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RESEARCH ARTICLE

WHAT WE DRINK IS IT SAFE? AN ASSESSMENT OF DRINKING WATER IN KOCH BIHAR DISTRICT, WEST BENGAL

Dilip Karmakar[1] and Dr. Bappa Sarkar[2]

1. Research Scholar, Department of Geography Cooch Behar Panchanan Barma University.
2. Assistant Professor, Head of the Department of Geography, Dinhata College.

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Abstract

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The groundwater quality of Koch Bihar District (West Bengal, India) has been assessed to determine the suitability of groundwater for drinking. Eight parameters have been taken into account for calculating the water quality index (WQI): pH, total hardness (TH), magnesium (Mg), calcium (Ca), carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-), chloride (Cl), iron (Fe) and sulfate ($SO4^{2-}$). Secondary data on water quality were collected from Central Ground Water Commission (2018), and the samples of water have been collected from the various locations and analyzed accordingly. The physico-chemical data were evaluated following the standards of BIS and WHO guidelines. The calculated WQI ranges from 23.62 to 95.12. In terms of groundwater quality for drinking purposes, Tufanganj-1 and Koch Bihar-1 seem to be the worst blocks. The magnesium (Mg) concentration exceeds the acceptable limit of 30 mg/l in Mathabhanga I, Mathabhanga II, Koch Bihar II, Dinhata II, and Sitai Block and Koch Bihar II exceeds its permissible limit (100mg/ l). The Iron (Fe) value exceeds the acceptable limit of 0.5 mg/l in Koch Bihar II. The Total Hardness (TH) value exceeds the acceptable limit (200 mg/l) in Mekhliganj, Mathabhanga-I, Koch Bihar-I, Koch Bihar-II, Tufanganj II, Dinhata II, Sitai. However, no sample crosses the maximum acceptable limit for pH, carbonate, chloride, and sulfate. It is suggested that water drawn from such sources be disinfected adequately before being used for drinking or other domestic purposes.

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Introduction:-

Water is a chief natural resource and prime constituent of the ecosystem. The surface and groundwater have deteriorated due to some natural and human factors. The hydrochemistry of groundwater mainly depends on the composition of rocks, regional climate, geology, rainwater percolation, the function of microorganisms, topography, and human interference. Groundwater is becoming polluted due to natural or anthropogenic ecological factors such as solid waste materials from industrial sewage disposal and barriers in surface water. Population growth, mainly in the developing world, puts tremendous pressure on water bodies. Overuse of groundwater for drinking, irrigation, or domestic purposes has resulted in groundwater depletion and made the wells unfit for consumption. Groundwater depletion occurred in those areas where other sources of water are not available. In major cities and towns across the country, the rate of depletion of groundwater levels and deterioration of groundwater quality has been declining day

Corresponding Author:- Dilip Karmakar
Address:- Research Scholar, Department of Geography ,Cooch Behar Panchanan Barma University.

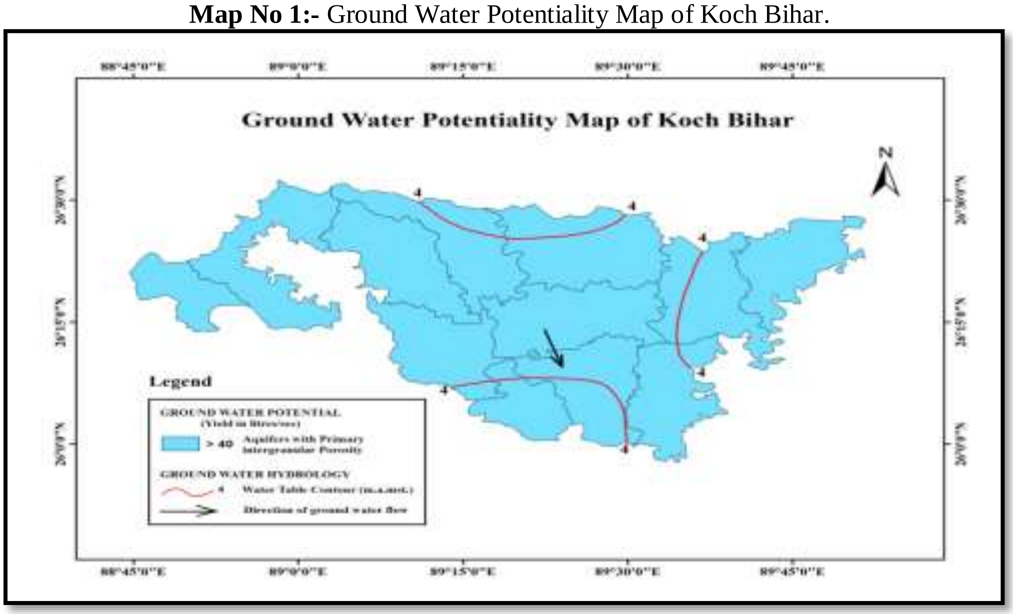
by day (Das et al. 1998; Garode et al. 2017, Ramasubramanian et al. 2004). It is estimated that the earth's total surface area is covered by 51 crore square kilometres, out of which the sea covers 36.1 crore kilometres. We are all aware that the human body requires a minimum of 3 litres of water per capita per day to sustain a healthy life. So, safe drinking water is the essential factor for good health. Water contamination harms water quality, health, economic development, and social prosperity (Milovanovic, 2007).

Children and adults are the worst sufferers of water-borne diseases. Providing safe and clean drinking water to all is a challenging issue in many parts of India, and it has been on top of the government plan for the last several years. It has beenguessed that, by 2025, more than three billion people in the world will be facing water base vulnerability. About 36% of urban and 65% of rural people lacked safe drinking water (WHO, 2009). More than 80% of all sicknesses or diseases in the human body are caused by inadequate sanitation, polluted water, and a lack of pure and safe drinking water (WHO, 2004).

