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Geogenic Contaminants in Groundwater of North East India - Status and Treatment Options

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Abstract : Ground water forms the major source of water supply for drinking purposes in most part of India. For proper utilization of water for various purposes, understanding of geo chemical controls and study of the extent of ground water contamination are of prime importance. There has been heavy dependence on ground water in recent decades due to growth in agriculture, population and industries in many parts of our country. The situation is not so alarming at present in the North-Eastern Region of the country. However, the occurrence of ground water of poor quality having high concentration of natural contaminants like iron, fluoride and arsenic has come to focus but comprehensive water quality monitoring has not been attempted for quality assessment. In this paper an attempt has been made to highlight some of these issues for scientific and sustainable approach in managing ground water resources and its quality. Major programmes are required to be launched for comprehensive assessment of ground water quality mapping, its relative vulnerability for pollution and identification of degraded water quality zones for quality improvement. Resource utilization should be done in a systematic and scientific manner with due consideration of the prevailing hydrogeological conditions and mass awareness should to be created at all levels for judicious and effective management of ground water resources and its quality with sustainability.

INTRODUCTION

Ground water forms the major source of water supply for drinking purposes in most part of the country. For proper utilization of water for various purposes, understanding of geo chemical controls and study of the extent of ground water contamination are of prime importance. The quality of ground water is particularly important to humans when the water is used for drinking water supply. The quality of ground water varies from place to place along with the depth of water table. It also varies with seasonal changes and is primarily governed by the extent and composition of dissolved solids present in it.

There has been heavy dependence on ground water in recent decades due to growth in agriculture, population and industries in many parts of our country. The situation is not so alarming at present in the North-Eastern Region of the country. However, scientific and sustainable approach is important in managing ground water resources and its quality.

The Central Ground Water Board (CGWB) is conducting systematic hydrogeological surveys, district ground water management studies, geophysical investigations and exploratory drilling and regular monitoring of ground water levels and quality. The change in water level is monitored periodically four times a year, i.e. during 1st to 10th January, 20th to 30th April (pre-monsoon), 20th to 30th August (peak monsoon) and 1st to 10th November (post monsoon), as part of ground water regime monitoring to know the behavior of the water table temporally and spatially. Water samples are being collected once a year in the month of April for physico-chemical analysis.

Apart from collection and analysis of ground water samples as a part of various scientific studies and exploration of fresh water aquifers, ground water samples are also being collected by CGWB once a year from the observation wells and analysed to create a background database and assess regional ground water quality changes. In addition, special studies have also been undertaken in the areas affected by natural contaminants such as fluoride and arsenic. Ground water in most part of the region is fresh. However, in some areas, ground water quality has been found to be contaminated due to hydrogeological reasons. There are pockets laced with natural contaminants like fluoride and arsenic. Ground water of all districts of Assam contains excess iron. Preliminary findings indicate that ground water of 5 districts of Assam contains excess fluoride and 21 districts contain excess arsenic. In this paper an attempt has been made to highlight some of these issues for scientific and sustainable approach in managing ground water resources and its quality.

IRON CONTAMINATION IN GROUND WATER

Iron in an essential element in both plant and animal metabolism. The concentration of iron in natural water is controlled by both physico chemical and microbiological factors. An additional factor involved in the mobility of iron in ground water is the presence of bacteria. High concentration of Iron in ground water has been observed in more than 1.1 lakh habitations in the country. The highly contaminated ground water by iron is in Assam, West Bengal, Orissa, Chhattisgarh and Karnataka. Localized pockets are observed in States of North East, Bihar, Uttar Pradesh, Punjab, Rajasthan, Maharashtra, Madhya Pradesh, Jharkhand, Tamil Nadu and Kerala.

In North Eastern Region, the amount of iron is relatively high and almost all States contain iron above the permissible level in drinking water. Maximum amount of iron is found in Assam, Meghalaya, Mizoram, Nagaland and Tripura (Singh, 2004). Distribution of iron in ground water of the shallow aquifers in the North East Region depict a picture that sporadic occurrence of iron in higher concentration (to the tune of more than 3 mg/L) are found in parts of Tinsukia, Dibrugarh, Dhemaji, Sonitpur, Golaghat, Nagaon, Karbi Anglong, Kamrup, Darrang, Nalbari, Barpeta and Goalpara districts of Assam; Tirap district of Arunachal Pradesh; East Khasi and Jaintia Hills districts of Meghalaya and South Tripura district of Tripura. The cause of high concentration of iron in ground water in the North East Region may be attributed to the occurrence of high iron bearing minerals in the Pre-cambrian and Tertiary geological formations.

