Available online at www.ewijst.org

ISSN: 0975-7112 (Print)
ISSN: 0975-7120 (Online)

Environ. We Int. J. Sci. Tech. 14 (2019) 169-182

Environment and We An International Journal of Science and Technology

# Assessment of groundwater quality with reference to fluoride and prevalence of dental fluorosis among school children: A Study of Panipat town (NCR)

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**Article history:**
Received 15 May 2019
Received in revised form
14 June 2019
Accepted 14 Jnue 2019
Available online
30 June 2019

**Keywords:**

Groundwater;
Fluoride;
Dental Fluorosis;
Ion Selective Electrode;
Parameter

**Abstract**

The present study was carried out to investigate fluoride and other water quality parameters of groundwater from Panipat Town of Haryana State. The fifty (50) groundwater samples were collected randomly through tube wells and hand pumps and analyzed. Fluoride concentration in groundwater and urine samples was determined using a fluoride ion specific electrode (Orion 96-09 BNWP) fitted with an Orion Star A329 ISE Meter, MA, USA. In present study TDS content ranged from 400-3000 mg/l. The total hardness of studied water samples varied from 140 to 1670 mg/l with a mean value of 583 ± 395 mg/l. The result reveals that only two water samples had hardness lesser than 180 mg/l. Total alkalinity varied from 180 to 1670 mg/l with a mean value of 736 ± 308 mg/l. The results reveal that at 49 locations, TA was higher than acceptable limits. The chloride content ranged from 25 to 789 mg/l with a mean of 237±147 mg/l. At 24 locations chloride content was higher than acceptable limit prescribed by BIS and WHO. In present investigation fluoride content ranged from 0.20 to 4.80 mg/l. The average fluoride content of studied groundwater samples from study area was 1.51±0.86 mg/l i.e. slightly more than maximum permissible limit. The study reveals that 29 samples had fluoride content within acceptable limit while 21 samples had fluoride content more than maximum permissible limit. The analytical results indicated considerable variations among the analyzed samples with respect to their chemical composition. Majority of the samples do not comply with Indian as well as WHO standards for most of the water quality parameters measured hence, routine monitoring of groundwater for drinking purpose in study area is necessary.

## Introduction

It is well known fact that water is source of life on earth and its adequate availability in terms of both quantity and quality is essential for human survival. In recent times as a result of increasing urbanization, industrialization and agricultural activities, there has been an increasing threat to the quality of surface waters in rivers and lakes. More over dependence on ground water has grown over the past few decades and the quantity and quality of groundwater is also under threat especially in arid and semi-arid regions of the world (Ray et al. 2017; Li et al. 2017a; Adimalla and Venkatayogi 2018a; Adimalla and Li 2018). Groundwater quality throughout the world is deteriorated due to anthropogenic as well as natural geogenic contaminants. One of the most important geogenic contaminant in groundwater is fluoride and has serious health issue.

The studies from many regions of the world have shown that excess of fluoride in drinking water has negative impacts on human health (Emenike et al 2018;Adimalla 2018; Shaji et al 2007; Narsimha and Sudarshan 2018). It has been estimated that more than 200 million people from 25 countries are facing various health issues i.e. fluorosis due to excess fluoride in groundwater (Apambire et al 1997; Ayoob and Gupta 2006; Narsimha and Sudarshan 2017; Subba rao et al 2017).

It has been estimated that approximately 66 million people in India are suffering from noxious and incurable disease fluorosis (Adimalla and Venkatayogi 2017; Narsimha and Sudarshan 2017). Groundwater is the major source of drinking water in different parts of India and it is heavily contaminated with fluoride (Ready, 2013; Sajit Kumar et al., 2014). The unchecked extraction of groundwater for various purposes and geological processes, weathering of fuoride bearing minerals in soil under different hydro-geological settings also contributed to higher groundwater fluoride levels and has now become one of the most important toxicological and geo-environmental issues in India (Agrawal et al., 1997, Subba Rao et al 2016). In early 1930s fluorosis was reported only in 4 states of India, in 1986 it was 13, in 1992 it was 15, in 2002 it was 17, in 2006 it was 20 and now it is 21(Ayoob and Gupta 2006; Narsimha and Rajitha 2018; Adimalla et al 2018). Thus, ingestion of heavily fluoride laden groundwater has become most serious health issue in most part of the country (Ayoob and Gupta 2006; Narsimha and Rajitha 2018).

Groundwater is the major source of drinking water in Haryana State and studies have shown that in most of the districts groundwater is laden with fluoride (Mor et al 2003; Meenakshi et al 2004; Singh et al 2007; Khaiwal and Garg 2007; Garg et al 2008; Yadav and Lata 2009; Singh 2011; Singh and Garg 2013; Haritash et al 2018). Ingestion of excess fluoride, mainly through fluoride-contaminated drinking water, caused different types of fluorosis. It has become important to study the fluoride contents in the groundwater in the fluorosis-affected areas and assess its effect on human population, particularly children in rural areas, who are the most exposed to such contaminated water. In spite of various studies there is lack of information regarding prevalence of fluorosis among the school children from Panipat town hence, present study was undertaken to assess the fluoride, other water quality parameters and the prevalence of dental fluorosis in school children in the Panipat Town (NCR) of Haryana, India. The study was carried out during May-June 2017.

