Exploration of Contamination in Groundwater of West Bengal State in India to Achieve Water Security: A Review

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Abstract:- West Bengal relies heavily on ground water for both agricultural activities and drinking purposes. Despite the fact that the state has decent ground water potential, recent unrestricted ground water use has led to overharvesting in certain areas. Because of this overconsumption, the suitability of groundwater is deteriorating due to the contamination from nearby aquifer rocks with natural pollutants such as arsenic, fluoride, and nitrate, among others. The purpose of this systematic overview is to gain a better understanding of the state's overall groundwater resources, with a focus on abundance, contamination, source of information, and remedial actions in the current scenario, using a range of scientific reports, academic papers, and case analysis. To achieve the water security goal in West Bengal, particularly in villages and developing areas, the identification of clean and pure and ecologically sustainable water resources is critical, and this retrospective study will assist in that endeavour.

Keywords:- *West Bengal, Groundwater, Contamination, Mitigation, Water Quality Parameters*

I. INTRODUCTION

Agriculture dominates the economy of West Bengal and it mainly depends on groundwater in the dry season. The superiority of groundwater is influenced by numerous reasons such as the quality of recharge water, composition of soils, rocks and interaction of them with groundwater, the reactions and the time of residence within the aquifer [1]. Except those, various anthropogenic activities are the main devil of quick deterioration of groundwater. India contains 15% of the global population but holds only 4 % of the total global freshwater reserve and several areas of India do not have adequate fresh and safe drinking water [2]. Nowadays groundwater contamination has become a significant concern predominantly in rural parts in India where people are fully bent on undergroundwater for domestic and drinking purposes [3]. The supply of fresh water per inhabitant in India is decreasing as the population grows and the amount of fresh water decreases. In 2001 and 2011, the average annual per capita water availability in India was already estimated to be 1816 m^3 and 1545 m^3, respectively, and this figure is expected to fall to 1486 m^3 and 1367 m^3 in 2021 and 2031, respectively [4, 5]. Groundwater overexploitation, contamination and pollution is now a serious problem in the developing and undeveloped countries such as India, Bangladesh, and Pakistan etc. because the countries have an enormous population, unscientific agricultural systems, lack of scientific awareness in withdrawal of underground water, lack of waste management etc. and hence they do not have access to hygienic potable water, suffer frequently from various water related diseases. [6]. Almost 71% of the surface of our planet is covered by water but we are facing problems due to quality issues. Due to insufficient source of surface water, the quick growth of population, urbanization, increase of agricultural activities and industrialization, there has been a remarkable growth in the demand of underground water resources as fresh pure water [7]. In general, groundwater in India has been secured and potable for drinking as well as all other living human requirements for many years, but it is now degraded due to a myriad of factors [8]. Hence suitable treatment is necessary now before use of the groundwater especially for drinking purposes in some parts of the country.

In West Bengal, underground water is also the primary supply of drinking and other domestic purposes. There are huge water resources but quality is in crisis in West Bengal. Accessibility of underground water in some areas of the state (Birbhum, Purulia and Bankura district) is declining and the societies in that parts have been facing tremendous scarcity of water in the summer season [9, 10]. These days, there is a shortage of acceptable quality portable water in coastal, industrial, and mining locations. Rainfall is sufficient and retention capacity of water in soil in the major areas of the state are good but nonstop withdrawal of water fro underground for drinking, domestic and agriculture etc. uses is affecting the quick drop of storage of underground water [11]. Groundwater is primarily used for drinking purposes, with a small fraction used for irrigation, industrialization, and other limited purposes [10, 12]. Chemical

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pollutants such as arsenic, nitrate, fluoride and other contaminants make groundwater unfit for human consumption in some areas of West Bengal state [6, 13, 14, 15, 16]. Extensive irrigation, fast growth of industries and huge population have made stress in the storage of underground water of West Bengal [17].

The state is covered by mainly cultivated land, some forests and few hill areas. Agriculture is one of the most significant means to earn livelihood and major rural populations are engaged in cultivation and other agricultural activities in West Bengal. Huge amounts agricultural wastes, pesticides and fertilizers used in agriculture seriously affected the groundwater and surface water in the state [18].So, me industries such as coal mines, jute industries, thermal power plant, textile industries, steel plant and small industries etc. are located in the state and water in the areas is heavily contaminated due to wastes of the industries [19, 20]. Underprivileged people in various companies and industries and mining zones suffer immensely from a non - availability of drinkable water because water in those areas is easily polluted as a consequence of multiple mining and industrial functions such as deforestation, land degradation, mine water discharge, waste disposal, reject washing, coal washing, and so on. Since the survival of our world is in jeopardy, water is no longer a state "issue." To address the current and future water difficulties, as well as related concerns affecting our society, economy, and environment, a multilevel and multidimensional strategy should be implemented. Major peoples in India don't know how to save water, how to clean water, how to improve water quality, how to reuse water and how to manage wastes [12]. Therefore proper awareness, proper education, systematic assessment, proper waste management and monitoring of quality of underground water are urgently necessary to save water.

The measurement of the biological, chemical and physical parameters of water in respect to accepted quality, human consequences, and intended uses can be defined as water quality monitoring and assessment [21]. The quality of groundwater may be influenced by the improper removal of liquid wastes, dumping of solid wastes, the depth of underground water and the character of the geographical elements with which the water in underground comes into contact [22]. In India, a massive community consciousness campaign and water strategy should be launched to raise knowledge about rainwater harvesting and water conservation among residents, among other things.

This article intends to highlight water-related challenges in West Bengal in the perspective of sustainable developments, as well as to examine current policies, strategies, performance, current conditions of groundwater contamination, cause of contamination and level of quality in West Bengal.

II. STUDY AREA

The underground water in the state of West Bengal has been selected as the focus of our research (Fig. 1). The study area is situated in India's eastern region. It shares its border with the country of Bhutan and the state of Sikkim to the north side, the state of Assam to the northeast side, the country of Nepal to the northwest side, the state of Odisha to the northwest side, the state of Bihar and Jharkhand to the west side, the Bay of Bengal to the south side and the country of Bangladesh to the east side.