In the eastern parts of Brahmaputra Basin, the iron content is in the range of 0.4 to 4.0 mg/L while in the north-western parts of the basin, iron is in the range of 0.3 to 3.0 mg/L in ground water. In Tripura, there is widespread occurrence of ground water with iron in the range of 0.3 to 1.2 mg/L.

In recent years, study of ground water conditions in Dhemaji district indicated that, concentration of iron ranges from below detection limit to 69 mg/L for samples collected from hand pumps and tube wells taping depth range of 6 to 30m.

FLUORIDE CONTAMINATION IN GROUND WATER

Fluoride is an essential element for human beings as it helps in normal mineralization of bones and formation of dental enamel. It adversely affects the health of human beings when their concentration exceeds the limit of 1.5 mg/L. About 96% of the fluoride in the body is found in bone and teeth. Fluoride is a double-edged sword. Ingestion of large amount of fluoride is as harmful as ingestion of its inadequate amount.

Inadequate quantities of fluoride cause health problems especially in children. In cold countries like USA, UK etc. problems are related to inadequate consumption of fluoride. In these countries, fluoride is added to water to prevent health hazards. There are areas where dental problems have reduced progressively by adding fluoride in water. Due to inadequacy of fluoride, children suffer from:

- Dental caries
- Lack of formation of dental enamel
- Lack of normal mineralization of bones
- All or a combination of the above

Fluoride poisoning and the biological response leading to ill effects depend on the following factors:

- Excess concentration of fluoride in drinking water
- Low calcium and high alkalinity in drinking water
- Total daily intake of fluoride
- Duration of exposure to fluoride
- Age of the individual
- Expectant mothers and lactating mothers are the most vulnerable groups as, fluoride crosses the placenta because there is no barrier and it also enters maternal milk.

Derangement in hormonal profile either as a result of fluoride poisoning or as a cause, aggravate the disease. Important hormones for healthy bone formation and bone function are clacitonin, parathormone, vitamin - D and cortisone.

Fluorosis, a disease caused by excess intake of fluoride, is a slow progressive, crippling malady. The tissues affected by fluoride are;

- Dental
- Skeletal
- Non Skeletal

Different fluoride doses (long term ingestion through water) and their effects on human body are given below:

Regional Scenario

High fluoride content beyond 1.0 mg/L in ground water has been reported from isolated pockets in Assam. Severe contamination of fluoride in ground water of Karbi Anglong and Nagaon districts of Assam and its manifestation in the form of fluorosis have also been reported (Susheela, 2001; Chakraborti et al., 2000). Subsequently, some reports in the newspapers about fluoride in ground water in certain parts of Guwahati, the capital city of Assam and the gateway to north-eastern India, has created confusion among the residents of the concerned areas in the city (Asomiya Pratodin, 2002).

CGWB recently compiled the information on the incidence of high fluoride concentration in ground water and it was observed that 14 blocks falling in 5 districts of Assam, viz., Karbi Anglong, Nagaon, Kamrup, Golaghat and Karimganj were found to have high fluoride concentration (>1.5 mg/L). A special study undertaken in parts of Karbi Anglong district reveals that a valley covering an area of about 200 km^2 comprising valley fill sediments/ sedimentaries surrounded by granitic rocks was highly affected with the fluoride concentration up to 20.6 mg/L. The affected areas include Parakhowa-Dengaaon, Baghapani-Dentaghat and Ramsapthar-Longnit sections of Karbi Anglong district (CGWB, 1999, 2002).

Fluoride (mg/l)	Effects on human body
Below 0.5	Dental caries
0.5 to 1.0	Protection against dental caries. Takes care of bone and teeth
1.5 to 3.0	Dental fluorosis
3 to 10	Skeletal fluorosis (adverse changes in bone structure)
10 or more	Crippling skeletal fluorosis and severe osteoclerosis

The striking feature is that all these contaminated areas lie on or close to faults/lineaments suggesting that the high fluoride could be related to the geological structure and tectonic features of the area. The fluoride contamination in valley fills is not in-situ and is possibly derived from adjoining high fluoride rocks, connected through deep fractures. The fluoride concentration varies widely with space. It is normally seen that the shallow zone (<15 m) is free from fluoride contamination.