## Materials and Methods

**Study area:** Haryana is one of the major agricultural states of India and it has regional pockets of high concentration of fluoride in groundwater throughout its stretch (Haritash et al. 2008). The groundwater samples were collected from Panipat city and nearby areas. Panipat is lying in the east central part of Haryana State is located between $29^0$ 09' 15": $29^o$ 27' 25" north latitudes and $76^o$ 38' 30": $77^o$ 09' 15" east longitudes (figure 1). The district forms a part of Indo gangetic plain and lies in Yamuna Sub basin of main Ganga basin. The district is occupied by geological formations of Quaternary age comprising of recent alluvial deposits belonging to the vast Gangetic alluvial plains. The area is semi-arid with low and erratic precipitation. Most of the rainfall is received from July to September during monsoon. The area is characterized by extreme temperatures in winter and summer and high wind velocity during summer. The subsoil water is stored in sand and gravel beds. The depth of water table varies from 5 to 25 meters in different aquifers. Hand pumps can easily be installed in study area and extensively used to pump out the water.

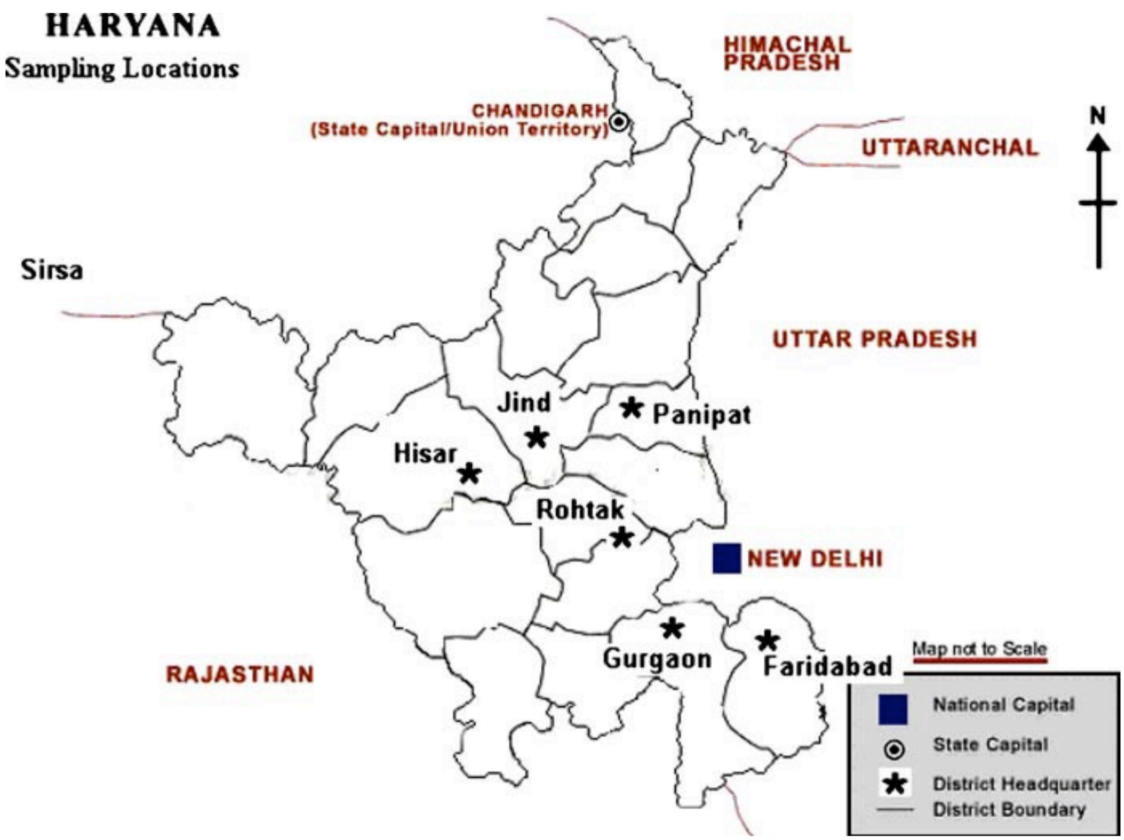


Figure 1: Location of Panipat Town in Haryana

**Sample collection and field methods:** The fifty (50) groundwater samples were collected randomly through tube wells and hand pumps from Panipat town and adjoining area. The groundwater sampling locations are shown in figure 2. Before collecting the sample water was left to run from the sampling source for 4–6 min to pump out the volume of water standing in the casing and then water samples were collected in pre-cleaned, sterilized polyethylene bottles of 500 ml capacity. Each sample's physical properties were measured in the field using portable meters (colour, odour, taste, electrical conductivity and pH) at the time of sampling. The collected samples were kept in ice box and transported immediately to the laboratory for analysis.

