Poll Res. 40 (1) : 211-216 (2021)
Copyright © EM International
ISSN 0257–8050

ASSESSMENT OF ARSENIC AND FLUORIDE CONTENT IN DIFFERENT DRINKING WATER SOURCES OF SECONDARY SCHOOLS IN GREATER GUWAHATI OF ASSAM, INDIA

MD YAMIN HASSAN[*1], MRIDUL BURAGOHAIN[1], MOYETREE SARMAH BEZBORUAH[2] AND INDIBOR BURAGOHAIN[3]

*[*1] Department of Chemistry, Assam Down Town University, Guwahati, Assam, India*
[1]Department of Chemistry, Lakhimpur Girls' College, North Lakhimpur, Assam, India
[2]Department of Chemistry, Assam Down Town University, Guwahati, Assam, India
[3]Post Graduate Training College, Dhemaji, Assam, India

(Received 6 July, 2020; accepted 4 September, 2020)

ABSTRACT

The present study was carried out to assess the drinking water quality in water sources used in different secondary schools of greater Guwahati, Assam with respect to arsenic and fluoride. In this study 40 samples were collected randomly from the study area during wet season in the year 2019. The study showed that 5%, samples were found contaminated with higher arsenic contents (WHO; arsenic 10 ppb for potable water). The most badly affected school was the Ganesh Mandir H.S. School where highest arsenic concentration was recorded 33.00 ppb at sampling point, A 25. With respect to fluoride the water samples of the study area were also contaminated by fluoride as 12.5% of analyzed water samples exceed the WHO drinking water standard (1.5 mg/L). The most badly affected school was the Hatigaon High School, at sampling point, F 51, where highest fluoride concentration was recorded 4.50 ppm.

KEY WORDS: Arsenic, Fluoride, Secondary schools, Guwahati, Assam

INTRODUCTION

Presence of varied numbers of pollutants including heavy metals in the water through natural and/or anthropogenic interventions imparts toxic and harmful effects to the environment and the individual (Chatterjee *et al.,* 2008). Human and ecological use of in-stream water depends on ambient water quality. Human alteration of the landscape has an extensive influence on watershed hydrology (Claessens *et al.,* 2006; Chang, 2007) and heat budget (Oke, 1987) which subsequently increases water temperature (Nelson *et al.,* 2007) and modifies in-stream biogeochemical processes that drive oxygen, nutrient, and sediment cycling (Baker, 2003). Therefore, identifying spatial and temporal changes in ground water quality has been a major focus of previous research. In West Bengal, India and Bangladesh, it is estimated that 100 million people in arsenic-affected areas are potentially at risk from groundwater arsenic contamination above the WHO guideline value of 10 μg/L (Chakraborti *et al.,* 2009; Chakraborti *et al.,* 2010). Eroded sediments and varied inputs of human activities like mining, pesticides, pharmaceuticals, etc. are thought to be the common sources of arsenic. Chronic arsenic exposure is detrimental to human health being associated with cancer of the skin, lung, liver, urinary bladder, and kidney (Bunnell *et al.,* 2007) and other diseases, including cardiovascular and peripheral vascular diseases, diabetes, peripheral neuropathies, portal fibrosis, and adverse birth outcomes (Xia *et al.,* 2009). Arsenic is a ubiquitous element found in the soil and rocks, natural waters and organisms that mobilizes through a combination of natural process and anthropogenic activities. Weathering, microbial metabolism and volcanic eruptions are some of the natural process through which ground water can be contaminated by arsenic. Anthropogenic activities like mining, combustion of fossil fuels, use of arsenical pesticides, herbicides and crop desiccants and agricultural additives for livestock are also responsible for exaggerating the arsenic in soil and groundwater. Though researches have made advancement in understanding the distribution, occurrence and mobilization of arsenic in groundwater on a global scale, on regional extent it is still poor and lacks proper knowledge and information. Most people of North East India are primarily dependent on dug-well, pond and naturally occurring spring water (Das *et al.,* 2015).