Vishwanath and Ananthamurthy (2004) showed that the drinking water is unfit due to sewage from the town having high electrical conductivity (1560µmho/cm), TSS, and phosphate. Due to mining in the Keonjhar District, some parameters like TS, TDS, and Fe indicated a marginal increase from the specified limit. Heavy metal pollution, mainly in urban areas, includes underground rock structures, industrial effluents, solid waste disposal, etc. It is also studied that heavy metal pollution in Delhi crossed the permissible limit of Cd, Fe, and Cr. It is being reported that the groundwater of the North Tripura district has been found to have bacteriological and chemical contamination. Another study in Arunachal Pradesh has been reported to be unsafe due to bacteriological contamination, shows that the groundwater contains more BHC, aldrin, and DDT than the surface water. As a result, assessing groundwater quantity and quality is critical for advancing civilization and creating a database for future water resource development initiatives. A water quality index (WQI) is a useful tool for any location that reflects the overall water quality status. Brown et al. (1970) created the general WQI and later modified it by Deininger (1975). As a result, it may aid in modifying environmental agencies' management and policies to sustain the environment. The prerequisite of safe drinking water is one of the prime conditions for overall social development.

Unfortunately, the basic facts in Koch Bihar district are that the people are unaware of drinking water contamination and its probable effects. Koch Bihar district, the study area, an alluvial deposited area, receives the maximum part of rainfall from the northeast monsoon. Sankosh, Raidhak, Gadadhar, Ghorghora, Kaljani, Torsa, and Mansai are the main perennial rivers that flow from north to south-east. During the winter seasons, people largely depend on groundwater resources for domestic and agricultural activities for their daily lives. Agriculture employs approximately 67 percent of the district's population (District Census Hand Book, 2011). The fluctuation of groundwater increases day by day during Boro cultivation (Sarkar, 2017). Shallow tube wells and deep tube wells were the primary sources of drinking water in the study area.

Map No 1:- Ground Water Potentiality Map of Koch Bihar.



Source- Central Groundwater Board and Survey of India Maps, 2007-08.

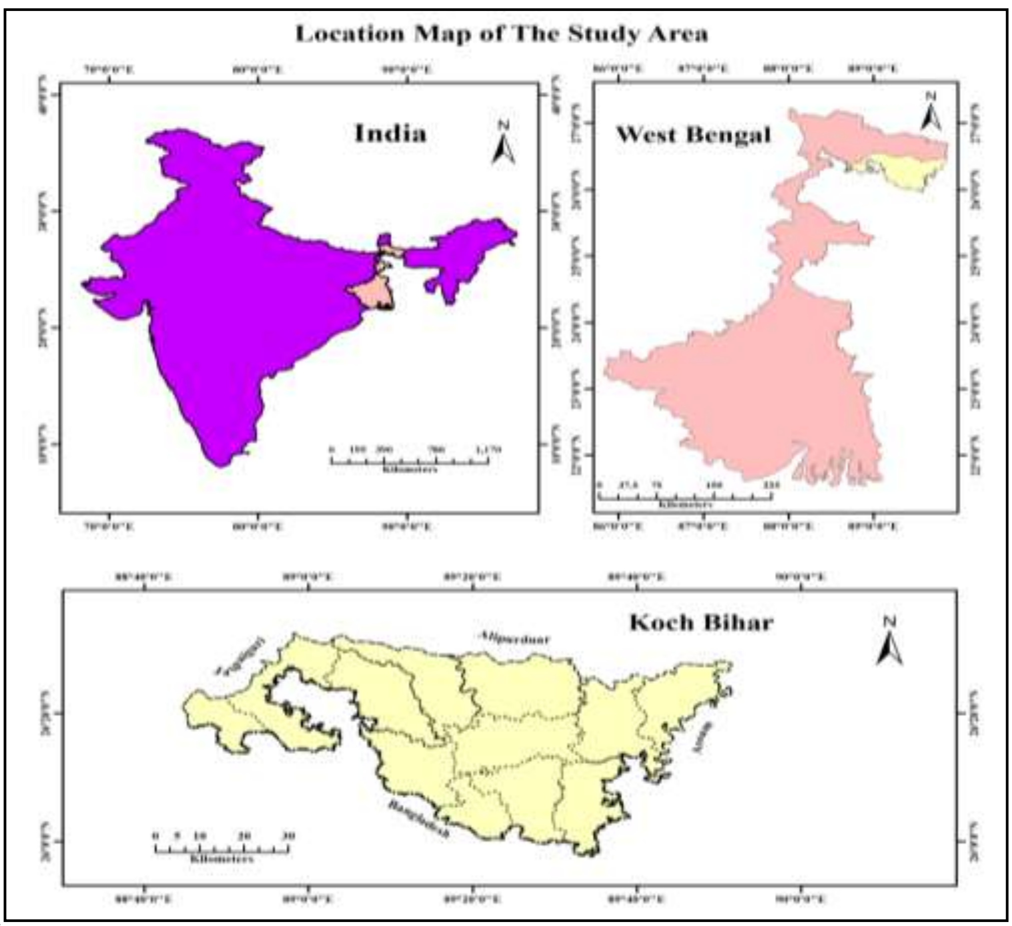
Location of the Study area

Koch Bihar district is bound by 26˚32´20´´N to 25˚57´40´´N latitudes and 89˚54´35´´E to 88˚47´40´´E longitudes. The geographical area of the district is 3387 sq. km. The district lies between the Tista-Torsa basins. The district is entirely underlain by quaternary alluvium and laid down by the south-flowing mountain streams and rivers. No older alluvium formations have been found anywhere in the district. The soil of the district is sandy to clayey alluvial. The district is characterized by a moderately humid climate with heavy rainfall. It receives adequate rainfall from the south-west monsoon, which sets in the mid of June and withdraws by the middle of October. As recorded, the maximum and minimum temperatures are 36˚C and 6˚C.

