J. Chemtracks 23 (1&2) 75-82, 2021

Abstracted / Indexed in
CAS
A division of the American Chemical Society
Chemical Abstract U.S.A.

ISSN 0973-239X
CODEN:JCOHF7
IMPACT FACTOR : 4.950

Studies on the estimation and mitigation of fluoride and arsenic content in the groundwater of some selected districts of West Bengal

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Manuscript received online 26 May 2021, accepted on 26 June 2021

Abstract: Water is the essence of life as 70% of the blood of a human body is water. 60% of the protoplasm of a cell in a human body is water. Hence, the drinking water must be safe, purified, and germless. Major sources of our drinking water are weir, bore holes, ponds, river, lakes, tube wells and hand pumps. Most of the surface water sources are either free from fluoride ion or Arsenic or contain traces or certain amount of fluoride ion and Arsenic. Arsenic is a toxic metalloid element present in contaminated water that can be fatal to human health. A new technical method for the mitigation of arsenic from groundwater/ surface water by the filtration process through the special laterite soil has been adopted in this study. After mitigation the amount of arsenic was found to be below detection level. WHO and EPA have recommended that the fluoride ion concentration in drinking water should not exceed 1.5 mg/lt. The concentration of fluoride ion in water has been determined accurately with the help of an electrochemical cell, known as the fluoride –ion-meter "ORION-4-STAR". Set of 3-5 standard solutions is arranged in a raw and the fluoride electrode is dipped in each of these solutions one by one. The electrode potential corresponding to each standard Solution is recorded in the voltmeter in milli volt which is increased linearly with the increase in the concentration of standard solutions.

(Keywords : TISAB (Total Ionic strength adjustment buffer), Calibration, Recalibration. Mitigation)

Introduction

WHO has described Arsenic as one of the lethal chemicals associated with major public health issues which causes chronic arsenic poisoning, called as arsenicosis which results due to drinking water contaminated with naturally occurring soluble inorganic arsenic is consumed by human being for a longer period.

18 districts of west Bengal have been reported to have groundwater contaminated with arsenic having concentration greater than WHO's maximum permissible limit (10 mcg/L) (Mukherjee et.al 2003). The most widespread arsenic-affected areas in the world are found in the Ganga-Brahmaputra plains in India and the Padma-Meghna plains in Bangladesh (Ghosh et.al.2015). In rural areas of West Bengal ground water is the most important source of drinking water. The rice is the main grain used in the diet in the state which, in the raw state, has been reported to contain 93.8% inorganic arsenic and 88.1% in cooked state (Halder et.al. 2015). As per the estimation of State Government, at least 79 blocks across the state were found severely affected, involving 26 million individuals across 2600 villages (Paul.et.al.2013). Treatment of chronic arsenic toxicity in west Bengal have completely failed in getting any clinical and biochemical benefits and this makes it more important to search for an easy and long term mitigation process which can be easily adopted and be utilized everywhere (Basu. et. al. 2005).

The Inorganic arsenic has been classified as a "human carcinogen" having maximum contaminant level 0.01 ppm (EPA 2014) by environmental protection agency of United states. Arsenic enters into ground water via natural and multiple anthropogenic pathways including smelting, combustion of fossil fuels and various agricultural practices. However, the predominant sources of Arsenic contamination are through the weathering of geologic materials. The toxic character of As (III) depends on its chemicals form present in our environment.

Arsenic can exist in five forms, namely As (III), As (v), Mono methyl Arsenic Acid, Di methyl Arsenic Acid and Arsenobetaine arranged in the order of decreasing toxicity in the environment.

The effect of inorganic arsenic contamination on the human health depends on the level of arsenic contamination in the drinking water and can take years to manifest (Basu.et.al.2005). In north 24 Paragana district, there are 12 blocks (160 villages), south paragana district 9 blocks (283 villages), Nadia district 11 blocks (122 villages), Murshidabad district 14 blocks (168 villages), Malda district 4 blocks (163 villages), Bardhman district 2 blocks (21 villages), Hooghly 1block (13 villages), Howrah 3 blocks (3 villages) and Kolkata there are 5 blocks which have been identified as arsenic affected district. According to publication of the Anand bazar Patrika, 2017, some researcher of Jadavpur University have examined experimentally taking 1080 samples of drinking water of 1080 different tube wells of 1080 different schools of the block 'Deganga' of North 24 Paragana district and they have found that 25% of the total 1080 samples i.e. 270 samples are affected with extremely high levels of Arsenic contamination. Hence one of the great problems in drinking water that raises concern over the world is that million of the people still have to use Arsenic contaminated water for their drinking purpose.