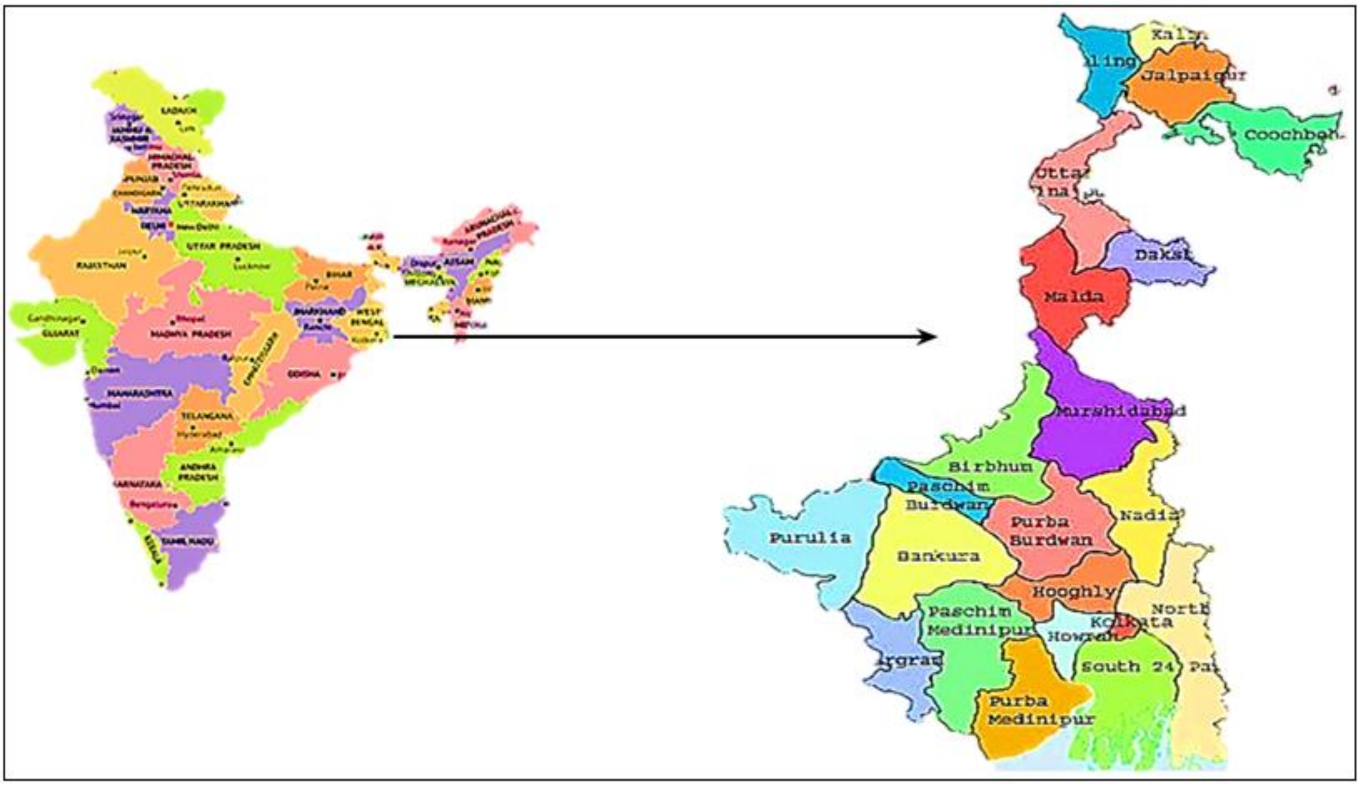

Fig. 1 West Bengal State (with District) in India.

In India, it is the fourteen biggest state by area but fourth-most populous state and second- most populous by density. The state has 23 districts, 341 blocks, 66 sub-division, 120 municipalities' and 37945 villages. West Bengal state has an area of 88,752 square kilometres (34,267 square miles) and it lies between latitude 21º 25′ 00″ N and 27º 13′ 00″ N and longitude 85º 50′ 00″ E and 89º 50 ′ 00′ E [23]. As per the 2011 census, the entire population was 91,276,115, with 46,809,027 males and 44,467,088 females [24]. Huge geographical diversity is shown in the state. Bengal acts as a link between the Himalayas and the Bay of Bengal. North Bengal's hills are separated from the Ganges delta plain in the south by the narrow Terai area. The Rarh region, while on the other hand, separates the Ganges delta in the east from the western plateau and highlands in the west. The plain area of the Ganges delta contains fertile alluvial soil which is placed by the River Ganges and its distributaries and tributaries. The plain's topography gradually rises toward the state's western border. The southern part of the state is bounded by the Bay of Bengal's coastal region, which includes the Sundarbans mangrove ecosystems, which serve as a geographical landmark. The highest peak in the state is Sandakphu (3,636 meter or 11,929 foot) [23].

The climate of West Bengal differs between subtropical humid in the north side and wet-dry tropical in the southern portion. Seasons which are observed clearly in the state are rainy season, summer, a short autumn, winter and a short spring. In summer the western part of the state experiences dry heat while the delta part exhibits humidity. The average temperature of west Bengal usually varies from 45 °C (113 °F) in summer to 15 °C (59 °F) in winter [23, 25]. In summer, 'Kalbaisakhi' (brief storms or thunderstorms) are frequently observed in the state. The rainy season (June to September) arrives mostly from the southeast to the northwest. The state's annual rainfall ranges from 123.4 to 413.6 cm [23, 25]. Highest rainfall is observed in the northern Himalayan portion. Low pressure of Bay of Bengal favours formation of storms during these seasons. Cold weather (December–January) on the plains is pleasant, with minimum average temperatures of 15 °C while harsh winter with snowfall is observed in the Himalayan region.

The Ganges, which also moves through the state as the Bhagirathi River and the Hooghly River, is the state's single most important river. The rivers Teesta, Atryee, Jaldhaka, Torsa, Mahananda, Nagor, Punorbhova, Tangon and others flow through the state. The main rivers in the western plateau area in the state are the Damodar, Dwaraka, Kangsabati, Ajay and Bharbhoni. There are so many rivers and creeks in the Sundarbans and Ganges delta location.

More than one-tenth of the state's total geographical region is occupied by forests and jungles. Soil in the state is fertile for plants and agriculture. Huge variety of plants and trees are observed in the state. Hugli River's delta establishes the western end of the 'Sundarbans' (National Park, coastal mangrove forest, UNESCO World Heritage site). 'Gorumara' National Park, 'Sundarbans' National Park, 'Singalila' National Park, 'Neora Valley' National Park and 'Buxa Tiger Reserve' are famous among the five national parks and the fifteen wildlife sanctuaries within the state. Industries in the state are mainly located in Kolkata region (along the Hugli River), Burdwan region (along the Damodar River) and Haldia region (petrochemical industry, cotton textiles, paper, jute, ships, automobiles, thermal power plant, chemicals, fertilisers, waggons, electronics and others). Except that tea production is famous in north Bengal (Darjeeling) region.

III. WATER SCENARIO WITH THE AID OF SCIENTIFIC JOURNALS

In the present study for the review of groundwater contamination in West Bengal numerous famous national and international research journals have been reported to evaluate the present condition of groundwater of the state.

