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Survey of fluoride content in drinking water in Ranchi City

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Abstract- Fluoride contamination of groundwater is a growing problem in many parts of the world. Fluoride is an essential element, which is good for the teeth enamel and helps to prevent dental caries. In excessive doses, however, it will lead to a chronic fluoride poisoning, fluorosis. Therefore it is very important to understand the mechanisms of mobilization of fluoride in groundwater in order to mitigate the problem as effectively as possible. The present study involves laboratory testing of various sources of drinking or potable water in Ranchi City of Jharkhand state. 50 water samples were collected and were tested in laboratory for estimating the concentration of fluoride. Fluoride concentrations in the water samples vary between 0.007 mg/L to 3.800 mg/L with highest concentration in Gonda village of Kanke. Potable water available in public hand pumps recorded the highest fluoride concentration. Most of the fluoride contaminated water sources were found in the north western, south western and southern parts of the Ranchi City.

Key words: Fluoride contamination, fluorosis, mobilization

INTRODUCTION

1. WATER

Water is essential for life to exist, and access to clean drinking water is a necessity for good health. The World Health Organization (WHO) has acknowledged this and included a part about access to sustainable and clean drinking water in the Millennium Development Goals.[1] However, clean drinking water is not available everywhere. There are reasons for this including water scarcity and pollution of existing water resources. The pollution can be from a natural source or due to anthropogenic activities. This study mainly addresses a specific pollution, namely FLUORIDE CONTENT (contamination) of Groundwater and Surface Water in Ranchi City.

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2. RANCHI

Ranchi District lies in the Southern part of Jharkhand State. The district has total area of area of 7698sq. km and is located between 22° 45' - 23°45' north latitude to 84° 45' to 84° 50' east latitude. Area is included under toposheet no.73A, 73B, 73E and 73F.

The district is highly dissected by rivers of varying magnitude. The major water divide in the district runs North to South through Ratu, Lodhma and Khunti. The area is the Eastern part is divided by Subarnarekha and Western part of the divide is drained by South Koel and Karo. The important river basins are Subarnarekha, South Koel, Damodar and the Kharkari.

1.2 SOURCES OF DRINKING WATER IN RANCHI CITY

The source of drinking water in Ranchi City includes both Surface Water and Groundwater.

1.2.1 SURFACE WATER

Surface Water is the water on the surface of planet. Water supply from surface water for drinking purpose includes:

- Ponds
- Lakes
- Dams

1.2.2 GROUNDWATER

Ground Water is the water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations. Water supply from ground water for drinking purpose includes following sources:

- Wells
- Bore wells
- RMC -Ranchi Municipal Corporation (Tap Water)

1.3 FLUORIDE AS CONTAMINANT

Fluoride in small doses has remarkable influence on dental system by inhibiting the dental cavities while higher doses it causes a disturbance of enamel structure.

1.4 ALLOWABLE FLUORIDE CONTENT IN POTABLE WATER

The permissible limits of fluoride in Drinking water is 1.0 - 1.5 mg/L as F(-). (Manual on Water supply and treatment 1991)US Public work services drinking water standards allow a fluoride concentration in drinking water from 0.8 to 1.7 mg/L dependent on the Annual Average of Maximum Daily Air Temperature of area concerned. (Table 1.4.1)

Table 1- Recommended limits of fluoride concentration (USPHS drinking water standards, 1962)

ANNUAL AVERAGE OF MAY DAILY AIR TEMPERATURE (^{o}C)	RECOMMENDED CONTROL LIMITS mg/L		
	LOWER	OPTIMUM	UPPER
10.0 – 12.1	0.9	1.2	1.7
12.2 – 14.6	0.8	1.1	1.5
14.7 – 17.7	0.8	1.0	1.3
17.8 – 21.4	0.7	0.9	1.2
21.5 – 26.2	0.7	0.8	1.0
26.3 – 32.5	0.6	0.7	0.8

