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ASIAN JOURNAL OF
SCIENCE AND TECHNOLOGY

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 12, Issue, 07, pp.11743-11753, July, 2021

REVIEW ARTICLE

GROUND AND SURFACE WATER QUALITY IN NORTH EASTERN REGION OF INDIA

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ARTICLE INFO

Article History:
Received 20th April, 2021
Received in revised form
19th May, 2021
Accepted 07th June, 2021
Published online 20th July, 2021

Key words:
North East Region, People, Ground Water, Arsenic, Iron, Fluoride, Industries, Mines, Pollution.

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ABSTRACT

North East (NE) region of India is highly diverse with hilly terrain and has abundant natural resources like forest, water, tea, oil and gas, coal, limestone Uranium etc. The region is witnessing significant fast rate of development of hydropower and industries. Therefore, change in the pattern of utilization of resources in this ecologically sensitive region and changes in lifestyles, culture, farming activities etc. are exerting pressure on the ecosystem. Activities like road building, urbanization, industry (mining, oil and gas exploration, power etc.) and hydel power projects form part of major developmental agenda of the NE region. The data presented in this paper show that groundwater quality in states of NE region has been affected by geogenic contamination from constituents like As, F, and Fe, and the concentration in many areas is beyond the permissible limits. The people of NE depend mostly on surface water (rivers, ponds, reservoirs and natural springs) for their domestic water requirement. Due to industrial and urban activities, surface water also gets polluted with various contaminants rendering them unsuitable for drinking purpose. The monitoring results indicate that lakes, tanks and ponds in the NE have reduced water quality. These water bodies have high organic matter and their BOD is above permissible limits. The water conservation and related management issues of the region and the legislative provisions that address the issues of water management, conservation and control of pollution are discussed.

Citation: Shahida P. Quazi, Mrityunjay Kar and V. P. Upadhyay. 2021. "Ground and surface water quality in North Eastern Region of India", *Asian Journal of Science and Technology*, 12, (07), 11743-11753.

INTRODUCTION

Functioning of the ecosystem depends on water which is essential for life. Millions of people around the world face water shortage. The United Nations General Assembly declared the years 2005 to 2015 as the International Decade for Action 'Water for Life' to promote efforts to fulfil international commitments of the Millennium Development Goals which aim at reducing by half the proportion of people without access to safe drinking water and to stop unsustainable exploitation of water resources (https://www.who.int/topics/millennium_development_goals/about/en/). The water for life decade coordinated by 'UN-WATER' was launched on 22nd March 2005. The World Summit 2002 in Johannesburg also adopted for developing integrated water resource management and water efficiency plans by 2005 and to halve the proportion of people who do not have access to basic sanitation by 2015, thus providing access to the poor people and ensuring the participation of women. The themes of 'Water for Life' Decade aimed to address the issues of scarcity, access to sanitation and health, water and gender, capacity-building, financing, valuation, Integrated Water Resources Management, trans-boundary water issues, environment and biodiversity, disaster prevention, food and agriculture, pollution and energy (WSSD, 2002) . World Water Day is celebrated each year on 22nd March emphasizing on worldwide need for increased integration and cooperation to ensure sustainable, efficient and equitable management of water resources.

Water, being a natural resource plays an important role in the socio-economic development processes and therefore, sustainable development and management of water is needed for meeting the requirement of energy, drinking water, and irrigation etc. The surface and ground water pollution, lowering of ground water table and depletion of discharge in water springs, siltation in lakes, reservoirs and ponds, salinization of croplands, etc are the commonly noticed problems. In various policies and programmes, concerns have been shown to conserve our water resources, in addition to preservation of our natural environment and alleviation of poverty and hunger. Water quality is becoming an important as well as emerging vital issue in India. Unequal distribution over varied regions results in water scarcity and unsuitability with respect to water quality (CPCB 2008a). Table 1 provides the water scenario at a glance in India (Upadhyay and Rao, 2007). Apart from the moderate to severe water shortage in India due to urbanization and industrialization (CPCB, 2010), the country is facing the issue of depleting water quality. The National River and Lake conservation plans, creation of Central Ground Water Authority and programmes for inter linking of rivers in the country are a few programmes towards integrated water resource management. River Valley projects are being taken as multipurpose reservoir project and the stored water is utilized for power generation, development of irrigation and water supply networks to town and cities (Upadhyay, 2004; Saio *et al*., 2017). North East (NE) region of India comprises of hills and plains on both sides of the river Brahmaputra and the Himalayan range around it.

Table 1. Water Resources at a Glance in India (Upadhyay, and Rao,. 2007)

S. No.	Parameters	Quantity(Cu.Km)
1.	Annual Precipitation Volume (Including snowfall)	4000
2.	Average Annual Potential flow in Rivers	1869
3.	Per Capita Water Availability (1997)	1967
4.	Estimated Utilizable Water Resources	1122
	(i) Surface Water Resources	690 Cu.Km.
	(ii) Ground Water Resources	432 Cu.Km.

Table 2. Drinking water standards for Arsenic (As), Fluoride (F), and Iron (Fe) stipulated by different agencies

Constituent	Drinking Water Standard				
	BIS 2012 (mg/L)		WHO, 2011 (mg/L)	USEPA (mg/L)	EU guideline (mg/L)
	Acceptable Limit	Permissible Limit			
Arsenic	0.01	0.05	0.01	0.01	0.01
Fluoride	1.0	1.5	1.5	4.0	1.5
Iron	0.3	No relaxation		0.3	0.2

With abundant natural resources like forest, water, tea, oil and gas, coal, limestone and Uranium etc., the region is highly diverse and is witnessing significantly fast rate of development of hydropower projects and industries. The region is surrounded by the international boundaries of four countries and is ecologically sensitive; therefore, change in the pattern of resource utilization and changes in lifestyles, culture, farming activities etc. will exert pressure on the ecosystem. The states of the northeast region are privileged by the provisions of Schedule VI of the constitution of India and have different property laws. The culture, ethnicity and traditions of the people have inbuilt system for protection and management of ecosystem, as they follow certain natural strategies and principles to protect the ecosystem. The developmental activities like road building, urbanization, development of industries (mining, oil and gas exploration, power etc.) and hydel power projects form part of major developmental agenda for NE region. North East India has varied topography and climatic conditions which vary from tropical to temperate and alpine depending upon elevation. Flood plain areas have very different water regime, storage and utilization practices compared to hilly regions. Several areas in the NE are suffering from water scarcity and pollution including water depletion and contamination. The present paper highlights the water conservation and management related issues of the region and the legislative provisions that address the issues of water management and conservation and control of pollution.