D. Saha et al (2021) [4] studied groundwater quality in Cooch Behar district. They used AHP and GIS Techniques to identify the future vulnerability of groundwater in the terms of groundwater level, potentiality and consumption in the district. They found that seven blocks in the district are not highly vulnerable, although the remaining five blocks are very much vulnerable. **A. Das (2020)** [13] published the results of a hydro-geochemical investigation of a shallow aquifer in Chakdah, Nadia district. They discovered that shallow aquifers (50 m) are frequently polluted with arsenic, whereas greater depth aquifers (>100 m) are rather arsenic-free. **B. P. Mukhopadhyay et al (2020)** [6] studied the quality of underground water and its effect on public health in the Murshidabad district. They showed that few places in the district have exceeded the concentration of Fe and As than the standard values. Magnesium bicarbonate type of water is predominating in those areas. In the Khoyrasole Block of Birbhum district**, S. K. Nag and S. Das (2020)** [3] looked into the groundwater quality. In the study they observed high to very high levels of iron (67% of the samples) and fluoride (53% of the samples). They showed that the groundwater is suitable for irrigation based upon SAR, MAR, PI and Chloro-Alkaline Indices. **S. C. Pal et al (2020)** [12] used the geospatial techniques to explore potentiality of underground water in the Purba Bardhaman district. They classified the district into five classes potential zones (very high, medium, low, high, and very low) of underground water account for 21.54 percent, 35.80 percent, 26.47 percent, 10.13 percent, and 6.06 percent of the total area, respectively. **D. Sukumaran et al (2015)** [26] evaluated groundwater quality Index of Howrah City. Consecutive studies on ground water of that area in 2012 and 2013 concluded the water quality as "nearing to poor" and "excellent" based on Water Quality Index (WQI) based but not suitable for drinking in terms of *fecal coliform* concentration. Alkalinity, Cl^-, TDS, and NO_3^- concentrations were observed to be higher than the standard range for drinking water in some stations. **S.K. Das and R.K. Das (2020)** [27] conducted a study on fluoride contamination in underground water of Tapan block, Uttar Dinajpur. They observed that all parameters were within the range of BIS except fluoride. The study observed that 18 % of the total water samples were high fluoride, and exceeded the permissible range (> 1.5 mg/l) as per WHO and BIS. The study also evaluated water types of the concern zone and probable geogenic source of contamination of fluoride. **P. Pattnaik and P. K. Bhowmick (2020)** [28] reported contamination of arsenic in Basirhat-1 Block, North 24 Parganas district. Water Quality Index (WQI) of that zone evaluated the unsuitability of water for direct drinking. Arsenic concentration was observed to be 24 to 4 times greater than the acceptable range. The Hazard Quotient (HQ) was determined and it was found between 2 and 9, indicating a potentially vulnerable health hazard owing to non-carcinogenic effect of arsenic. The study captures an even more worrisome scene of the area, with 1 to 4 people per 1000 people in the block at risk of cancer due to poisoning of arsenic. **N. Das et al (2019)** [18] reported a study on groundwater quality in Birbhum district. The result of Principal Component analysis showed that it extracts 5 main factors accounting for 80 perent of the total variance, with F^- being the 1st factor extracted because fluoride concentration was high in the district. Using the Wilcox diagram, they discovered that approximately 50% of the samples out of a total sample were characterised as excellent to good, the remaining 25% as good to permissible, 20% as permissible to doubtful, and 5% as doubtful to unsuitable. Gibbs diagram displayed sixty eight percent samples fitting to the class of rock dominance and the rest tirty two percent in precipitation dominance class. **A. Kundu and S. K. Nag (2018)** [29] reported groundwater quality in Kashipur Block of Purulia district. Typically the nature of the underground water of the block is acidic. **Raju Thapa et al (2018)** [9] published an article on sensitivity analysis in vulnerability zones in India's Birbhum district. According to the sensitivity analysis the study clearly revealed the vulnerability index which is mostly influenced by the net recharge of the groundwater. **A. Chowdhury (2017)** [30] used an Artificial Neural Network (ANN) to investigate Total Dissolved Solid (TDS) in underground water in Nadia district. **S. K. Nag and S. Das (2017)** [10] assessed the quality of underground water in Bankura I and II block of the district Bankura. The discovered result in the study were pH (6.4 to 8.6), total hardness (30 to 730 mg/l), electrical conductivity (80 to 1900 μS/cm), TDS (48 to 1001 mg/l), Iron (0 to 2.53 mg/l), HCO_3^- (48.8 to 1000.4 mg/l), Ca^{2+} (4.2 to 222.6 mg/l), Cl^- (5.6 to 459.86 mg/l) and SO_4^{2-} (0 to 99.03 mg/l). The results showed that the underground water is good for drinking as well as irrigation purpose. **P. Sahu et al. (2016)** [15] investigated the geochemistry of underground water in the Southern Bengal basin. They classified the aquifers into three categories: 'excellent,' 'good,' and 'poor.' Three broad types ('fresh', 'brackish' and 'mixed') hydro chemical facies of the underground waters are observed. They demonstrated that the abundance of key ions in groundwater is caused by percolating water of weathering feldspathic and ferromagnesian minerals. Arsenic pollution is reported in Rajarhat New Town and adjacent regions of West Bengal. **S. K Nag and B. Suchetana (2016)** [31] reported a study on groundwater quality in Rajnagar Block, Birbhum district. Sulphate concentration levels were beyond the allowable level. The water was bicarbonate type and 'Water Quality Index' displays that seventy five percent of pre-monsoon water samples are 'extremely good' to 'good' for drinking, while the value drops to fifty six percent after the monsoon. The computed values of Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC) and Sodium Adsorption Ratio (SAR) suggested a water range that is suitable for cultivation. **A. Gayen (2015)** [32] studied groundwater in the fluoride affected alluvial track of South Dinajpur district. F was found sporadically in the tube wells, and the F concentration in groundwater increased with depth in those sampling sites. The F concentration of the medium duty hand pump fitted tube well in the tract is greater than 5mg/l, whereas the F concentration of the greater depth aquifer is greater. **A. K. Batabyal and S. Chakraborty (2015)** [1] conducted a study on hydrogeochemical analysis and groundwater quality in Bardhaman district. The hydro geochemistry based on Piper diagram of the groundwater publicized that the water falls in the category of Ca-Mg-HCO_3 type (28.5%) both seasons (pre- and post-monsoon) and other were Ca-Mg-Na-HCO_3 type (10.7%), Ca-Na-Mg-HCO_3 Type (17.8%), Ca-HCO_3 (10.7%) type and Ca-Na-HCO_3-Cl (14.3%) type. They found the ground water is excellent for irrigation. **K. Das et al (2015)** [16] investigated fluoride in groundwater of South Dinajpur and Malda district. They observed that 7.90% of the sample displayed high fluoride i.e.; beyond the range of WHO standard. They also disclosed that the fluoride ions showed (+ve) correlation with sodium ions and (-ve) correlation with calcium ions on the basis of multiple linear regression model, correlation study and factor analysis. Piper diagram revealed that the water was with Na-HCO_3 rich. **S. Patra et al (2015)** [33] studied quantitative analysis of groundwater of Hooghly district. To assess the district's groundwater status, different aquifers maps and statistical methods such as standard deviation, groundwater storage change, and so on were used. The investigation demonstrated that different Hooghly district blocks such as Pandua, Chanditala-II, Balagrah, Haripal, Singur, and Chanditala-I and Tarekeswar have a high decline tendency of average static level of underground water in post and pre-monsoon. **N. Singh et al. (2014)** [7] investigated hydrogeochemistry and underground water characteristics in the 24-Parganas district. They used Schoellerand Durov diagrams which indicated calcium, magnesium and bicarbonate as predominant ions. Saturation index was also calculated and they observed that water is oversaturated with iron, while under saturated with anhydrite and gypsum. They revealed that the underground water was not fit for intake and it can be used for domestic and irrigation purposes. **S. K. Nag and S. Das (2014**) [17] investigated the quality of underground water in Suri Blocks (I and II), Birbhum. The water was found to be abstemiously appropriate for irrigation. Extremely high RSC values for about eighty percent of samples in the post-monsoon session imply an alkaline threat to the soil. Piper's tri linear diagram showed that the water was HCO_3 type (fresh type). Water Quality Index outcomes displayed that ninety percent of the water are fit for consumption during the post-monsoon season, while sixty percent are unsafe for drinking during the pre-monsoon. The groundwater quality of Gangajalghanti Block, Bankura district has been reported by **S. K. Nag (2014)** [22]. All the chemical constituents of the groundwater have been found well within limit and hence fit for irrigation and drinking purposes. **D. Kar et al (2011)** [20] reported the water quality of Durgapur Industrial Belt, West Bengal. They investigated the correlation between the density and abundance of chironomid population with physico-chemical parameters of water. The investigation discovered that chironomid larvae were plentiful in site IV during the study period. TDS, phosphate, nitrate, water and air temperature, humidity, conductivity, light intensity, total alkalinity, hardness, chloride, dissolved oxygen value disclosed substantial seasonal variation among the four studied sites during the study. **S. Chakraborty and P. K. Sikdar (2011)** [11] studied on Arseniferous Aquifer of groundwater of the of English Bazar Block, Malda District. Apart from a few regions where levels of As exceed the acceptable range of 0.05 mg/l, mostly in tube wells tapping the aquifer at depths ranging from 15 to 57 metres, groundwater in this block is suitable for drinking as well as agricultural use. There had been eleven villages where the groundwater contained high levels of arsenic, twelve villages where more than half of the groundwater contained arsenic, and the remaining villages where the entire aquifer could be tapped for household, industrial, and irrigation activities. **M. K. Jha et al (2010)** [34] conducted a study on groundwater in Salboni block, Paschim Medinipur district using multi-criteria decision analysis, GIS, and remote sensing techniques. The potential zone map of the underground water in the study showed that the ‘poor’ zone covered 27.53 percent, the ‘good’ zone 27.14 percent, the ‘moderate’ zone 45.33 percent of the area. **T. Roychowdhury (2010)** [35] investigated the contamination of arsenic in underground water in Gaighata block in North 24 Parganas district. Groundwater in all the one hundred seven mouzas over thirteen gram-panchayats in the block holds arsenic beyond 0.01 ppm and in ninety one mouzas, arsenic has been observed beyond 0.05 ppm. About 59.2 percent and 40.3 percent of the groundwater samples hold arsenic above 0.01 ppm and 0.05 ppm, respectively. About 106560 and 72540 populations were drinking arsenic-contaminated water higher than 0.01 ppm and 0.05 ppm, respectively. **B. Purkaitand and A. Mukherjee (2008)** [36] also conducted a study on arsenic contamination in underground water of district Malda. They detected that extreme concentration of arsenic beyond the permissible range arises within 10 to 30 m depth. The average arsenic concentration of Kaliachak-1, Kaliachak-2, Kaliachak-3 and English Bazar block were l0.2253 ppm, 0.1923 ppm, 0.1755 ppm, 0.1324 ppm respectively. S. **C. Mukherjee et al. (2005)** [37] investigated the serious nature of chronic arsenic exposure-related health consequences in the Murshidabad district. They inspected 25,274 persons from one hundred thirty nine rural arsenic-affected villages in distrit Murshidabad for evidence of multi systemic features and acquired biological specimens only from the sick people, including head hair, nail, and spot urine, as well as the tube - wells water they were drinking. Out of the 25,274 persons who were checked, 4813 (19%) had arsenical skin lesions. About 2595 children were tested for arsenical skin lesions but 122 (4%) had arsenical skin lesions.

