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# Evaluation of Fluoride Contamination in Groundwater Sources in Palamu District, Jharkhand, India

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**Abstract:** This study provides an overview of the fluoride (F) content in drinking water sources and the extent of human exposure to different levels of fluoride contamination in the four blocks of Palamu district. Groundwater is the main source of drinking water for the area residents. The permissibility and concentration of fluoride in groundwater samples from different sites in Chainpur, Daltonganj, Bishrampur and Pandu blocks of the Palamu district, Jharkhand, was determined by field kit and laboratory test, respectively. Samples with non permissible concentration of fluoride on an average indicate higher proportion in Daltonganj, Pandu and Chainpur blocks as compared to Bishrampur block. A significantly higher concentration 4.2 mg $L^{-1}$ was found in Daltonganj block i.e. in the depth range of 0-50 feet. Looking into the total samples (2864) the percentage distributions of non permissible samples indicate that the depth range of 100-150 feet is highly vulnerable to fluoride occurrence. Maximum fluoride concentration and average concentration were highest in samples from hand pumps which are generally pumping from shallow aquifers.

**Key words:** Fluoride concentration, drinking water, groundwater, Jharkhand, Palamu

## INTRODUCTION

The groundwater quality and quantity is very important in various fields like irrigation, agriculture and public water supply (Derakhshani and Alipour, 2010; Derakhshani and Bazregar, 2010; Alipour and Derakhshani, 2010; Shanthakumari *et al*., 2007; Rahmani and Kushafar, 2007). Ground water is an important source of water for many communities which usually have high soluble solids but low microbial contamination (Naeem *et al*., 2007; Adnan *et al*., 2005). In the world, around 200 million people from 25 nations have great health risks, with high fluoride in the drinking water (Ayoob and Gupta, 2006). In India, almost 60-65 million people drink fluoride contaminated groundwater and the number affected by fluorosis is estimated at 2.5 to 3 million in many States, especially Andhra Pradesh, Bihar, Jharkhand, Gujarat, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh (Susheela, 1999; Chakraborti *et al*., 2000; Muralidharan *et al*., 2002; Pillai and Stanley, 2002). Fluoride is common in semiarid climate with crystalline igneous rocks and alkaline soils (Handa, 1975). The main source of fluoride in groundwater is considered to be fluoride-bearing minerals such as fluorspar ($CaF_2$), fluorapatite [$Ca_5(PO_4)_3F$], cryolite and hydroxylapatite in rocks (Farooqi *et al*., 2007). Fluoride in small amounts is an essential component for normal mineralization of bones and formation of dental enamel (Bell and Ludwing, 1970). However, excessive intake of fluoride through water and food consumption can cause dental and skeleton fluorosis (Sorg, 1978; Mahramanlioglu *et al*., 2002). Due to its strong electronegativity, fluoride is attracted by positively charged calcium in teeth and bones (Susheela *et al*., 1993). Palamu district comprising the study area is located in the north western part of the Jharkhand state suffers due to high concentration of fluoride in groundwater. The ground water forms a major component of water supply in the rural as well as urban areas. Fresh water resources constitute the most important resources to sustain quality life and therefore, suitable water supply in terms of quality and quantity is of vital importance (Baghvand *et al*., 2006).

The area primarily comprised of metamorphic rocks (granite and granitoid gneisses) of Archean age associated with sedimentary rocks (sandstone, shale and coal seems) in which fluoride occurs with constituent minerals. The present study evaluated the

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spatial reference to its concentration, depth and geographical distribution in the region. The high fluoride concentration beyond the permissible limit is causing various health hazards. According to WHO (2004) the permissible limit for F is 0.5-1.5 mg $L^{-1}$. In India, safe limit of F in potable water is considered between 0.6 and 1.2 mg $L^{-1}$ (ISI, 1983). Lower concentration of F than that of the prescribed limit (0.6 mg $L^{-1}$) causes dental caries, while higher concentration of fluoride (>1.5 mg $L^{-1}$) result in fluorosis. Therefore, supplement fluoridation to the optimum level is deemed necessary to avoid dental decay in water consumers (Al-Oud, 2004).