Table 1:- Location of Water sampling sites of Koch Bihar district.

Sl No.	Sampling sites	latitude	longitude
1	Haldibari(Haldibari Town)	26˚35´52´´	88˚75´69´´
2	Koch Bihar-I(HarishpalChowpathy)	26˚32´24´´	89˚44´26´´
3	Koch Bihar II(Baneswar)	26˚39´06´´	89˚49´57´´
4	Mathabhanga I(Mathabhanga Town)	26˚34´17´´	89˚19´97´´
5	Mathabhanga II(Ghokshadanga)	26˚42´43´´	89˚27´51´´
6	Mekhliganj (Changrabandha)	26˚41´85´´	88˚91´76´´
7	Dinhata I(Gosanimari)	26˚14´29´´	89˚36´42´´
8	Dinhata II(Dinhata Town)	26˚13´88´´	89˚45´88´´
9	Sitai(Sitai bazar)	26˚06´41´´	89˚29´98´´
10	Sitalkuchi(Sitalkuchi)	26˚16´28´´	89˚17´81´´
11	Tufanganj I(Tufanganj)	26˚31´53´´	89˚66´67´´
12	Tufanganj II(Balarampur)	26˚32´71´´	89˚65´06´´

Source: Samples taken by the researchers



Map No 2:- Location Map.

Database and Methodology:-

Twelve blocks of Koch Bihar district have been selected to establish the groundwater quality. The secondary data was collected from the central groundwater board. Dug wells are the main source for water sample collection sites. The calculation of WQI has been made using the Weighed Arithmetic Index method (Brown et al., 1973) in the following steps:

The method has been widely used by using the following formula-

$$WQI=\sum QiWi/Wi$$

The water quality rating scale (Qi) against each parameter is calculated by using the following equation- Qi=100(Vi-Vo/Si-Vo)

Where,Viis the concentration of ith parameter in the examined water

V_O is the standard value of the parameter(except pH=7.0 and D.O=14.6mg/l)

Si is estimated the standard value of the ith parameter

The unit weight (Wi) is calculated by using the following formula-

Wi=K/Si

Where,K=Proportionality constant and its also be calculated by using the following equation-

$$K=\frac{1}{\sum(\frac{1}{si})}$$

Besides water quality, the present work concentrates on the physico-chemical parameters with the BIS, 2012 standard in drinking water. The researchers rely on the physico-chemical data collected from India's Central Groundwater Year Book (2018-2019) for this analysis.

Table 2:- Physico-chemical data of water samples in different blocks of Koch Bihar district.

Name of the Block	pH	TH (mg/l)	Mg (mg/1)	Ca (mg/1)	$HCO3^-$ (mg/1)	CL^- (mg/1)	Fe^- (mg/1)	$SO4^{2-}$ mg/1
Haldibari	7.52	208	23	80	97.6	35.6	0.05	85
Mekhliganj	7.44	214.4	8	100	122	39.1	0.12	115
Mathabhanga I	7.49	263.7	62	100	122	32	0.46	150
Mathabhanga II	7.63	139	32	45	54	32	0.36	100
Sitalkuchi	7.5	62.7	5.3	40	48.8	14.2	0.11	45
Koch Bihar I	7.51	428.8	12	150	183	53.3	0.25	190
Koch Bihar II	7.28	522.2	102	130	158.6	106.7	0.54	175
Tufanganj I	7.9	76.2	19	35	42.7	14.2	0.15	65
Tufanganj II	7.38	274.6	12	155	189.1	21.3	0.1	185
Dinhata I	7.58	147.8	3.1	100	122	17.8	0.12	110
Dinhata II	7.84	298.9	59	120	146.4	28.4	0.38	145
Sitai	7.43	299.5	69	35	42.7	60.4	0.34	125
Standard (min)	6.5	200	30	20	200	250	0.3	200
Standard (max)	8.5	800	100	50	400	1000	0.5	400
Mean	7.54	459.5	33.86	90.83	110.74	37.91	0.24	124.16
SD	0.54	174.2	30.31	44.00	51.46	24.91	0.15	24.49

Source: Central Groundwater Year Book of India (2018-2019).

Table 3:- Water Quality Parameters and BIS Standards for Various Constituents.

Parameters		Acceptable limit	Permissible limit
pH	Log Scale	6.5-8.5	6.5-8.5
TH	**mg/l**	200	600
Mg		30	100
Ca		20	50
HCO3		200	400
Cl		15-35	4-10
Fe		0.3-0.5	--
SO4		200	400

Source: Bureau of Indian Standard, 2012.

Table 4:- Water Quality Index, BIS.

WQI Value	Rating of water quality	Grading
0-25	Excellent	A
26-50	Good	B
51-75	Poor	C
76-100	Very poor	D
>100	Unsuitable	E

Source: BIS, 2012

Results and Discussion:-

Physico-chemical analysis of drinking water:

Table-1 shows the physicochemical data collected in Koch district, Bihar, during 2018-19, along with the standard deviation and range value.Eight parameters are discussed here. Each parameter is closely related to the others.

Hydrogen Ion Concentration (pH)

pH is one of the important characteristics of drinking water as it can control the other chemical parameters. The permissible limit range of pH for drinking water is 6.5-8.5 (Bureau of Indian Standards, 2012). After analysing the pHdata of the groundwater in the study area, it has been observed that the groundwater of Koch Bihar is almost alkaline. Several blocks of Koch Bihar district have pH values that show neutral to mildly alkaline. Fig 1 shows that the pH of all samples is above the minimum limit but below the maximum limit. The average availability of pH in the district was 7.54, which is within the desirable limit.

