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Salient Features of Excess Fluoride Invasion into Human Health in Fluoride Affected Villages of Birbhum District (West Bengal, India)

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ABSTRACT

The prime source of fluoride is geological strata, but human being gets fluoride from different sub-sources, e.g., underground water, soil, crops, air etc which are connected directly or indirectly with the geological strata. The source through which mostly the fluoride enters the human body is underground water.Fluoride compound (F^-) is necessary for a certain content to eradicate the dental caries and to strengthen the bones. Fluoride remains in a certain amount in water. According to World Health Organization (WHO, 2002) the permissible limit of fluoride in underground water is 1.5 mg/L andaccording to Bureau of Indian Standard (BIS, 2009) the permissible limitof fluoride in underground water is 1 mg/L.Crossing this limit (1.5 mg/L) fluoride contaminates the water. If the same water is used mainly for drinking purpose then health hazard may occur. This health hazard is known as fluorosis. Person once attacked by this is never cured fully from this. Patients lost their ability to do work.This paper gains its importance to elaborate the physical and social causes of fluoride incursion into human health and negative effect of excessive fluoride consumption in five fluoride affected sample villages in Birbhum district. Physical causes are related with the invasion of fluoride mainly through fluoride contaminated water sources. On the other hand, social causes are associated with the personal behaviour and several constraints present in the respect villages. At last, impact has been elaborated briefly on the basis of clearly defined drinking water sources.

Introduction:

The problem of high concentrations of F^- in underground water in India was first reported in Nellore district, Andhra Pradeshin 1937 (Short et al., 1937). At present, there are at least 17 states in India that are affected with elevated F^- levels in drinking water (WHO, 2006). During a rapid assessment survey by Public Health Engineering Department, Government of West Bengal (2005), 729 sources were found to be contaminated with fluoride above 1.5 ppm in 43 blocks of seven districts of West Bengal, with the affected population being approximately 2.26 lakhs. Fluorided affectedseven districts are Purulia, Birbhum, Bankura, Malda, South Dinajpur, North Dinajpur and South 24-Parganas (Keller, E., 1976).Though underground water contamination by fluoride is a recent issue but it has become a very common problem to the people specially those of remote areas through out the world with the increasing demand of water. Fluoride related diseases are known as Fluorosis. Different sorts of Fluorosis can be grouped into three-

- Dental fluorosis
- Skeletal fluorosis
- Non-skeletal fluorosis

Seven blocks of Birbhum District have been affected so far. Five villages have been selected as sample villages for the purpose of study.

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Data source and Methodology:
Pre-field:

In the pre-field session, the problem of the study area has been identified.Books and research papers from various journals through internet and library searching with the help of 'open access process' have been studied. Study villages were selected by purposive sampling because the purpose is to study the affected villages only. The random sampling technique has been chosen to select house-holds because in this techniqueall the house-holds would have equal chance to be selected.After that,the trial questionnaire has been made because the final questionnaire was to be prepared on the basis of any correction or change after testing the trial questionnaire in the field.

Field:

The trial questionnaire has been tested at the field. After making necessary correctionof the trial questionnaire,the final questionnaire has prepared.House-hold survey was conducted on the basis of a final questionnaire. So, house-hold data and necessary photographs were the primary data. Secondary data have been collected from CMOH-II (of Suri Sadar hospital), West Bengal PHED, respective block office and village panchayat, respective water test laboratory and primary health centre etc.

Post-field:

In the post-field session, the master table has been prepared where each column represents field surveyed raw data andsecondary data regarding the specific components.Master table has been incorporated with in the MS-ACCESS software. From the master table with the help of MS-ACCESS simple frequency table and two ways cross classified contingency tableshave been prepared. During preparation of table, the data has been made scale-free and size-free because sometimes data becomes scale-biased and size-biased.Data has been represented necessarily with the help of Figures.The map has been prepared with the help of Arc-GIS-10 mapping software.Finally the paper writing has been started.

Location of the study area:

Study villages have been chosen from Birbhum district. Those villages are Nasipur (Nalhati-I CD-Block), Bhabanandapur (Nalhati-I CD-Block), Nawapara-Junidpur (Rampurhat-ICD-Block), Fullachak (KhoyrasoleCD-Block), Lauberia (KhoyrasoleCD-Block) (Map: 1).