## MATERIALS AND METHODS

**Study area:** The area under investigation comprised of Daltonganj, Bishrampur, Chainpur and Pandu blocks in Palamu districts in Jharkhand State. In these blocks, groundwater is the main source of drinking water. Socioeconomic conditions are very poor and the villagers depend entirely on agriculture and allied activities suffering from various degree of malnutrition. The study area is located between 23°47′N to 24°23′N latitude and 83°48′ E to 84°13′ E longitude and with an area of 1396 $km^2$ (Fig. 1).

**Survey and analysis:** The survey involved water sample collection from Public Wells (PUW), Private Wells (PW), Household Hand Pumps (HHP), Public Hand Pumps (PHP) and water sources in the Health Centers (HC) and Schools (SC). The 2864 water samples were collected out of which 277 (9.7%) samples were tested in laboratory for estimating the concentration of fluoride by using SPADNS method and remaining samples were tested onsite by using the field test kit provided by UNICEF (Jal Tara kit). Field test involve collection of 50 mL of water sample in the test tube and then 2.5 mL of Zirconyl Alizarine was added to it. The water sample was allowed to stand for 25-30 min for complete reaction and color development. The appearance of yellow colors in water sample indicates presence of higher concentration of fluoride beyond permissible limit. The sampling locations were recorded by Global Positioning System (GPS) whereas, Geographic Information System (GIS) was used for spatial distribution of F with reference to block boundaries digitized from administrative atlas from Census of India (Jharkhand), 2001.

## RESULTS

Fluoride concentrations in the laboratory tested 277 groundwater samples from different parts of the study area ranged from 0.02 to 4.2 mg $L^{-1}$ with a mean of 1.63 mg $L^{-1}$ (Table 1). With reference to permissible limit (0.5-1.5 mg $L^{-1}$) it can be stated that Pandu block followed by Daltonganj and Chainpur blocks have high percentage of water sources with fluoride under non permissible limit. However, maximum fluoride concentration (4.2 mg $L^{-1}$) was found in Daltonganj block. Samples with non permissible concentration of fluoride on an average indicate higher proportion in Daltonganj and Pandu blocks as compared to Chainpur and Bishrampur blocks.

Looking into a the total dataset of 2864 sample tested in the field however, Pandu block exhibit majority of

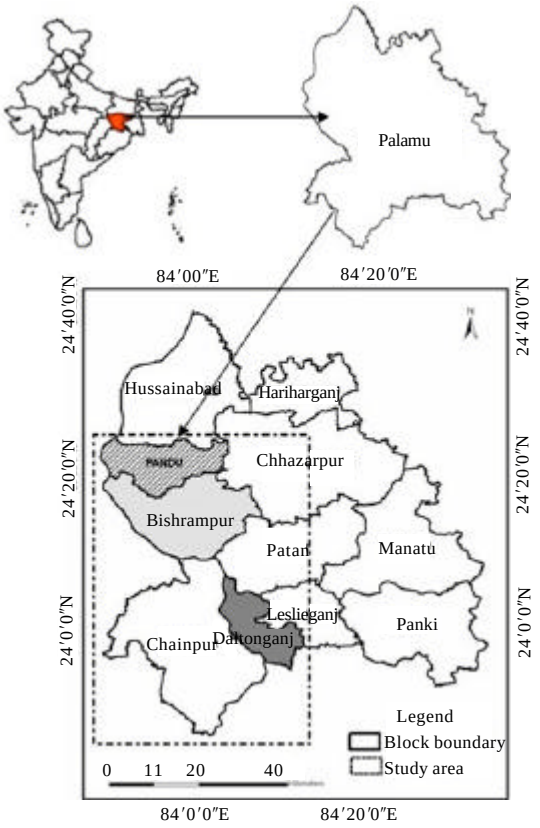


Fig. 1: Location map of the study area

Table 1: Statistics of fluoride concentrations in laboratory tested samples with reference to percentage of samples under permissible (P) and non permissible limit (NP)