According to the census 2011, the total rural population of West Bengal is 91,300,000 (Nine crore thirteen lakh), with highest population density of 1029 people per sq. Km, in 3,354 village panchayats in 23 districts. Groundwater-fluoride problems have been recorded in over 200 districts in 19 Indian States (FR&RDF). In Andhra Pradesh, Gujarat, Rajasthan, and Telangana, 50–100% of districts are affected by high-fluoride drinking water. In Bihar, Haryana, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Orissa (Odisha), Punjab, Tamil Nadu, and Uttar Pradesh, 30–50% of districts are affected; and in Chhattisgarh, Delhi, Kerala, and West Bengal, the figure is less than 30% (RGNDWM, 1993). According to project report of West Bengal Government for drinking water, fluoride-contaminated groundwater was first detected in West Bengal in 1997. Excessive concentrations were noted in the Nasipur area of Nalhati I block in the district of Birbhum, after which the government took rapid action to provide an alternative water supply based on river-bed tube wells from River Tripita.

In order to achieve its Vision 2020 to provide safe, reliable and sustainable drinking water to about 1.65 million of fluoride and salinity affected people in the areas of Bankura, North 24 paraganas and Medinipur districts in the state, the government of West Bengal has launched a project supported by Asian Development Bank (Government of Bengal,2011). According to a report prepared during the preparatory stage of the said project, Bankura district of west Bengal is the worst fluoride affected area and Murshidabad district stands second. The fluoride concentrations in the contaminated groundwater of those areas are as high as 1.06-1.75 mg/l (WBPCB report 2016). According to the PHED, government of West Bengal, 11.9 % of the rural population of West Bengal is at risk from fluoride contamination of drinking water.

The presence of fluoride in the ground water or fresh water sources causes greatest inorganic threat to health. Though the permitted limit of fluoride concentration in drinking water as set by WHO is 1.5 mg/L, the allowed concentration of fluoride in India has been set as

1.0 mg/L. Approximately200 million people or more have been reported at risk worldwide from fluoride concentrations value above the desirable limit set by WHO in ground water and natural fresh water (Edmunds and Smedley, 2013). Saxena and Sewak in 2015 have reported approximately 67 million populations in India at risk due to consumption of fluoride concentration above the desirable limit in drinking water and 8 million people suffering from skeletal fluorosis. The skeletal or dental fluorosis is the most prevalent health problem which is related to the long term exposure to fluoride from drinking water. The developed stages of symptoms of fluorosis are irreversible. In dental fluorosis, the interaction of fluoride with enamel of tooth results in the decolouration and consequent loss of tooth. Children are very much prone to the fluoride exposure due to which their growth of teeth and bones are severely affected. The severity of the disease depends largely on and the dose and extreme of exposure. The total number of fluorosis cases nationwide was 1.2 million people as of 1 April 2014as per the report given by ministry of Health and Family welfare, Government of India.

In the present paper, attempts have been made to estimate fluoride concentration in ground water of various regions in West Bengal along with its pH measurements for the mitigation of fluoride.

Methodology adopted for the present study:

The only aim and objective of this study is to provide a cheap and easy method to estimate and mitigate the arsenic content in ground water/ surface water of the district of Hooghly and Paschim Midnapur of west Bengal in order to eradicate the dreadful diseases caused by arsenic contaminated drinking water. A new technical method for the mitigation of arsenic from groundwater/ surface water of the district Hooghly and Paschim Medinipur by the filtration process through the special laterite soil by using atomic absorption spectrometer has been adopted in this study. Before filtration, the estimation of arsenic present in the samples (SBT) was performed followed by the filtration of samples of water through a special laterite soil for mitigation of arsenic and by using AAS.

For the study of fluoride concentration, Fluoride-ion-meter- ‘ ORION-4-STAR was used. For preparation of stock solution and other experimental needs, a magnetic stirrer with a Teflon coated small negative needle, volumetric flasks(made up of polypropylene as as glass containers may react with the fluoride) of 50ml and 100ml capacity, 25ml capacity beakers and 10 ml capacity pipettes (all made up of polypropylene) were used. The standard fluoride solution was prepared by dissolving 221 mg of pure NaF in distilled water taken in a 1000 ml volumetric flask and finally the solution was made up to mark by adding distilled water. The total ionic strength adjustment buffer (TISAB) was used. The electrode connected with the ORION-ion- meter 4-star were frequently recalibrated by checking the potential reading of 1 mg/lt standard fluoride solution and adjusting the calibration control, if necessary until the meter reading as before. The intermediate standard fluoride solution concentration 10 mg/lt and working standard fluoride solutions were prepared.