Fluoride a naturally occurring mineral is essential in small quantities for proper growth and maintenance of teeth and bones in humans. However, its excess consumption causes irreversible damage to teeth and bones, a phenomenon known as dental and skeletal fluorosis (Mohan *et al.,* 2020). Fluoride contamination in groundwater is widespread especially in China, India, Nigeria, South America (Andes and western Brazil) and Africa (Rift valley zone), northwest Iran, Pakistan, Kenya, and Sri Lanka (Eatson *et al.,* 2005). High fluoride in groundwater has been reported from nineteen states in India with fluoride contamination in groundwater resources being widespread, intense, and alarming (Raj *et al.,* 2017; Jeong, 2001). In India, the excessive presence of fluorides in groundwater is noticed in nearly 177 districts covering 20 states, affecting more than 65 million people, including 6 million children. The problem of excessive fluoride in groundwater in India was first reported in 1937 in the state of Andhra Pradesh. Telangana State is one of the fluoride affected states in the country and is considered to be endemic to fluorosis (Narsimha *et al.,* 2017). Current review emphasized the elevated level of fluoride concentrations in the groundwater and associated potential health risk globally with a special focus on Assam, North East India (Das *et al.,* 2003; Sharma *et al.,* 2011; Saikia *et al.,* 2011; Dutta *et al.,* 2010; Lahkar *et al.,* 2015; Saikia *et al.,* 2011). Natural sources are connected to various types of rocks and to volcanic activity. Agricultural (use of phosphatic fertilizers) and industrial activities (clays used in ceramic industries or burning of coals) also contribute to high fluoride concentrations in ground water (Rasool *et al.,* 2017). The WHO guideline value for fluoride in drinking water is 1.0 mg/L above 1.0 mg/L mottling of teeth may occur to an objectionable degree. Concentrations between 3 and 6 mg/L may cause skeletal fluorosis. Continued consumption of water with fluoride levels in excess of 10 mg/L can result in crippling fluorosis. High concentration of fluoride for extended time period causes adverse effects of health such as skin lesions, discoloration, cardiovascular disorders, dental fluorosis and crippling skeletal fluorosis (Brunt *et al,* 2004; Gaoa *et al.,* 2013).

MATERIALS AND METHODOLOGY

(A) Profile of the study area

Kamrup (Metro) is presently chosen as the study area. Kamrup metro is that the principal city of the whole North- Eastern India. The Kamrup (Metro) is located approximately along $26^0\ 11^{/}$ (N) latitude and $91^0\ 45^{/}$ (E) longitude. The study area is 54.75 m above the mean sea level, covering about 24 km in the East-West direction and about 9 km in the North-South direction. The mighty Brahmaputra flows along the Northern boundary of the study area while the Southern and Eastern boundaries are made by a number of hill ranges, which are extensions of the Khasi Hills. The Jalukbari-Azara plain makes the Western boundary of the study area. The study area also covers Amingaon and North Guwahati on the Northern side of the Brahmaputra. Structurally, the study area is situated on the 50 m thick alluvium of the middle Brahmaputra valley. The study area is situated on an outcrop of the stable rocky foundation of the Shillong Plateau. The study area is the main corridor for passage to the entire north eastern states of Assam, Meghalaya, Mizoram, Tripura, Manipur, Nagaland and Arunachal Pradesh. In the study area plateau and the floodplains of the Brahmaputra confront each other. The study area is covered with several hills of different sizes and shapes. The hills in the northern areas are Nilachal or Kamakhya Hill (North-West), Chitrasala or Kharghuli Hill (North), South-central areas are Narakasur Hill, Kalapahar and Fatasil Hill and eastern areas are Narengi, Hengerabari, etc. (Statistical Hand Book, Assam, 2017)

