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Hydrogeochemical Appraisal and Groundwater Quality Assessment using Water Quality Index(WQI) Of Birma River Basin, Uttar Pradesh

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Abstract

Groundwater, since long has been utilised as a perennial source of water in Bundelkhand area especially for drinking and irrigational purposes. The present study analyses physico-chemical parameters of 14 groundwater samples collected across Birma river basin, Hamirpur and Mahoba district, Uttar Pradesh viz. pH, electrical conductivity(EC), Alkalinity, Total dissolved solids(TDS), Biological oxygen demand(BOD), chemical oxygen demand (COD), Total hardness(TH), Turbidity, Calcium(Ca^{2+}), Magnesium(Mg^{2+}), sodium(Na^+), Potassium(K^+), Bicarbonates(HCO_3^-), Sulfate(SO_4^-), Nitrate(NO_3^-), Chloride(Cl^-), Fluoride(F^-), Iron to analyse groundwater quality. Based on these parameters water quality index (WQI) has been calculated for classifying the area into excellent, good, poor, etc. It ranges from 19.99 to 79.30. In general, the WQI of the study area shows good quality of groundwater and is suitable for drinking purpose excluding localities of Akauna, Bilgaon, Dhanauri and Kulpahar where it has been classified under poor category. Hill-Piper Trilinear diagram shows dominance of Ca-Na-HCO_3 type in the area signifies geogenic contamination of Na and Ca bearing salt/minerals and implications of anthropogenic activities. This study aims to provide useful input to the strategy makers for judicious ground water management especially for the areas where ground water has been estimated unfit for human consumption without proper treatment.

Keywords: Groundwater, Birma, WQI, Hill- Piper Trilinear.

1. Introduction

India, is a country which is mostly reliant on groundwater for its drinking, irrigation and municipal demand of water. With continue upsurge in urbanisation and industrialisation, the demand of groundwater is higher than the supply which has substantially affected by the climate change. Population growth is a major setback for any country's growth , esp India ,which has a gigantic population and leads to discharge of pollutants in groundwater. India constitutes about 15% of the total population but it has access to only 4 % of freshwater resources , thereby overburdening on groundwater for every necessity is very evident. There are numerous places/cities in India which are densely populated but they lack proper sewage and drainage which in turn end up merging into the major river like Ganges . Besides, chemical based agricultural practices has adopted an excessive use chemical fertilizers and pesticides, thereby causing further contamination of groundwater as well as soil. The accessibility and groundwater quality are severely affected at an alarming rate due to anthropogenic activities viz. overexploitation and improper waste disposal (industrial, domestic and agricultural) to groundwater reservoirs (Panda and Sinha 1991; Kavitha et al.,. 2019a, 2019b). The groundwater quality fluctuates due to seasonal fluctuations, water depth and surface environments (Gebrehiwot et al.,. 2011). Water being the basic necessity of all life on earth , once contaminated , it becomes difficult to purify it as it takes extreme amount of cost, energy and labour. It is therefore, important to monitor groundwater as well as surface water and model devices in such a way so as to protect it from further contamination. The groundwater quality can be analysed in physical, chemical and biological characteristics of water. These characteristics are related to public health and pristinety of water. For groundwater management, hydrogeological (porosity, permeability, specific yield/retention, transmissivity, storativity, hydraulic conductivity etc.) and hydrogeochemical (pH, EC, TH, TDS, BOD, COD, Alkalinity etc.) studies of aquifers are an integral part. Factors such as surface runoff, infiltration, dissolved salts/minerals in groundwater, weathering, evapotranspiration, disposing of solid/liquid, leaching of metallic wastes, further influence the said parameters (Sefie , et al., 2018; Karroum , et al., 2017; Devic , et al., 2014; Barbieri , et al., 2014; Mukate , et al., 2017). The paucity and variation in water resources escalates by the threats and impactful human activity that agitates water regimes and degrades water quality and also by some overutilize resources. Water pollution under any circumstances is a matter of concern due to many anthropogenic interference and is identified by many precedent studies (Adimalla 2019, 2020; Bahita et al.,. 2021a, 2021b; Jasrotia and Kumar 2014; Jasrotia et al.,. 2018; Karunanidhi et al.,.2021a, 2021b; Li et al.,. 2014, 2017).