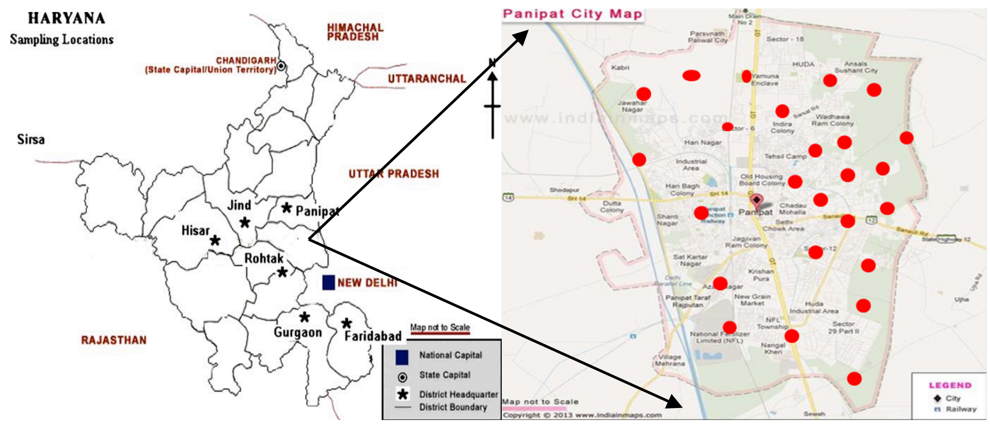


Figure 2: Groundwater sampling locations in Panipat town and nearby areas

**Reagents and standards**: Analytical grade chemicals were used throughout the study without further purification. To prepare all the reagents and calibration standards, double distilled water was used. All the experiments were carried out in triplicate. The glassware were washed with dilute nitric acid (1.15) followed by several portions to distilled water.

**Analyzed Parameters and Methods:** The ground water samples were analyzed to assess various chemical water quality parameters, viz., pH, electrical conductivity, total dissolved salts, total alkalinity, total hardness, sodium, potassium, calcium, magnesium, carbonate, bicarbonate, chloride, sulphate, phosphate and fluoride content. All the water quality parameters were analyzed by using standard methods prescribed by APHA (1995). The pH and electrical conductivity of the water were determined on site. The pH was measured using Eutech-Cybernetics pH scan meter. The conductivity was determined using Eutech-Cybernetics EC scan meter. The TDS were calculated using a formula from the United States Salinity Laboratory (1954). Fluoride concentration in groundwater and urine samples was determined using a fluoride ion specific electrode (Orion 96-09 BNWP) fitted with an Orion Star A329 ISE Meter, MA, USA.

**Dental Fluorosis Survey**: To investigate the impact of fluoride on dental health a survey was carried out among school children of Government School, Panipat. The Performa designed by Rajiv Gandhi National Drinking Water Mission was used to compile information and to assess the dental fluorosis.

## Result and Discussion

The analytical data for various water quality parameters is presented in table 1. In table 2 comparison of groundwater quality of the area under study with drinking water standards (Indian and WHO) is presented. All the analyzed ground water samples from study area were free from color, odor and turbidity. The taste was slightly saline at some of sampling sites and revealed considerable variations in the water samples with respect to their chemical composition.

The pH value of groundwater in the study area varies from 6.80 to 8.90. It was observed that most of the analyzed water samples were alkaline in nature except five samples. The average pH was 7.64 ± 0.56 and pH of all the water samples was within the safe limits.

The electrical conductivity (EC) varied from 0.62 to 4.68 mS with a mean of 1.68±0.71 mS. The electrical conductivity test is carried out to measures the concentration of ions in a solution. In other words it is property of solution which indicates that how well the water conducts an electrical current and it is proportional to the concentration of ions in solution. EC has a wide applicability with respect to agricultural use, but for the drinking use high value of EC denotes proportionately high value of calcium, magnesium, sodium and potassium. The high salinity and mineral contents may be responsible for higher EC content at studied locations.

The total dissolved salts (TDS) content were ranged from 400-3000 mg/l. The average TDS content was 1082± 456 mg/l. Water containing less than 500 mg/l of dissolved solids is suitable for domestic use. In present study, 90% water samples were above the specified limit (500 mg/l) for TDS. Water containing more than 1,000 mg/l of dissolved solids is likely to contain enough of certain constituents to cause noticeable taste or make the water unsuitable for drinking. The higher amount of TDS is may be due to the presence of higher concentration of salts of sodium, calcium, and magnesium. The drinking water has been classified by Rabinove et al (1958) on the basis of salinity contents and according to that 20 samples were non saline and 30 samples were slightly saline (Table 3). The sources of dissolved salts in ground water may be natural (e.g. soil minerals) as well as anthropogenic (e.g. agrochemicals). The health risk due to consumption of drinking water with high dissolved salts reported from Haryana by Gupta and Misra (2018).

Hardness in groundwater is imparted by the sum of polyvalent metallic ions. Although different ions contribute to hardness but calcium and magnesium are the major components. Groundwater is naturally hard may be due to weathering and dissolution of limestone, dolomite and chalk etc.