B) Sampling information and Analysis

For the study, 40 samples were collected randomly from the drinking water sources of different secondary schools of greater Guwahati of Assam (Table 1). The sampling was done during wet season in the year 2019. Samples were collected in clean and sterile one-liter polythene cans to obtain a composite sample, 1:1 HNO_3 solution was added to each of the water samples (to make pH <2.0) and stored in an ice. In regards to this study analysis of arsenic content of the water samples were done by using Atomic Absorption Spectroscopy (Model- 240AA by Agilent Technologies) with Flow Injection Analyze Mercury Hydride Generation System (Model FIAS-100) at 193.7 nm (detection limit 0.02 µg/L) as per the standard procedure (Eatson *et al.*, 2005). Fluoride contents were determined by SPADNS method. SPADNS (2-(*p*-sulphophenylazo)-1,8-dihydroxy-3,6-naphthalein disulphonate) was obtained from E-Merck and SRL (Das *et al.*, 2003).

RESULTS AND DISCUSSION

The experimental findings of the experimental data and their statistical analysis are summarized in Table 2 and 3. The distribution of arsenic and fluoride in water sources of the study area have been presented in Figure 1 and 2.

Results of analysed water samples revealed that 5% of the analysed samples exceed the permissible limit (10 ppb) set by WHO/BIS (WHO, 2008; BIS, 1991). The observed values of concentration for arsenic content in the water samples ranges from

Table 1. Schoolwise geographic coordinates of sampling location in the study area