4.1.2. Total Hardness (TH):

Carbonate, bicarbonate, calcium, and magnesium are the major constituents that measure the hardness of groundwater. As per theBIS (2012) standard, the desirable hardness limit in drinking water is 200 mg/l. Out of twelve blocks; six blocks show the hardness more than the desirable limit. The maximum concentration was found in the Koch Bihar II block (522.2mg/l), and the minimum concentration was observed in the Sitalkuchi block (62.7 mg/l). This has been depicted in Fig 2.

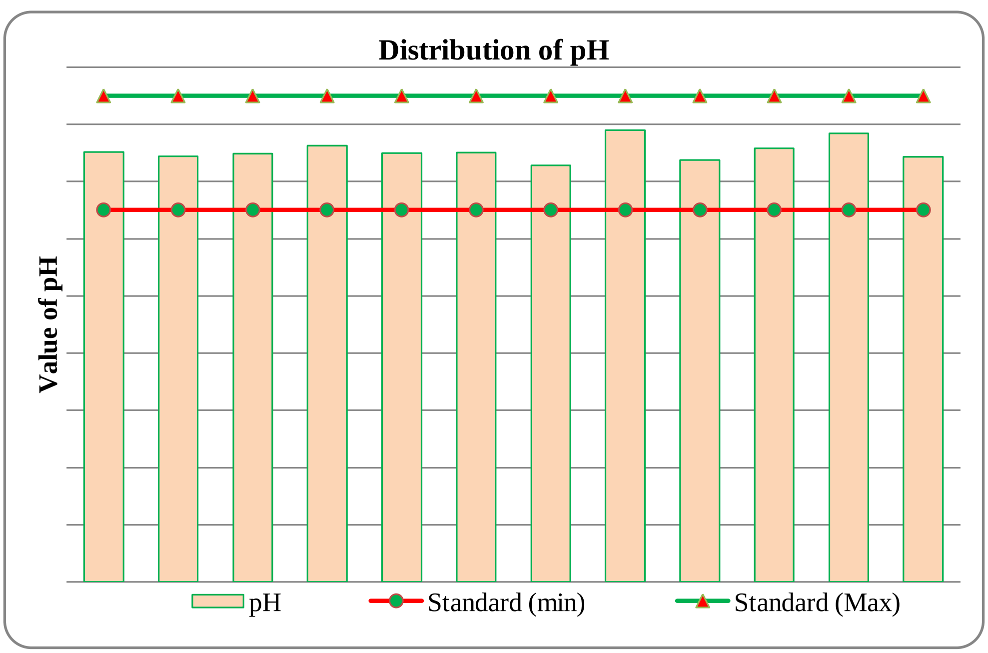


Fig.1:- Distribution of TH.

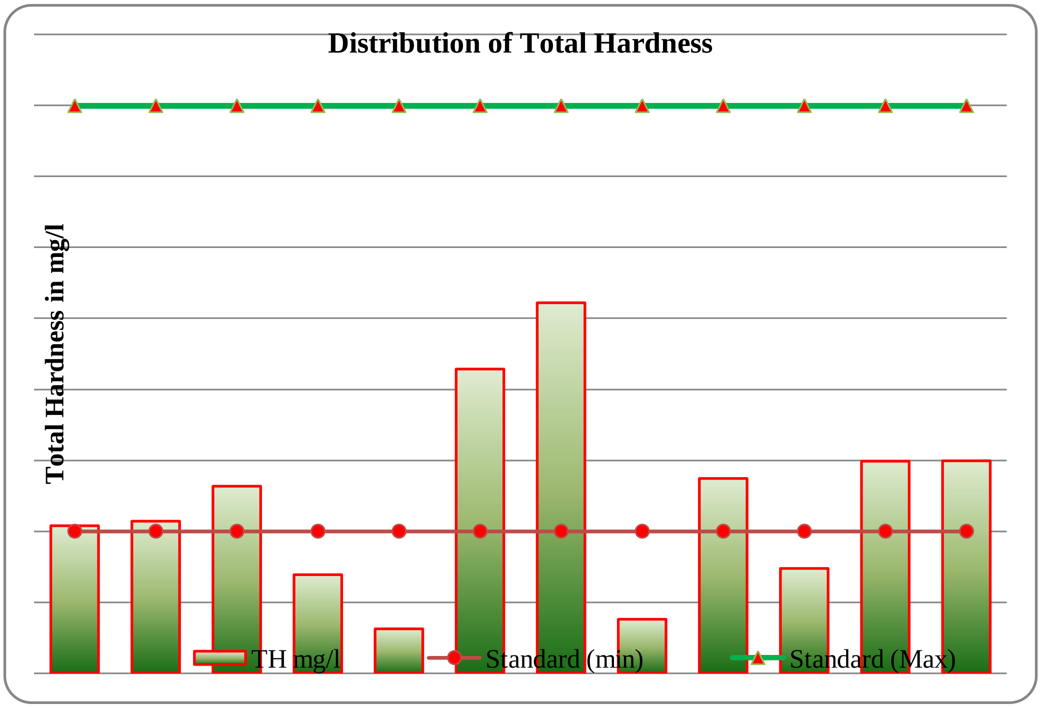


Fig 2:- Distribution of TH.