| Block name | No. of samples | (NP) >1.5 mg $L^{-1}$ | (P) <1.5 mg $L^{-1}$ | NP (%) | NP maximum (mg $L^{-1}$) | NP average (mg $L^{-1}$) |
|---|---|---|---|---|---|---|
| Bishrampur | 59 | 2 | 57 | 8.70 | 1.82 | 1.25 |
| Chainpur | 53 | 23 | 30 | 51.11 | 2.60 | 1.57 |
| Daltonganj | 152 | 87 | 65 | 65.91 | 4.20 | 1.86 |
| Pandu | 13 | 5 | 8 | 83.33 | 2.28 | 1.84 |

Table 2: Fluoride concentration in water samples at different depth ranges (laboratory tested samples with fluoride under non permissible limit)

| Depth range (feet) | No. of samples | Max. F conc. | Avg. F conc. | SD | Variance |
|---|---|---|---|---|---|
| 0-50 | 45 | 4.20 | 2.19 | 0.69 | 0.48 |
| 100-150 | 32 | 2.28 | 1.58 | 0.27 | 0.07 |
| 150-200 | 24 | 2.80 | 1.61 | 0.40 | 0.19 |
| 200-250 | 3 | 1.90 | 1.58 | 0.28 | 0.08 |
| 50-100 | 12 | 2.80 | 1.53 | 0.34 | 0.12 |
| >250 | 1 | 1.90 | 1.44 | 0.29 | 0.08 |

Table 3: Statistical information of fluoride concentration for field tested samples (FT) and laboratory tested samples (LT)

| | | FT | | LT | | |
|---|---|---|---|---|---|---|
| Water source | No. of samples | NP | NP (%) | NP | Max. F conc. | Avg. F conc. |
| HC | 6 | 0 | 0.00 | 0 | 0.0 | 0.00 |
| HHP | 515 | 57 | 11.06 | 7 | 2.8 | 1.89 |
| PW | 519 | 42 | 8.09 | 7 | 1.9 | 1.56 |
| PHP | 1345 | 291 | 21.63 | 145 | 4.2 | 1.78 |
| PUW | 242 | 33 | 13.64 | 19 | 2.8 | 1.67 |
| SC | 237 | 48 | 20.25 | 28 | 2.8 | 1.51 |

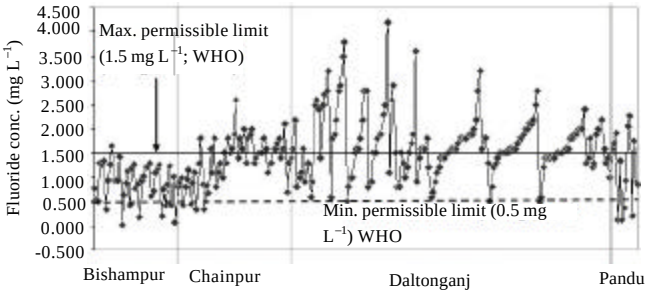


Fig. 2: F concentration in four blocks of Palamu district

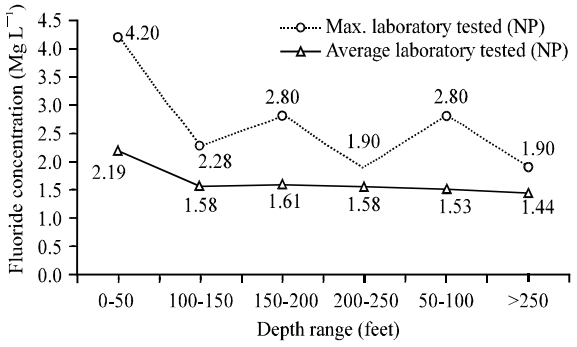


Fig. 3: Average F concentration value plotted against different depth range (feet)

sources with fluoride under non permissible limits, followed by Daltonganj and Chainpur blocks with least in Bishrampur block (Fig. 2). This indicates more testing of samples in the laboratory to strengthen the results of field test database for evaluating the fluoride concentration in Pandu block.