Groundwater Quality: Groundwater plays an important role in supply of drinking water throughout the world. Although only 0.9% of the total water supply on the earth comes from the groundwater, it is the preferred source of drinking water (Dutta,, 2013) and acts as the main supplier of drinking water in rural areas and supplementary supplier in urban areas in India (CGWB, 2014). Groundwater contributes to both drinking water (80%) and agricultural needs (50%) in rural areas. More than half of the total irrigated areas and around 70-80% of the total irrigated areas in India are dependent on ground water (Dains and Pawar, 1987). Groundwater is a critical resource for the socioeconomic development of the country, catering to domestic, irrigation and industrial sector. In recent years, concerns have aroused due to depleting resources (dried wells and lowering of water levels in the aquifers) along with deteriorating groundwater quality impacting the rural water demand and supplements in urban areas (CGWB, 2014). Ground water quality is dependent on the varied geological formation, hydrogeological condition, climatological and topographic settings, type and depth of soils and rock-water interaction. In addition, impact due to anthropogenic activities, such as, industries, urban sewage and waste landfills, mining, atmospheric contribution and composition of surface water bodies also influence the groundwater quality (CGWB, 2010). Groundwater becomes non-potable when the ingredients present in water exceed the prescribed desirable limits. In India, most widely used standard for drinking water quality is the Bureau of Indian Standard: IS 10500-2012.

Other international guidelines are: 1) World Health organizations (WHO) Guidelines 2011, 2) European Union (EU) guidelines, and 3) U.S. Environmental Protections Agency (USEPA) Guidelines. The permissible limits for the three contaminants which have significantly affected the water quality of NE region are given in Table 2. These contaminants will be discussed in the present review article.

Contamination of Groundwater in the NE Region: People of NE mainly depend on natural springs, rivers, ponds and dug wells for their freshwater requirement. With many springs becoming seasonal, most of the domestic water requirement is being fulfilled from groundwater through shallow and deep tube wells (Bordoloi, 2012). The contamination of groundwater with Arsenic (As), Fluoride (F), Iron (Fe) and Nitrate deeply affects the overall domestic water requirement of the NE people.

Arsenic Contamination in North East India : High As concentration is found in groundwater in the unconsolidated aquifers along the alluvial and deltaic plains of southern, south-eastern and eastern region of Asia with the problem being aggravated since the densely populated area is dependent on the shallow aquifer as their source of drinking water (CGWB, 2014) and approximately 40 million people are within the risk zone of As contamination (Acharya, 2005; Saha, 2009). After the first groundwater contamination was detected in 1983 (west Bengal), several states including Assam and Manipur (Brahmaputra and Imphal river flood plain) have been detected with **As** concentration of 50-986 µg/L (Das *et al*., 2015). Arsenic contaminated areas in Assam are in Sivsagar, Jorhat, Golaghat, Sonitpur, Lakhimpur, Dhemaji, Hailakandi, Karimganj, Cachar, Barpeta, Bongaigaon, Goalpara, Dhubri, Nalbari, Nagaon, Morigaon, Darrang & Baksha districts with a concentration above the permissible limit (CGWB, 2014). Arsenic concentration has also been observed in Bishnupur, Thoubal districts of Manipur (CGWB , 2014) (Figure 1). Singh (2004) and Chakraborti *et al*. (2008) reported **As** contamination in several NE states. A study in monsoon and non monsoon seasons of 2003-2004 in the eight states of NE India, analysing more than 4000 water samples from 200 wells and other drinking water sources, revealed As contamination in Assam (21 out of 24 districts), Tripura (3 districts), Arunachal Pradesh (6 districts), Manipur (1 district) and Nagaland (2 district) (Singh, 2004; Singh, 2007) (Figure 1). In Assam, maximum As concentration was observed in Titabor, Dhakgorahm Selenghat and Moriani blocks of Jorhat districts, Nalbari district and Boginodi and Lakhimpur blocks of Lakhimpur district. Arsenic concentration was in the range of 100-200 µg/L in Barpeta, Dhemaji, Darrang and Golaghat districts. The remaining 11 out of 21 contaminated districts had as concentration in the range of 50-100 µg/L. The districts of Karbi Anglong, NC Hills and Morigaon were without as contamination (Singh, 2004) (Figure 1A). In another study, As content was detected in water samples collected from 137 hand pumped Tube wells from different parts of Assam with a maximum concentration of 490 µg /L (Chakraborti *et al*., 2004).