Results and Discussion:

1. Physical causes of fluoride contamination:

For each and every village of study interaction between underground water and geological strata is responsible for the fluoride contamination (Schematic Figure: 1). Level of fluoride in the contaminated water is depending mainly on the fluoride concentration in the rocks. How the underground water gets contaminated by fluoride has been explained study-village wise in brief-

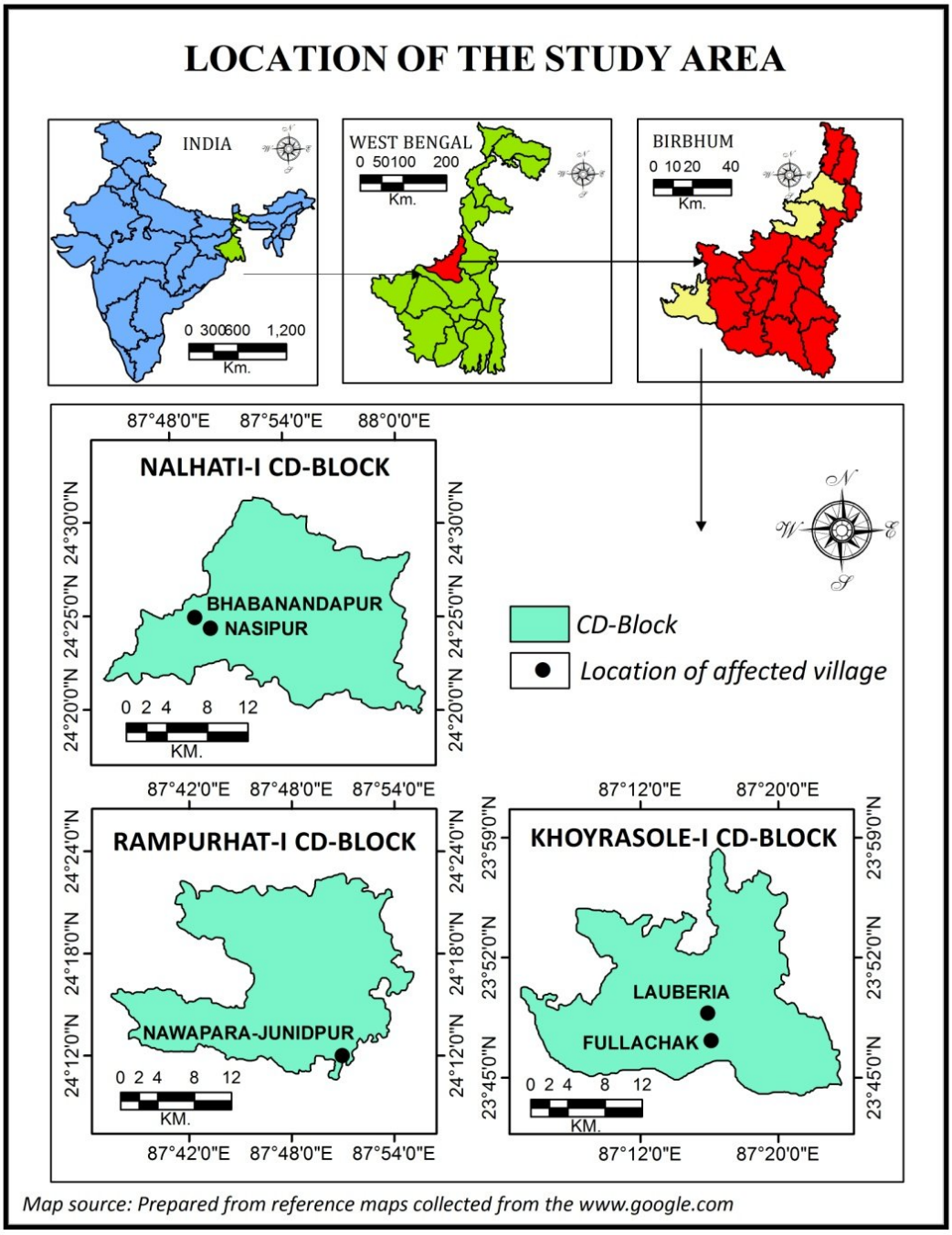
1.1 Physical causes of fluoride contamination at Nasipur:

The villageNasipur is located at Nalhati Block-I of Birbhum district. This block is located at the extreme western part of the Birbhum district, West Bengal. "Geologically, the area consists of fine-grained, hard, and compact basaltic rocks" (Chatterjee, 2004). "Basaltic rock and water interaction with it is responsible for the increased F^- in the artesian well"(Majumdar, 1975). "Granitic rocks are quarried near Panchra (23°46' N, 87°20' E) and Dubrajpur (23°48' N, 87°22' E). These are also available near Ranihabal (24°06' N, 87°20' E), Abdarpur (24°01' N, 87°31' E) and from places in the vicinity, e.g. Kushkhaspur, Haridaspur, Chak Mukunda, Chuarili and Kurabali"(Majumdar, 1975). Nasipur village is under the Haridaspur gram panchayet. So, it is understood that geological strata beneath the Nasipur include the granite along with the basalt.

