 12.66 | 164.54 | 65.043 | 0.56 |
| 13. | $Mg^{2+}$ | mg/L | - | 2.56 | 33.25 | 12.382 | 0.66 |

The chloride concentration was ranged from 22.27 to 267.74 mg/L. Except the location Kothali, the chloride content in that region faced the WHO acceptable limit appreciably. Nitrate concentration varied from 0.006 to 1.913 mg/L and found to be within acceptable limits in all stations.

**Table 2:** Classification of the water samples based on total hardness

| S.No | Description | Hardness (mg/L) | No. of Samples |
|---|---|---|---|
| 1 | Soft | 0 – 60 | 2 |
| 2 | Moderately Hard | 61 – 120 | 11 |
| 3 | Hard | 121 – 180 | 19 |
| 4 | Very Hard | >180 | 29 |

### 3.2 Fluoride

The frequency distribution of the groundwater samples containing different amounts of fluoride showed in fluoride histogram (Fig.2). The fluoride concentration was ranged from 0.936–4.34 mg/L with highest fluoride level at Ackkanickenpatti (4.34 mg/L) and lowest at

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Saminatham (0.936 mg/L). In terms of frequency distribution, the fluoride level lower than 1.0 mg/L was observed as 3.28% at two locations (Rajavinkovil and Saminatham), between 1 and 1.5 mg/L it was 14.75% at nine locations and at the fluoride level greater than 1.5 mg/L, it was 81.97% at fifty locations. There are maximum numbers of village (21 samples) fall on the region of fluoride concentration between 1.5 – 2.0 mg/L.

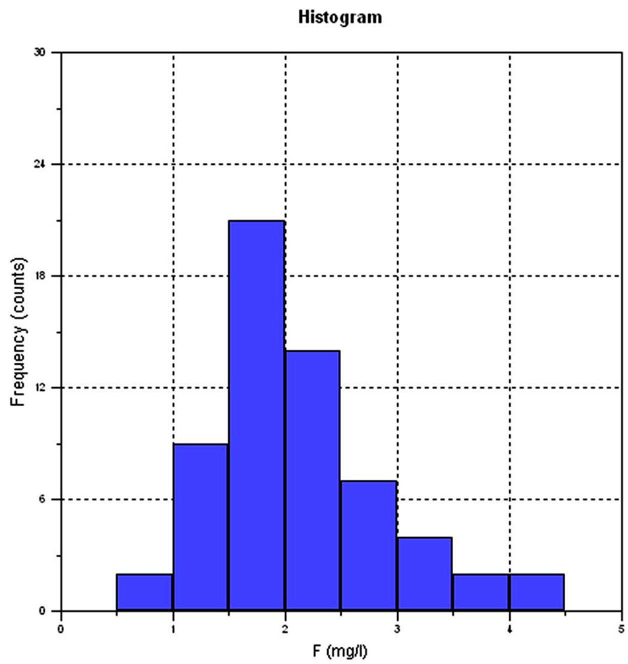


**Figure 2:** Frequency distribution of fluoride in ground water samples at study site

In addition, 42 samples having the hazardous fluoride range between 1.5 – 3.0 mg/L and high fluoride hazards affect eight villages having the value 3.0 – 4.5 mg/L (Table 4). The ground water samples from the panchayats namely Vedanatham (3.89), Thennampatti (3.52), Ackkanickenpatti (4.34) and Kothali (4.08) having very high fluoride content in this Ottapidaram block. In general, the western part panchayats of this block affected by high fluoride and only the three panchayats namely Vedanatham (3.89), Mullur (2.99) and P.duraisamipuram (3.15) having high fluoride in middle and eastern part.

From the experimental analysis, the concentration of fluoride does not correlated with other chemical characteristics of the groundwater most probably. It may due to the presence of different types of fluoride bearing minerals with different solubility. Considering WHO safe limit 1.5 mg/L of fluoride in drinking water, nearly 82% of the tested waters are contained injurious concentration of fluoride for drinking water purposes. A safe limit of 10 mg/L of fluoride has been proposed for all types of crop plants. Our data suggest that almost all waters tested can utilize for irrigation. Only the waters at eleven locations can use for drinking purposes. This similar trend observed to Ramanaiah et al. (2006) in his study area..