MATERIALS & METHOD

2.0 AREA OF STUDY

2.0.1 RANCHI CITY

The Survey of Fluoride Content in Drinking Water was conducted in Ranchi City, which lies at 23^{o}22 N 85^{o} 20 E having municipal area of 175.12 square kilometers, average elevation of 651 m above sea level and a population of 1,126,741 (2011 census); taking into account the different sources of drinking or potable water. The survey was carried out in the month of August. The different sources of water used for drinking purpose in Ranchi City are:-

- Wells
- Handpumps
- Ponds
- Dams (Getalsud, Rukka, Kanke, Dhurwa)
- Ranchi Municipal Corp. (RMC) Water Supply

The field survey involved the surface water and groundwater sample collection from private wells, household handpumps, public handpumps, ponds and dams mentioned above as well as RMC water supply.

A total of 50 samples were collected and were tested in YUGANTAR BHARATI, Analytical &Environmental Engineering Laboratory, Sidroll, Namkum, Ranchi.

The following are the areas covered for water supply from the respective dams:

- Getalsud- Vikas, Rukka, Booti More, Kokar, Deepatoli, Kantatoli, NamkumChavni, Bahubazar, Siromtoli , Over Bridge, Railway Colony, Chutia, Nivaranpur, Main Road, Lalpur,Vardaman Compound, Hindpiri, Church Road, Morabadi, Bariyatu Road, RIMS, Ratu Road, Pisca More, Harmu Road, Kishore Ganj, Madhukam, Pahari Mandir Area, Upper Bazar and nearby areas.
- Kanke (Gonda)- Kanke Rd. areas on both side, CM House, Raj Bhawan, Vidhan Sabha Adhyaksh Awaas, Chief Justice Awaas, RINPAS and areas nearby are supplied with water.

- Dhurwa- Also called Hatia Dam, supply water to H.E.C, H.E.C Company, Dhurwa, Hatia, Singh More, Latma, Jagganathpur, Birsa Chowk, Doranda, Hinoo, SAIL & Mecon Colony, Shukla Colony, Hawai Nagar and areas nearby.

2.0.2 FIELD WORK

Field Work for the present project "Survey of Fluoride Content in Drinking Water in Ranchi City" involved the testing of temperature and pH of the water samples on-site. Out of 50 samples 34 samples were tested for their temperature and pH and recorded.

2.1 ANALYTICAL METHOD

Fluoride Content was determined by means of an ION - SELECTIVE ELECTRODE, which makes it possible to measure the total amount of free and complex-bound fluoride dissolved water. The method can be used for water containing at least 20 µg/ litre.[2]

2.2 ION - SELECTIVE ELECTRODE METHOD

2.2.1 GENERAL DISCUSSION

a. Principle

The fluoride electrode is an ion - selective sensor. The key element in the fluoride electrode is the laser type doped lanthium fluoride crystal across which a pontential is established by fluoride solutions of different concentrations. The crystal contacts the sample solution on one face and an internal reference solution at the other. The cell may be represented by:

Ag | AgCl , Cl - (0.3 M) , F- (0.001 M) | LaF3 | test

The fluoride electrode can be used with standard calomel reference electrode and almost any modern pH meter having an expanded multi-volt scale. Calomel electrode contains both metallic and dissolved mercury, therefore, dispose of them only in approved sites or recycle. For this reason, the Ag| AgCl reference electrode is preferred.