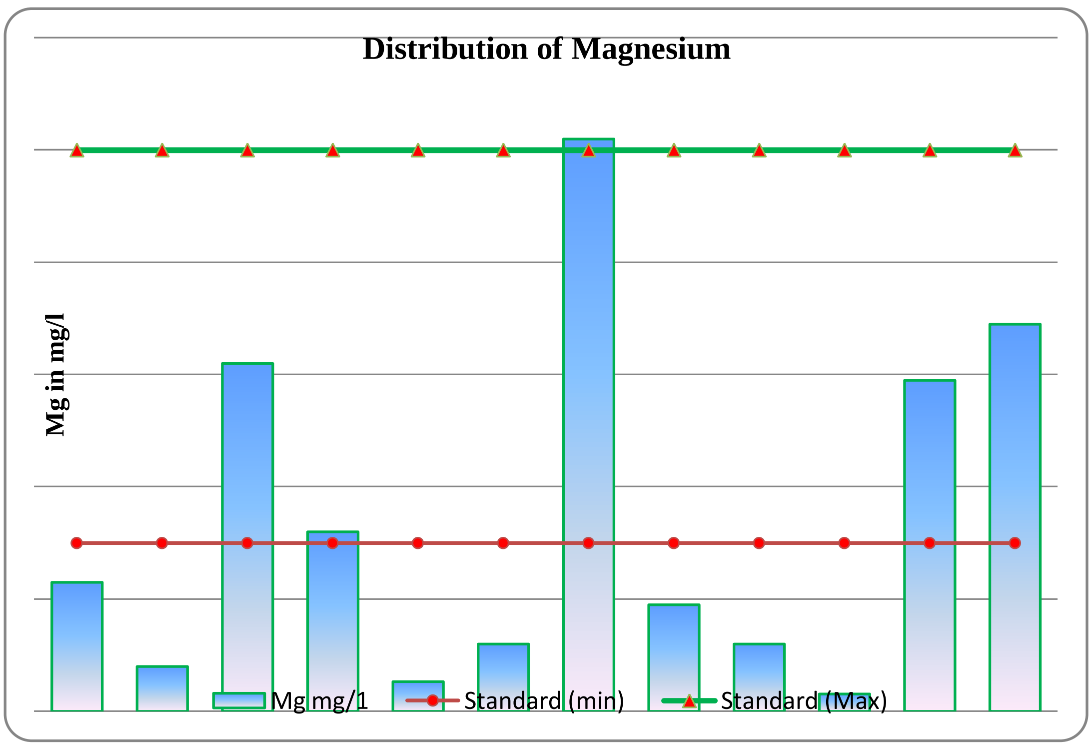


Fig 4:- Distribution of Ca.

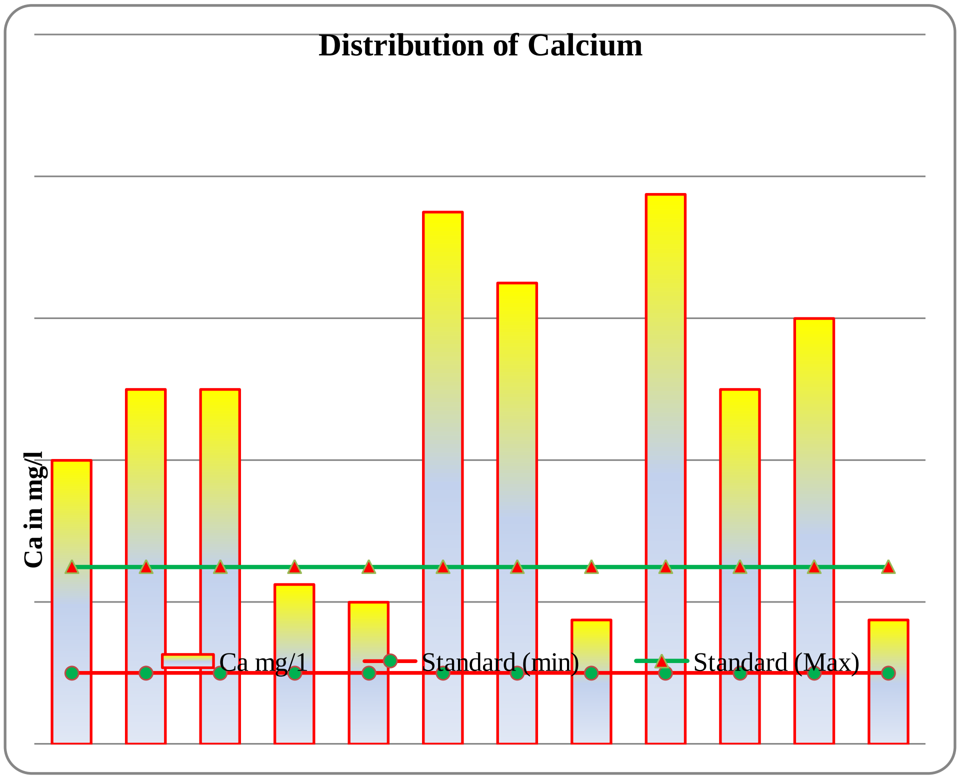


Fig 3:- Distribution of Mg.