Sl. No.	Sample No. Arsenic	Sample No. Fluoride	School Name	Sample Source (Depth)	Geographical Location North (N)	Geographical Location East (E)
1	A-1	F-1	Narengi High School	DTW (130ft)	$26^{0}10^{/}31.15^{//}$	$91^{0}49^{/}48.70^{//}$
2	A-2	F-2	Bonda Anchalik High School	RW (40ft)	$26^{0}11^{/}12.63^{//}$	$91^{0}50^{/}37.08^{//}$
3	A-3	F-3	Raghunath Choudhury High School	RW (60ft)	$26^{0}10^{/}48.83^{//}$	$91^{0}50^{/}28.74^{//}$
4	A-4	F-4	Swahid Kushwal Konwar High School	SW	$26^{0}12^{/}32.49^{//}$	$91^{0}52^{/}$ 9.98//
5	A-5	F-5	Chandrapur High School	RW (30-35 ft)	$26^{0}14^{/}6.79^{//}$	$91^{0}55^{/}31.14^{//}$
6	A-6	F-6	Panbari High School	RW (30-35 ft)	$26^{0}11^{/}33.73^{//}$	$91^{0}58^{/}59.82^{//}$
7	A-7	F-7	Pachim Mayong High School	RW(30-35 ft)	$26^{0}12^{\prime}16.57^{\prime\prime}$	$91^{0}51^{\prime}50.39^{//}$
8	A-8	F-8	Guwahati Refinery High School	SW	$26^{0}10^{/}54.78^{//}$	$91^{0}48^{/}13.33^{//}$
9	A-9	F-9	Janata Hindi Vidyalaya	SW	$26^{0}10^{/}53.72^{//}$	$91^{0}48^{/}11.89^{//}$
10	A-10	F-10	Noonmati High School	SW	$26^{0}12^{/}16.56^{//}$	$91^{0}51^{/}50.39^{//}$
11	A-11	F-11	New Guwahati Adarsha High School	DTW (200 ft)	$26^{0}10^{/}51.32^{//}$	$91^{0}46^{/}55.37^{//}$
12	A-12	F-12	New Guwahati Rly. Colony High School	SW	$26^{0}10^{/}51.32^{//}$	$91^{0}46^{/}55.37^{//}$
13	A-13	F-13	Pub-Guwahati High School	DTW (440 ft)	$26^{0}11^{/}16.35^{//}$	$91^{0}47^{/}20.15^{//}$
14	A-14	F-14	Jyoti Nagar High School	DTW (240 ft)	$26^{0}11^{/}1.38^{//}$	$91^{0}47^{/}11.39^{//}$
15	A-16	F-16	Pub-Guwahati High School	RW(30-35 ft)	$26^{0}11^{/}2.10^{//}$	$91^{0}46^{/}16.44^{//}$
16	A-17	F-17	Bhaskar Vidyapith H.S. School	SW	$26^{0}10^{/}41.18^{//}$	$91^{0}46^{/}32.22^{//}$
17	A-19	F-19	Geetanagar High School	SW	$26^{0}10^{/}21.15^{//}$	$91^{0}47^{/}20.10^{//}$
18	A-20	F-20	Satgaon High School	RW (30-35 ft)	$26^{0}9^{/}22.47^{//}$	91^{0} $50^{/}17.25^{//}$
19	A-21	F-21	Hengrabari High School	RW (30-35 ft)	$26^{0}9^{/}31.32^{//}$	91^{0} $49^{/}6.74^{//}$
20	A-23	F-23	Tepuram Teron High School	SW	$26^{0}8^{/}41.45^{//}$	$91^{0}48^{/}36.47^{//}$
21	A-18	F-18	Rajgarh Girls' High School	DTW (700 ft)	$26^{0}10^{/}17.44^{//}$	$91^{0}46^{/}14.66^{//}$
22	A-24	F-24	Bagharbari High School	RW (30-35 ft)	$26^{0}8^{/}12.70^{//}$	$91^{0}49^{/}46.09^{//}$
23	A-25	F-25	Ganesh Mandir H.S. School	RW (30-35 ft)	$26^{0}7^{/}45.34^{//}$	$91^{0}48^{/}38.87^{//}$
24	A-45	F-45	Japorigog High School	SW	$26^{0}9^{/}23.16^{//}$	$90^{0}47^{/}9.82^{//}$
25	A-46	F-46	Zoo Road Vidyapeeth High School	SW	$26^{0}10^{/}10.36^{//}$	$91^{0}47^{/}3.85^{//}$
26	A-49	F-49	Dispur Govt. H.S. School	RW (30-35 ft)	$26^{0}8^{/}50.06^{//}$	$91^{0}47^{/}18.33^{//}$
27	A-50	F-50	Gopal Boro Govt. H.S School	SW	$26^{0}8^{/}34.80^{//}$	$91^{0}46^{/}47.11^{//}$
28	A-51	F-51	Hatigaon High School	SW	$26^{0}8^{/}1.96^{//}$	$91^{0}47^{/}5.71^{//}$
29	A-52	F-52	Phaguna Rabha High School	SW	$26^{0}8^{/}26.61^{//}$	$91^{0}46^{/}46.30^{//}$
30	A-53	F-53	Narakasur High School	RW (30-35 ft)	$26^{0}7^{/}41.85^{//}$	$91^{0}48^{/}36.35^{//}$
31	A-56	F-56	Sabitri Bharali High School	SW	26^{o}8/22.95//	91045/9.57//
32	A-57	F-57	Rukminigaon Valika Bidyapeeth	TW (70ft)	$26^{0}8^{/}50.06^{//}$	$91^{0}47^{/}18.33^{//}$
33	A-58	F-58	Dakhin Beltola High School	SW	$26^{0}6^{/}54.34^{//}$	$91^{0}47^{/}34.60^{//}$
34	A-59	F-59	Beltola High School	SW	$26^{0}7^{/}21.24^{//}$	$91^{0}48^{/}13.11^{//}$
35	A-62	F-62	Ulubari H.S. School	SW	$26^{0}10^{/}9.55^{//}$	$91^{0}45^{/}49.57^{//}$
36	A-63	F-63	Sri Arobinda Bidyamandir High School	TW (70ft)	$26^{0}9^{/}56.88^{//}$	$91^{0}44^{/}58.10^{//}$
37	A-65	F-65	Guwahati Madrassa High School	SW	$26^{0}10^{/}48.76^{//}$	$91^{0}44^{/}53.71^{//}$
38	A-66	F-66	Bengali Girls' High School	DTW (340ft)	$26^{0}10^{/}58.06^{//}$	$91^{0}44^{/}49.25^{//}$
39	A-67	F-67	Bengali H.S School	DTW (400ft)	$26^{0}11^{/}00.11^{//}$	$91^{0}44^{/}43.04^{//}$
40	A-68	F-68	Banikanta Memorial Girls H.S School	DTW (360ft)	$26^{0}10^{/}19.40^{//}$	$91^{0}45^{/}4.66^{//}$