The fluoride electrode measures the ion activity of fluoride in solution rather than concentration. Fluoride ion activity depends on the solution total ionic strength and pH, and on fluoride complexing species. Adding an appropriate buffer provides a nearly uniform ionic strength background, adjusts pH, and breaks up complexes so that, in effect, the electrode measures concentration.

b. Interference

Fluoride forms complexes with several polyvalent cations, notably aluminium and iron. The extent to which complexation takes place depends on solution pH, relative levels of fluoride and complexing species. However, CDTA (Cyclohexylenediaminetetraacetic acid) a component of buffer, preferentially will complex interfering cations and release free fluoride ions. Concentrations of aluminium, the most common interference, upto 3.0 mg/L can be complexed preferentially. In acid solution, F- forms a poorly ionized HF.HF complex but the buffer maintains a pH above 5 to minimize hydrogen fluoride complex formation. In alkaline solution hydroxide ion also can interfere with electrode response to fluoride ion whenever the hydroxide ion concentration is greater than one-tenth the concentration of fluoride ion. At the pH maintained by the buffer, no hydroxide interference occurs.

Fluoborates are widely used in industrial process. Dilute solutions of fluoborates or fluoboric acid hydrolyse to liberate fluoride ion but in concentrated solution, as an electroplating wastes, hydrolysis does not occur completely. Distill such samples or measure fluoroborate with fluoroborate selective electrode. Also distill sample if the dissolved solids concentrations exceed 10000mg/L.

c. Quality Control (Q.C)

The QC practices considered to be an integral part of each method.

2.2.2 APPARATUS

a. Expanded scale or digital pH meter or ion selective meter.

b. Sleeve type reference electrode - Do not use fiber - tip reference electrodes because they exhibit erratic behavior in very dilute solutions.

c. Fluoride electrode

d. Magnetic stirrer

e. Timer

2.2.3 REAGENTS

a. Stock fluoride solution - Dissolve 221.0 mg Anhydrous Sodium Fluoride, NaF, in distilled water and dilute to 1000 ml;

1.00 ml = 100 µg F^-

b. Standard fluoride solution - Dilute 100 ml stock fluoride solution to 1000 ml with distilled water;

1.00 ml = 10.0 µg F^-

c. Fluoride buffer - Place approximately 500 ml distilled water in 1-L beaker and add 57 ml glacial acetic acid. 58 g NaCl and 4.0 g 1,2 Cyclohexy lenediaminetetraacetic acid CTDA. Place beaker in a cool water bath and add slowly 6 N NaOH (about 125 ml) with stirring, until pH is between

5.0 and 5.5. Transfer to a 1-L volumetric flask and add distilled water to the mark. This buffer, as well as a more concentrated version, is available commercially. In using the concentrated buffer follow the manufacturer's direction.

2.2.4 PROCEDURE

a. Instrument Calibration:-

No major adjustment of any instrument normally is required to use electrodes in the range of 0.2 to 2.0 mg F-/ L. For those instruments with zero at center scale adjust calibration control so that the 1.0 mg F-/ L standards reads at the center zero (100 mV) when the meter is in the expanded scale position. This cannot be done on some meters that do not have a millivolt calibration control. To use selective ion meter follow the manufacturer's instructions.

b. Preparation of fluoride standards:-

Prepare a series of standards by diluting with distilled water 5.0, 10.0 and 200 ml of standard fluoride solution to 100 ml with distilled water. These standards are equivalent to 0.5, 1.0 and 2.0 mg F^-/ L.

c. Treatment of Standard and Samples:-

In 100 ml beakers or other convenient containers add by volumetric pipet from 10 to 25 ml standard or sample. Bring standards and samples to same temperature preferentially, room temperature. Add an equal volume of buffer. The total volume should be sufficient to immerse the electrodes and permit operation of stirring bar.

d. Measurement with electrodes:-

Immerse electrode in each of the fluoride standards solution and measure developed potential while stirring on magnetic stirrer. Avoid stirring before immersing electrodes because entrapped air around the crystal can produce erroneous readings or needle fluctuations. Let electrodes remain in solution 3 min (or until the reading is constant) before taking a final millivolt reading. A layer of insulating material between stirrer and beaker minimizes solution heating. Withdraw electrodes, rinse with distilled water, and blot dry between readings.