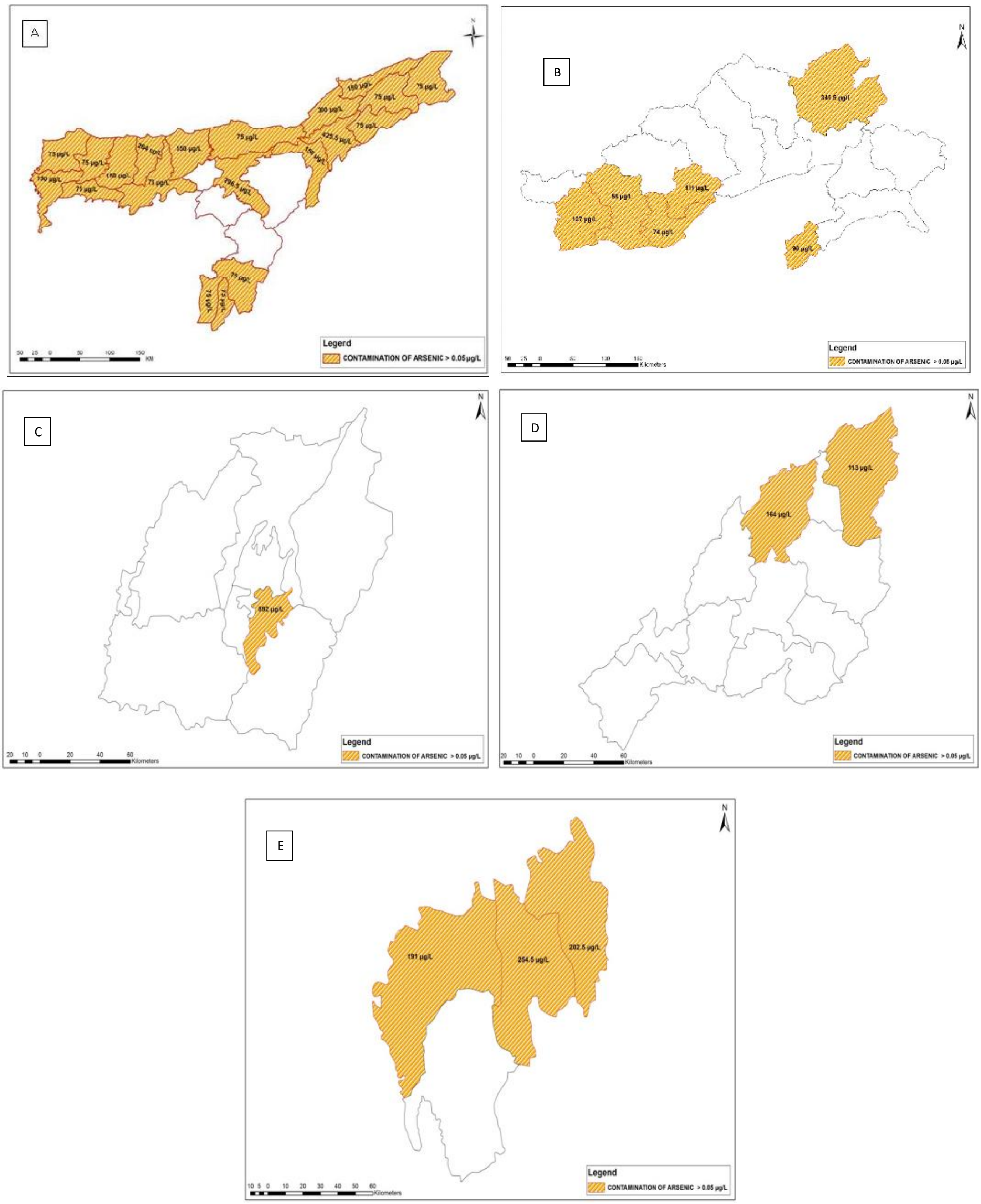

Figure 1. Maps showing Arsenic contaminted states in Assam (A), Arunachal Pradesh (B), Manipur (C), Nagaland (D), Tripura (E). Data used in this figure has been taken from Singh (2004). Values shown in the figures are the median Arsenic concentration observed in that state. Locations with As contamination include: A. Assam:Nagaon (Lowkhowa, Paschim Koliabar, Doboka, Binakandi, Raha, Borhompur, Pakhimora and Kathiatali), Jorhta (Moriani, Titabor, Selenghat), Lakhumpur (Lakhimpur, Telahi, Ghaimora Gossai, Nowboisha, Karunabari, Boginadi, Narayanpur, Bihpuria), Nalbari (Barama, Paschim Nalbari, Pub Nalbari Tumulpur), Golaghat (South Golaghat, Podumoni), Dhubri (Mankachar, Jangal Fekamari, Mahamay), Darrang (Bahmolla (Sipajhar)), Barpeta (Mandia, Kolkussia Chakchaka, Bajali), Dhemaji (Sissiborgoan, Dhemaji Jonai); B. Arunachal Pradesh: Papum Papre (Doimukh), West Kameng (Dirang), East Kameng (Pakke), Lower Subansiri (Yazali, Yada Vill Dokum), Dibang Valley (Hunli, Midland), Tirap (Khonsa); C. Manipur: Thoubal (Khunyai, Kakching Market, Nighthou Lekei); D. Nagaland : Mokok Chong (Tzudikong, Tuli, Merapani), Mon (Lonling, Borjan, Naginimara); E. Tripura: West Tripura (Jirania), Dhalai (Salema, Halhali, Halhooli, Kamalpur, Joyanagor), North Tripura (Sanitala, Rajabari Dharma Nahar).

In Arunachal Pradesh, six districts close to the border with Assam were contaminated with As (Singh, 2004) with highest concentration detected in Midland block (618 µg/L) of Dibang valley district (Figure 1B). In Manipur, As contamination was 986 µg /L in Khunyai, 858 ug/L in Kakching Market, and 798 µg /L in Ningthou Lekei of Thoubal district (Singh, 2004) (Figure 1C). Chakraborti *et al*. (2008), detected As contamination in 628 water samples from tube wells from Imphal East, Imphal West, Thoubal and Bishnupur districts. Here As was >10 µg /L in 63% tube wells, between 10 and 50 µg /L in 23% tube wells, and >50 µg /L for 40% tube wells. In Tripura State , the districts of West Tripura (Jirania block), Dhalai (Salema, Halhali, Halhooli, Kamalpur, Joyanagar block), and North Tripura (Sanitala, Rajbari, Dharma Nagar block) are contaminated (Singh, 2004) (Figure 1E). Highest As content (65-444 µg/L) was observed in the Dhalai district with 42.1% of the total analyzed samples contaminated (Singh, 2004). Mokukchung and Mon districts of Nagaland were found contaminated with As concentration ranging from 50-278 µg /L for Mokukchung and 67-159 µg /L for Mon district,respectively which are situated close to Jorhat district of Assam (Singh, 2004) (Figure 1D). Singh (2004) indicated that the affected locations of Assam and Tripura were close to the affected areas in Bangladesh.

Industries in North East India and their implication on Arsenic Concentration: With the economic progress being closely linked to energy demand, the need for oil and gas will also grow considerably. As per the Vision 2030 report, it is proposed to increase oil and gas production in NE India. The exploration activities, expansion of piped natural gas (PNG) network, and LPG distribution system reaching even the remote areas are on the increase (Vision, 2030). Table 3 provides the details of the exploration and drilling projects and oil refineries in the NE states. Some exploration projects overlap with districts that have high As concentrations. Similar is the case for Manipur and Tripura, (Table 3 and Figure 1C, E). Arsenic and other trace elements are found in oil and other fossil fuels, with their concentration depending on the source (Cozzarelli, *et al*., 2016). Analysis of 23 crude oil samples have shown arsenic concentration in the range 10 and 37 µg/L (Stigter *et al*., 2000). Though reports suggest that in petroleum hydrocarbons, As is not a major contaminant; perturbation to the existing naturally occurring As geochemistry by induction of biodegradable organic carbon including petroleum hydrocarbons may result in mobilization of naturally occurring As, and increase in ambient As level (Brown *et al*., 2010). Soluble hydrocarbons may stimulate biological activity, resulting in the degradation of dissolved hydrocarbon. According to Brown *et al*.(2010), Arsenic will regress to its pre-existing geochemistry with concentration that is above or below the maximum contaminant level once the petroleum hydrocarbon is attenuated. Given the fact that the exploration drilling projects in NE India are in the areas that have high As concentration, proper management with due consideration for the specific site As geochemistry is required in all exploration and oil refinery projects.

Iron (Fe) Contamination in North East India: Fe occurs either in the soluble ferrous form or insoluble ferric form as a common ingredient of soil and ground water. Iron concentration in water is dependent on both physico-chemical and microbiological factors and is generally derived from weathered ferruginous oxide and sulphide minerals in rock formations of igneous sedimentary and metamorphic origin (CGWB, 2010). High Fe concentration has been observed in Cachar, Darrang, Dhemaji, Dhubri, Goalpara, Golaghat, Hailakandi, Jorhat, Kamrup, Karbi Anglong, Karimganj, Kokrajhar, Lakhimpur, Morigaon, Nagaon, Nalbari, Sibsagar, Sonitpur districts of Assam (Figure 2A), Bishnupur, Thoubal districts (Figure 2C) in Manipur and in observational wells of East Garo Hills, East Khasi Hills, Jaintia Hills districts (Figure 2D) in Meghalaya. Fe concentration in some districts of Assam is reported as high as 20-49 mg/l (CGWB 2010; Singh, 2004). High Fe content was detected in West Kameng (4.931 mg/L), East Kameng (1.051 mg/L) and Papun Pare (1.955 mg/L) districts in Arunachal Pradesh (Singh, 2004). In Manipur, Fe content in the Thoubal district was 0.74-4.32 mg/L (Singh, 2004) and 1.80-16.52 mg/L (CGWB, 2010). Fe content in the district of Meghalaya was as follows: East Garo Hills - 1.29 - 4.88 mg/L; East Khasi Hills - 7.20; Jaintia Hills - 3.20 mg/L. Fe concentration above the BIS limit has also been observed in districts of Dhalai, North Tripura, South Tripura, and West Tripura) (CGWB, 2014 ; Singh, 2004) in Tripura state.