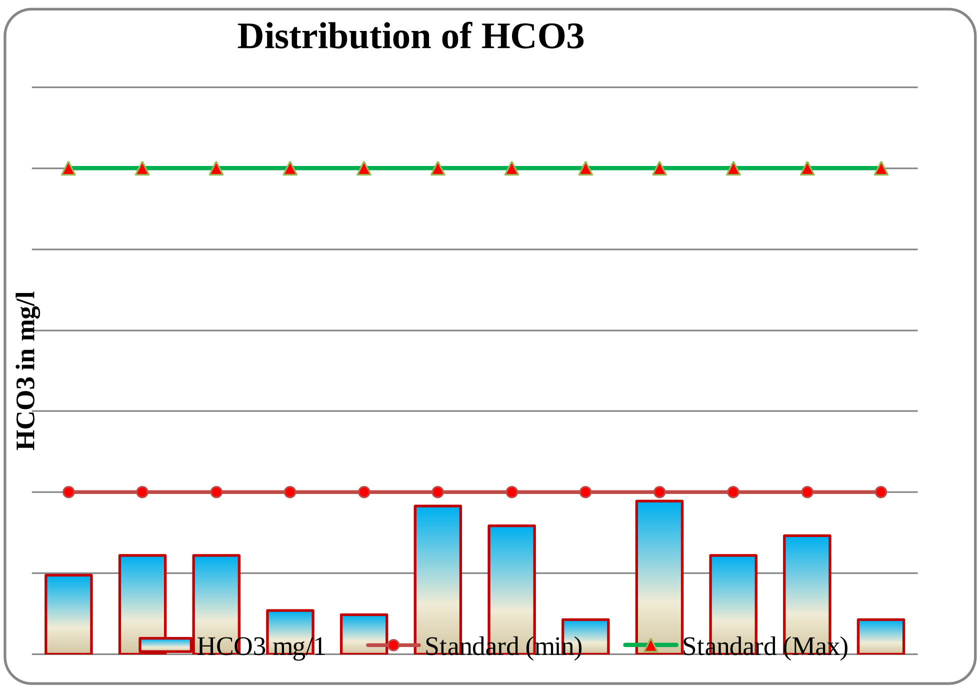


Fig.4:- Distribution of Ca.

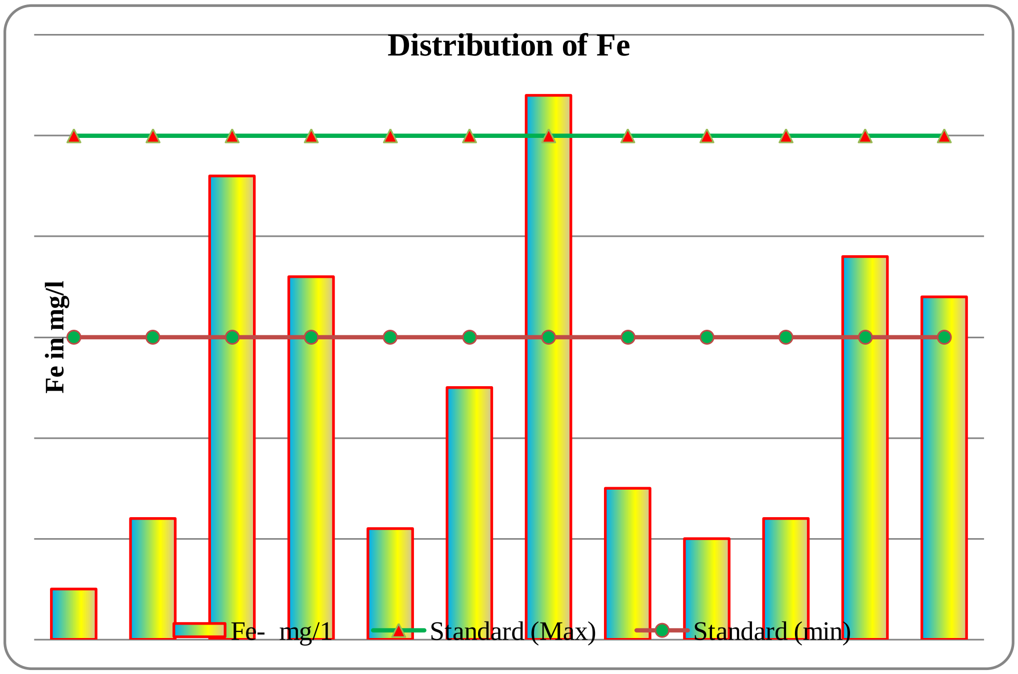


Fig.5:- Distribution of HCO_3.

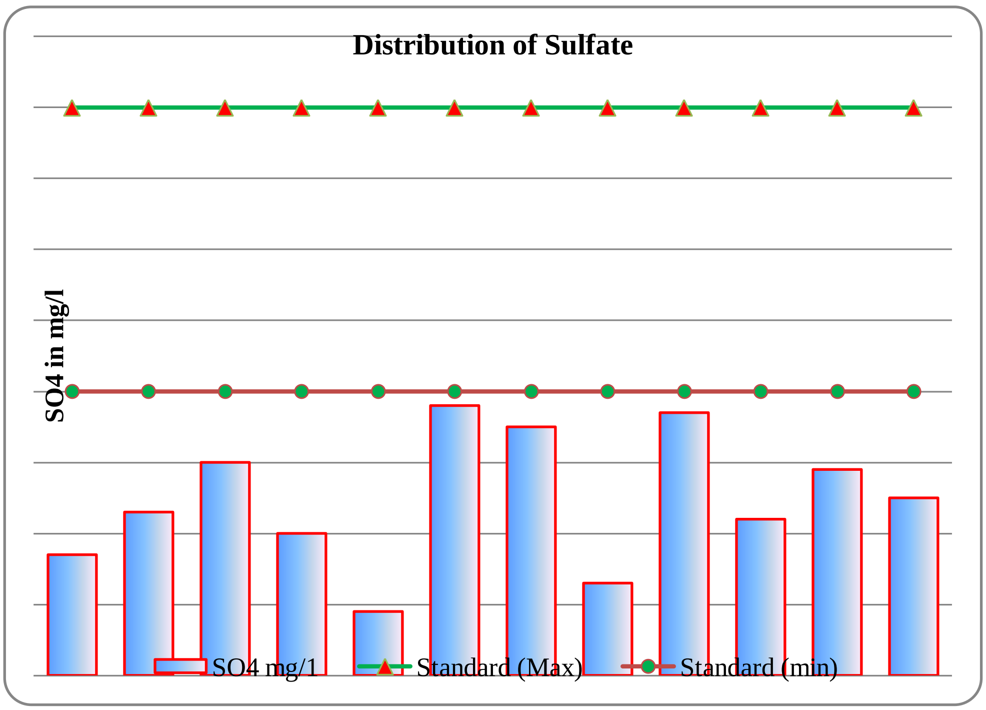


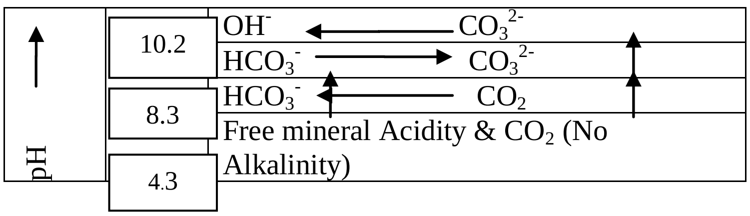
Fig 6:- Distribution of Cloride.