IV. GEOLOGY OF WEST BENGAL

Huge variations in geology are found in West Bengal. Miscellaneous rock types are originated in the state varying from the archaeanmetamorphites to the quaternary unconsolidated deposits [38]. An approximately major portion of the state is occupied by sub – Recent to Recent alluvial and deltaic deposits, while the remainder is typically covered by a diverse range of hard rocks.

The following are the three physiographic units that make up the state.

- North region is ‘Extra – peninsular’.
- South – West region is ‘Peninsular masses’.
- East and South region are ‘Alluvial and deltaic plains’.

V. HYDROGEOLOGY OF WEST BENGAL

The state is covered by two hydrogeological broad units viz., (A) porous formation unit and (B) fissured formation unit [38].

- *Porous Formation:*

A thick pile of sediments covered by the river Ganga-Brahmaputra system which occupied nearly two-thirds of the state. These sediments is unconsolidated which are composed of a succession of Quaternary clay, gravel overlying Mio-Pliocene sediments, sand and silt. Recent and Older Alluvium make up the Quaternary sediments. The primary porosities of the sediments regulate the movement and occurrence of underground water in the hydrogeological unit. The weathered zone is usually between 10 and 25 metres thick, but it can be over 35 metres thick in isolated patches. The weathered zone is the primary reservoir of underground water, and the fractures beneath the weathered zones form the potential phreatic aquifer.

- *Fissured Formation:*

Proterozoic schists and gneisses, Siwalik rocks of Extra-Peninsular and younger gondawanas supergroup regions in the district of Jalpaiguri and Darjeeling to the north side and Archaean to schists in Peninsular and Proterozoic gneisses section covering in western side of Birbhum district, Burdwan district, Bankura district, and northern side of Medinipur district and entire district of Purulia. The Purana deposits, younger Gondwana and Rajmahal basaltic tracts in the eastern area of the state which fall under fissured formation. Movement and occurrence of underground water in this fissured formation is covered by the three zones viz., zone ‘Saprolitic’, ‘Weathered Mantle’ zone and ‘Secondary porosity’ zone.

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VI. GROUND WATER LEVEL

The recorded groundwater level (depth) is broadly classified into four classes: >10, 10 – 5 m, 5 – 2 m and 2 - 0 m. The underground water depth in the West Bengal state varies medium ranges. Deepest water level (depth) has been recorded at Orgram (36.82 mbgl) in Paschim Bardwan district in pre-monsoon, at Bahari (32.7 mbgl) in Birbhum district in monsoon, at Bahari (32.61) in Birbhum district in post-monsoon. The details depths of groundwater in different seasons in the West Bengal state are given in fig. 2 [38].