Table 1: Ground water quality at Panipat Town of Haryana

| S.N. | pH | EC | TDS | TH | $Na^+$ | $K^+$ | $Ca^{2+}$ | $Mg^{2+}$ | $CO_3^{2-}$ | $HCO_3^-$ | TA | $Cl^-$ | $SO_4^{2-}$ | $PO_4^{3-}$ | $F^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.5 | 1 | 642 | 1021 | 120 | 11 | 190 | 132 | 24 | 451 | 1020 | 485 | 101 | 0.12 | 2.50 |
| 2 | 8.7 | 1.7 | 1107 | 1090 | 60 | 20 | 190 | 149 | 48 | 695 | 1090 | 120 | 141 | 0.33 | 1.90 |
| 3 | 8.9 | 1.14 | 733 | 630 | 190 | 14 | 120 | 80 | 90 | 159 | 630 | 155 | 104 | 0.20 | 1.20 |
| 4 | 7.9 | 2 | 1281 | 180 | 100 | 10 | 60 | 17 | 0 | 403 | 180 | 100 | 81 | 0.18 | 0.49 |
| 5 | 8.3 | 0.85 | 547 | 470 | 80 | 15 | 140 | 29 | 0 | 159 | 470 | 200 | 73 | 0.14 | 0.85 |
| 6 | 8.9 | 1.63 | 1047 | 640 | 410 | 20 | 80 | 107 | 66 | 464 | 640 | 160 | 115 | 0.11 | 0.44 |
| 7 | 8.0 | 2.08 | 1333 | 830 | 820 | 11 | 120 | 129 | 0 | 439 | 830 | 250 | 91 | 0.11 | 0.57 |
| 8 | 7.3 | 2.2 | 1409 | 1580 | 370 | 12 | 100 | 323 | 0 | 427 | 1580 | 250 | 91 | 0.33 | 1.90 |
| 9 | 7.2 | 1.65 | 1061 | 1220 | 420 | 20 | 325 | 100 | 0 | 317 | 1220 | 695 | 123 | 0.19 | 0.61 |
| 10 | 6.8 | 1.97 | 1261 | 1351 | 410 | 13 | 225 | 192 | 0 | 476 | 1351 | 789 | 286 | 0.21 | 1.50 |
| 11 | 6.9 | 1.94 | 1247 | 1210 | 250 | 10 | 117 | 223 | 0 | 159 | 1210 | 129 | 211 | 0.00 | 2.30 |
| 12 | 7.1 | 2.25 | 1445 | 1083 | 210 | 10 | 157 | 168 | 0 | 512 | 1083 | 305 | 80 | 0.05 | 1.80 |
| 13 | 7.3 | 1.68 | 1080 | 1100 | 210 | 11 | 200 | 146 | 0 | 537 | 1100 | 315 | 91 | 0.01 | 1.70 |
| 14 | 7.2 | 1.85 | 1184 | 1160 | 100 | 11 | 440 | 197 | 0 | 732 | 1160 | 130 | 85 | 0.50 | 0.20 |
| 15 | 7.3 | 2.26 | 1450 | 750 | 90 | 12 | 200 | 61 | 0 | 903 | 750 | 350 | 39 | 0.08 | 1.80 |
| 16 | 7.8 | 2.09 | 1338 | 410 | 110 | 11 | 130 | 21 | 0 | 744 | 410 | 25 | 80 | 0.10 | 2.40 |
| 17 | 7.7 | 1.66 | 1067 | 830 | 110 | 10 | 185 | 89 | 0 | 366 | 830 | 260 | 65 | 0.09 | 0.70 |
| 18 | 7.9 | 1.03 | 663 | 490 | 310 | 21 | 170 | 16 | 0 | 232 | 490 | 256 | 89 | 0.00 | 0.90 |
| 19 | 7.8 | 1.92 | 1234 | 1670 | 170 | 20 | 310 | 217 | 0 | 659 | 1670 | 70 | 89 | 0.01 | 2.10 |
| 20 | 6.8 | 1.93 | 1239 | 610 | 170 | 0 | 220 | 15 | 0 | 744 | 610 | - | 76 | 0.01 | 2.60 |
| 21 | 7.0 | 1.9 | 1220 | 760 | 171 | 0 | 250 | 33 | 0 | 732 | 760 | 199 | 125 | 0.01 | 2.20 |
| 22 | 7.8 | 2.36 | 1513 | 630 | 210 | 11 | 140 | 68 | 0 | 573 | 630 | 185 | 60 | 0.02 | 4.80 |
| 23 | 8.0 | 1.66 | 1064 | 490 | 120 | 12 | 190 | 14 | 0 | 366 | 490 | 192 | 70 | 0.01 | 0.70 |
| 24 | 8.1 | 1.87 | 1200 | 810 | 60 | 20 | 320 | 13 | 0 | 12 | 810 | 175 | 75 | 0.36 | 1.70 |