Fluoride concentration in different rocks is not same (Figure: 1).We can see here that the basalt contains the lowest amount of fluoride among the rock types shown in the Figure. The concentration of fluorides is five times higher in granite than in basalt rock (Figure: 1). So, it can be said that geological strata beneath the Nasipur is related with the granite as well as basalt which contain fluoride. The water interacts with the fluoride bearing layer and amount of fluoride increases in that water. That water becomes the underground water source for the villagers of Nasipur. It is also important to say that higher the depth, higher the chance of increasing fluoride in water.

"Chotonagpur Plateau of Bihar is also reported with cases of fluorosis. It is very close to hills of Bihar (Jharkhand) border, and it is a part of Chotonagpur plateau. The underground water pollution in the region may be an extension of the Bihar malaise" (Chatterjee, 2004). "The source of this fluoride contamination in underground water at Nasipur may

Map:1



Map source: Prepared from reference maps collected from the www.google.com

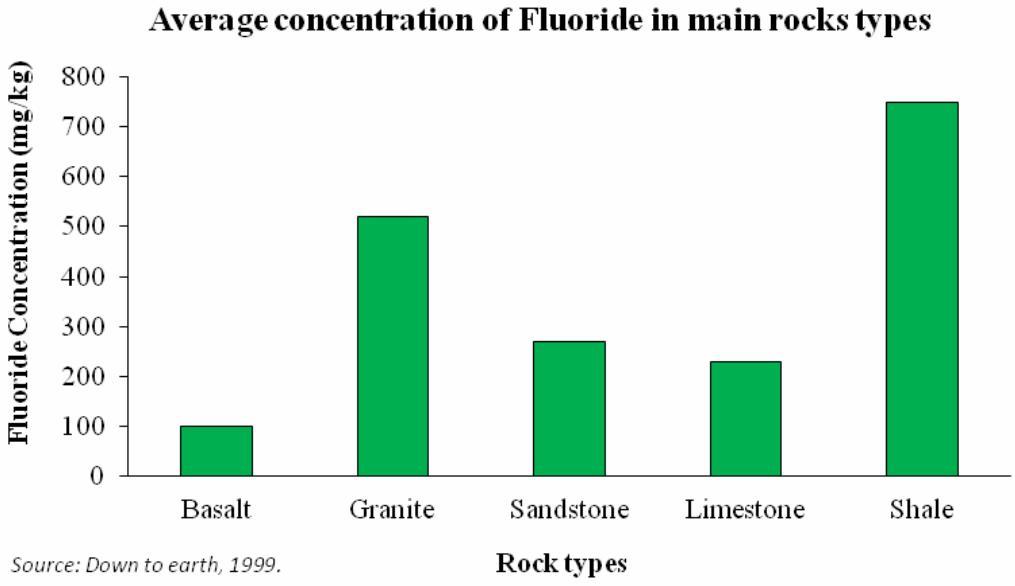


Fig. 1

be due to the presence of intertrappean sedimentary beds that were originally enriched in fluoride at the time of deposition and subsequently became soluble in entrapped water by favourable physico-chemical conditions" (Gupta et al., 2006).

1.2 Physical causes of fluoride contamination at Bhabanandapur:

The physical setting of this village is almost similar to the Nasipur village. Basalt and granite are present at the surface. Below the surface layer underground water is present. Water reacts with the fluoride compound of rocks. Thus the amount of fluoride in drinking water increases more than the permissible limit. This is the reason why the fluoride contamination of underground water occurs at this village.