TW: Tube Well; RW: Ring Well; SW: Supply Water; DTW: Deep Tube Well

Table 2. Schoolwise geographic coordinates of sampling location in the study area

Sl. No	Sample No.	Arsenic (ppb)	Sample No.	Fluoride (ppm)
1	A-1	BDL	F-1	0.46
2	A-2	BDL	F-2	0.12
3	A-3	BDL	F-3	0.13
4	A-4	BDL	F-4	0.12
5	A-5	BDL	F-5	0.12
6	A-6	BDL	F-6	0.21
7	A-7	BDL	F-7	0.19
8	A-8	BDL	F-8	0.14
9	A-9	BDL	F-9	0.14
10	A-10	BDL	F-10	0.21
11	A-11	BDL	F-11	0.81
12	A-12	BDL	F-12	0.14
13	A-13	BDL	F-13	0.63
14	A-14	BDL	F-14	0.23
15	A-16	BDL	F-16	0.24
16	A-17	BDL	F-17	0.59
17	A-19	BDL	F-19	0.86
18	A-20	BDL	F-20	2.60
19	A-21	BDL	F-21	0.53
20	A-23	BDL	F-23	3.10
21	A-18	BDL	F-18	0.37
22	A-24	BDL	F-24	0.72
23	A-25	33.00	F-25	0.54
24	A-45	BDL	F-45	0.12
25	A-46	BDL	F-46	1.50
26	A-49	BDL	F-49	0.74
27	A-50	BDL	F-50	0.12
28	A-51	BDL	F-51	4.50
29	A-52	BDL	F-52	0.40
30	A-53	BDL	F-53	0.30
31	A-56	2.00	F-56	0.78
32	A-57	BDL	F-57	0.63
33	A-58	BDL	F-58	0.63
34	A-59	BDL	F-59	1.20
35	A-62	BDL	F-62	0.12
36	A-63	9.00	F-63	0.38
37	A-65	BDL	F-65	0.11
38	A-66	BDL	F-66	0.20
39	A-67	BDL	F-67	0.29
40	A-68	BDL	F-68	0.38

BDL to 33.00 ppb. The highest arsenic concentration was recorded at sampling point, A-25 of Ganesh Mandir Higher secondary School. Long term exposure to As contaminated water may lead to various diseases such as conjunctivitis, hyperkeratosis, hyperpigmentation, cardiovascular diseases, disturbance in the peripheral vascular and nervous systems, cancer of the skin, lung, liver, urinary bladder and kidney skin, gangrene, leucomelonisis, nonpitting swelling, hepatomegaly

Table 3. Statistical analysis of water samples

Stastical analysis	Arsenic	Fluoride
Mean	1.100	0.640
Standard deviation	5.305	0.874
Median	0.000	0.375
Mode	0.000	0.120
Std Error of Mean	0.839	0.138
Variance	28.140	0.763
Skewness	5.728	3.065
Std Err of Skewness	0.387	0.387
Kurtosis	34.077	10.180
Std Error of the Kurtosis	0.775	0.775
Range	0.000 – 33.000	0.110 - 4.390
Maximum	33.000	4.500
Minimum	0.000	0.110
Sum	44.000	25.600
Percentile (25)	0.000	0.140
Percentile (50)	0.000	0.375
Percentile (75)	0.000	0.653

and splenomegaly (Jack *et al.*, 2003).