Table 1 Range of Water Levels (Depths) in Different Season

Range of Water levels (m bgl)	Level of Groundwater (%) in Pre- Monsoon (April 2019)	Level of Groundwater (%) in Monsoon (August 2019)	Level of Groundwater (%) Post-Monsoon (November 2019)	Level of Groundwater (%) in Winter (January 2020)
0-2	9.9	25.1	21.3	8.8
2-5	28.4	32.8	44.0	45.5
5-10	39.9	23.5	19.7	27.4
10-20	18	15.7	11.8	14.6
>20	3.6	3.0	3.2	3.8

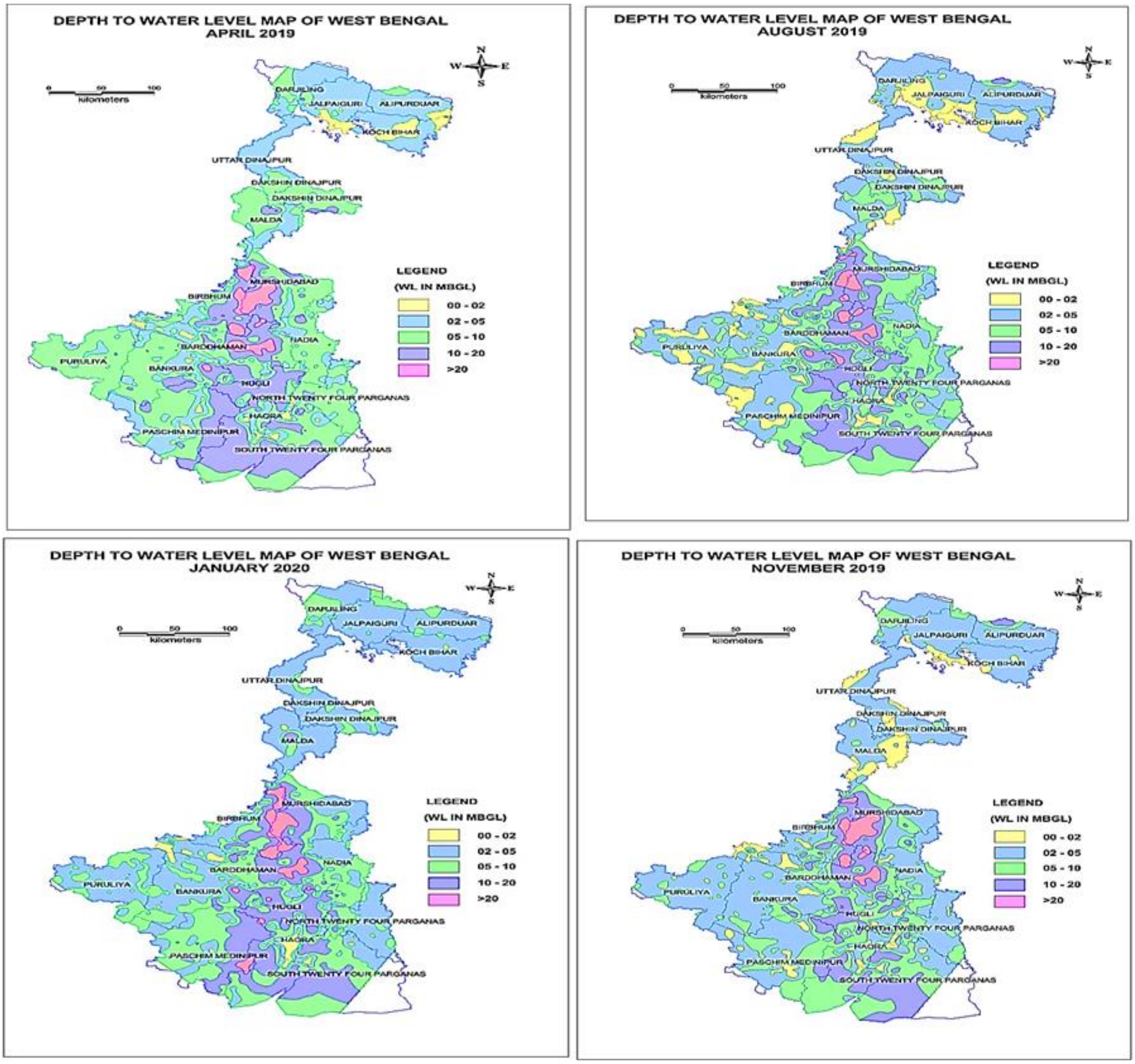

Fig 2 Groundwater Level (Depth) in the Pre Monsoon, Monsoon, Winter and Post Monsoon in West Bengal.

VII. FLUCTUATION OF GROUND WATER LEVEL

Fluctuation of underground water level (or depth) is one of the most important factors as the ground water quality is also dependent on it. Fluctuation of underground water level has occurred mainly due to overdraft of groundwater and amount of rainfall. It is the natural variations of underground water depth for a specific period compared to the depth throughout the similar month of the earlier year. It provides an indication about the alteration in the quantity of rainfall and draft of groundwater between the consecutive two years. The average fluctuation in depth of underground water from April in 2019 to April in 2020 was typically constrained within 0.0 meter to 2.0 meters (54%) which specifies that the state's regional fluctuation of underground water depth is primarily controlled within 2 m. Seasonal fluctuation in depth between April and November in 2020 was controlled by rising patterns such as 0.0 meter to 2.0 meter (37.1 %) increasing category, followed by 2.0 meter to 4.0 meter (9.6%) and > 4.0 meter (4.4%) increasing category. However, sometimes fall in depth of underground water occurs but reduction of depth was typically controlled within 0.0 meter to 2.0 meter category (38.9%). Fluctuation in depth from April in 2020 to January in 2021 is typically controlled by increase in depth of water but the fluctuation is typically constrained within 2 meter (68%).

VIII. STATUS OF GROUND WATER

In West Bengal (based on GEC, 2015 methodology) the net groundwater availability (As on March-2017) was 39.64 BCM, total annual ground water recharge was 43.82 BCM, gross annual groundwater draft for all user was 19.94 BCM (18.74 BCM for irrigation, 0.79 BCM for domestic, 0.40 BCM for industries) [38].

IX. GROUND WATER QUALITY

The investigation of physiochemical properties is vital in order to obtain an accurate picture of water quality. The geochemistry of groundwater is primarily determined by factors such as the rock or soil through which water of rain percolates, the sedimentological history of the rock types, the chemical characteristics of the rock types, the climatic condition of the area, the role of human activities and the role of microorganisms. The values of different water quality parameters of underground water in West Bengal state [38] and standard values [39, 40] of the water quality parameters for drinking are given in Table 2.

Table 2 Ground Water Quality of West Bengal

Parameters	**Unit**	**BIS Standard (IS: 10500, 2012)**		**WHO Standard (2017)**		**Measured Values of the Parameters**	
		Acceptable Limit	**Permissible Limit**	**Acceptable Limit**	**Permissible Limit**	**Minimum Value**	**Maximum Value**
Temperature	^{0}C	-	-				
pH	-	6.5 - 8.5	-	7.0 - 8.5	-	5.99	9.7
Electrical conductivity	µs/cm	300	-	300	-	45.0	6315
TDS	mg/l	500	-	500	-	31.0	4041.6
Turbidity	NTU	10	25	10	25		
Total Hardness	mg/l	300	600	500	-	10.0	1610
Carbonate	mg/l					3.0-162	
Magnesium	mg/l	30	-	-	-	1.2	319.5
Chloride	mg/l	250	1000	200	600	1.1	1790.2
Copper	mg/l	0.05	-	1	-		
Fluoride	mg/l	1.5	1.9	1.0-1.5	-	0	6.1
Sodium	mg/l					1.0	652.8
Calcium	mg/l	75	200	-	-	2.0	166
Potassium	mg/l					0.2	390
Alkalinity	mg/l	200	600	100	-	65.0	1600
Sulphate	mg/l	200	400	200	400	0	299.9
Bicarbonate	mg/l					18.3	1952
Nitrate	mg/l	45.0	45.0			0	325.9
Iron	mg/l	0.3	1			0	46.5
Arsenic	mg/l	0.01	0.05	0.05	-	0	0.266
Uranium		0.03		0.03		0	0.034
Manganese		0.1	0.3			0	7.235
Copper		0.05	1.5			0	0.045
Zinc		5	15			0	35.923
Chromium		0.05				0	0.148
Lead		0.1				0	0.035

X. ASSESSMENT OF GROUND WATER QUALITY PARAMETERS

The quality of water and analysis of water quality is primarily depended on the chemistry of constituents in water. In today's world, examining the water quality before using it for any purpose is very important and necessary. The present study carefully explains the following essential water quality parameters of the groundwater and their analysed values in West Bengal.