The uneven spatial distribution of fluoride concentration can be attributed to variation in fluoride bearing minerals in the host rocks, geological structure, ground water movement, hydro chemical environment and possible influence of high temperatures and pressures.

It is observed that the reporting of occurrence of high concentration of fluoride in ground water in Assam is sporadic and inconclusive. It is therefore necessary that the further R&D work is focused on defining this problem in terms of the area affected, aquifers/horizons affected, people affected and range of concentrations in ground waters. The alternate sources available, water treatment technology and economics of the same are studied in detail and the people are provided with safe and sufficient water by Municipal and Local authorities. Proper monitoring of water quality and health of the affected people is coordinated by Primary Health Centers.

Fluoride Removal Technologies

Several methods are available for removing excessive fluorides in drinking water and may be broadly divided into two groups.

i) Those based upon exchange process or adsorption
ii) Those based upon addition of chemicals during treatment.

The material used in contact beds includes processed bone, natural or synthetic tri-calcium phosphate, hydroxy apatite magnesia, activated alumina, activated carbon and ion-exchangers.

Chemical treatment methods include the use of lime either alone or with magnesium and aluminium salts again either alone or in combination with coagulant aid. Other methods include addition to fluoride water of material like magnesia, calcium phospate, bentonite and fuller's earth, mixing and their separation from water by settling and filtration.

Table 1. District Wise Fluoride Affected Blocks in Assam

S.No.	District	No. of Blocks	No. of Affected Blocks	Name of Affected Blocks (more than 1.5 mg/L)
1.	Karimganj	7	1	Loairpowa
2.	Golaghat	8	1	Golaghat East
3.	Nagaon	19	5	Jogijan, Binnakandi, Pachim, Kaliabor, Kaliabor, Kathiatoli
4.	Karbi Anglong	11	5	Howraghat, Samelangso, Longsomepi, Lumbazong, Rongkhong
5.	Kamrup	18	2	Bejera, Chandrapur (GMCArea)
Total		63	14	

ARSENIC CONTAMINATION IN GROUND WATER

Arsenic is a natural element of the earth's crust. It is used in industry and agriculture. It is also a by-product of copper smelting, mining and coal burning. Arsenic adversely affects the health of human being when their concentration exceeds the limit of 0.01 mg/L. High concentrations of arsenic are found mostly in ground water from natural deposit in the earth or from some industrial and agricultural activities.

The table below shows the lifetime risks of dying of cancer from arsenic in tap water (for different concentration and assuming 2 liters consumed per day) based on the National Academy of Sciences' 1999 risk estimates:

Regional Scenario

In recent years, arsenic in ground water has been reported from north eastern states like Assam, Tripura, Manipur, Arunachal Pradesh and Nagaland (Singh, 2004). More than 300mg/L of arsenic was found in many places. Maximum arsenic concentration was observed in Jorhat, Dhemaji, Golaghat and Lakhimpur in the State of Assam; West Tripura, Dhalai and North Tripura Districts in the State of Tripura; Thuobal in Manipur; Dibang Valley in Arunachal Pradesh and Mokokchung and Mon Districts in the State of Nagaland (Singh, 2004). This alarming picture of the arsenic contamination in ground water in the region and continuous consumption of this water has the potential of posing serious health hazard to the local population. Recently, Singh (2006) has described a conceptualization of the mechanisms of arsenic mobilization and process of contamination in ground water of Ganges–Brahmaputra river basin and stressed the need for a more detailed integrated study to understand the sources, release mechanisms and mobilization of arsenic in the multi-layered aquifer system in the Ganges and Brahmaputra river basins. Except for the state of West Bengal, the extent of the problem is not fully known and the number of people at risk is impossible to estimate with any degree of confidence. A thorough survey is therefore needed to assess the magnitude of the problem in these states and to take appropriate measures like generating awareness about health problems associated with arsenic and providing safe drinking water to the affected population.