The fluoride content in the analyzed samples was found to vary from 0.11-4.39 ppm. The study area were also contaminated by fluoride as 12.5% of analyzed water samples exceed the WHO drinking water standard (1.5 ppm). The most badly affected school was the Hatigaon High School, at sampling point, F 51, where highest fluoride concentration was recorded 4.50 ppm. In most of the samples analysed, the fluoride concentration in water was

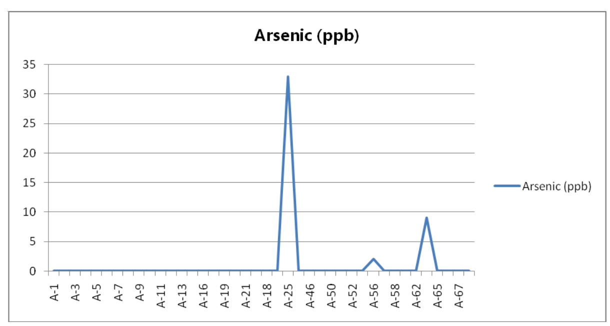

Fig. 1: Distribution of arsenic

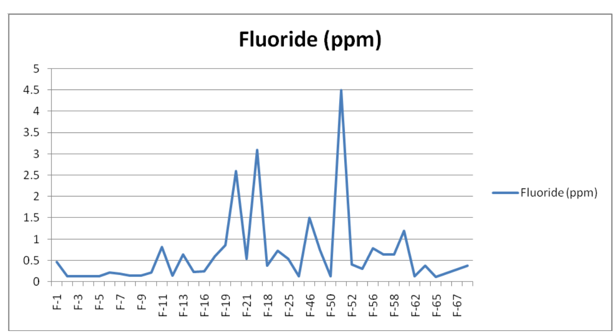

Fig. 2: Distribution of fluoride

less than 0.7 ppm may cause dental carries. Fluorides are released into the groundwater mostly through water–rock interaction by various fluoride-bearing minerals. Fluorite (CaF_2) is the sole principal mineral of fluorine occurring in nature, and is commonly found as an accessory in granitic gneiss. Fluorine is also abundant in other rock-forming minerals like apatite, micas, amphiboles, and clay minerals (Narsimha *et al.,* 2017). Fluoride contamination of groundwater is an alarming problem on a global scale. In several parts of the world, biogeochemical processes have resulted in dissolution of naturally occurring fluoride into groundwater. Dissolution of fluorite (CaF_2) and/or fluorapatite (FAP) [$Ca_5(PO_4)_3F$], pulled by calcite precipitation, is thought to be the dominant mechanism responsible for groundwater fluoride contamination. However, in the absence of any significant anthropogenic sources in the study area, the basic cause for the excess fluoride content seems to be geogenic in origin. Climate and tectonic factors may also play some part in affecting the fluoride concentration of the groundwater. The interaction of the fluoride-bearing minerals with water and aquifer is likely to be an important factor; since the decomposition, dissociation and dissolution are the main chemical processes for the occurrence of fluoride in groundwater (Dutta *et al.,* 2010).

CONCLUSION

The paper aimed to assess the drinking water quality used in different secondary schools of greater Guwahati, Assam with respect to arsenic and fluoride. The study revealed that 5% of the water samples in the study area had arsenic content higher than the recommended maximum permissible level of 10 ppb while 12.5% of of the water samples had fluoride content higher than the recommended maximum permissible level of 1.5 ppm as prescribed by WHO. The arsenic contamination in the water samples may be due to the use of various insecticides, herbicides, pesticides and fungicides which allow the source of water to be xenobiotic contamination. In addition to this the uses of arsenical compounds and additive in livestock feed, particularly for poultry may be a demerit. Moreover several agricultural practices, industrial debrises and households' sewages can be strong evidence of arsenic contamination in the water sources. Due to absence of any anthropogenic source of enrichment of fluoride, geogenic origin seems to be the only reason behind the present scenario. Therefore a thorough consideration of the geological setup of the study area and the analytical results of the present investigation indicates towards a strong geological origin of the fluoride in ground water sources of the study area. Presence of horneblende diorite and amphibolites along the lenticular bands of granitic gneiss can be attributed to the presence of higher fluoride concentration in the groundwater of the study area. The higher fluoride concentration implies that there is an urgent need to implement suitable measures for remediation possibly some local defluoridation techniques that could stop the immediate damage to human health.