The electrode was connected with the Fluoride ion meter (ORION-4-STAR). In a polypropylene beaker of 25 ml capacity accurately measured 10 ml of the standard solution of lower concentration was taken by the help of a clean pipette and was placed over a magnetic stirrer followed by addition of 1 ml total ionic adjustment buffer (TISAB). Before taking a final multivolt reading, the electrode is allowed to remain in the solution for 3 minutes. If the reading is not as per reading of the standard solution, the display value is carefully adjusted as per the standard. The electrode is allowed to remain in the sample until a steady reading is displayed. The fluoride concentration of other samples was determined in the similar way.

Contribution to the existing knowledge:

Many technological methods have already been discovered for the mitigation of arsenic in drinking water which is not accepted perfectly in large scale uses. These are:

(i) Coagulation and filtration method: This treatment can effectively remove many suspended and dissolved constituent from water besides arsenic, notable turbidity, iron (Fe), Manganese (Mn), Phosphate (PO_4^{3-}), and fluoride (F^-). Thus coagulation and filtration to remove arsenic will improve other quality parameter resulting in ancillary health and esthetic benefits. However, the optional conditions vary for removal of different constituents and coagulation to remove arsenic may not be optional for removal of other compounds, notably phosphate and fluoride (F). During coagulation and filtration, Arsenic is removed through three mechanisms (Edwards, 1994). (a) Precipitation, (b) Co-Precipitation, and (c) Adsorption

All three of these mechanisms can independently contribute towards contaminant removal.

(ii) Ion Exchange Resin method: Different resins have differing selectively sequences and resins have been developed specifically to optimize removal of sulphate, nitrate and organic matter. Various strong base anion exchange resins are commercially available which can effectively remove arsenate from solution, producing effluent with less than 1 mg / l arsenic. Arsenite, being unchanged, is not removed

(iii) Adsorption method: Arsenite is removed either through co precipitation or adsorption on to pyrite. The drawback of zerovalent iron is that the treated water contains very high ferrous iron. Therefore, another removal treatment process is needed to remove the ferrous iron.

(iv) Membrane method: Synthetic membranes are available, which are selectively permeable. The structure of the membrane is such that some molecules can pass through, while others excluded or rejected. Membrane filtration has the advantages of removing many contaminants from water, including bacteria, salts and various heavy metals.

(v) A rapid field detection method: Arsenic detection by Auricchloride ($Aucl_3$) on whatman filter paper No-3. The Arsine gas subsequently came in contact with $Aucl_3$ soaked filter paper and reducted the $Aucl_3$ metallic gold.

(vi) Nano filtration method: The NF membrane ESIO used in this experiment is made of Aromatic Polyamide, and it's the nominal salt rejection of ESIO is 99.6% the groundwater, to which 200 mg As/L of arsenite. [As(III)] and arsenate [As(v)] is added, was used for feed water. The NF membranes coupled with the bicycle pumping system are ESIO (Nitro Denko co Ltd.) and HS5110 (Toyobo co Ltd.) of which nominal salt rejection is 99.6 % and 94% respectively, and are made of Aromatic polyamide.

(vii) Bicycle pump reverse osmosis process: It was possible to operate the NF process coupled with a bicycle pump system. It the ratio of arsenite to arsenic (As(III)/As) were low, rejection of arsenic by NF would be enough. On the other hand, if arsenide is a major component (As(III)/As), NF could not satisfy drinking water standards because arsenite rejection was relatively low.

(viii) Novel Method- Engineering application: Experimental results prove that this noble method is very effective in removing arsenic in its pentavalent form, Arsenate [As(v)]. Hence the arsenic in the form of As(iii) in ground water should be oxidised to As(v). The groundwater from Wells could be pumped over a series of cascades to aerate the water (Johnson et.al 2001).

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Results and Discussion:

A number of absorbing materials have been developed based on their availability and cost of preparation. Jing et.al. 2005 and Westerhoff et. Al.2006, have reported some of those absorbents as granular ferric oxide and hydroxide, activated alumina granular titanium dioxide etc. Laterite soil has also been reported to be very effective in arsenic absorption (Maji et. Al. 2007). However, the literature and studies on such work are very limited. In the present study attempts have been made for the removal of arsenic from ground water/ surface water by the filtration through a special laterite soil.

Before the experiment, the amount of arsenic in the untreated water sample water was measured first by using AAS (Atomic Absorption Spectrometer). Then the filtration method by using is special laterite soil was performed. Contaminated drinking water was first passed through the inlet pipe into a 75 cm long and 9 CM diameter PVC tube containing special laterite soil and after filtration through special laterite soil the filtrated and treated water was finally collected from the outlet pipe. Now the amount of arsenic contamination was measured from the filtrated and treated water by Atomic Absorption Spectrometer.

Now it is seen that the MCL of arsenic in the filtered and treated water is 10 µg/L or less.