Table 2. Arsenic Concentration in Tap Water Vs Cancer Risk

Arsenic Level	Approximate Total Cancer Risk
0.5 ppb	1 in 10,000
1 ppb	1 in 5,000
3 ppb	1 in 1,667
4 ppb	1 in 1,250
5 ppb	1 in 1,000
10 ppb	1 in 500
20 ppb	1 in 250
25 ppb	1 in 200
50 ppb	1 in 100

In recent years, arsenic in ground water has been reported from various parts of Assam and adjoining areas, which mostly fall in the vast riverine tracts of Brahmaputra River. However, reports have also come from Barak River valley areas. Chakraborty et al. (2004) reported that Dhemaji district is worst affected. Public Health Engineering Department has conducted its own study partly in collaboration with UNICEF, however, detailed findings are yet to be published.

Occurrence of high concentration of arsenic in ground water has been reported from 3 blocks of Dhemaji District in Assam. Preliminary study in Dhemaji district by CGWB during 2005-06 indicated that concentration of arsenic ranges from 0.025 to 0.55 mg/L for samples collected from hand pumps taping depth range of 6 to 30 m. However, their analytical results showed wide variations for samples from same wells collected at different times. Hence, during 2006-07, the area had been resampled and analysed at referral laboratory of CGWB (Southern Region) as well as at NERIWALM. Analysis results from CGWB (Southern Region, Hyderabad) show that concentration of arsenic during pre-monsoon ranges from Below Detection Limit to 0.249 mg/L. Arsenic concentration is higher in Dhemaji, Bordoloni and Sisiborgaon blocks and less in Murkong Selek block. The highest concentration of arsenic was recorded from the shallow aquifer zone with a depth of 5.5m at Bheketi.

The concentration levels of post-monsoon analytical data of arsenic in Dhemaji district followed the same trend of higher concentration in the shallow aquifers. The concentration of arsenic ranges from < 0.001 to 0.109 mg/L during post-monsoon period. High concentration of arsenic content was also detected from a shallow hand pump of 13.5 m depth at Moridhol.

Keeping in view the updated scenario of ground water in the district, it is advisable to test the potability of ground water before using it for drinking and cooking purposes. A long term environmental planning is also essential to blunt the danger from such pollution problems. The status of chemical quality of ground water regime and its utilized formulation for future ground water development programme and drinking water management strategy must assume a greater significance.

Arsenic Removal Technologies

Arsenic Removal Plants (ARP) have been designed by various organizations using different technologies and some of these have been installed in the arsenic affected areas in the State of West Bengal. The salient features of some of these plants are discussed below.

i) Plants developed by Department of Public Health Engineering, Bangladesh: Two bucket arsenic mitigation method developed by the Department of Public Health Engineering (DPHE), Bangladesh and Danida is based on the oxidation of all aqueous arsenic to As(V) and subsequent co-precipitation with aluminum sulfate (alum).

ii) Plants developed by B.E. College, Howrah: This system was developed using activated alumina which can adsorb As(+5) significantly and also As (+3) to some extent. Use of activated alumina brought down iron content along with arsenic. Once its capacity is exhausted, activated alumina can be regenerated.

iii) Plants developed by All India Institute of Hygiene and Public Health, Kolkata: This system is based on coagulation-flocculation-sedimentation-filtration method. Water is treated using bleaching powder at the rate 2 mg/L and alum at the rate of 40 mg/L. Bleaching powder is added for oxidation of As (+3) to As(+5). The system comprises circular tanks with a capacity of 1000 litre. Finally, the water passes through a tank (sand media) containing gravels of 5 mm thick to remove suspended particles.

iv) Plants developed by M/s. Pal Trockner Pvt. Ltd.: M/s. Pal Trockner Pvt. Ltd. has installed unit at Barasat, 24 Parganas. The system is developed by M/s. Harbauer, GmbH, Germany and is called Absorp AS. It is a granular activated ferric hydroxide with a specific surface of 250-300 m^2/g and a porosity of 75-80%. Drinking water containing Arsenite and Arsenate while passes through adsorbent (Adsorp As) bind on the surface of ferric hydroxide, building inner spherical complexes. This bonding is irreversible under normal environmental condition. This granular activated ferric hydroxide reactor is fixed bed absorbers operating like conventional filtration process with a down water flow. This unit consists of a gravel filter followed by an adsorption tower filled with adsorber. This granulated ferrous hydroxide is produced by the reaction of iron tri chloride with caustic soda and subsequently submitted to a comprehensive refining process.