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### 3.3 Scatter plots, Piper and Wilcox diagrams

The two-dimensional scatter plot is one of the most familiar graphical methods for data analysis. It illustrates the relationship between two variables. From the Figure 3(a), it easily

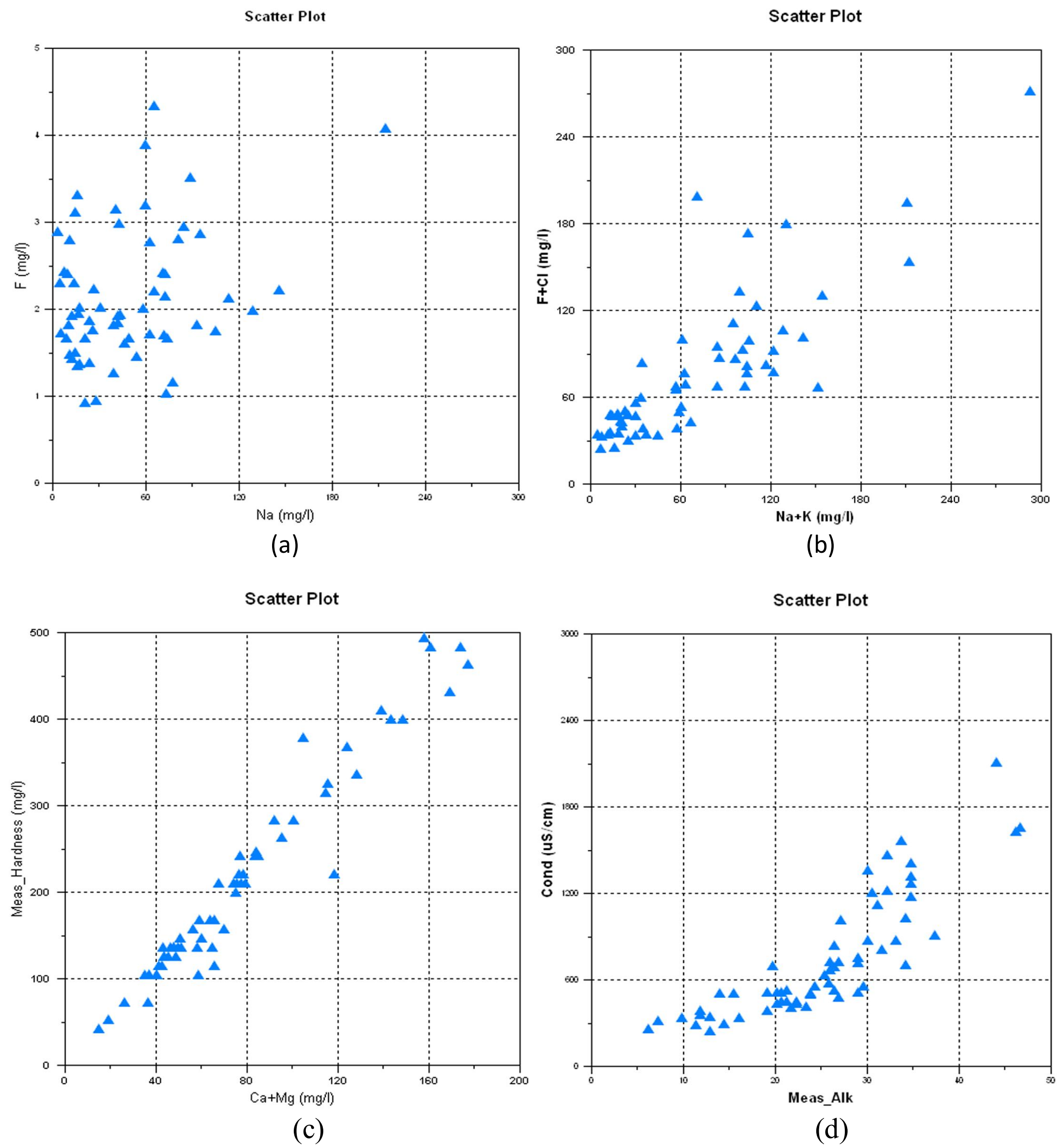


**Figure 3:** Scatter plots for (a) Sodium ions Vs Fluoride concentration (b) sum of sodium and potassium ions verses sum of fluoride and chloride ions (c) the sum of calcium and magnesium ions with total hardness and (d) alkalinity with conductivity

observed that there is no demonstrated connection between fluoride and sodium and having the correlation factor 0.166. Fluoride with chloride shows a smooth relationship with Na+K (Fig.3b). A strong positive correlation obtained for the scatter plot of total hardness versus

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Ca+Mg (Fig.3c). It indicates that the concentration of calcium and magnesium desires the hardness of water in this Ottapidaram block region. Also a weak positive correlation observed when conductivity plotted against alkalinity data which is shown in Figure 3(d). Interestingly fluoride was not correlates with any of the studied parameters significantly. It proves that the rocks having fluoride does not distributes eventually and having different composition at different places. Morgan et al. (1998) explained the different distribution of two variables and its interpretation.