Magnesium (Mg) and Calcium (Ca)

Calcium and magnesium generate both transient and permanent hardness, which is referred to as total hardness. Several studies have found a link between hardness in drinking water with the concentration of magnesium and calcium and the risk of cardiovascular disease, growth retardation, reproductive failure, and other health issues. According to BIS 2012, the minimum and maximum desirable limits are 30 and 100 mg/l. It produces cathartic and diuretic effects on human health (Trivedi, 1990). Most of the blocks have been found within the permissible limit. Mg concentration was highest in Koch Bihar II block (102 mg/l) and lowest in Dinhata-I, Sitalkuchi, and Mekhliganj.On the other hand, the concentration of Ca is greater than the permissible limit in all the blocks of the district.

Carbonate and Bi-Carbonate:

Carbonate (CO_3^{2-}) and bi-carbonate (HCO_3^-) are salts of carbonic acid (H_2CO_3), a key parameter in water chemistry.The concentration of carbonate and bi-carbonate depends on the pH of the water. At less than 4.3 pH, there is no trace of CO_3^{2-}or bi-carbonate (HCO_3^-) anions. At a pH level of 8.3, all CO_2 converts to HCO_3^- and beyond pH 8.3, the HCO_3^-starts converting into CO_3^{2-}. $CO_3^{2-}$and HCO_3^- combined with Ca^+ and Mg^+ form $CaCO_3$ and $MgCO_3$, which increases the total alkalinity and pH.H_2CO_3, HCO_3^- and CO_3^2 are the three carbonate species that control the total alkalinity and depend on the pH of the water and water temperature. Thus, pH and total alkalinity are very much interrelated.



At pH below 4.3 = No Alkalinity
4.3 to 8.3 = CO_2 starts to convert HCO_3^-
8.3 = Only HCO_3^- present
> 8.3 = HCO_3^- is being converted to CO_3^{2-}
10.2 = All HCO_3^- have been converted to CO_3^{2-}
> 10.2 = CO_3^{2-} is converted to OH^- ion

So, the higher the alkalinity, the higher is the pH or vice-versa. The normal range of TA is 50-200 mg/L. Very low alkalinity (<100 mg/L) increases the pH and makes the water acidic.The total alkalinity concentration in all the Koch Bihar district sample sites is within the desirable limit for drinking water purposes. It was observed that the carbonate and bi-carbonate concentrations in the district were below the admissible and permissible limits.

Chloride (Cl):

Chlorine (CL^-) is a toxic element. Chloride is one of the key inorganic anions in fresh water and wastewater (Garg, 2006). The major forms of chlorides are NaCl, KCl, $CaCl_2$, and HCl in surface and underground water. It serves as an indicator of pollution**.** Still, when it receives one electron or combines with other cations, it forms chloride, which becomes essential to living organisms. Sreenivasan (1965) pointed out that a 4-10 mg/L chloride concentration indicates water purity. Chloride is related to pH, TA, EC, TDS, Free CO_2, and bicarbonates. A high concentration of chlorides is harmful to humans and aquatic life because it slows down growth and reproduction.The normal range of chlorides in rivers and other freshwater lies between 15-35mg/L. It has been observed that the value of chloride was below the admissible and permissible limit in the whole district. Thus, it is evident that drinking water is safe in terms of chloride throughout the district.

Iron (Fe) :

The concentration of iron in the groundwater of Koch Bihar District varies from 24.49 to 190. The Bureau of Indian Standards has set acceptable levels of 300 g/L and a maximum permissible limit of 1,000 g/L for drinking water (BIS 1991). The concentration of iron (Fe) in all the blocks of Koch Bihar has been recorded within the desirable limit. Both physico-chemical and microbiological factors influence the content of iron in natural water. Iron migrates as hydrated ions, insoluble hydrated iron complexes with inorganic and organic ligands, and is adsorbed to suspended Fig.7 Distribution of Fe materials. Fig. 7 shows that Koch Bihar II has the highest concentration of Fe, followed by Mathabhanga-I & II, Dinhata-II, and Sitai. The minimum iron concentration was observed in Haldibari, Sitalkuchi, Tufanganj-I&II and Dinhata-I.

Sulfate ($SO4^{2-}$)

Sulfates are naturally occurring minerals that combine sulfur and oxygen and are found in some soil and rock formations, including groundwater. Over time, the mineral dissolves and is freed into the groundwater. Sulfate minerals, like other minerals, can produce scale building in water pipes and are attributed to a bitter taste in water that can have a gastrointestinal impact on human health. It can cause dehydration, especially in infants. The maximum and minimum sulfate contaminate levels are 200 mg/L and 400 mg/L, respectively. The groundwater quality in terms of $SO4^{2}$ in the present study area is within the desirable limit, as the mean value of sulfate in the study area is 124.17 mg/l. The concentration of sulfates in all the samples in all the blocks is below the desirable and permissible limit (Fig. 8).