Fluoride (F) Contamination in North East India: Globally 65% of endemic fluorosis is caused by fluoride contaminated drinking water (Felsenfeld and Robert 1991). In India, more than 40 million are impacted by dental fluorosis (Karthikeyan *et al*., 2005). Subarayan *et al* (2012) reported that 50% groundwater resources in India is contaminated with fluoride. Various factors such as temperature, pH, precipitating ions and colloids, solubility of fluorine bearing minerals, anion exchange capacity of aquifer minerals, contact time between water and geological formations, along with the size and type of geological formations traversed by water affect the fluoride dynamics (Apambire *et al*., 1997). Concentration higher than 1.5 mg/L has been observed to cause serious health problems such as stiffness of the back and difficulty in performing natural movements at higher concentrations (such as 5.0-10.0 mg/L) (CGWB, 2010). Fluoride concentration above the BIS limit (1.5 mg/L) has been observed in Goalpara, Kamrup, Karbi Anglong, Nagaon, Golaghat, Karimganj districts of Assam. In the areas with alluvial red soil and Precambrian metamorphic basement rock complex of Karbi Anglong and Nagaon districts of Assam, high concentration of F has been reported by Dutta *et al*., (2006) and CGWB (2010) (Fig. 3A). Groundwater analysis of 75 samples from 32 villages and 8 towns of Karbi-Anglong and Nagaon districts of Assam revealed fluoride levels above 1.0 mg/L in 43 samples (Chakravarti *et al*., 2000). Hasne *et al* (2019) reported high concentration (1.63 g/L to 3.25 mg/L) of F in 4 out of 8 studied blocks with no uniformity in F concentrations in the water samples. The authors also concluded that high F concentration was due to the F-rich minerals in the zone. Occurrence of dental fluorosis (31%) and skeletal fluorosis (1.7%) among 2063 people from 8 villages in Karbi - Anglong district has been reported by Chakravarti *et al* (2000). Hasne *et al*. (2019) reported high non-carcinogenic risk from elevated F contaminated drinking water in both adult and children.

Regulation on Management of Groundwater: Ground water (GW) is the most precious and essential component of water resource for sustenance of life. Recent pace of development as well as need of the people, especially of the urban population has threatened the availability of the precious groundwater. Since GW is not an inexhaustible resource of fresh-water, a balance between discharge of GW and recharge must be maintained. Indiscriminate drilling of tube-wells and excessive drawl is lowering the water table. In the absence of substantial vegetation cover, rainfall is not arrested, as a result the precipitation rushes straight down to the rivers and eventually to the sea, without sufficiently recharging the ground-water. Deforestation and consequent decline in forest cover is also contributing to lowering of the water table in addition to anthropogenic harvesting of the resource. Central Ground Water Authority (CGWA) has been constituted by the Ministry of Environment & Forests with a specific mandate for regulation and control of GW management and development of the country (Upadhyay, 1998). CGWA shall also regulate indiscriminate boring and withdrawal of ground water in the country and issue necessary regulatory directions with a view to preserve and protect ground water under this Regulatory Act and notify an area or such areas where there is over exploitation, pollution, salinity, hazard etc., The jurisdiction of the Authority shall be the whole of India. The Authority functions under the administrative control of the Ministry of Water Resources. The Central Ground Water Board / Authority takes up regular monitoring of ground water resources and awareness programmes on water management in the country. The CGWA is delegated with powers under Section 5 of the Environment (Protection) Act, 1986 for issuing directions and taking such measures in respect of all the matters referred to in sub-section (2) of Section 3 of the said Act.

Table 3. Number of Environmental Clearances (EC) given to Drilling and Petrochemical projects in the North East States (http://envfor.nic.in2018-Ministry of Environment, Forest & Climate Change, New Delhi)

Sl. No.	District (Project)	No. of EC
ARUNACHAL PRADESH (Exploratory Drilling)		
1	Changlang	3
2	Ningru	2
3	Lohit	1
ASSAM (Exploratory Drilling)		
1	Golaghat	9
2	Jorhat	5
3	Sivasagar	10
4	Karimganj	1
5	Cachar	9
6	Hailakandi	1
7	Dibrugarh	7
8	Karbi Anglong	1
9	Sonitpur	1
10	Tinsukia	14
11	Duliajan	1
12	Dima Hasao	1
13	Nagaon	1
14	Dhemaji	1
15	Morigaon	1

Sl. No.	District (Project)	No. of EC
ASSAM (Refinery and Petrochemical)		
1	Digboi Refinery (Tinsukia)	6
2	Numaligarh Refinery (Golaghat)	9
3	Bongaigaon Refinery	8
4	Guwahati Refinery (Kamrup)	4
5	Lepetkata+ Assam Petrochemical (Dibrugarh)	2+1=3
TRIPURA(Gas exploration and Production)		
1	Khowai	1
2	South Tripura	4
3	West Tripura	8
4	North District	3
MANIPUR (Refinery)		
	West Imphal	2
MIZORAM (Exploratory Drilling)		
1	Aizawl, Lunglei, Mamit, Sechhip	1
2	Kolasib	1
1	NAGALAND (Mining)	1

Table 4. Lakes, Tanks and Ponds in the various states of NE not complying with the standard BOD limit for the year 2010, 2012, 2016 and 2019(CPCB,2012; 2016; 2019a)

Lakes/Tanks/Ponds	Year 2010	Year 2012	Year 2016	Year 2019	Lakes/Tanks/Ponds	Year 2010	Year 2012	Year 2016	Year 2019
	B.O.D (mg/L)	B.O.D (mg/L)	B.O.D (mg/L) (max)	B.O.D (mg/L) (max)		B.O.D (mg/L)	B.O.D (mg/L)	B.O.D (mg/L) (max)	B.O.D (mg/L) (max)
Assam									
Dighali pukhuri (Guwahati)	24	12	10.6	5.80	Daloni Beel (Jogighopa)	6.4	4.2	3.9	2.6
Elangabeel System Pond.	44	50	84	17.5	Borpukhuri (Nazirza)	6.4		6.2	
Deepar Beel (Guwahati)	16	8.2	11.4	4.8	Rajadinia Pukhuri (Abhayapur)	6.4l	8.0		4.20
Gala Beel (Dergaon)	11.2	4.8	3.7	2.6	Gaurisagar	6.4	4.5	3.9	3.70
Bishnu Puskar Pukhuri. (Hajo)	11	8.8	14.1	14.5	Rajmaw Pukhuri (Jorhat)	5.4	4.0	3.4	3.70
Gopjur Tank.	10.8				Bor Beel. (Jakai)	5	6.7	4	4.50
Rajapukhuri (Gauripur)	10.2			2.4	Mer Beel (Madhabpur)	3.6	3.8	22	18
Jaipal Pukhuri (Sipajhar)	9.8	6.2	18.4	7.8	Chand Dubi Beel.	3.5			2.60
Mahamaya Mandir Pukhuri	9.6	5.0	9.2	2.5	Rajadinia Pukhuri			6.1	4.20
Subhagya Kunda Pond	9.5		10.4	7.0	Saran beel		6.1	10.2	5.40
Ganga Pukhuri (Nalbari)	8.6	6.8	7.6	4.0	Raja pukhuri		5.21	12.6	2.40
Sivasagar Tank	8.4				Gophur pond		4.6	9	5.60
Hordai Pukhuri (Chraidew)	4.2	4.2	6						
Baskandi Pond	4	4.2	5.6	3.8					
Padumpukhuri. (Tezpur)	8	11.0	24	6.4					
Botodriva Satra Pond. (Nagaon)	8	7.8	12.1	8.8					
Goysagar Tank. (Sibsagar)	7	3.4	3	2.2					
Manipur					**Meghalaya**				
Loktak at, Bishnupur			4.7	4.5					
Loktak lake, Thanga			4.7	4.5	Lake (Barapani)	10.2	12.0	13.8	8.4
Kongabazaar pond		29.8	26.8	3.6	Wards Lake (Shillong East)	9.0	9.0	7.4	4.8
Kakwa bazaar pond		5.8	12	3.3	Tripura				
Pumlen lake &lamjao pukhuri.		4.3	4.5	4.7	Rudrasagar. (Sonumura)	3.4	3.4	3.7	2.9
Langmeidong pukhuri.		4.2	9.9	3.8	Laxmi Narayan Bari.	3.2	3.8	10	2.70
Ngairangbam		4.0	4.0	4.1					