ACKNOWLEDGEMENTS

Authors are thankful to Department of Chemistry, Tezpur University, Assam, India, for kind help in analysis of water samples. Authors are also thankful to Ms. Puja Sarmah, Project Assistant, Department of Chemistry, Lakhimpur Girls' College, for her kind help in statistical analysis.

REFERENCES

Baker, A. 2003. Land use and water quality. *Hydrol. Proc.* 17 (12) : 2499-2501.

BIS, 1991. Bureau of Indian Standards, 10500: Second Revision ICS No. 13.060.20; downloaded from: *http://www.bis.org.in/sf/fad /FAD25(2047)C.pdf*

Brunt, R., Vasak, L. and Griffioen, J. 2004. Fluoride in groundwater: Probability of occurrence of excessive concentration on global scale. *International Groundwater Resources Assessment Centre, Report nr. SP* 2004-2

Bunnell, J. E., Finkelman, R. B., Centeno, J. A. and Selinus, O. 2007. Medical geology: Aglobally emerging discipline. *Geologica Acta.* 5 (3) : 273-281

Chakraborti, D., Das, B., Rahman, M. M., Chowdhury, U. K., Biswas, B., Goswami, A. B., Nayak, B., Pal, A., Sengupta, M. K., Ahamed, S., Hossain, A., Basu, G., Roychowdhury T. and Das, D. 2009. Status of groundwater arsenic contamination in the state of West Bengal, India: A 20-year study report. *Mol. Food Res.* 53 : 542-551.

Chakraborti, D., Rahman, M. M., Das, B., Murrill, M., Dey, S., Mukherjee, S. C., Dhar, R. K., Biswas, B. K., Chowdhury, U. K., Roy, S., Sorif, S., Selim, M., Rahman, M. and Quamruzzaman, Q. 2010. Status of groundwater arsenic contamination in Bangladesh: A 14-year study report. *Water Research.* 44 : 5789-5802.

Chang, H. J. 2007. Comparative streamflow characteristics in urbanizing basins in the Portland

Metropolitan Area. *Hydrol. Process*. 21 : 211-222.

Chatterjee, S., Chattopadhyay, B. and Mukhopadhyay, S. K. 2008. Elemental profile of abiotic components of the East Calcutta Wetlands, a Ramsar site in India. *Land Contamination & Reclamation.* 16(4) : 365-379.

Claessens, L., Hopkinson, C., Rastetter, E. and Vallino, J. 2006. Effect of historical changes in land use and climate on the water budget of an urbanizing watershed. *Water Resour. Res*. 42.

Das, B., Talukdar, J., Sarma, S. Gohain, B., Dutta, R. K. Das, H. B. and Das, S. C. 2003. Fluoride and other inorganic constituents in groundwater of Guwahati, Assam, India. *Current Science.* 85 (5).

Das, S., Bora, S. S., Lahan, J. P., Barooah, M., Yadav R. N. S. and Chetia, M. 2015. Ground water arsenic contamination in North Eastern states of India, *Journal of Environmental Research and Development.* 9 (3) : 621-632.

Dutta, J. Nath, M., Chetia, M. and Misra, A. K. 2010. Monitoring of fluoride concentration in ground water of small tea Gardens in Sonitpur District, Assam, India: Correlation with physico-chemical Parameters. *International Journal of ChemTech Research CODEN (USA).* 2 (2) : 1199-1208.