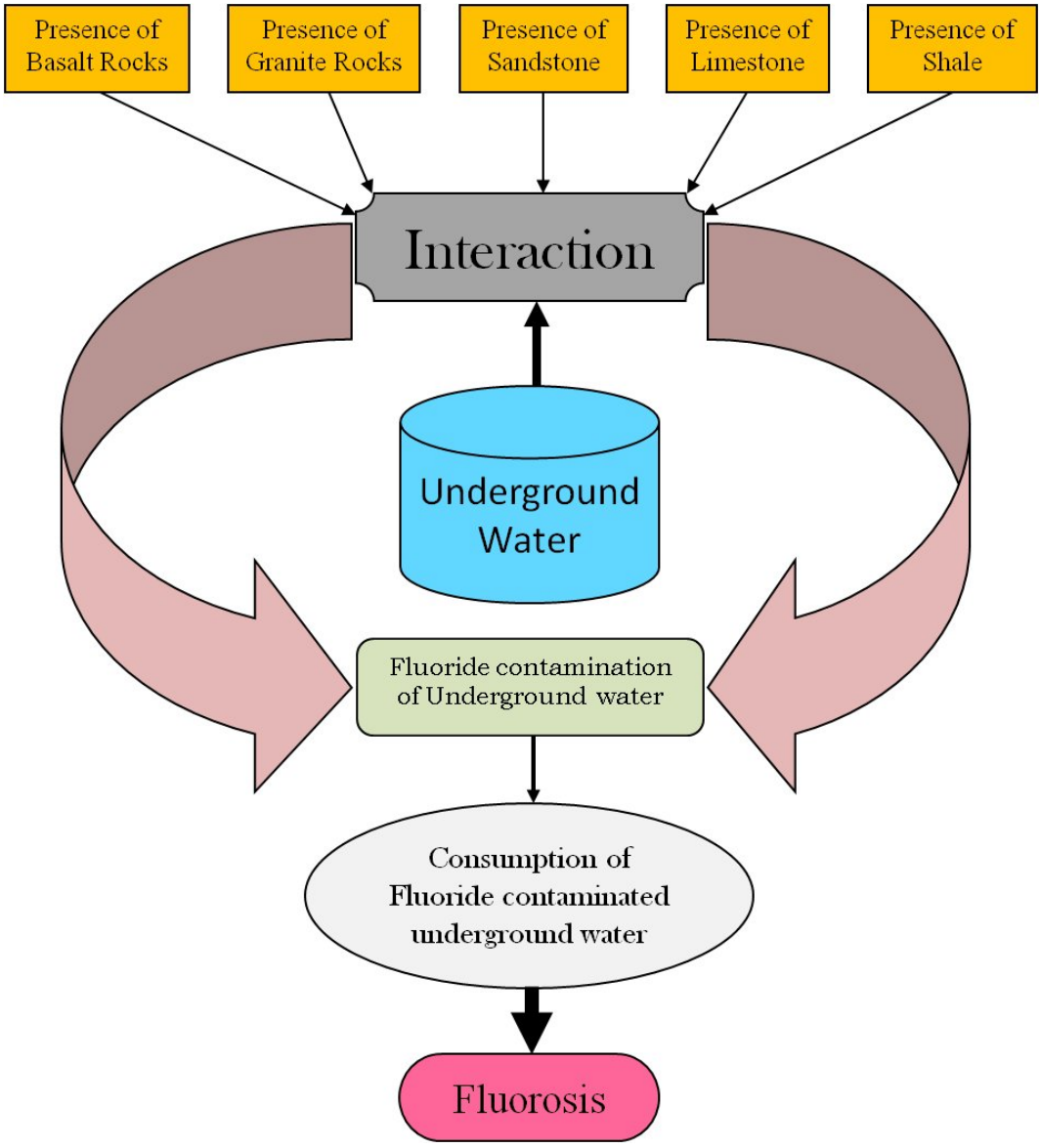
1.3 Physical causes of fluoride contamination at Nawapara-Junidpur:

"Basalt traps (Middle to Upper Jurassic); the Rajmahal traps are found about 48 km. north of the Raniganj coalfield along the western margin of northern portion of the district. Basalt flows overlie the Upper Gondwana formation in Dewanganj area, often with baked contact. Places, where traps occur, are Saldanga, Baramasia, Sagarbandhi, Nawapara, Palasbani, Maluti etc"(Majumdar, 1975). It means the study region (Nawapara-Junidpur) is affected by basalt formation. On the other hand "Tertiary gravels and other sedimentary rocks (sandstones and shale), about 45.7 m. to 76.2 m. in thickness, occur in Birbhum, Burdwan, Bankura and Midnapur districts"(Majumdar, 1975). Basalt which is impermeable lies below the sandstone and shale in the study region because it has been formed before the tertiary sandstone and shale. Water is easily infiltrated through the permeable sandstone and shale and lie for a long period being obstructed by the impermeable basalt below sandstone and shale. Thus water reacts with the fluoride-rich rocks for a long time. Fluoride content in basalt is 100 mg. /kg. Fluoridecontent is 2.5 times higher in sandstone and more than 7 times higher in shale than that of basalt (Figure: 1). So, the geological formation is the prime source of fluoride to make the fluorosis endemic here.

A schematicFigure given below showsresultant fluoride contamination due to the interaction between fluoride bearing rocks and underground water leading to fluorosis in Birbhum District (Schematic Figure: 1).

1.4 Physical causes of fluoride contamination at Lauberia:

At Lauberia granite rock is present at the surface. Underground water reacts with the granite rocks and the water becomes highly contaminated with fluoride. "There is a curious mass of granite at Dubrajpur, about



Schematic Figure1. Resultant fluoride contamination due to interaction between fluoride bearing rocks and underground water leading to fluorosis
Source: Prepared by author

15 miles south-west of the Civil Station of Suri. The rock rises perpendicularly to the height of 30 or 40 feet, and is broken up or split into numerous irregular massive fragments from the action of sun and rain"(Majumdar, 1975).It is observed that fluoride concentration in granite is 520 mg./kg. which is second highest after shale (Figure: 1). So we can imagine to what extent granite affects the underground water.