CGWA may resort to invoking penal provisions contained in Sections 15-21 of the said Act for offences and violations. CGWA accords permission to industrial projects, housing projects and mining projects for withdrawal of groundwater for construction/operation of the projects with certain criteria which are as follows:

Industries: All new/existing industries, industries seeking expansion, infrastructure projects and mining projects abstracting ground water, unless specifically exempted, will be required to seek No Objection Certificate from Central Ground Water Authority or, the concerned State/ UT Ground Water Authority.

However, following categories of consumers shall be exempted from seeking No Objection Certificate for ground water extraction:

- (i) Individual domestic consumers in both rural and urban areas for drinking water and domestic uses.
- (ii) Rural drinking water supply schemes.
- (iii) Armed Forces Establishments and Central Armed Police Forces establishments in both rural and urban areas.
- (iv) Agricultural activities.
- (v) Micro and small Enterprises drawing ground water less than 10 cum/day.

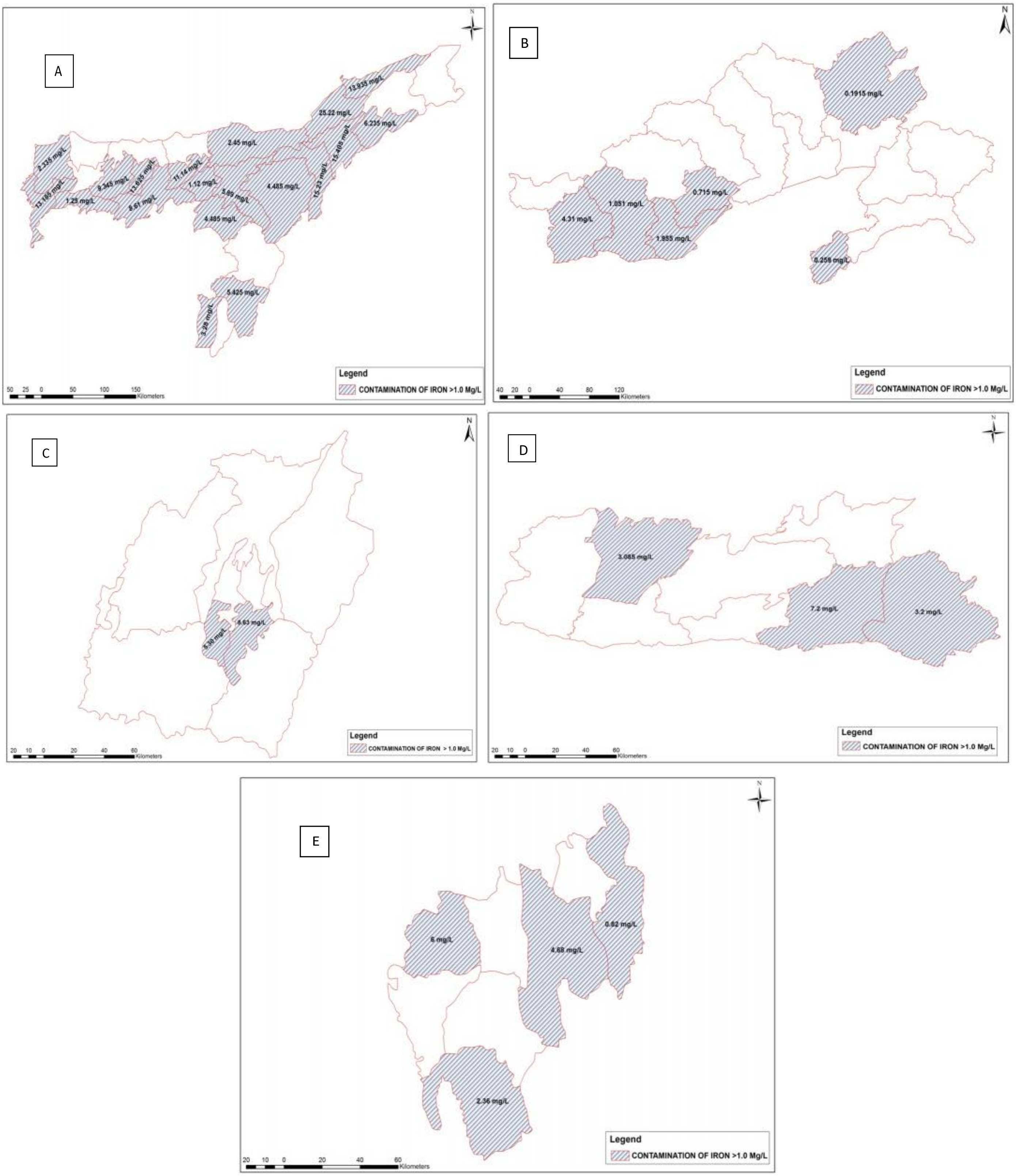

Figure 2. Maps showing Iron concentration > 1.0 mg/L in Assam (A), Arunachal Pradesh (B), Manipur (C), Meghalaya (D), Tripura (E). Data used in this figure has been taken from Singh, (2004) and CGWB, (2018). Values shown in the figures are the median Iron concentration observed in that state. Locations with As contamination include: A. Assam : Nagaon (Lokhowa, Paschim Koliabar, Doboka, Binakandi, Raha, Borhompur, Pakhimora, Kathitali. Phulaguri, Nagori, Bichamari, Borchukhaba, Bamuni tinali, Samugur); Jorhat (Moriani, Titabor, selneghat, Dabarapar charali, Kolamukh), Lakhimpur (Lakhimpur, Telahi, Ghaimora Gossa, Nowboisha, Karunabari, Boginadi), Nalbari (Barama, Paschim nalbari, Pub nalbari, Tumulpur), Golaghat (South Golaghat, Podumoni, Bokakhat, Kamargaon, Golaghat, Oating), Dhunri (<amkachar, Jangal Fekamari, Mahmaya, Bilasipara, Chapar, Dhubri town), Darrang (Bahmolla (Sipajhar), Bengnari, Paneri, Mangloi , Oeang, Kalaigaon, Baitamri (Beltala chawk), Udalgiri, Barpeta (Mandia, Kolkussia Chak Chaka, Bajali, Sorbhog), Dhemaji (Sissiborgoan, Dhemaji Jonai, Bordolloni), Bongaigaon (Abhayapuri, Medhipara), Cachar (Borkhola, Borajalinga, poilapul, Shivtila), Kamrup (Rajapara, Amingaon ii, Agyathuri, Azara, Kahilpara), Karbi Anglong (Bokajan, Deopani, Dillai, Manja, Dengaon, Phuloni), Karimganj (Dhaulia), Lakhimpur (Bihpuria, Pathalipam, Bhogpur charali, Narayanpur, Panigaon), Sivsagar (Bandarmari, Betbari Alimore, Moranhat, Sapekhati), Sonitpur (Jamuguri north, Sootia, Gophur, Garumari); B. Arunachal Pradesh : Papum Pare (Doimukh), West Kameng (Dirang), East Kameng (Pakke), Lower Subansiri (Yazali, Yada Vill dokum), Dibang Valley (Hunli, Midlan), Tirap (Khonsa); C. Manipur : Thoubal (Khunyai, Kakching market, Ningthou Lekei, Irungmapal, Khongjam); D. Meghalaya : East Garo Hills (Kharkutta), East Khasi Hills (Balat, Shillong), Jaintia Hills (Dauki); E. Tripura : West Tripura (Jirania), Dhalai (Salema, Halhali, Halhooli, Kamalpur, Joyanagor), North Tripura (Sanitala, Rajbari Dharmanagar), South Tripura (Subroom);