[CAUTIONS -Blotting may poison electrodes if not done gently]. Repeat measurements with samples. When using expanded scale meter or selective-ion meter, frequently recalibrate the electrode by checking the potential reading of the 1.00 mg F^-/ L standard and adjusting the calibration control, if necessary, until meter reads as before. If a direct-reading instrument is not used, plot potential measurement of fluoride standards against concentration on two-cycle semi logarithmic graph paper. Plot milligrams F^- per liter on the logarithmic axis (ordinate), with the lowest concentration at the bottom of the graph. Plot millivolts on the abscissa. From the potential measurement for each sample, read the corresponding fluoride concentration from standard curve.

The known-additions method may be substituted for the calibration method described. Follow the direction of the instrument manufacturer.

Selective-ion meters may necessitate using a slightly altered procedure, such as preparing 1.00 and 10.0 mg F^-/ L standards or some other concentration.

Follow the manufacturer's directions. Commercial standards, often diluted with buffer, frequently are supplied with the meter. Verify the stated fluoride concentration of these standards by comparing them with standards prepared by the analyst.

2.2.5 CALCULATION

$$mg\ F^- / L = \frac{\mu g\ F^-}{mL\ sample}$$

2.2.6 PRECISION and BIAS

A synthetic sample containing 0.850 mg F-/ L in distilled water was analyzed in 111 laboratories by electrode method.

RESULTS

The present study entitled "Survey of Fluoride Content in Drinking Water in Ranchi City" was carried out in Yugantar Bharati, Analytical & Environmental Engineering Laboratory, Sidroll, Namkum, Ranchi. The results obtained during the course of this study are being discussed in the light of literature and being presented in this chapter.

The temperature of the groundwater in Ranchi City ranged from 25.9°C to 31.4°C with an average of 28.2°C. The pH varied from 7.1 to 8.2 with a mean value of 7.3.

Table 2- The following results were obtained:

Sl. No	AREA	TYPE OF SOURCE	ZONE	F^{-} CONC
1	KARAM TOLI	POND	NORTH EAST	0.320 ppm
2	KARAM TOLI	PUBLIC WELL	NORTH EAST	0.310 ppm
3	KARAM TOLI	R.M.C	NORTH EAST	0.450ppm
4	GETALSUD	DAM	NORTH EAST	0.360ppm
5	GETALSUD	TUBE WELL	NORTH EAST	0.650ppm
6	RUKKA	DAM	NORTH EAST	0.330ppm
7	RUKKA	R.M.C	NORTH EAST	0.340ppm
8	RUKKA	TUBE WELL	NORTH EAST	0.370ppm
9	SAMLONG	PRIVATE WELL	NORTH EAST	0.280ppm
10	SAMLONG	PRIVATE TUBE WELL	NORTH EAST	0.210ppm
11	GOSSNER COLLEGE	TUBE WELL	NORTH EAST	0.280ppm
12	KANTA TOLI(Bus Stand)	TUBE WELL	NORTH EAST	0.430ppm
13	KANTA TOLI	TUBE WELL	NORTH EAST	0.100ppm
14	CHUTIA	R.M.C	NORTH EAST	0.180ppm
15	LALPUR	TUBE WELL	NORTH EAST	0.180ppm
16	SIROM TOLI(MundaChowk)	TUBE WELL	NORTH EAST	0.043ppm
17	RANCHI UNIVERSITY	TAP WATER	NORTH EAST	0.250ppm
18	RANCHI UNIVERSITY	TUBE WELL	NORTH EAST	0.270ppm
19	PATHALKUDWA(Hargari Rd.)	TUBE WELL	NORTH EAST	0.070ppm
20	PATHALKUDWA(By Lane)	TUBE WELL	NORTH EAST	0.074ppm
21	PATHALKUDWA(Nayatoli Rd.)	TUBE WELL	NORTH EAST	0.056ppm
22	OXFORD SCHOOL	TUBE WELL	NORTH EAST	0.065ppm
23	GANDHI NAGAR	PRIVATE TUBE WELL	NORTH EAST	0.740ppm
24	BAHU BAZAR	R.M.C	NORTH EAST	0.160ppm
25	KOKAR (RIMS road)	TUBE WELL	NORTH EAST	0.290ppm
26	KOKAR	TUBE WELL	NORTH EAST	0.380ppm
27	KHORA TOLI	TUBE WELL	NORTH EAST	0.290ppm
28	ST.ANNE'S GIRLS' SCHOOL	TUBE WELL	NORTH EAST	0.300ppm
29	BARIATU (RIMS road)	TUBE WELL	NORTH EAST	0.390ppm
30	PURULIA ROAD	PRIVATE WELL	NORTH EAST	0.370ppm
31	DANGRA TOLI (Peace road)	TUBE WELL	NORTH EAST	0.360ppm
32	**KANKE (Gonda)**	**TUBE WELL**	**NORTH WEST**	**3.800ppm**
33	DORANDA	TUBE WELL	SOUTH EAST	0.320ppm
34	RATU (Garikhana)	TUBE WELL	SOUTH EAST	0.086ppm
35	**RANCHI AIRPORT**	**TUBE WELL**	**SOUTH EAST**	**1.200ppm**
36	DHURWA	DAM	SOUTH WEST	0.350ppm
37	**DHURWA**	**R.M.C**	**SOUTH WEST**	**1.600ppm**
38	DHURWA	TUBE WELL	SOUTH WEST	0.290ppm
39	H.E.C COLONY	TUBE WELL	SOUTH WEST	0.270ppm
40	H.E.C PLANT	TUBE WELL	SOUTH WEST	0.110ppm
41	HULUNDU (Satrangi)	PRIVATE TUBE WELL	SOUTH WEST	0.250ppm
42	DIBDIH BYPASS	TUBE WELL	SOUTH WEST	0.190ppm
43	**DIBDIH BYPASS**	**PRIVATE WELL**	**SOUTH WEST**	**1.100ppm**
44	ARGORA	TUBE WELL	SOUTH WEST	0.400ppm
45	HATIA (Railway Station)	TUBE WELL	SOUTH WEST	0.007ppm
46	HATIA	TUBE WELL	SOUTH WEST	0.130ppm
47	TUPUDANA	TUBE WELL	SOUTH WEST	0.450ppm
48	FISHERY RESEARCH CENTRE	POND	SOUTH WEST	0.160ppm
49	**BIRSA CHOWK**	**TUBE WELL**	**SOUTH WEST**	**2.600ppm**
50	ASHOK NAGAR (By road)	TUBE WELL	SOUTH WEST	0.140ppm

DISCUSSIONS

The aim of the present survey was to investigate the fluoride levels in water samples taken from different sources utilized for drinking purpose. Since fluoride plays a vital role in human health therefore it was selected for this study.

From the survey it is clear that Ranchi City is safe from fluoride contamination but high fluoride levels are found in some areas namely Kanke (Gonda Village), Birsa Chowk, Dhurwa (R.M.C), Ranchi Airport and Dibdih Bypass ranging from 1.100ppm to 3.800ppm. These areas mostly lie in the western and southern parts of ranchi city. Fluoride in high concentration is found in ground water of southern, western and southwestern zones of the Ranchi city.[3] The water is found to be slightly acidic in nature and high in iron concentration in most of the zones. Two out of Fifty samples showed high iron content depicted by their red/brown colour. Also, it was observed that samples with arsenic and iron content had low fluoride levels.