| 25 | 8.7 | 1.05 | 673 | 510 | 190 | 20 | 130 | 45 | 114 | 244 | 510 | 35 | 66 | 0.18 | 0.32 |
| 26 | 8.8 | 0.72 | 464 | 420 | 100 | 12 | 90 | 47 | 90 | 110 | 420 | 160 | 27 | 0.13 | 0.62 |
| 27 | 8.5 | 1.42 | 914 | 740 | 80 | 12 | 130 | 101 | 88 | 122 | 740 | 110 | 41 | 0.05 | 1.90 |
| 28 | 7.3 | 1.56 | 998 | 220 | 410 | 12 | 110 | 40 | 0 | 419 | 525 | 426 | 34 | 0.32 | 1.40 |
| 29 | 7.3 | 1.4 | 896 | 210 | 820 | 20 | 75 | 54 | 0 | 358 | 458 | 252 | 182 | 0.05 | 1.32 |
| 30 | 7.7 | 2.03 | 1300 | 150 | 370 | 21 | 70 | 33 | 0 | 478 | 565 | 259 | 305 | 0.05 | 1.10 |
| 31 | 7.1 | 1.25 | 800 | 260 | 420 | 22 | 76 | 25 | 0 | 539 | 615 | 177 | 478 | 0.00 | 1.04 |
| 32 | 7.6 | 2.81 | 1800 | 220 | 410 | 13 | 85 | 17 | 0 | 539 | 625 | 156 | 286 | 0.01 | 1.30 |
| 33 | 6.9 | 3.43 | 2200 | 440 | 250 | 10 | 53 | 29 | 0 | 358 | 489 | 175 | 192 | 0.01 | 1.35 |
| 34 | 6.9 | 4.68 | 3000 | 410 | 210 | 11 | 65 | 28 | 0 | 360 | 488 | 190 | 193 | 0.05 | 1.08 |
| 35 | 7.2 | 2.18 | 1400 | 310 | 210 | 11 | 75 | 27 | 0 | 335 | 455 | 180 | 490 | 0.03 | 1.45 |
| 36 | 7.3 | 2.18 | 1400 | 290 | 100 | 10 | 85 | 24 | 0 | 424 | 515 | 250 | 154 | 0.05 | 1.50 |
| 37 | 7.3 | 1.71 | 1100 | 240 | 90 | 10 | 95 | 19 | 0 | 405 | 510 | 265 | 149 | 0.00 | 1.52 |
| 38 | 7.5 | 0.78 | 500 | 250 | 110 | 10 | 65 | 20 | 0 | 420 | 535 | 435 | 207 | 0.01 | 1.50 |
| 39 | 7.6 | 0.78 | 500 | 280 | 110 | 10 | 78 | 23 | 0 | 539 | 640 | 300 | 207 | 0.00 | 1.04 |
| 40 | 7.6 | 1.87 | 1200 | 300 | 310 | 12 | 70 | 50 | 0 | 688 | 790 | 325 | 163 | 0.02 | 1.35 |
| 41 | 7.3 | 1.56 | 1000 | 310 | 170 | 12 | 100 | 36 | 0 | 775 | 885 | 350 | 161 | 0.01 | 4.40 |
| 42 | 7.3 | 1.4 | 900 | 315 | 170 | 0 | 95 | 38 | 0 | 837 | 935 | 390 | 155 | 0.54 | 1.00 |
| 43 | 7.4 | 0.93 | 600 | 245 | 171 | 0 | 125 | 31 | 0 | 479 | 595 | 225 | 148 | 0.05 | 1.98 |
| 44 | 7.5 | 0.93 | 600 | 290 | 210 | 11 | 90 | 72 | 0 | 418 | 515 | 115 | 97 | 0.00 | 1.90 |
| 45 | 7.3 | 1.56 | 1000 | 380 | 160 | 10 | 90 | 21 | 0 | 529 | 630 | 171 | 103 | 0.00 | 1.35 |
| 46 | 7.3 | 1.4 | 900 | 400 | 150 | 21 | 60 | 27 | 0 | 358 | 485 | 75 | 70 | 0.01 | 1.15 |
| 47 | 7.7 | 1.4 | 900 | 200 | 310 | 10 | 80 | 390 | 0 | 597 | 695 | 182 | 122 | 0.14 | 2.12 |
| 48 | 7.8 | 1.25 | 800 | 140 | 330 | 31 | 100 | 107 | 0 | 597 | 678 | 149 | 224 | 0.12 | 1.60 |
| 49 | 8.0 | 0.78 | 500 | 220 | 260 | 21 | 140 | 100 | 0 | 657 | 785 | 348 | 353 | 0.04 | 1.10 |
| 50 | 8.0 | 0.62 | 400 | 370 | 250 | 20 | 50 | 18 | 0 | 545 | 685 | 131 | 105 | 0.05 | 1.71 |