1.5 Physical causes of fluoride contamination at Fullachak:

The condition of Fullachak is similar to the Nawapara-Junidpur. Sedimentary rocks (sandstones and shale) are at the surface and granite rock lies below it. The concentration of fluoride in shale and sandstone is respectively 750 mg./kg. and 270 mg./kg. (Figure: 1).

Underground water is stored in between them. Consequently water reacts with mentioned rocks and becomes highly contaminated with fluoride.

2. Socio-economic causes of fluoride contamination:

In most of the times, socio-economic causes are not the prime. Despite, we can-not avoid it because socio-economic causes exaggerate the probability of invasion of fluoride into human body simultaneously with the physical causes. Socio-economic causes have been discussed below-

2.1 Socio-economic causes of fluoride contamination at Nasipur:

When the fluorosis disease was detected at Nasipur village, the tube wells and wells which were inside the village sealed and the water of Tripita Nala was

Photograph 1. Accumulated fluoride contaminated water in unfilled basalt mine
Source: Captured during field survey

started to be supplied through the tap by the Government. "The Tripita Nala flows east from the Santal Parganas, enter the district at 87°44' E & 24°17'30" N., becomes perennial east of 87°45' E. and joins the Brahamni as left bank tributary at 87°50' E. & 24°17' N." (Majumdar, 1975). But the villagers drink water from alternative source when tap service is halted. Tap service is provided at the particular time of each day. Many poor villagers miss to collect or store the tap water at the right time. Beside this if electric load shading occurs then water is not provided. Then almost all villagers use alternative water sources, e.g. water stored in unfilled stone mine (Photograph: 1), neighbouring village tube well, well outside the Nasipur village or canal. All these alternative sources excepting canal are affected by the fluoride because all these sources are adjacent to granite and basalt rock.

"Beside water, food items especially agricultural crops are heavily contaminated with fluoride as they are grown in the areas where the earth's crust is loaded with fluoride bearing rocks"(Garg and Singh, 2007). '...use of fertilizers and pesticides and other sources of contamination (Garg and Singh, 2007)' is another cause to recharge the soil by fluoride.

It is noteworthy that most of the workers of a young generation working at the stone mine around the Nasipur village is addicted to the tobacco chewing through out the day. Tobacco is such a drug element which contains very high amount of fluoride. This habit has destroyed their tooth. Yellow and brown stain occurred (Photograph: 2). Subsequently, pitting chipped off occurred. Then at young age they lost their dental ability by delayed eruption.

Photograph 2. Exaggeration of dental fluorosis due to tobacco chewing
Source: Captured during field survey

"The sources of atmospheric fluoride include the burning of coal and manufacturing of steel, lead, copper and nickel. It is liberally used for making super phosphate- an inorganic fertilizer indiscriminately utilised in the third world countries. Plants absorb fluoride from the atmosphere as well as from the soil. Man obtains fluoride compound from plants and water" (Chatterjee, 2004). This may be a cause of fluorosis at Nasipur.

2.2Socio-economic causes of fluoride contamination at Bhabanandapur:

When the tap water is discontinued for any reason or some of the villagers fail to store the tap water then they drink water from the personal tube well or wells which are from the same contaminated layer. Beside this similar to the villagers of Nasipur they have also

objection regarding the purity of the water (but the tap water is fluoridefree) which has led to the gastric problem. Thus they usually prefer the black tea or licker tea most of the time instead of milk tea. Consequently, they geta high amount of fluoride from tea. Rice contains fluoride 5.9 mg./kg., where as tea contains fluoride 60-112 mg./kg (Table: 1). It means the tea has fluoride which is 10-20 times to that of rice. So we can imagine the effect of black tea. As the milk contains the calcium thus, it is able to reduce the severity of fluoride in milk tea to some extent.

2.3Socio-economic causes of fluoride contamination at Nawapara-Junidpur:

The Nawapara-Junidpur village is located at the right bank of Dwarka River. Though, the villagers of this village are also suffering from the fluorosis but the story of this village is slightly different. Tap supply or no other alternative water supply has been provided to the villagers here. There are ten tube wells entirely within these two villages. Four of them are affected by fluoride (Table: 2).

Table 1. Normal fluoride content in various food items

Food Item	Fluoride (mg/kg)	Food Item	Fluoride (mg/kg)
Cereals		**Fruits**	
Wheat	4.6	Banana	2.9
Rice	5.9	Mango	3.2
Maize	5.6	Apple	5.7
		Guava	5.1
Pulses		**Beverages**	
Gram	2.5	Tea	60 - 112
Soybean	4.0	Coconut water	0.32 - 0.6
Vegetables		**Spices**	
Cabbage	3.3	Coriander	2.3
Tomato	3.4	Garlic	5.0
Cucumber	4.1	Ginger	2.0
Ladyfinger	4.0	Turmeric	3.3
Spinach	2.0	**Food from Animal Sources**	
Mint	4.8	Mutton	3.0 - 3.5
Brinjal (egg plant)	1.2	Beef	4.0 - 5.0
Potato	2.8	Pork	3.0 - .5
Carrot	4.1	Fishes	1.0 - 6.5

Source: Prevention and Control of Fluorosis in India: Vol. 1 (Health Aspects) (Ed. Susheela, A. K.) Rajiv Gandhi National Drinking Water Mission, New Delhi.