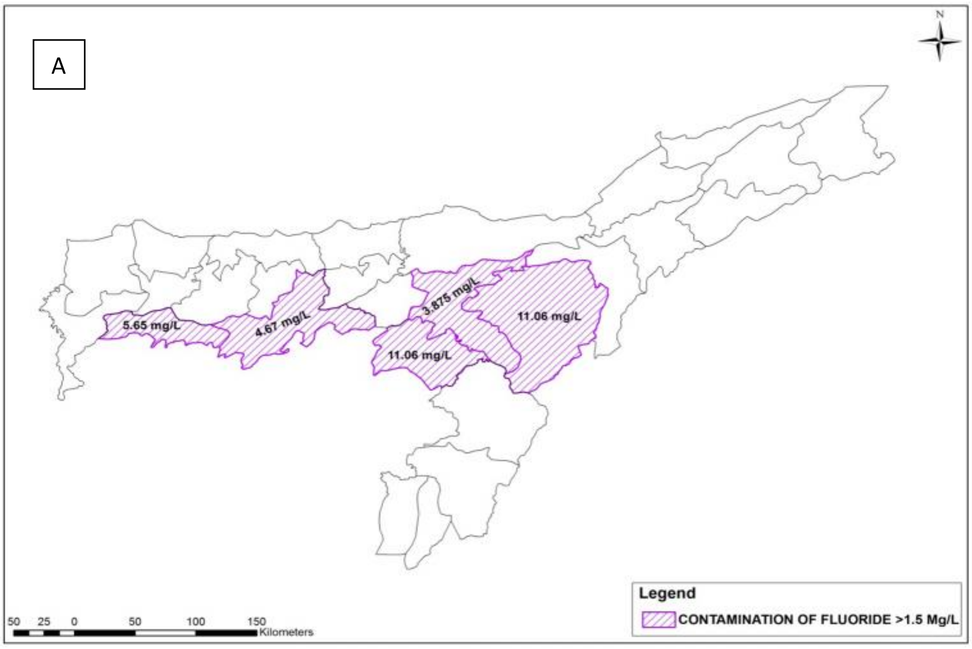

Figure 3. Map showing Fluroide concentration > 1.5 mg/L in Assam (A), Data used in this figure has been taken from CGWB (2010, 2018). Values shown in the figure are the median Fluoride concentration observed in that state. Fluoride contaminated locations include: A. Assam: Kamrup (Hajo -Alikash Adarsh, Hatigaon, Narangi H Schoolo, Rukmini Gaon, Sewalipath, Hatigaon, Sri P H B Colony- Birkuchi), Karbi Anglong (Phuloni, Bokulia, Centre Bazar, Dengaon, Disobai, Dokmuka, Eradiaghal pani, Jamuna Jaipang, ParaTeke Gao, Amlakhi, Kheroni, Longnit, Ramsapathar, Baghpani, Jaisuguri, Manjha, Rongkanthir, Garam Pani, Phonbirik, Rangita, Samtarogaon, Sarsobey, Sonapur), Goalpara (Dorrangiri) and Nagaon (Jamunimukh, Jaynagar)

CGWA mandates major and minor industries to recycle and reuse at least 40% of the wastewater (for safe category), 50% of the waste water (for semi-critical category), and full recycling and reusing of waste water in the critical and over exploited category. In the safe category, acquiring of NOC for industries is subject to adoption of artificial recharge of groundwater. Withdrawal in all categories is permitted, subjected to ground water recharge with the withdrawal not exceeding 200% (for semi critical category), not exceeding 100% (for critical category) and 50% of the recharged quantity (for over-exploited category)[34]. For water intensive industries, permission to withdraw groundwater is not granted in over exploited areas. However for other areas, NOC is granted with the withdrawal limited to ~ i) 200% of ground water recharge (for safe category) , ii) 100% of ground water recharge (semi-critical category), and iii) 50% of ground water recharge (for critical category). NOC shall not be granted in Over-exploited areas for ground water abstraction to any new industry or expansion of existing industries involving increase in quantum of ground water abstraction except Micro, Small and Medium Enterprises (MSME). New packaged water industries in Overexploited areas, of MSME category will not be given NOC. For ground water extraction by industries, NOC shall be granted subject to the following specific conditions:

i) NOC shall be granted only in such cases where local government water supply agencies are not able to supply the desired quantity of water.
ii) All industries shall be required to adopt latest water efficient technologies so as to reduce dependence on ground water resources.
iii) All industries abstracting ground water in excess of 100m3/d shall be required to undertake annual water audit All such industries shall be required to reduce their ground water use by at least 20% over the next three years through appropriate means.
iv) Construction of piezometers within the premises and installation of appropriate water level monitoring mechanism shall be mandatory for industries drawing/ proposing to draw more than 10 m3/day of ground water
v) Roof top rain water harvesting/ recharge in the project premises is mandatory. Industries shall store the harvested rain water in surface storage tanks for use in the industry.
vi) Injection of treated/ untreated waste water into aquifer system is strictly prohibited.
vii) Industries need to undertake necessary well head protection measures to ensure prevention of ground water pollution.
viii) All industries drawing ground water in safe, semi-critical critical assessment units and over-exploited assessment units shall be required to pay ground water abstraction charges

Infrastructure projects: For Housing and Residential Townships, CGWA mandates that the usage of groundwater (which is not for domestic and drinking purpose) should not exceed 25% of the total ground water abstraction. Project authorities are also required to submit their requirement along with a letter from the Government Water Supplying Agency providing them with water. Moreover for these projects, unless there is risk for contamination or the area gets water logged, CGWA mandates that the runoff from the projects may be used for artificial recharging or may be stored for future use or both (CGWA , 2015).

Mining Projects: Mining projects are required to follow the same criteria as the industries with respect to recharge and recycle/reuse (Upadhyay, et. al., 2018). Project is required to submit mining plan along with mine seepage computation/modelling studies. Modelling studies on ground water regime should be carried out and report submitted to the Regional Directorate of CGWB periodically. CGWA also mandates the installation of piezometers for monitoring of ground water level within the premises and in the peripheral areas, with records being maintained and submitted to regulating agency (CGWA, 2015).