v) Plants developed by the PHED, Govt. of West Bengal: The Arsenic removal plant designed by PHED involves chemical oxidation using chlorine, coagulation by rapid mixing using ferric chloride, sedimentation and filtration. In this process, As(+3) present in water is oxidized to As(+5) and then Arsenic in both forms are removed from aqueous solution by coagulation, sedimentation and filtration process.

vi) Plants developed by M/s. Adhiacon Pvt. Ltd., Kolkata: The plant developed by M/s. Adhiacon Pvt. Ltd. is based on catalytic precipitation method. The principle of this system is to commence filtration with oxidation of arsenite to arsenate by the energy generated from the water with the help of media (potential difference). The system triggers off a series of catalytic reactions by which many soluble metal ions i.e. chromium, lead, copper, iron etc. are precipitated as their insoluble hydroxide. This reaction is having a cascading effect in which arsenate ions reaction with ferric hydroxide form insoluble form of arsenate. The system comprises three cylinders. The first cylinder is packed with media (the composition of media is not disclosed) and second cylinder with media and granulated activated carbon separately. The hydroxides coated over granules through reaction are removed through back flushing to third cylinder for storing. Requirement of flushing depends on the concentration of metals in raw water. The flow rate is 1000 litre /hour.

vii) Plants developed by School of Environmental Studies (SOES), Jadavpur University, Kolkata and CSIR, New Delhi: School of Environmental Studies (SOES), Jadavpur University, Kolkata in collaboration with CSIR has developed table and filter candle. The main ingredient of the candle is fly ash. Use of fly ash makes the filter candle hard. Investigations were carried to study the impact of the candle on water. The filter in combination with a chemical tablet can remove almost 100 percent both AS(+3) and As(+5) from ground water. The system is cost effective, durable and meant for daily use.

viii) Plant Developed by M/s RPM Marketing Pvt. Limited: The system is based on adsorption method using Activated Enhanced Hybrid Alumina (AEHA). The system has two chambers. The first chamber packed with gravel followed by a chamber of 50 liters capacity containing activated enhanced hybrid alumina. The installed capacity of this unit is 1,50,000 liters. The flow rate is about 15 liters / min.

ix) Plant Developed by M/s Anir Engineers Inc.: The system is based on the adsorption technique using Fixed Bed Granular Ferric Hydroxide (GFH). GFH is prepared from ferric chloride solution by neutralization and precipitation with sodium hydroxide. The grain sizes vary from 0.2 to 2.0 mm, as the grains with water resulting high density of available adsorption sites. This in turn, enhances the adsorption capacity. It is operated with downstream water and operated in the pH range between 5 to10. The typical residual mass is in the range 5 - 25 gm / m^3 treated water.

CONCLUSIONS AND RECOMMENDATIONS

i) Development of ground water in North East Region is still in nascent stage. There is ample scope for development of this replenishable natural resource and ground water development from shallow as well as deeper aquifers. However, resource utilization should be done in a systematic and scientific manner, with due consideration of the prevailing hydrogeological conditions.

ii) The region being hilly, only 30% of the existing valley area can be developed. In the hilly area, there is a very little scope for ground water development. The probable option available is to harvest rainwater through roof tops of buildings in hilly areas.

iii) Since the hilly terrain of the region is bestowed with many perennial springs, these can be developed for domestic use. Spring development may also be a viable solution for water supply in those areas.

iv) The most severe threat for the ground water in the urban sectors of the region is its vulnerability towards pollution. Shallow water table condition combined with high transmissivity of the aquifer material is contributing the potent environment. Additionally, geriatric unlined sewerage system, unplanned garbage disposal, filling up of marshy lands, conversion of agricultural low lands to residential/ commercial plots as well as cutting of hill slopes together are disturbing the natural flow pattern and threatening the ground water quality. Legal framework with strict water related laws are important to achieve sustainability towards ground water abstraction and pollution.

v) Finally, ground water being a common resource, social awareness has to be created at all levels for judicious and effective management of ground water resources with sustainability. Development would be such that the nature's resources would be harnessed optimally with a specific aim towards replenishment. The policy should have impact assessment procedure in place and should have capacity for restoration of the ecological imbalances if needed. It is, therefore, essential to educate the masses on need and ways for regulation, conservation and augmentation of ground water resources.

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