All parameters have been expressed as mg/L except pH and EC. The units of EC are mS.

The total hardness of studied water samples varied from 140 to 1670 mg/l with a mean value of 583 ± 395 mg/l. The result reveals that only two water samples had hardness lesser than 180 mg/l. According to Durfor and Becker (1964) groundwater is classified in to four categories on the basis of hardness. According to them soft waters have hardness less than 60 mg/l; moderately hard waters have hardness in the range of 61 to 120 mg/l; hard waters are those which have hardness in the range of 121 to 180 mg/l and very hard waters are those which have hardness more than 180 mg/l. A perusal of data shows that groundwater from study area exhibits high alkalinity, chloride and sulphate content and it is well proved that these contributes to hardness (Thapliyal et al 2011).

Table 2: Comparison of groundwater of Panipat with drinking water standards (BIS & WHO)

| Parameters | Range | | | | ISI Standards | | WHO Limit |
|---|---|---|---|---|---|---|---|
| | Min. | Max. | Mean | S.D. | Accept. Limit | Max. Limit | |
| pH | 6.80 | 8.90 | 7.64 | 0.56 | 7.0-8.5 | 6.5-9.2 | 8.0-8.5 |
| EC | 0.62 | 4.68 | 1.68 | 0.71 | - | - | - |
| TDS | 400 | 3000 | 1082 | 456 | 500 | 1500 | 500 |
| TA | 180 | 1670 | 736 | 308 | 200 | 600 | - |
| TH | 140 | 1670 | 583 | 395 | 200 | 600 | 100 |
| $Na^{+}$ | 60 | 820 | 233 | 163 | 50 | - | - |
| $K^{+}$ | 00 | 31 | 13 | 6.18 | - | - | - |
| $Ca^{2+}$ | 50 | 440 | 137 | 82 | 75 | 200 | 75 |
| $Mg^{2+}$ | 13 | 390 | 79 | 82 | 200 | 400 | 50 |
| $CO_3^{2-}$ | 00 | 114 | 10 | 28 | 75 | 200 | 75 |
| $HCO_3^{-}$ | 12 | 903 | 468 | 199 | 30 | - | 150 |
| $Cl^{-}$ | 25 | 789 | 237 | 147 | 200 | 1000 | 200 |
| $SO_4^{2-}$ | 27 | 490 | 143 | 101 | 200 | 400 | 200 |
| $PO_4^{3-}$-P | 00 | 0.54 | 0.10 | 0.12 | - | - | - |
| $F^{-}$ | 0.20 | 4.80 | 0.86 | 0.20 | 1.0 | 1.5 | 1.0 |

All parameters have been expressed as mg/L except pH and EC. The units of EC are mS.

Table 3: Classification of ground water samples on the basis of Salinity

| Sr. No. | Type of groundwater | Range of TDS (mg/l) | No. of samples |
|---|---|---|---|
| 1. | Non-saline | <1000 | 20 |
| 2. | Slightly saline | 1000-3000 | 30 |
| 3. | Moderately saline | 3000-10000 | 00 |
| 4. | Very saline | >10000 | 00 |

Hardness of water has negative as well as positive impacts. Very hard water is not only suitable for drinking purpose but also has various drawbacks e.g. it consume more soap during leathering, form scale deposits on pipes, basins, pots and boilers. However, in certain conditions hardness may also be advantageous e.g. metal ions form a thin layer of scales in water supply pipes which prevents the corrosion and entry of heavy metals. This process is known as plumbosolvency. As per Durfor and Becker (1964) classification water was very hard at 48 locations (table 4). The calcium content of studied groundwater samples were ranged from 50 to 440 mg/l. The average calcium content was 137±82 mg/l. The magnesium content was ranged from 13 to 390 mg/l with a mean of 79±83 mg/l. It has been reported by Mor *et al.* (2009) that $Ca^{2+}$ and $Mg^{2+}$ are common cations existing in groundwater of semi-arid location of India.

Table 4: Classification of the water samples on the basis of total hardness

| Sr. No. | Category | Hardness (mg/l) | No. of samples |
|---|---|---|---|
| 1. | Soft | 0-60 | 00 |
| 2. | Moderately hard | 61-120 | 00 |
| 3. | Hard | 121-180 | 02 |
| 4. | Very hard | >180 | 48 |

Alkalinity is a property of water that helps to neutralize the acid impacts. In other words we can say that this is the property of water which resist or dampen changes in pH. The various compounds which impart alkalinity to water are bicarbonates, carbonates, and hydroxides etc. These anions help in removal of H+ ions and increase the pH of the water. Total alkalinity (TA as $CaCO_3$) varied from 180 to 1670 mg/l with a mean value of 736 ± 308 mg/l. The results reveal that at 49 locations, TA was higher than acceptable limits. Carbonate content was ranged from 0 to 114 mg/l with a mean of 10.4±28 mg/l. Bicarbonate content ranged from 12 to 903 mg/l with a mean of 468 ± 199 mg/l. The literature shows that high alkalinity is may be due to intense chemical weathering of the parent granite rock.

Sodium content of studied groundwater samples varied from 60 to 820 mg/l with an average value of 233±163 mg/l. All the samples had higher sodium content and it may be the one of the major contributor to salinity of groundwater (Chari and Lavanya, 1994). The potassium content varied from 0 to 31 mg/l with a mean of 13±6 mg/l. Generally sodium and potassium ions are naturally present in groundwater but various anthropogenic activities e.g. domestic and industrial effluents and wastes may also contribute these ions to groundwater. Generally concentration of potassium ions is lesser than sodium ions in groundwater. Moreover, sodium concentration more than 50 mg/l makes water unfit for drinking and other domestic use and may cause health issues.