Depthwise distribution of fluoride concentration (Table 2) indicates that 0-50 feet depth range is highly vulnerable with highest average concentration of 2.19 mg L$^{-1}$. Thereafter, the average concentration remain static although, exhibit a slightly decreasing trend. Looking into the maximum concentration, abnormally high concentration up to 4.2 mg L$^{-1}$ was found between 0-50 feet followed by an up and down trend of concentration as shown in Fig. 3.

The groundwater samples were collected from various sources. Out of 2864 samples, 6 samples were collected from Health Center (HC), 515 from Household Hand Pump (HHP), 519 from Private Well (PW), 1345 from Public Hand Pump (PHP), 242 from Public Well (PUW) and 237 samples from school (SC) (Table 3). School and public handpump are the water sources which is mostly contaminated with excess of fluoride as larger percentage of non permissible points are found in both sources. Among laboratory tested samples (277), with non permissible fluoride concentration, the maximum concentration (4.2 mg L$^{-1}$) was found in public hand pump and minimum (1.9 mg L$^{-1}$) in private well. The average concentration of fluoride is highest in household hand pump.

## DISCUSSION

The Chainpur, Pandu and Daltonganj blocks are affected with high concentration of fluoride as (1.57, 1.84

and 1.86 mg $L^{-1}$, respectively). Whereas, Bishrampur block with lower concentration of fluoride (1.25 mg $L^{-1}$). The higher concentration of fluoride may be due to the presence of fluoride-bearing minerals in groundwater as the majority of the area in fluoride affected blocks are underlain by granitic rocks. Also, during its complex flow history, groundwater passes through various geological formations leading to consequent contamination in shallow aquifers which is largely tapped for drinking water supply in India (Chofqi *et al*., 2004). Therefore, groundwater contains more fluoride than surface water resources due to greater contact times with fluoride-bearing minerals in rock-water interactions (Edmunds and Smedley, 1996; Hem, 1985). Further, looking into fluoride concentration below lower permissible limit of 0.5 mg $L^{-1}$, it was found that Bishrampur although, not affected by higher concentration of fluoride exhibit fluoride concentration below lower permissible limit which indicate more possibility of dental caries in this block. Similarly some samples reflect lower fluoride value even in Chainpur and Pandu blocks, whereas, Daltonganj block exhibit negligible percentage of samples with fluoride concentration below lower permissible limit. It is to remark that Daltonganj, Chainpur and Pandu blocks need to be looked for high concentration of fluoride and related diseases whereas Bishrampur block for lower concentration of fluoride and related diseases. Lower concentration of fluoride than that of the prescribed limit (0.6 mg $L^{-1}$) causes dental caries, while higher concentration of fluoride (>1.5 mg $L^{-1}$) result in fluorosis. In India, dental fluorosis has been previously described in human beings ingesting 0.5 and 0.9-1.0 mg $L^{-1}$ fluoride in drinking water (Ray *et al*., 1981) while at concentration of 3.4 to 3.8 mg $L^{-1}$, 100% dental fluorosis has been reported (Choubisa *et al*., 1996). In Rajasthan, 89.3% cases with dental fluorosis at 7.6 mg $L^{-1}$ and 100% at 3.8-50 mg $L^{-1}$ fluoride concentrations have been observed (Choubisa and Sompura, 1996).

In the study area among the lab tested sample (277) the highest concentration of fluoride i.e., 4.2 mg $L^{-1}$ was found at a depth of 0-50 feet followed by an up and down trend of concentration. The up and down trend represent that a higher concentration zone may be followed by a lower concentration zone. Abnormally high concentration in shallow aquifer at depth 0-50 feet may reflect possibility of extensive groundwater abstraction with less recharge in these aquifers which result in increased concentration of fluoride.