Table 2. Fluoride content (mg./l) in tube wells with different locations at Nawapara-Junidpur

Sl. No.	Location of Tube well with in the village	Fluoride level (mg./l)
1	**South-western side**	**2.52**
2	**Northern side**	**1.56**
3	South-eastern side	0.35
4	Central part	0.36
5	Central part	0.42
6	**Northern side**	**2.81**
7	**Northern side**	**1.91**
8	Southern side	0.73
9	Northern side	0.58
10	**Community Filter (Southern side)**	**3.56**
11	Central part	1.28

Source: PHED, West Bengal, 2006

A defluorided tank (called as 'Community filter') had been established at Nawapara-Junidpur village by UNICEF (United Nations International Children's Emergency Fund) taking the technology of BESU (Bengal Engineering and Science University) during 2007. That's why alumina needed to filter the water has not been replaced. Alumina inside it is needed to be replaced after every 3 to 4 months. As a result of this, the level of fluoride of water of that tank is 3.56 mg/l (Dec, 2013) which is recently highest of all drinking water sources (Table: 2). According to Rampurhat Paribesh Parisheba (under PHED) villagers violated the rules and regulation of using the tank. There were two rules- i) no one is permitted to abuse the filtered water by bathing and washing except for drinking and cooking. ii) villagers have to pay rupees five per family per month. Both of these rules were violated by villagers. Consequently, alumina is not replaced.'Community filter' is under use with-out new alumina.

Secondly, two filters per family have been given by the same organisation as stated aforesaid. Those are also running without new alumina. Most of them are well-known about the fact but very much reluctant about this, because villagers are unable to replace the old alumina. That's why those filters are out of service. Among the sample households studied, recently a broad portion of villagers are drinking water from aforesaid four affected tube wells. Others have also drunk water of those sources, but recently they are collecting water from non affected sources. However, near their primary school a tube well was highly affected (11.1 mg/l) which has been sealed officially, but the seal has again been opened by few villagers to use the water, because of the absence of any tube well nearby.

The soil of the concerned villages is also contaminated by the fluoride. Agricultural products get various types of minerals from the soil. That's why agricultural products growing in Nawapara-Junidpurvillage also contains the fluoride more than permissible limit which is also responsible for increasing amount of fluoride in the food of the villagers.

We can show here an estimation of per day fluoride consumption through diet for one adult villager of study area. Based on ICMR (Indian Council of Medical Research) guide, amount of crop and vegetables in regular diet chart can be like this- (here only those items have been taken into consideration which have been tested for the study area (Table:3 and 4, Figure: 2 and 3).

Table 3. Fluoride content (mg./l) in tube wells with different locations at Nawapara-Junidpur

Food items	Estimated intake (gm./day)	Normal concentration of F^- (mg./day)	F^- intake (mg. /day) by an adult villager of study area	Excess F^- intake (mg. /day)
Rice	500	2.95	6.16	3.21
Potato	150	0.42	0.60	0.18
Spinach	35	0.07	0.40	0.33
Brinjal	50	0.06	0.72	0.66
Tomato	10	0.03	0.09	0.06
Onion	5	0.02	0.05	0.03
Water	3 L	4.50	6.00	1.50
		8.05	**14.02**	**5.97**

Source: ICMR (Indian Council of Medical Research) guide (last three columns from right side have been calculated by author from table 4).