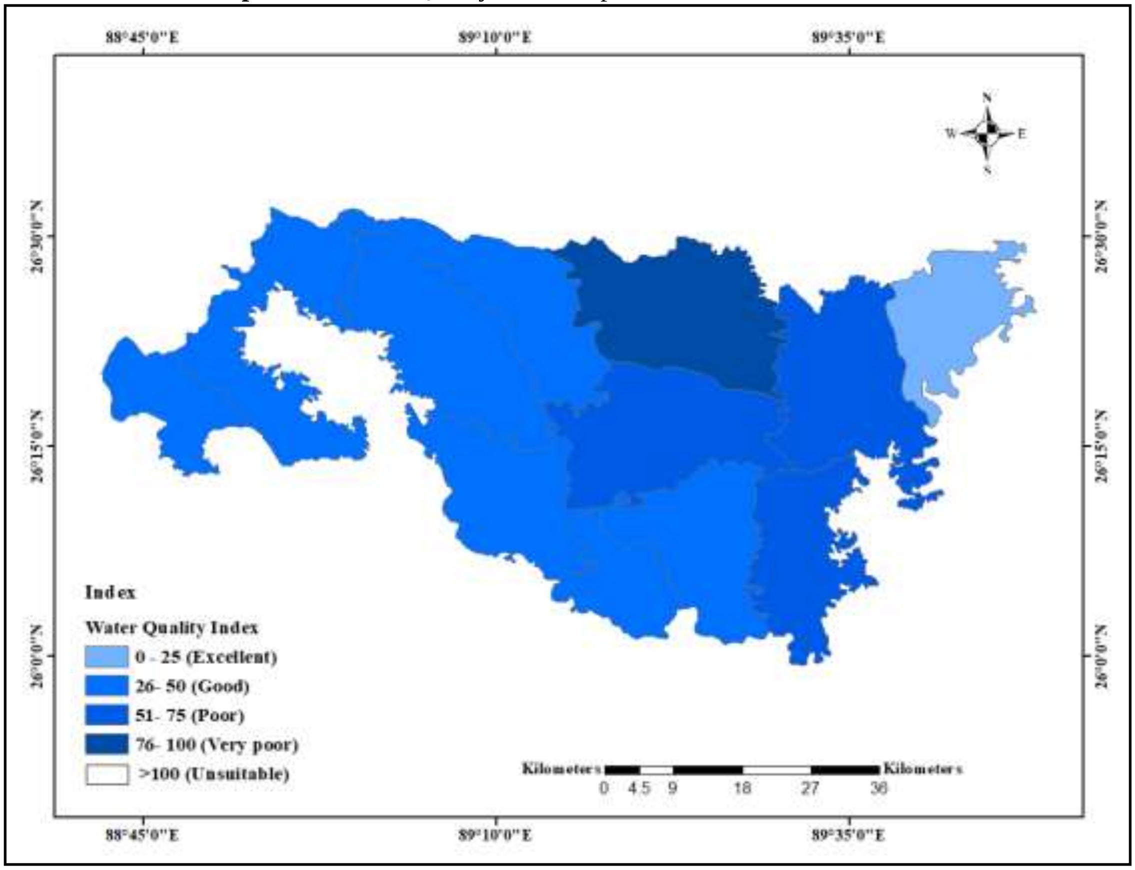
Water Quality Index (WQI):

The water quality index (WQI) model is a widely used technique for assessing surface as well as groundwater quality. It employs aggregation techniques to reduce large amounts of water quality data to a single value or index. The WQI model has been used around the world to assess water quality (surface and groundwater) using local water quality criteria. In general, WQI models have four stages: (1) parameter selection, (2) parameter sub-indices, (3) parameter weightings, and (4) aggregation of the sub-indices to compute the overall water quality index.In this study, the water quality was calculated using Brown et al. (1973) to assess the district's water quality.The result has been tabulated in table 5.

Table 5:- Water quality Values and relative description of water samples.

Sl.No.	Name of the Block	WQI Value	Description	Grade
1	Haldibari	35.6	Good	B
2	Mekhliganj	32.92	Good	B
3	Mathabhanga I	34.82	Good	B
4	Mathabhanga II	39.3	Good	B
5	Sitalkuchi	30.49	Good	B
6	Koch Bihar I	58.14	Poor	C
7	Koch Bihar II	95.12	Very poor	D
8	Tufanganj I	53.41	Poor	C
9	Tufanganj II	23.62	Excellent	A
10	Dinhata I	37.38	Good	B
11	Dinhata II	54.88	Poor	C
12	Sitai	30.48	Good	B

Map No 3:- Water Quality Index Map of Koch Bihar District, 2018.



Source: Computed by the researcher.

According to the WQI, excellent water is seen in Tufanganj II. Haldibari, Mathabhanga I, Mathabhanga II, Mekhliganj, Sitalkuchi, Sitai, and Dinhata I show the good quality of water. The poor cases are seen with headaches, and Koch Bihar I, DinhataII,Tufanganj I. Municipalities have a water supply system. Still, villages do not have water supply and purification systems everywhere in the study area. However, some municipalities have water supply systems, though the water quality is poor. Koch Bihar Municipality has six overhead water tanks, but according to WQI, the water is poor.

Conclusion and Recommendation:-

There are at least 21 models used globally and divided into original, 1st level modification, and 2nd level modification. About 110 research articles were published in different countries and different types of water bodies. The present researchers applied the Brown et al. (1973) model to assess the water quality of Koch Bihar district. Besides WQI, the researchers have attempted to analyze the physico-chemical analysis of drinking water of the present study area, taking eight available parameters. The analysis provides mixed results and needs to be further investigated with more parameters taken into consideration. It is a unique work for the region. The results reflect the overall water quality of the district. It is revealed that the groundwater has been found suitable in Koch Bihar district for use in irrigation and allied purposes. As we know that contamination in the drinking water is fatal to human health, regular monitoring or management is required to improve the water quality in the district.

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