Looking into the total samples of 2864, the distributions of percentage of non permissible samples indicate that depth range of 100-150 feet is highly vulnerable to fluoride occurrence (Table 4) This substantiate that highest as well as more fluoride contamination occur up to 150 feet as compared to deeper levels of more than 150 feet. The possible explanation for lower percentage of non permissible samples at shallow depth at places may be attributed to possible recharge of groundwater from surface sources, whereas at deeper levels i.e., >250 feet less groundwater abstraction along with possibility of fluoride absorption at upper level cannot be ruled out. This indicates that very deep aquifer is safer then shallow aquifer. Also, the artificial recharge may reduce fluoride concentration.

Considering the large number of field tested samples (2864), it is apparent that school and public handpump are the water sources which are mostly contaminated with excess of fluoride as larger percentage of non permissible points are found in both sources (Fig. 4). Keeping in view the statistics of water sources with non permissible fluoride concentration it can be remarked that wells are better source of water than handpumps and household handpumps are better than public hand pump.

Therefore, school and public hand pump water sources need to be taken up for reducing concentration of fluoride as they cater to the water needs of large proportion of the population as well the most vulnerable, the school children, belonging to poor socioeconomic group of tribal population.

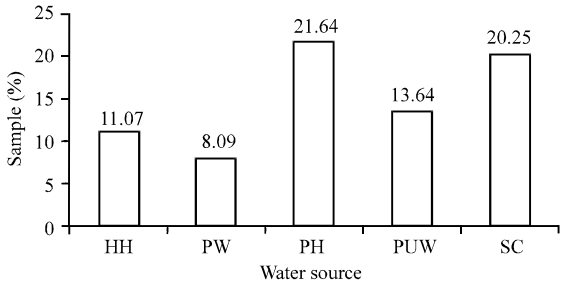


Fig. 4: Percentage of field and laboratory tested samples with F under non permissible limit in four block of Palamu district

Table 4: Statistics of non permissible water samples in different depth ranges (all samples)

| Depth range (feet) | No. of samples | No. of NP samples | NP samples (%) |
|---|---|---|---|
| 0-50 | 1062 | 142 | 13.37 |
| 100-150 | 593 | 134 | 22.60 |
| 150-200 | 763 | 141 | 18.48 |
| 200-250 | 74 | 13 | 17.57 |
| 50-100 | 326 | 38 | 11.66 |
| >250 | 46 | 3 | 6.52 |

## CONCLUSION

The fluoride concentration was detected at elevated levels in drinking water of Palamu district. Very high F concentrations (up to 4.2 mg $L^{-1}$) are found in the public hand pumps in Daltonganj block within the depth of 0-50 feet. At places the lower percentage of non permissible samples at shallow depth may be attributed to possible recharge of groundwater from surface sources, whereas, at deeper level i.e., >250 feet, less groundwater abstraction along with possibility of fluoride absorption its upper level cannot be ruled out. This indicates that very deep aquifer is safer then shallow aquifers and also the artificial recharge may reduce fluoride concentration. Lack of awareness about hazardous effects of drinking water with higher fluoride concentration then the prescribed limit, poor knowledge about appropriate preventive measures and limited access to safe drinking water could be some factors forcing people to use these contaminated water sources with excess fluoride concentration. Among the water sources examined, water samples collected from schools had about 20% of samples with fluoride concentration in non-permissible limits. Therefore, the remedial processes to reduce fluoride concentration should focus on drinking water sources in Schools. It would be important to determine the health problems that might be caused by excess as well as lower fluoride intake in this region to determine the gravity of the problem. The Daltonganj, Chainpur and Pandu blocks need to be looked for high concentration of fluoride and related diseases whereas, Bishrampur block for lower concentration of fluoride and related diseases.

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