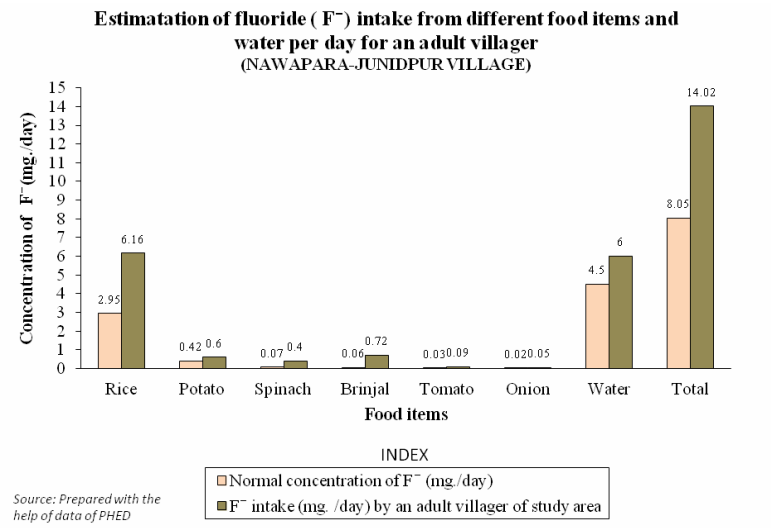


Fig. 2

Table 4. Fluoride content in different food items and water

Sl. No.	Crop/vegetables and water	Normal F⁻ content (mg. /kg.)	F⁻ content (mg. /kg.) at Nawapara-Junidpur
1	Rice	5.9	12.31
2	Potato	2.8	4.01
3	Spinach	2.0	11.37
4	Brinjal	1.2	14.46
5	Tomato	3.4	8.75
6	Onion	3.7	9.19
7	Water	1.5	>2 mg./l. (average)

Source: Gupta, S and Banerjee, S, (2011). Fluoride accumulation in crops and vegetables and dietary intake in a fluoride-endemic area of West Bengal. The International Society for Fluoride Research, New Zealand, 44(3)153–157.

It can be said that an adult person is consuming fluoride 8.05 mg/day in the non-affected region but that of Nawapara-Junidpur is consuming 14.02 mg./day. So, an extra amount of fluoride of 5.97 mg./day is being taken by them. That is similar to 74.16 % per day(Table: 3 and 4, Figure: 2 and 3). That is a reason which is encouraging the fluorosis within the villagers.

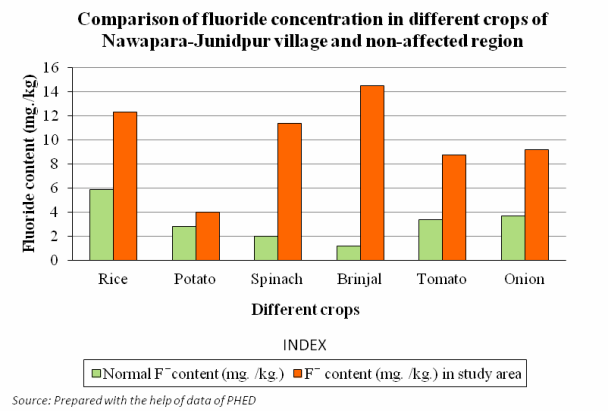


Fig. 3

2.4Socio-economic causes of fluoride contamination at Lauberia:

This village is also situated at Khoyrasole Block. There are 7 tube wells within and around the village. 4 of them are contaminated by fluoride. Three are not contaminated by fluoride (Table: 5).

Of those three non-contaminated tube wells, only one is within the village but taste of water is brackish. That's why water of that tube well is not preferred by them.Of rest of two one is away from habitation and its water is brackish in taste.

The last one is better because that is not contaminated by fluoride. At the same time its taste is not brackish. But that is outside the village as well as away from the habitation. That's why some of the villagers select the contaminated water form fluoride affected tube well.

Table 5. Fluoride content (mg./l) in tube wells with different locations at Lauberia

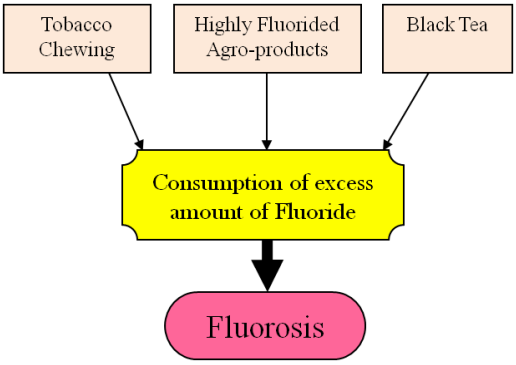
Sl. No.	Location of Tube well with in the village	Fluoride level (mg./l)
1	Northern side	0.25
2	**Central part**	**2.86**
3	**Eastern side**	**3.43**
4	**Southern side**	**3.75**
5	**Northern side**	**3.06**
6	Northern side	0.21
7	Central part	0.33

Source: PHED, West Bengal, 2006.

2.5Socio-economic causes of fluoride contamination at Fullachak:

They are bound to drink the underground water because no other alternative is present there. Fluoride contaminated government tube wells have been sealed. However, still, there are some private or personal wells and tube wells which are not tested. However villagers choose the water for drinking purpose based on the concept that whether the water is brackish in taste or not. They do not bother about the fact of fluoride contamination. Only one tube well is better in the taste as well as not contaminated by fluoride. But that is beyond the habitation.

A schematic Figure given below shows consumption of extra amount of fluoride due to socio-economic causes leading to fluorosis in Birbhum District (Schematic Figure: 2).