- *Temperature:*

Many physical, biological and chemical characteristic of water are controlled by temperature diversely. The groundwater temperatures are influenced by some factors such as climate, topographic changes, depth of the water column and environment etc. The average temperature of west Bengal usually varied from 45 °C (113 °F) in summer season to 15 °C (59 °F) in winter season [38].

- *pH:*

The pH of water is an indicator to consider water quality. Typically it is a scale of 0 to 14 where 7 indicate neutral condition, > 7 indicates acidic condition and < 7 indicates basic condition of water. pH is buffered in natural water bodies. pH of ground water in West Bengal ranged from 5.99 (Votpatty, Baruapara, Jalpaiguri) to 9.73 (Balagarh, Hooghly) [38].

- *Electrical Conductivity:*

Electrical conductivity of water indicates the amount of ions or salts present within the water.

The electrical conductivity of underground water depends on minerals or salts presents, sewage or effluent or other pollutants mixing, erosion of specific geologic materials [41].The electrical conductivity in the underground water of the state varied from 45 µS/cm at 25°C (at Nagrakata in Jalpaiguri) to 6315µS/cm at 25°C (at Khanrapara in South 24 Parganas) [38].

- *Alkalinity:*

The existence of OH^-, HCO_3^- and CO_3^- ions in water are mainly accountable for alkalinity of water but other salts of weak acid such as phosphate, ammonium, borates, silicates and some organic bases are also accountable for total alkalinity of water. The total alkalinity as $CaCO_3$ in the underground water of the state varied from 15.0 to 1600 mg/l [38].

- *Total Hardness:*

It is an essential parameter for water of drinking, irrigation and industrial purposes. Carbonates, chlorides bicarbonates and sulphates salts of magnesium and calcium ions are chiefly responsible for hardness in water. Heart disease and kidney stones may occur due to high hardness in water. The total hardness in the underground water of the state varied from 10 to 1610 mg/ as $CaCO_3$ [38].

- *Calcium and Magnesium:*

Magnesium and calcium both are essential parameters for water investigation and monitoring of any water body. Hardness of water also depends on magnesium and calcium concentration. Magnesium and calcium in underground water ranges from 2 to 166 mg/l and 319.5 to 842 mg/l respectively [38].

- *Iron:*

Iron is a metal that is found in underground water as ferrous or ferric ions. Iron in water is not toxic but concentration above approved limit has some adversarial effect in plants, animals and human body. Maximum concentration (46.5 mg/l) was observed in Piariganj, Barddhaman District [38].

- *Total Dissolved Solid (TDS):*

Different ions, salts, materials and minerals etc. in water are cumulatively counted by the simple and easy parameter as Total Dissolved Solid (TDS) for various purposes. The TDS in underground water of West Bengal state varied from 31.0 to 4041.6 mg/l [38].

- *Carbonate:*

The concentration of carbonate ions is interrelated with alkalinity and pH of water. The occurrence of carbonates is showed when pH value of water touches to 8.3. Carbonates in water are converted into bicarbonates at lesser pH value than 8.3. The carbonate ion concentration in underground water of West Bengal varied from 3.0 to 162 mg/l [38].

- *Bicarbonate:*

Bicarbonates are one of the most abounded anions in freshwater. The bi-carbonate concentration varied in underground water of West Bengal state varied from 18.3 mg/l to 1952 mg/l [38].

- *Nitrate:*

Nitrate in underground water is an anthropogenic pollution indication. It [38] in West Bengal varied from 0 to 325.9 mg/l.

- *Chloride:*

Chloride ions are one of the maximum plentiful anion in natural water. Normally little presence of chloride ions are observed in natural water due to the salts dissolution but chloride ions are major as an ion in the sea water. The concentration of chloride ions in the underground water of West Bengal varied from 1.1 mg/l to 1790.2 mg/l [38].

- *Arsenic:*

Arsenic is extremely fatal and can arise a wide range of health problems and even cancer in human. The underground water of seven districts of the state viz. Howrah district, Malda district, N 24 Parganas district, Nadia district, Hugli district South 24 Parganas district and Murshidabad district were reported to have >0.01 mg/l arsenic. According to Mukhopadhyay et al, 2020 the Arsenic concentration varies from 0.009 ppm to 0.05 ppm in Mursidabad districts. The arsenic affected areas in West Bengal are shown [38] in fig. 3.