Eatson, A. D., Clesceri, L.S. and Rice, E. W. 2005. Greenberg A.E., *Standard Methods for the Examination of Water and Wastewater* (21st ed.). 4-138, Centennial Edition, USA

Gaoa, X. B., Zhangb, F. C., Wangb, C. and Wanga, Y. X. 2013. Coexistence of high fluoride fresh and saline groundwaters in the Yuncheng Basin, Northern China. *Procedia Earth and Planetary Science*, *Elsevier.* 7 : 280 -283.

Jack, C. N. G., Wang, J. and Shraim, A. 2003. A global health problem caused by arsenic from natural sources. *Chemoshpere*. 52 : 1353-1359.

Jeong, C. H. 2001. Effect of land use and urbanization on hydrochemistry and contamination of groundwater from Taejon area, Korea. *Journal of Hydrology.* 253: 194-210.

Lahkar, M. and Bhattacharyya, K.G. 2015. Fluoride contamination threat in the groundwater of Assam, India: A case study in the high concentration zone of Nagaon. *Journal of Applied and Fundamental Sciences.* 1 (1) : 85-92.

Mohan, R., Gogoi, S., Bora, A. J., Baruah, G., Bordoloi, S., Ali, A. A., Sarma, H. R. and Dutta, R. K. 2020. Field experience of Fluoride Nilogon: a method of fluoride removal from groundwater. *Current Science*. 118 (2) : 255-263.

Narsimha, A. and Sudarshan, V. 2017. Contamination of fluoride in groundwater and its effect on human health: a case study in hard rock aquifers of Siddipet, Telangana State, India. *Appl Water Sci*. 7: 2501-2512, DOI 10.1007/s13201-016-0441-0

Narsimha, A. and Sudarshan, V. 2017. Contamination of fluoride in groundwater and its effect on human health: a case study in hard rock aquifers of Siddipet, Telangana State, India. *Appl Water Sci*. 7: 2501-2512, DOI 10.1007/s13201-016-0441-0.

Nelson, K. C. and Palmer, M. A. 2007. Stream temperature surges under urbanization and climate change: data, models, and responses. *J. Am. Water Resour. Assoc*. 43 : 440-452

Oke, T.R. *Boundary Layer Climates.* Methuen, New York, 1987.

Raj, D. and Shaji, E. 2017. Fluoride contamination in groundwater resources of Alleppey, southern India. *Geoscience Frontiers*. 8 : 117-124.

Rasool, A., Farooqi, A., Xiao, T., Ali, W., Noor, S., Abiola, O., Ali, S. and Nasim, W. 2017. A review of global outlook on fluoride contamination in groundwater with prominence on the Pakistan current situation. *Environ Geochem Health*. doi: 10.1007/s10653-017-0054-z

Saikia, M. M. and Sarma, H. P. 2011. Fluoride geochemistry of Kollong river basin, Assam, India. *Archives of Applied Science Research.* 3(3): 367-372.

Saikia, M.M. and Sarma, H. P. 2011. Hydro-geochemical characterization of groundwater of Nagaon district of Assam, India. *Journal of Environmental Research and Development*. 6(1).

Sharma, P. and Sarma, H. P. 2011. Groundwater quality assessment of Pachim Nalbari block of Nalbari district, Assam based on major ion chemistry. *International Journal of ChemTech Research CODEN (USA),* 3 (4) : 1914-1917

Statistical Hand Book, Assam"; Directorate of Economics and Statistics; Govt. of Assam, Guwahati-28; 2017

WHO, 2008. Guidelines for drinking water quality. *World Health Organization*, Geneva

Xia, Y., Wade, T. J., Wu, K., Li, Y., Ning, Z. and Le, X. C. 2009. Well water arsenic exposure, arsenic induced skin-lesions and self-reported morbidity in Inner Mongolia. *International Journal of Environment Resource Public Health.* 6 : 1010-1025.