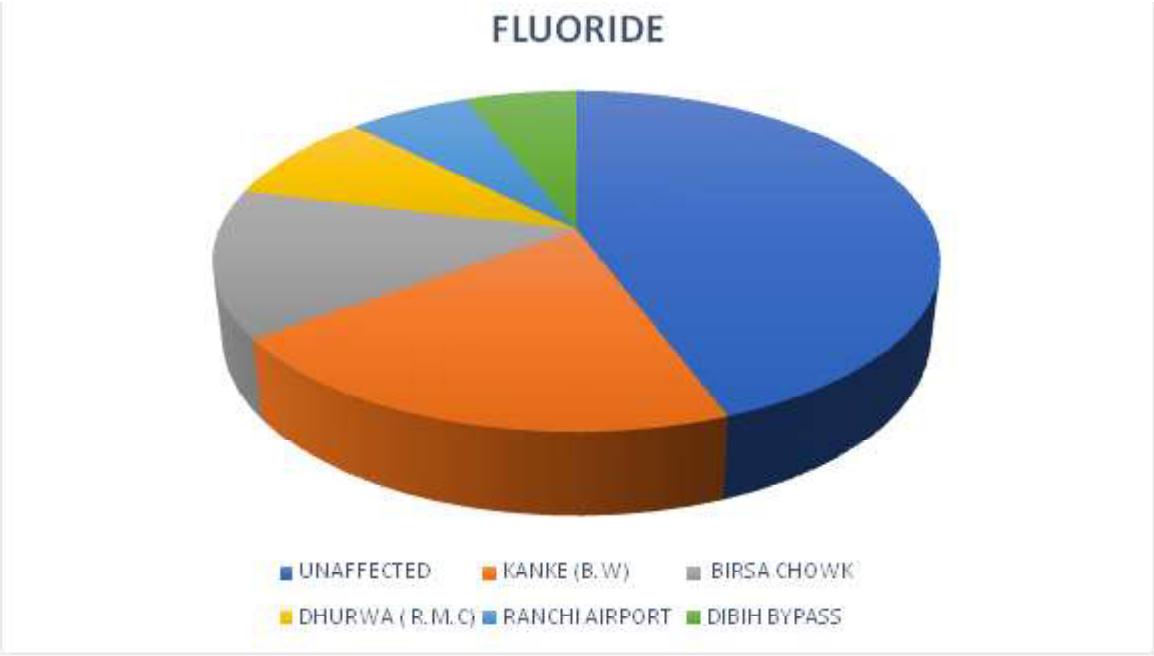
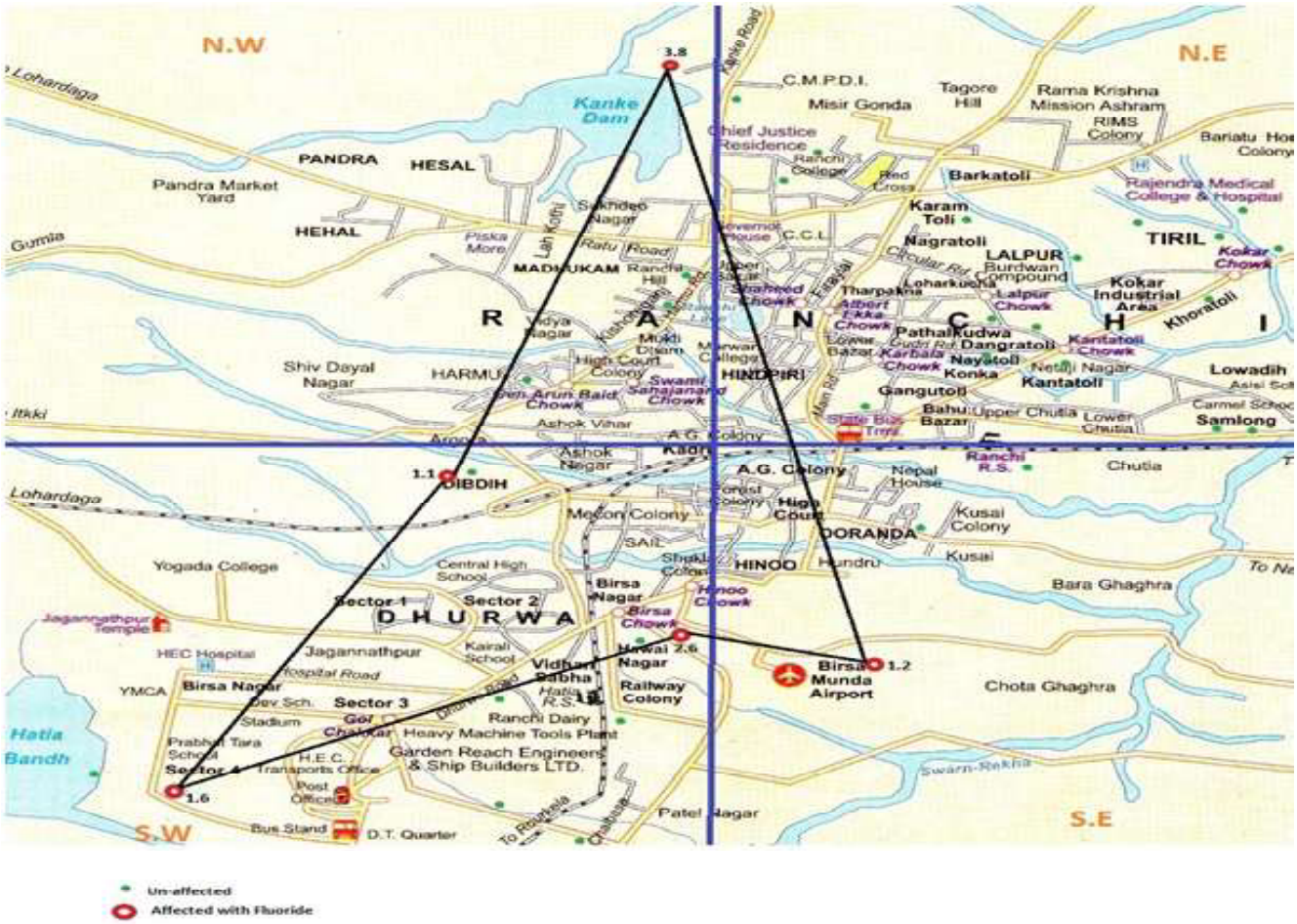