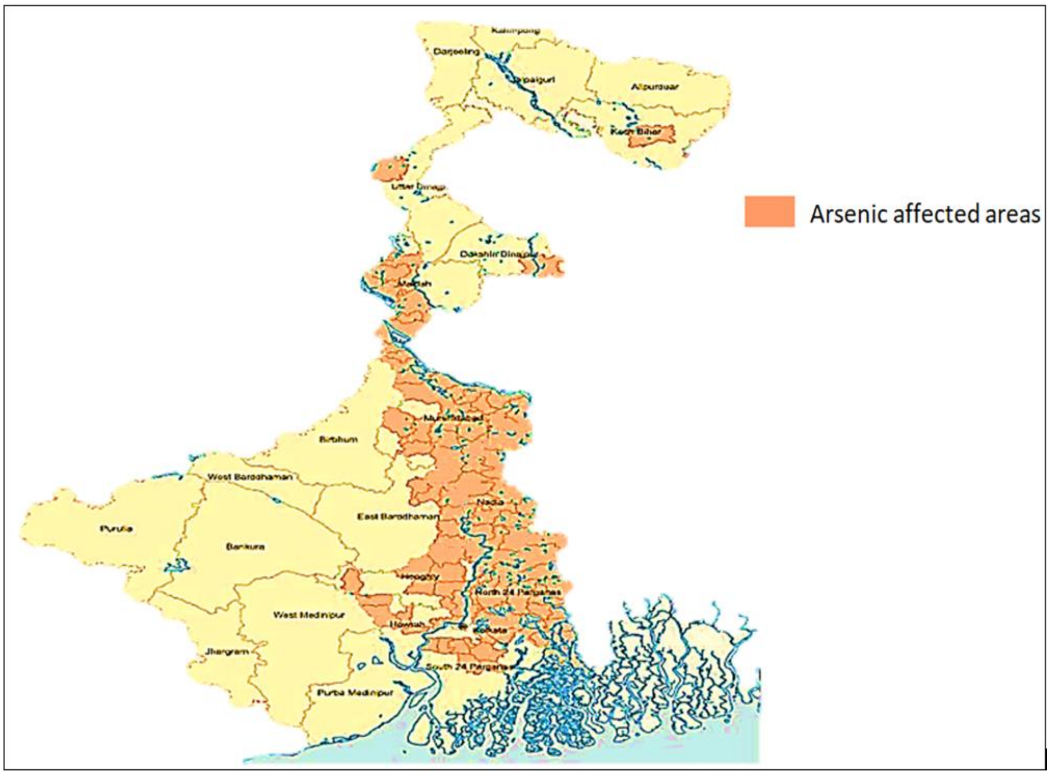

Fig 3 Arsenic Affected Areas in West Bengal

- *Sulphate:*

The sulphate concentration in underground water was within the maximum allowable limit all over the state. Generally sulphate ions are entered into fresh water through industrial wastes, dissolution of many sulphate salts, mineral and compound etc. The sulphate concentration in West Bengal ranged [38] between 0 and 299.9 mg/l.

- *Sodium and Potassium*

Potassium and Sodium in water is most important parameters for drinking and irrigation water. Human body system and animals are also reliant on sodium and potassium ion through their food or drinking water. High Sodium concentration in water destroys porosity of the soil making it difficult for irrigation. Generally exceptionally high sodium is observed in sea water. The Na and K concentrations varied [38] from 1.6 mg/l to 652.8 mg/l and 0.2 to 390 mg/l respectively in West Bengal.

- *Fluoride:*

The chief sources of the fluoride in underground water occur due the dissolution of Fluoride bearing minerals from the rock into the groundwater system by weathering process. Fluoride is an essential micronutrient for humans but excessive consumption of fluorine (>1.5 mg/l) causes fluorosis. Fluoride varied [38] from 0.0 to 6.1 mg/l in underground water of the state. The Fluoride affected areas [38] in west Bengal are shown in fig. 4.

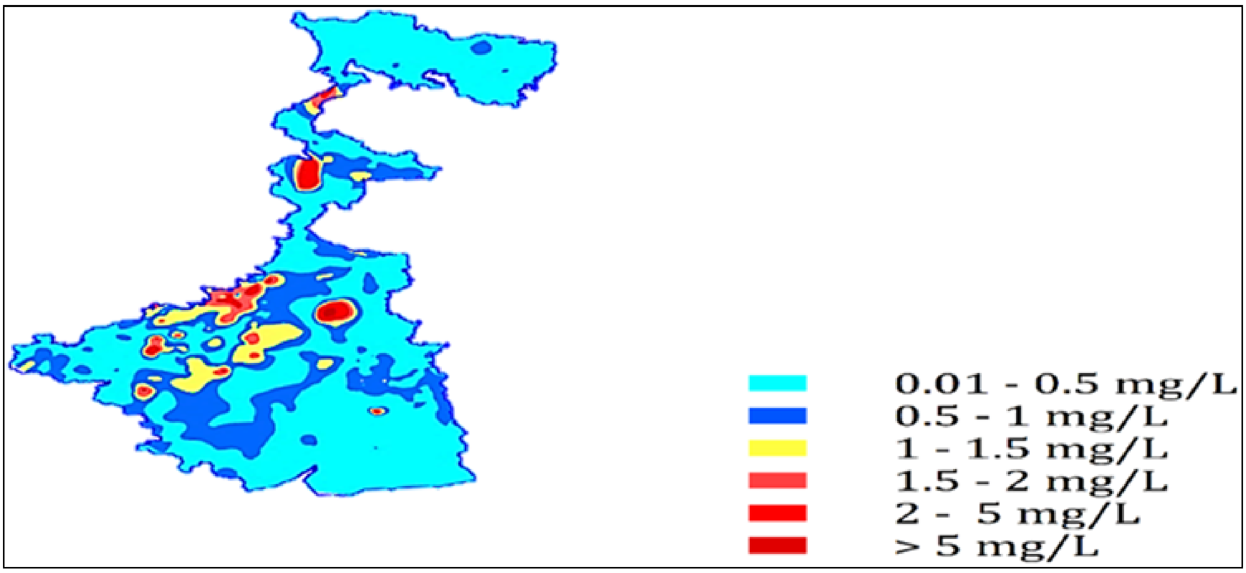

Fig 4 Fluoride Affected Areas in West Bengal

➢ *Heavy Metals:*

Heavy metals such as Lead, Cadmium, Nickel, Chromium, Manganese, Copper, Zinc, Mercury etc. maybe present in groundwater due to geogenic and anthropogenic causes. Industrial wastes contain huge amounts of heavy metals which enter into streams, lakes, rivers, sea and groundwater. The heavy metals affected seriously on plants, animals and human beings when those are present beyond the permissible limit. The concentrations of Lead, Chromium, Manganese, Copper, Zinc and Uranium in groundwater in West Bengal were found to be 0 – 0.035 mg/l, 0 – 0.148 mg/l, 0 – 7.235 mg/l, 0 – 0.045 mg/l, 0 – 35.923 mg/l and 0 – 0.034 mg/l respectively [38].

XI. CHEMICALS CONTAMINATION AND ITS EFFECTS

We know that some chemical elements which are mandatory by the plants, animals and human beings in certain acceptable ranges but when present in too low or too high ranges, may effect numerous problems or diseases. Plants, animals and human beings consumed the required elements through food and water. The main chemical contaminations in underground water in West Bengal state are concise in Table 3.