Schematic Figure 2. Consumption of extra amount of fluoride due to socio-economic causes leading to fluorosis. Source: Prepared by author

3. Impact of fluoride contaminated underground water:

In case of Nasipur and Bhabanandapur villages,villagers who drink water from tap and fluoride contaminated sources are comparatively much more affected by fluorosis than the villagers who drink water only from the tap (Table: 6). At Nawapara-Junidpur village,villagers who drink water from fluoridecontaminated tube wells and filter without new alumina are much more affected than the villagers who drink water from tube wells not contaminated by fluoride. Similarly, at Lauberia village, villagers who drink water from fluoridecontaminated tube wellsare much more affected than the villagers who drink water from fluoridecontaminated as well as non-contaminated tube wells. On the other hand at Fullachak village, villagers who drink water from fluoridecontaminated and non-contaminated tube wellsare much more affected than the villagers who drink water from tube wells not contaminated by fluoride(Table: 6).

Conclusion:

So, after investigating the causes of fluoride contamination, it can be said at a glance that interaction of fluoride bearing rocks and underground water is the staple physical reason of fluoride contamination at the study area. Socio-economic causes also promote the occurrence of fluorosis in patients, though very slowly but those causes can-not be ignored.

The problem of fluoride has become endemic in affected villages of Birbhum district because it does not occur anywhere. Nasipur, Bhabanandapur,

Table 6. Effect of fluoridein respect to different sources of drinking water

Sl No.	Name of the villages	Sources of water	Percentage distribution of surveyed households	Effect of all sorts of fluorosis
1.	Nasipur	Tap water and fluoride contaminated sources (unfilled stone mine, tube wells, wells)	90	Comparatively high
		Tap water	10	Comparatively low
2.	Bhabanandapur	Tap and fluoride contaminated sources (tube wells, wells)	92	Comparatively high
		Tap water	8	Comparatively low
3.	Nawapara-Junidpur	Fluoridecontaminated tube wells and filter without new alumina	50	Comparatively high
		Tube wells not contaminated by fluoride	50	Comparatively low
4.	Lauberia	Fluoridecontaminated tube wells	26	Comparatively high
		Fluoridecontaminated and non-contaminated tube wells	74	Comparatively low
5.	Fullachak	Fluoridecontaminated and non-contaminated tube wells	40	Comparatively high
		Tube wells not contaminated by fluoride	60	Comparatively low

Source: Field investigation.

Nawapara-Junidpur, Lauberia and Fullachak of Birbhum District are the study villages having this problem. Its occurrence has been determined mainly by geological strata. Presence of fluoride bearing rocks like basalt, granite etc. are responsible for it. Though the prime source of fluoride is geological strata but human being gets it mainly from underground water. Some policy measures and action programmes have been provided by the government to confront this serious problem.

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I express my deep sense of respect and gratitude to Professor Dr. Debashis Das for his valuable guidance through out the research-paper work. I am thankful to people of the sample villages who shared their valuable time with me during household survey. I also owe my heartfelt thanks to all the staffs of PHED, CMOH (Suri Sadar Hospital) and BMOH of respective block level hospital, members of respective gram panchayat, staffs of Primary Health Centre of respective block for their support by knowledge and data.

Reference:

Chatterjee, S. N. (2004). Fluorosis menace cripples Nasipur village- A case study. *Water Resources: Development and management* , 115-118.

Garg, V. K., & Singh, V. (2007). Fluoride in drinking water and Fluorosis. *Green Dages* , 1-5.

Gupta, S., & Banerjee, S. (2011). Fluoride accumulation in crops and vegetables and dietary intake in a fluoride-endemic area of West Bengal. *Fluoride, 44(3)*, 153-157.

Gupta, S., Banerjee, S., Saha, R., Datta, J. K., & Mondal, N. (2006). Fluoride geochemistry of underground water in Nalhati-I Block of the Birbhum District, West Bengal, India. *Fluoride, 39(4)* , 318-320.

Keller, E. (1976). *Environmental Geology.* Ohio: C. Merill.

Majumdar, D. (1975). *West Bengal District Gazetteers-Birbhum District.* Calcutta: State Editor.

PHED, W. B. (2006). *Summary of Water Quality Status in West Bengal*. Public Health Engineering Department, Government of West Bengal.

Short, H. E., McRobert, G. R., Bernard, T. W., & Mannadinayar, A. S. (1937). Endemic fluorosis in Madras Presidency. *Indian Journal of Medical Research, 25* , 553-561.

Standard), B. (. (2009). *Indian Standard Specifications for Drinking Water, Second Revision of IS: 10500.*

WHO. (2002). Environmental Health Criteria 227. *World Health Organisation* , 268.

WHO. (2006). *Fluoride in Drinking Water.*