Chart 1- Showing the fluoride concentrations in affected and unaffected areas



Ranchi city map showing affected & unaffected areas. Fluoride in high concentration is found in ground water of southern, western and southwestern zones of the Ranchi city (Priyadarshini. N., 2009).

High fluoride concentrationsare associated with high TDS, high pH, high Na concentrations, and high sodium absorption ratios (SAR). This suggests that elevated fluoride levels are the result of enhanced fluorite solubility due to Ca depletion and high ionic strength and the release of fluoride from colloid surfaces under high pH conditions.[4] High fluoride concentrations are linked to high sodium contents and pH, and low Ca^{2+} concentrations. The weathering of volcanic rocks increases pH which in turn triggers the dissolution of CO_2. The consequent increase in HCO^{3-} and CO_3^{2-} causes oversaturation in the groundwater compared to calcite, leading to the precipitation of this mineral. This precipitation lowers the Ca^{2+} concentration in solution and leads to a sub-saturation for fluorite in the system. As a result, fluorite will dissolve and an increase in F^- concentration is observed.[5]

The following chart shows that most parts of Ranchi City is unaffected by high levels of fluoride whose value ranges from 0.007ppm to 0.740ppm shown in blue. While Kanke (Gonda village) showing the highest level of fluoride detected with 3.800ppm shown in orange, Birsa Chowk with 2.600ppm shown in grey, Dhurwa (R.M.C) with 1.600ppm shown in yellow exceeding the optimum value of fluoride i.e., 1.5 mg/L set by WHO. While Ranchi Airport (dark blue) and Dibdih Bypass (green) bore wells showing fluoride content of 1.2 and 1.1 ppm (mg/L) respectively, though not exceeding the optimum value but still considered high.

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