Table 3 Chemicals Contamination of Groundwater in West Bengal

Contaminats	**Affected District**	**Potential Health and Other Effects**	**Ref**
Arsenic	Nadia, Murshidabad, Kolkata, North 24 Parganas, South 24 Parganas, Uttar dinajpur, Dakshindinajpur, Bardwan, Malda, Hoogly, Howrah, Cooch Behar	A carcinogenic. Arsenic is extremely poisonous and long-period use of drinking water with high concentrations can lead to extensive range of health complications in humans. Arsenic has been shown to be carcinogenic, mutagenic, and teratogenic. Skin lesions such as melanosis and keratosis, as well as skin cancer, are symptoms of chronic arsenicosis. As sensitization has also been related to bladder and lung cancers, as well as other disorders such as heart diseases, breathing issues, liver disease, kidney problems, decreased blood haemoglobin, and diabetes.	6,7,11,13,14,15,28,35,37,38
Fluoride	Birbhum, Malda, Uttar Dinajpur, Purulia, South Dinajpur, Nadia, Bankura, Burdwan	Dental or skeletal fluorosis is perhaps the most common health problem associated with chronic fluoride ingestion from drinkable water. Dental fluorosis (>2mg/l) ('mottled enamel') is a disorder in which fluoride comes into contact with dental enamel, making discoloration as well as possible tooth weakening or loss. While regular consumption in excess (>5mg/l) may give rise to bone fluorosis and other skeletal fluorosis (<10mg/l).	16,27,29,32,38
Iron	Howrah, Nadia, Murshidabad,Birbhum, Purulia, Bankura, South 24 Parganas Bardwan, Alipurduar, South Dinajpur, North 24 Parganas,	Imparts a bitter astringent taste to water and a brownish colour to laundered clothing, utensils and plumbing fixtures.Essential for human health [Hemoglobin Synthesis] Excess stored in Spleen, Liver, Bone marrow & causes Haemochromatosis.	3,6,10,15,22,38
TDS	North and South 24 Pgs, Purulia, Bankura, Murshidabad, Howrah, Hooghly, Kolkata, Bardhaman, Nadia and Midnapur Districts.	Elevated TDS levels indicate that it is unsafe for drinking and can cause a variety of illnesses like nausea and digestive problems, respiratory problems, skin irritation, vomiting, dizziness, and so on. Drinking water with a high TDS level for an extended period of time exposes the body to various chemicals and toxins, which can result in chronic health problems such as cancer, liver problems, and kidney problems.	30,38
Bicarbonate	North and South 24 Pgs, Purulia, Bankura, Murshidabad, Howrah, Hooghly, Kolkata, Barddhaman, Midnapur	High level bicarbonate causes swelling (edema) because bicarbonate holds sodium; it can enhance the risk of swelling caused by excess fluids in the body. People with liver disease, ulcer in stomach and heart failure may also occur due to excess intake of bicarbonate. It is a very important parameter for agriculture and excess bicarbonate in water is unfit for irrigation.	38
Chloride	Howrah. South 24 Parganas	Chloride increases the electrical conductivity of water and thus increases its corrosivity. Chloride in high concentration may cause Kidney disease, dehydration and acidosis.	38
Nitrate	Bankura, Howrah,	Excessive nitrate consumption can be potentially	26,38

	Bardhaman, Purulia	dangerous, particularly for infants. Consuming excessive nitrate contaminant water can cause methemoglobinemia (blue baby syndrome).	
Sulphate	Birbhum	Sulphate levels above 250 mg/l may make the water taste bitter or like medicine. High sulphate levels may experience diarrhoea and dehydration as a result of the drinking water. High concentration may be associated with various disease, chronic diarrhoea and even death. High sulphate concentration may also rust plumbing, mainly copper piping.	21
Chromium	Murshidabad, Bankura, Birbhum and South 24 Parganas	Health effects related to hexa-valent chromium exposure include cramps, stomach and intestinal bleedings, diarrhoea, and kidney and livir damage.	38
Zinc	North 24 Pargans, Kolkata and Darjeeling	Ingesting too much zinc causes stomach cramps, nausea and vomiting. Very high concentration over numerous months can lead anaemia through reducing the absorption of copper.	38
Manganese	Hooghly, Cochbehar, Bankura, Bardhaman, Malda,Birbhum, Darjeeling, Howrah, Jalpaiguri, Kolkata, Murshidabd, North 24 Parganas, Paschim Medinipur, Purulia, Nadia and South 24 parganas	• Manganese can cause discolouration and an unpleasant taste in drinking water. Excess intake of manganese occur headaches, eye issues, sore throat, anxiety, irritability, insomnia, memory loss, hand tremors.	38
Uranium	Malda, Mursidabad, nadia, North 24 Parganas, South 24 Paraganas, Purulia	Carcinogenic, liver damage or both. Long term chronic intakes of uranium isotopes in water can lead to internal irradiation.	38,42, 43

XII. CAUSES OF CHEMICAL CONTAMINATION

Groundwater contains several minerals and elements with different concentrations depending upon variations in places, geology, geography and time. Geogenic and anthropogenic both are the causes of chemical contamination of groundwater [6]. The hydrogeological regions characterise the distribution of As and F in groundwater in West Bengal, with As found primarily in association with aquifers of deltaic young alluvial and F^- primarily in aquifers of granite-gneiss basement. Other contamination might be due to minerals enriched soil and rocks contacted with aquifer/groundwater and leaches or seepages of various wastes into groundwater. Enrichment of bicarbonate ions may possibly be credited to the dissolution of CO_2 from air in soil and interaction with salts or minerals in soil, accentuated by Base Exchange, microbial action and other associated. The contaminants such as Arsenic, Fluoride, Iron, Bicarbonate, Chloride, Nitrate, Sulphate, Zinc, Chromium, Manganese, Uranium etc. enter into groundwater from

- Minerals in rocks, soil and sediments by natural processes (geogenic).
- Metals and non-metals wastes by different mining and industrial activities.
- Chemical fertilizers, pesticides and different agricultural wastes by agricultural activities.
- Inorganic, organic and biological wastes by different hospitals and laboratories activities.
- Petroleum, metals and other wastes by vehicle activities.
- Metal, non-metal and biological contaminants (domestic wastes) by household activities.

XIII. MITIGATION OF THE CHEMICALS CONTAMINATION

Mitigation of groundwater chemical contamination problems is quite difficult but there are some ways which can prevent potential health and other effects of human beings. The ways are

- Monitoring and survey for contamination less underground water and use of alternative aquifers for pure groundwater.
- Mark all contaminated water sources to concuss local people.
- Treatment or purification of fluoride and arsenic-contaminated water.
- Use of non-groundwater options such as reservoir, river, pond and pipe water supply etc.
- Rainwater harvesting
- Supply of treated or fresh water at community scale for poor people.

- Use Filter or membrane. It is the simplest technique for purification of water. Membrane filtration technology may be classified into different categories like Micro filtration (MF), Nano filtration (NF), Reverse osmosis (RO), Ultrafiltration (UF), considering membrane porosity and trans-membrane gradient.
- Education and awareness of humans about the value and pollution of water.

XIV. CONCLUSIONS

The state holds plenty of freshwater such as groundwater, river water, reservoir water and pond water etc. but there are huge misuses and abuses of water which may lead to a crisis of freshwater in near future. In our present study, a review of ground water resources of West Bengal has been carried out to draw a clean picture of the groundwater quality for concuss about groundwater. This will help current water resources planning of West Bengal and provide an overall idea for contamination of ground water in West Bengal. All major chemical parameters are within the permissible limit of BIS and WHO drinking water standard except arsenic, fluoride and iron etc. contamination in some districts. Thus it is observed that the quality of groundwater in the entire state is suitable for industrial, irrigation, domestic and drinking purposes except in nitrate, uranium, arsenic and fluoride etc. infested areas of the state. The current position of water sustainability is insufficient and uneven in the state. There is a necessity for an extensive policy framework and dedicated organizations to work on water data monitoring, water governance and information distribution and Integrated Water Resources Management. The present study will provide an acute awareness among the people of West Bengal about the quality, contamination, source of contamination and remedial actions in the current scenario of the groundwater. The degree of current and potential water related problems are invisible.—Our civilization has been preoccupied with much more visible socio-political issues rather than with the peaceful death of water. We require a socio-political revolution in the direction of life's most valuable natural resource – water! In West Bengal, an appropriate awareness programme and water management plans for groundwater sources are required, which can assist individuals and communities in using pure drinking water and reducing pollution problems.

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- *Disclosure Statement*

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