Al-Salim and Matte (2009) used the Piper–Hill diagram to illustrate hydrogeochemical composition of ground water samples. This diagram is particularly useful to bring out chemical relationships among groundwater samples in more terms that are definite and for detecting changes or trends in ground water chemistry across an area or through time. These plots include two triangles, one for plotting cations and the other for plotting anions. The cation and anion fields are combining to show a single point in a diamond-shaped field, from which inference is drawn based on hydrogeochemical facies concept (Back and Hanshaw, 1965). Data of the study area are present by plotting them on a Piper tri-linear diagram (Fig.4). It clearly explains the variations and domination of cation and anion concentrations in studied ground water samples. Calcium type of water predominated in all samples and in anion concentration, bicarbonate type of water predominated. It shows that sample occurred places having the rock type of mixed Ca-Mg-$HCO_3$ and Ca-Mg-Cl.

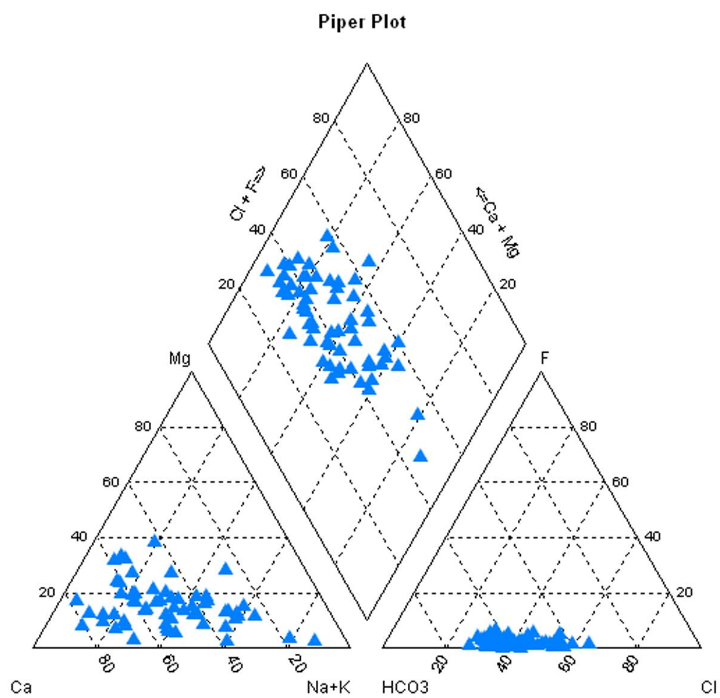


**Figure 4:** Piper diagram of groundwater samples from the Ottapidaram block in India.

SAR (Sodium Adsorption Ratio) is an important parameter for determining suitability of ground water for irrigation because it is a measure of alkali / sodium hazards to crops (Richard, 1954). M.Kumaresan and P.Riyazuddin (2006) discussed their results using Wilcox

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– diagram. Figure 5 obtained by plotting of SAR and electrical conductivity by the US salinity diagram – Wilcox diagram (Wilcox, 1955) and illustrates that the nineteen ground water samples fall in the field of C3S1, indicating high salinity and low Na water, remaining forty-one samples fall in the field C2S1 indicating medium salinity and low Na which can be used for irrigation.

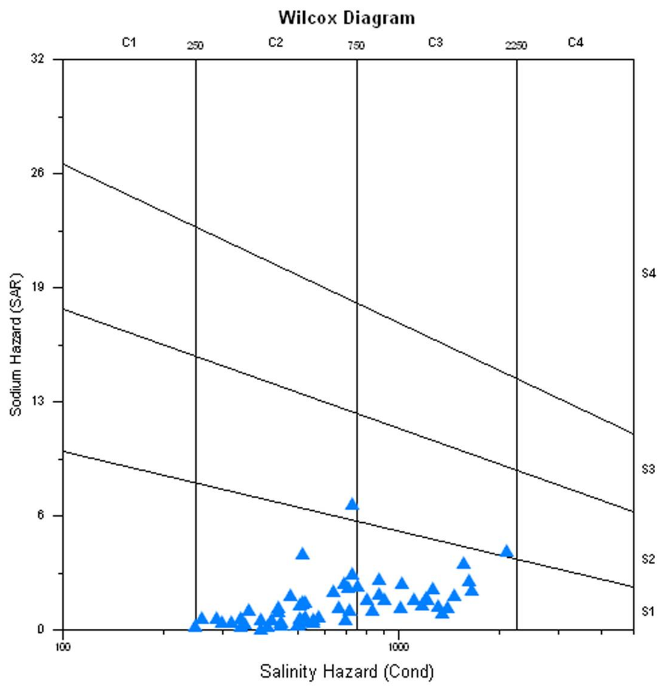


**Figure 5**: Wilcox classification of ground water samples of study area

## 4. Conclusion

The groundwater sources in the Ottapidaram block of Tuticorin, India have been evaluated for its chemical composition and suitability for irrigation uses with special concern of fluoride. Most of the water samples do not meet the water quality standards for fluoride concentration and many other quality parameters except eleven village panchayats and at risk from a potential fluorosis. Hence, it is not suitable for consumption without any prior treatment. Though they are not apt for drinking purpose, Wilcox diagram reveal that the most of the groundwater samples are suitable for irrigation purposes under normal condition.

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