Chloride in groundwater may be originated from natural as well as manmade sources. The natural sources are chloride rich minerals while manmade sources may include septic tanks, fertilizers, industrial and domestic effluents etc. Chloride content of analyzed water samples ranged from 25 to 789 mg/l with a mean of 237±147 mg/l. As per BIS and WHO, the acceptable limit of chloride content for drinking water is 200 mg/l. At 24 locations chloride content was higher than acceptable limit prescribed by BIS and WHO. According to Das and Malik (1988) the possible sources which contribute chloride in groundwater may be minerals like apatite, mica, and hornblende also from the liquid inclusions in the igneous rocks. Presence of high chloride content in groundwater makes it salty and bitter i.e. unfit for drinking purpose. Moreover, excess chloride may cause economic loss due to corrosion of iron and steel.

The sulphate content of analyzed groundwater samples ranged from 27 to 490 mg/l with an average of 143 ± 101 mg/l. It is a naturally occurring ion which contributes to total hardness in water. Sulphate content more than 200 mg/l is objectionable for domestic purposes. At forty locations, sulphate content was higher than acceptable limit prescribed by BIS and WHO. The presence of excessive amount of sulphate content in groundwater may causes gastro-intestinal irritation and purgative effects.

The phosphate content ranged from 0 to 0.54 mg/l with an average of 0.10 ± 0.12 mg/l. Generally groundwater consist of negligible concentration of phosphate however, different sources which may contribute phosphate to groundwater are domestic sewage, septic tanks leakage, indiscriminate use of fertilizers and animal excreta etc.

Fluoride has both beneficial and adverse effects on human health (table 5). Its deficiency i.e. consumption of less than 0.5 mg/l F enhance dental caries, lack of formation of dental enamel, and deficiency of mineralization of bones (Jones et al. 1997; Acharya et al. 2008) while excess intake i.e. more than 1.5 mg/l may lead to dental fluorosis (WHO, 1996, 2008). However, Nawlakhe and Bulusu (1989) have reported that skeletal and crippling fluorosis may occur when drinking water having F concentration more than 3 mg/l and consumed for 8-10 years. The severity of fluorosis depends on the level of fluoride content and duration of its exposure (Gazzano et al 2010). Thus, excess intake of fluoride cause dental, skeletal and crippling fluorosis and non skeletal fluorosis (Zhang et al., 2003).

Table 5: Fluoride Content in drinking water and various effects on human health

| Fluoride content in mg/l | Corresponding effects on human health |
|---|---|
| ≤ 1.0 | Prevent caries |
| 1.0-3.0 | Dental fluorosis |
| 3.0-4.0 | Stiff and brittle joints/bones |
| ≥ 4.0 | Deformities in knees; crippling fluorosis; bones finally paralyzed resulting inability to walk or stand straight |

In present investigation fluoride content ranged from 0.20 to 4.80 mg/l. As compare to Panipat very high fluoride content i.e. in the range of 1.0 to 40.0 mg/l has been reported from the Faridabad area of Haryana (Singh and Garg 2012). According to Bureau of Indian Standards (1992) the desirable fluoride concentration in drinking water under Indian condition is 0.6 to 1.2 mg/l and in absence of alternate source of water it can be extended up to 1.5 mg/l. Hence, range between beneficial and adverse effects of fluoride consumption is quite narrow. In other words we can say that risk of dental fluorosis is more rather than decrease in dental caries with increased fluoride intake. Thus, less than 1.0 mg/l of fluoride content in drinking water is optimal for prevention of dental caries and bone mineralization especially in children (WHO 1997; Hussain et al., 2010).

The average fluoride content of studied groundwater samples from study area was 1.51±0.86 mg/l i.e. slightly more than maximum permissible limit. A perusal of data indicates that 29 samples had fluoride content within acceptable limit while 21 samples had fluoride content more than maximum permissible limit. Moreover, five samples had fluoride content lesser than optimum value of 0.6 mg/l as prescribed by BIS (1992). Fluoride could have originated from fluoride bearing minerals such as fluorite, apatite and micas and hence the problems consequently occur in area, where the element is most abundant in the host rocks. Moreover, it has been concluded that availability and solubility of F- minerals, velocity of flowing water, temperature, pH, concentration of calcium and bicarbonate in water etc. also influences the level of fluoride in water (Garg et al 2008).

It is important to mention here that children consuming this water may suffer from dental caries. In present investigation 58% samples were within the range of 1.5 mg/l F while 42% had fluoride content beyond the maximum permissible limit. All the analyzed water samples have been categorized in to four groups as there was large variation in the fluoride content. The samples which had fluoride content up to 1.0 mg/l grouped as safe; 1.1 to 1.5 mg/l as problematic; 1.51 to 3.0 mg/l as problematic and above 3.0 mg/l as highly problematic (figure 3). According to World Health Organization maximum permissible limit for fluoride in drinking water is 1.5 mg/l however, it is universally unacceptable. In tropical country like India people consume 4-5 litre water/day i.e. ingestion of more fluoride through water. Hence, in tropical country like India this limit may be reviewed (Galagan and Vermillion 1957).