Table 1

Name of municipality	Total Population	Population density/Km^2	Gender ratio	As in sample before treatment	As in sample after treatment
Komra Sansad	1826	1534	1.04	BDL	BDL
Srimantpur	>2173	>592	1.02	0.01	BDL
Kharar municipality	12118	1181	1.02	BDL	BDL
Ghatal municipality	219555	1000	1.06	BDL	BDL
Arambagh Municipality	285207	1100	1.04	0.02	BDL
Tarakeshwar municipality	30947	2348	1.08	0.15	BDL
Balagar (2) Hooghly	----	-----	-----	0.014	BDL
Balagar (1) Hooghly	-----	-----	-----	0.010	BDL
Srimantpur primary school, Paschim Midnapur	-----	-----	-----	0.010	BDL
Arambag municipal, Hooghly	-----	-----	-----	0.020	BDL

On the basis of the above cited results, the following conclusions can be drawn:

Before Mitigation amount of Iron of the five different places according to the increasing order are: 0.74 = 0.74 < 0.78 = 0.78 = 0.78.→Barasat = Balagar (I) < Balagar (II) = Srimantapur Jr. High School = Srimantapur Pry. School.

After mitigation: Amount of Arsenic of the five different places are equal. BDL = BDL = BDL= BDL= BDL→ Srimantapur Pry. School = Srimantapur Jr. High School = Balagar (I) = Balagar (II) = Barasat Horitala.

After Mitigation amount of iron of the five different places according to the increasing order are 0.02 < 0.17 = 0.17 < 0.25 < 0.30. →Barasat Horitala < Srimantapur Jr. High School = Srimantapur Pry. School < Balagar (I) < Balagar (II).

Table -2

Details of Fluoride Content in Various food items is shown in the following Table (Source: M.Phil thesis, by Kajal Kumar Chakraborty)

Sl.No.	Source of food item	Fluoride (PPM)	S.L. No	Source of food item	Fluoride (PPM)
1	Dried Seaweed	326.0	10	Shrimp	4.5
2	Sardines	11.0	11	Crab	2.2
3	Wheat Germ	2.4	12	Chicken	1.5
4	Cheese	1.7	13	Soyabeans	1.4
5	Butter	1.5	14	Beef	1.2
6	Eggs	1.3	15	Spinach	1.0
7	Lamb	1.2	16	Whole Wheat	0.8
8	Parsley	0.9	17	Tea	32
9	Pork	0.7			

Table -2

Estimation of Fluoride Content and PH in different Rivers of the districts of Hooghly and Paschim Medinipur of the State West Bengal.

Sl.No.	Source of Fluoride Content	Estimated Fluoride Content	PH
1	Ganga River	0.482	8.01
2	Damadar River	0.322	7.80
3	Darakeswar River	0.312	7.89
4	Silabati River	0.244	7.46
5	Rupnarayan River	0.268	7.85
6	Thumi/Sankari River	0.310	7.82

Table-3

Estimation of Fluoride Content and PH in different Municipalities and Grampanchayets in the district of Hooghly and Paschim Medinipur of the State West Bengal :

Sl. no	Location	Estimated Fluoride Content	PH	Sl. no	Location	Estimated Fluoride content	pH
1.	Kharar Municipality	0.327	7.99	10	Birsing G.P.	0.320	7.40
2.	Ghatal Municipality	0.308	8.15	11	Kishorepur G.P.	0.280	7.30
3.	Khirpai Municipality	0.309	8.00	12	Salepur I G.P.	0.285	7.40
4.	Ramjibanpur Municipality	0.250	8.02	13	Salepur II G.P.	0.282	7.45
5.	Chandrakona Municipality	0.312	8.11	14	Mansuka I G.P.	0.305	8.05
6.	Midnapur Municipal	0.335	8.34	15	Mansuka II G.P.	0.308	8.10
7.	Arambagh Municipal	0.305	8.01	16	Ajabnagar G.P.	0.320	7.92
8.	Tarakeswar Municipal	0.302	8.02	17	Bali G.P.	0.260	7.30
9.	Sultanpur G.P.	0.291	7.25				

It can be seen from the tables that the fluoride content of rivers vary significantly with pH. The water of the river having near neutral pH has less fluoride concentration. This same can also be seen from table 3, where the estimated fluoride content of Sultanpur G.P., Kishorepur G.P, Bali G.P. are less at near neutral pH. The variation of fluoride concentration in ground water may be seen as a result of varying dilution and also due to variation of dissolved cacium concentration in it.

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An International Peer Reviewed Research Journal of Chemistry
Abstracted / Indexed in : Chemical Abstract U.S.A.
JC- 1441/2K21 (ISSN:0973-239X), INDIA
Journal Chemtracks Vol. 23 (1&2), 75-82, January to December 2021