Surface Water Quality and Contamination: With the GW quality being affected due to geogenic contamination from constituents like As, F, and Fe, people of NE may have to depend on surface water reservoirs (rivers, ponds, and natural springs) for their domestic water requirement. However, due to industrial activities, surface water also gets polluted with various contaminants rendering them unsuitable for drinking purpose. The monitoring results (CPCB, 2010) indicate that water of lakes, tanks and ponds in the NE have reduced water quality. These water bodies have high organic matter and show BOD above permissible limit. Table 4 highlights the water resources in the various states of NE not complying with the standard BOD limit. However, the water quality of lakes, tanks and ponds in the various states meets the water quality criteria with respect to total coliform and faecal Coliform counts. However, faecal coliform counts in Umiam Lake at Barapani & Ward Lake at Shillong East in Meghalaya are high. With respect to dissolved Oxygen (DO) level, it is lower than the desired level in Elangabeel Pond, Deepar Beel at Boragaon, Bor Beel at Jakai, Botodriva Satra Pond at Nagaon, Mer Beel at Madhabpur and Gaurisagar Tank in Assam, and Loktak Lake at Thana and at Karang Island in Manipur. The data from riverine system (medium and minor rivers) of the NE states (Manipur, Meghalaya, Mizoram and Tripura) show that river water of R.Iril at Porampet, Manipur and Kharkhla at Jaintia Hills is acidic (CPCB, 2010). Similarly water of River Nambul at Bishnupur in Manipur is acidic and the pH of the river Kharkhla reached 2.5 in the year 2012 indicating very high acidic state (CPCB, 2012). Dissolved Oxygen was below the standard limit at the following locations: River Nambul at Hump Bridge (0.2 mg/l), Heirangoithong (0.3 mg/l), Naoremthong (3.5 mg/l) & Singda Dam (3.9 mg/l); River Imphal at Kangla Moat & River Wangjing at Wangjing Thoubal (2.9 mg/l); River Iril at Lilong (3.1 mg/l) and River Lokchao at Bishnupur (3.7 mg/l) in Manipur.

High BOD values were observed in river water samples of R.Nambul collected at Hump Bridge (19 mg/L), and Heirangoithong (11.1 mg/l) in Manipur. In Meghalaya, Rivers Umatrew at Byrnihat east and River Kharkhla at Jaintia Hills had high BOD values of 8.5 mg/L and 7.8 mg/L respectively. Tripura had high BOD values for River Haora at Chandrapur (4.8 mg/L) and River Gumti (3.8 mg/L) at South Tripura[5]. In the 2012 report (CPCB , 2012) high BOD values were reported for River Nambul at various locations such as at Bishnupur, Heirangoithong, Hump Bridge, Singda Dam, Naoremthong and Samusang with the highest BOD values of 167.1 mg/L at Bishnupur. BOD levels in Nambul improved with levels for Hump bridge being6.0 mg/L and Heirangoithong being 6.2 in 2019 (CPCB. 2019a) . In Manipur , River Imphal at Kangla Moat; River Iril at Lilong River Barak at Senapati River Thoubal Litan, Yaripok and Phadom at Litan ; River Maha at Chandel, River Manipur at Sekmaijan had far lower BOD values. In Meghalaya, BOD values at River Umtrew at Byrnihat East and River Kharkhala at Jaintia Hills was in the range of of 7.5 to 8.8 mg/L. In Tripura, River Haora and River Gumti had low BOD value like 2010 (CPCB, 2012). BOD level decreased to 5.8 for River Umtrew at Byrnihat East in 2019 (CPCB, 2019a) For Rivers Haora and Gumti BOD values ranged between 2.5-3.8 and 1.9-2.9 respectively in 2019 (CPCB, 2019b). As per standard, unpolluted rivers should have a BOD below 1 mg/L, moderately polluted rivers between 2 to 8 mg/L, untreated sewage between 200 and 600 mg/L and treated waste water/municipal sewage should have 20 mg/L or less. Industrial activities also require large amount of freshwater. CPCB(2010) reported that due to industrialization and urbanization, the total water requirement by 2025 for industrial use is estimated to rise to 191 bcm (18% of the total requirement). Poor environmental management systems in several industries such as thermal power stations, chemicals, leather processing, sugar mills have resulted in the discharge of waste water containing toxic metals and organics, polluting both surface and groundwater (CPCB,2010). Mining is one of the industrial activities that causes significant water pollution. Mining contributes to the economic development of the country, but at the same time has a deteriorating effect on the environment (Tiwary, 2001). Opencast and underground coal mining methods result in discharging huge amount of mine water which might be acidic or neutral depending on the pyrite content in the coal and inorganic impurities. Acid mine drainage lowers the pH of the surrounding water resources and also increases the amount of total suspended solids, total dissolved solids and heavy metals in coal mining areas of Arunachal Pradesh, Assam and Meghalaya. Moreover leachate water from overburden dump contains significant concentration of Fe, Copper (Cu), Manganese (Mn), and Nickel (Ni) (Tiwary, 2001). Impact of coal mining on water quality has been extensively studied by Swer and Singh (2004 a,b) and SoE (2009). In the "rat-hole" mining method, coal piled on the sides of the roads around mining areas becomes a major source of water and soil pollution. Similar to coal mining, limestone mining in several NE states causes water pollution in the nearby areas (Upadhyay *et al*., 2018). Eugene and Singh (2014) conducted a study on the degradation of water quality as a result of limestone mining in the East Jaintia Hills, Meghalaya. Analysis of water samples collected from locations near limestone quarries and cement plants indicated that pH, EC, TDS, total hardness, alkalinity, Calcium, and Sulphate concentration was high (Eugene and Singh, 2014) . Impacts of mining become aggravated in NE areas, since rivers are mostly rain fed and there is acute shortage of potable water in summer months.

Industrial pollution has been affecting all components of ecosystem including human and wildlife. There is strong reaction among people and Hon'ble Supreme Court of India and NGT have been giving series of judgments and directions to control river pollution, urban pollution and industrial pollution in various parts of the country. Industrial development must integrate environmental concerns with productivity and with equal emphasis on sustainable resource utilisation and production. The prime objective, especially in large and medium industries, should be to control water pollution and carry out water treatment and recycling that may help water conservation and management. Mapping of pollution routes and discharge points, identification and characterization of pollutants will help controlling water borne diseases. There is lack of proper data on the actual extent of pollution. Further, hazard identification and risk assessment and water balance study may help industries to save water and to that extent control of water pollution. The industrial discharges are regulated under various provisions of Acts & Rules. There are industry specific and general standards for effluent discharges and the industries are to comply with these discharge parameters and ensure the water quality for healthy living. The general standards are applicable for all industries, operations or processes other than those industries, operations or process for which standards have been specified in Schedule of the Environment (Protection) Rules, 1989.