Table 6 present the results of dental fluorosis survey from Government School, Panipat. The result revealed that 55.68% school children were suffering from varying grade of dental fluorosis. The relationship between the levels of fluoride in drinking water and the incidence of dental fluorosis vary from place to place (Shivashankara et al., 2000). The study by Haritash et al (2018) from Hisar, Haryana has reported prevalence of dental fluorosis among 77% girls and 68% boys.

Table 6: Incidence and Severity of Dental Fluorosis among School Children at Panipat

| Age group (Years) | No. of individuals examined | No. of D.F. individual | Stage of dental fluorosis | | | Type of dental fluorosis | | |
|---|---|---|---|---|---|---|---|---|
| | | | Chalky white | Yellowish brown | Brown black | Horizontal streak | Spots | Both |
| 6-10 | 07 | 05 | 02 | 03 | 00 | 00 | 05 | 00 |
| 11-15 | 135 | 83 | 49 | 34 | 00 | 22 | 52 | 09 |
| > 15 | 113 | 54 | 22 | 27 | 05 | 13 | 34 | 07 |
| Total | 255 | 142 | 73 | 64 | 05 | 35 | 19 | 16 |

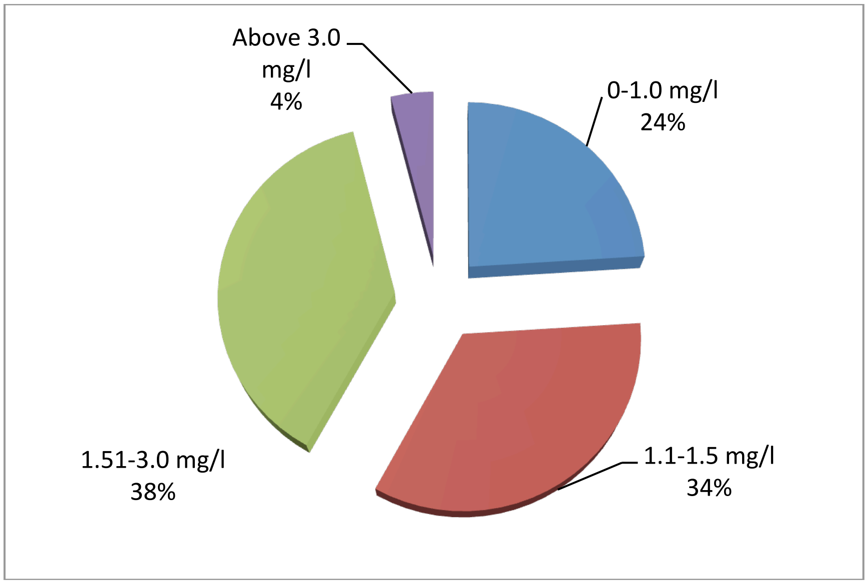


Figure 3: Percentage of samples in different fluoride ranges from Panipat town.

Although drinking water that contains fluoride has been an important contributor to dental and skeletal fluorosis. However, there are other sources which may contributes to fluorosis are fluoridated toothpaste, tobacco and betel nuts chewing, industrial exposure, use of fluoride supplements and infant formulae manufactured in fluoridated areas and prepared using fluoridated water.

## Conclusion

The groundwater quality of Panipat town and adjoining area was assessed for fluoride and other drinking water quality parameters. The moderately high concentration of most of the studied water quality parameters indicates that aquifer may be enriched with minerals naturally and contaminated due to anthropogenic causes. It is pertinent to mention that Panipat is an industrial town e.g. it consist of lot of textile and dye units, a thermal power plant, petroleum refinery, fertilizer plant and a lot of small scale industries. The study exhibits that groundwater was alkaline and very hard at most of the studied locations. Moreover, fluoride content ranged from 0.20 to 4.80 mg/l. In present investigation 58% samples were within the range of 1.5 mg/l F while 42% had fluoride content beyond the maximum permissible limit. The dental fluorosis survey revealed that from 255 school children, 55.68% were suffering from varying grade of dental fluorosis.it is pertinent to mention here that beside water there may be other sources which may contributes to fluorosis. The residents of area are advised to use surface water and groundwater should be treated for consumption and other domestic use.

***Acknowledgment:*** *The author is thankful to the University Grants Commission, New Delhi for providing financial support for this research work as UGC Major Research Project entitle "Fluoride in*

*Groundwater: Its Impacts and Removal" (F. No. 41-1107/2012 (SR) dated 26th July 2012). The author would also like to thanks to the unanimous reviewers and editors for their valuable comments and suggestions which helped to improve the manuscript. Moreover, authors acknowledge the help of the residents of Panipat town during sampling and collection of samples.*

***Author's Contributions**: Dr. Bhupinder singh (Assistant Professor and Head) has developed research idea; wrote manuscript and also carresponding author and Ms. Anuradha (UGC, MRP Project Fellow and presently research scholar at KUK) has done data collection and analysis.*

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