Legislative support and action

Legislations: Under the Constitutional provisions of India, Article 48A imposes duty on each state to 'protect and improve the environment and to safeguard the forests and wildlife of the country'. The Article 51A (g) imposes a duty on every citizen 'to protect and improve the natural environment including forests, lakes, rivers, and wildlife'. Reference to the environment has also been made in the Directive Principles of State Policy as well as the Fundamental Rights. The Environment (Protection) Act 1986 which came into force soon after the Bhopal Gas Tragedy is considered an umbrella legislation as it fills many gaps in the existing laws. It empowers the central government to protect and improve environmental quality, control and reduce pollution from all sources, and prohibit or restrict the setting and /or operation of any industrial facility on environmental grounds. The Environment (Protection) Rules 1986 lay down procedures for setting standards of emission or discharge of environmental pollutants. The Water (Prevention and Control of Pollution) Act (1974) establishes an institutional structure for preventing and abating water pollution. Polluting industries must seek permission to discharge waste into effluent bodies. The CPCB (Central Pollution Control Board) and State Pollution Control Board were constituted under this Act and have been delegated with powers to take appropriate action for prevention and control of pollution. The other old Acts like, The Easement Act (1882) allows private rights to use a resource that is, groundwater, by viewing it as an attachment to the land. It also states that all surface water belongs to the state and is a state property. The Indian Fisheries Act (1897) imposes penal offences whereby the government can sue any person who uses dynamite or other explosive substance in any way (whether coastal or inland) with intent to catch or destroy any fish or poison fish in order to kill. The River Boards Act (1956) enables the states to enrol the central government in setting up an Advisory River Board to resolve issues in inter-state cooperation. The Merchant Shipping Act (1970) aims to deal with waste arising from ships along the coastal areas within a specified radius.

The policy statement for Abatement of Pollution (1992) aims at developing legislation and regulation, fiscal incentives, voluntary agreements, educational programmes and information campaigns. The policy stresses on the need of certain framework such as preventing pollution at the source, best applicable solution, polluters' pay for pollution, focus on highly contaminated areas and river stretches and decision making should involve public. The National Environment Policy (2006) aims at integrating environmental concerns with all sectors of development for a sustainable growth in the country. Legislative tools must ensure that the people are educated and made aware of the importance of water-quality and they must understand the dangers of its excessive use and discharge which ultimately contaminate the ecosystem. The decline in water-quality will substantially damage public health and the well-being of communities. These Legislations may initiate an approach of providing incentives to industries and other such organizations which take measures for conservation of water resources like rain water harvesting, recirculation of treated industrial wastewater for reuse, community tanks for recharging of ground water, etc. Given the severity of water scarcity along with depleting water quality conditions, challenges for better management of the water is expected to become more evident in the future. CPCB (2010) has defined the challenges under the following broad areas: 1) Reuse and recycling of waste water, 2) Increasing efficiencies and diminishing loses, 3) removal and treatment of water pollution, and 4) recharging groundwater aquifers.

Water pollution should be controlled with the help of regulatory laws and policies along with monitoring processes. Industries should maintain "zero discharge" status with the help of state of the art technology for water treatment and fully adopt reuse and recycling of wastewater. Industries should be provided with incentives who promote waste water reuse and recycling. Industries not installing ETPs should be asked to provide a time line for instalment of ETP by regulators for the treatment of effluents. Regulations on the abstraction of water from the ground and discharge of industrial wastewater should be strengthened (CPCB, 2010; CPCB 2008b). To achieve this, guidelines have to be maintained and strict vigilance should be adopted along with charges imposed on residual pollution to encourage recycling and reuse of effluents and adoption of zero discharge (CPCB, 2008). As mentioned above, industries should construct rainwater harvesting structures for the recharging of the ground water in consultation with central or state ground water authorities and the water collected in the harvesting pond can be used for other purposes such as makeup water during operations of the plant in some industries.

There is strong need to strictly bring the housing societies and housing complexes, big hotels etc, to adopt appropriate on-site waste water treatment facilities for recycling of wastewater for gardening and other non-domestic uses. Domestic and industrial water-use practices must make efforts to reduce wastewater volume and load. The cost of waste management should be borne by impact creators which include urban population and industries, according to the "polluter pays principle". This will serve the purpose of water recycling and reuse adoption systems, minimization or elimination of waste products and also provide revenue to finance waste water treatment investments (CPCB, 2008b). North East is still undergoing industrialization. As part of corporate social responsibility (CSR), industrial enterprises should spend a certain amount of money towards socially beneficial projects. Industries should partner with local authorities, gram panchayats, NGOs, and identify projects and implement strategies and set up measurable physical targets, with an objective to provide safe potable drinking water and to bring an overall improvement in the quality of life of the rural people (MDWS, 2012). Other objectives include conservation, recharging and sustainability measures with regards to drinking water in the rural areas and improvement of conditions of weaker sections of the society and SC/STs. The activities that may be included as part of CSR could be 1) supply of piped water to household., 2) construction of centralized / on site water treatment plants with the option that the maintenance is carried by the industry for at least 5 years in rural and semi urban areas, 3) monitoring of the presence of heavy metals, etc. in raw source water and in treated water by setting up testing labs etc (MDWS, 2012).

The Way Forward: Groundwater is a major source of water on the planet which is emerging as a critical issue for cities and towns around the world. Sustainable and equitable use of GW has to be ensured for water availability through water conservation technologies, improved agricultural systems and cropping patterns adapted to different climatic zones, and conservation-based life styles. The very concept of sustainability is challenged by the recent trends of over exploitation of the water resources leading to the most extreme water deficient situations in the world. Demand management and common approach of augmenting supply along with legislations and policy measures must be applied for efficient and cost-effective use of water by agriculturists, industry and households. Further, exploring options for recharging the aquifer, rainwater harvesting, storage and recharge / recycling waste water for industrial use and desalination must be considered to augment water resources. Areas with declining GW level, pollution, salinity hazards, etc. in NE region should immediately be taken up by authorities to evolve district-wise groundwater planning and management programmes. Apart from this challenging problem to control the depletion of GW, more emphasis needs to be given for control of pollution of GW sources. The GW contamination is posing severe health hazards in many areas in NE region. The data collected by CGWB and others as discussed in the paper reveal that GW is contaminated with high As, Fe, F in many districts of the NE region states.

The pollution of drinking water sources needs to be immediately tackled. Participation of local voluntary organizations, the district authorities and village panchayats will help CGWA to identify and map the problem areas and to take appropriate action for management of groundwater development. All development projects like industries, mining and housing in the NE region may be prohibited to harvest groundwater resources from critical areas. All industrial discharges must meet the prescribed norms. Zero effluent discharge from industries and surface water harvesting must be made mandatory in these areas. All concerned urban authorities should enforce Rain Water Harvesting and Recharge schemes for housing projects. The problem of GW depletion and pollution can be controlled with the help of the public and with strict enforcement of legal instruments. Severe penalty for defaulters and incentives for those who care and conserve the natural resources will be an effective approach. Long term plan for control and management of rainwater, surface water, and GW and appropriate measures to conserve soil moisture to increase water availability to crops is required to meet the demand of human population, agriculture and industries by using efficient technologies and the best practices. Present situation of water pollution in NE states requires immediate improvement on all the fronts of water quality issues, with good management practices and solutions. Through various regulations and policies, more stringent penalties can be enforced on violators and incentives can be provided to industries which include schemes for drinking water supply to communities, water recharge and harvesting under the CSR activities.

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