India with second highest population in the world stands first in groundwater consumption, even summing up the total usage of USA and China. Groundwater, being at subsurface is less prone to pollutants or contamination comparatively to surface water, and is directly use for drinking purpose esp in developing countries (Dhal and Swain 2022). Not only in India, globally the groundwater crisis is not hidden. Access to clean water is the basic fundamental right of every human being, but unknowingly we are using it outrageously without thinking of the future generation. Our future generation has equal rights to all the natural resources available on earth and it is our accountability to use it prudently.

In order to maintain the purity of groundwater as well as surface water, it is significant that groundwater monitoring and modelling is most effective tool. The Geographic Information System(GIS), is one such tool which creates, manages, analyses, and maps all types of data. It can merge diverse data into one map, for instance, street, building and vegetation data all can be merge into one map as it enables one to analyse patterns related to terrain. GIS helps in anticipating the spatial distribution of physico-chemical parameters, which in turn enables us to identify, critical and safe zone of groundwater , and can be fruitful in identifying primary and secondary sources for groundwater contamination(Thilagavathi et al. 2015;Khan et al. 2020). The WQI provides a single number that communicates in general water quality, at a particular place and time, depending upon the water quality parameters. The main objective of WQI is to turn intricate water quality parameters into simpler one for better understanding of groundwater by classifying them into excellent, good poor and very poor zones. It helps in portraying the intricate water quality parameters into an elementary way so as to make it easier for public health policy makers to strategize in such a way by considering socio economic conditions of a certain place. The WQI also give ways in better understanding of groundwater resources that are spatially and temporally incompatible with surface water resources. The dissolved salts/minerals strongly effect the hydrogeochemistry of groundwater and weathering of minerals from several rocks (Cerar and Urbanc 2013; Sidibé et al. 2019). Total 14 samples were collected, and hydrogeochemistry of the collected samples shows that Na^{++}>Mg^{+}>Ca^{+}>K^{+} are the major cations while major anions are HCO_3^->Cl^->NO_3^->SO_4^->F^-. It shows that Na^+ is the preceding alkali while Mg^+ and Ca^+ is the preceding alkaline earth metal. Na^+ in groundwater in generally formed from disintegration and decomposition of halide and silicate minerals such as feldspar(Khan et al.2020). The Hill- Piper Trilinear diagram derived from Rockworks. Critically evaluating the diagram shows that most of the sample falls under Ca-HCO3 type, one sample falls under Na-Cl type and one is of the mixed Ca-Mg-Cl type. While critically evaluating the hydrogeochemistry of groundwater, it is evident that the nature of aquifer is technically controlled by physico chemical parameters , intensity of contamination and its source((Brhane 2018 , Aghazadeh et al. 2017). Hence to , improve groundwater quality certain parameters like use of insecticides, pesticides, septic tanks management , needs to be observed annually . The aim of this study is to keep track on groundwater quality using WQI for drinking purposes using IDW interpolation technique and statistical method for better usage of groundwater for human consumption.

2. Study Area

Birma river is a downstream tributary of Betwa river, originating from Madarka village, Chhatarpur district, Madhya Pradesh (25 ◦ 05’ 23.36”N to 79 ◦ 33’ 38.70”E). It crosses three districts Chhatarpur (M.P), Mahoba and Hamirpur (U.P). The basin lies in between 25 ◦ 05’ 23.36’’N to 25 ◦ 52’ 53.71”N latitude and 79 ◦ 33’ 38.70”E to 79 ◦ 54’ 06.98”E longitude. The study area is characterized by subtropical climatic conditions, prolonged summer and mild winter and moderately heavy rainfall in monsoon. Birma watershed is classified in 10 Sub-watershed named (S1- S10). The Watershed covers an area of 2589.77 Km 2 with a perimeter of 418.6 Km. The Birma river flows from south towards north direction and exhibits a fifth-order drainage system. The Geometric parameters of its Sub-watershed is shown in the Table-1. An Earthen dam Swami Bramha Nand Dam (Maudha Dam) is built on Birma River which is main source of irrigation and drinking water supply in the area. Majhgawan tank and Bela Sagar reservoir are a part of Birma river basin. Birma river basin shows sub- dendritic to dendritic drainage pattern. The study area covers Survey of India Topographic sheet numbers 54O/6 to 54O/16.The study area represents subtropical climate characterized by prolonged summer, mild winter and moderately heavy rainfall which receives 95% of rainfall from SW monsoon. The summer season starts from March to June then accompanied by south-west monsoon which lasts till September. The winter season starts from mid-October to February.

3. Geological and Hydrological setup of the area

Geologically, the study area is a part of Bundelkhand Granitic Complex (BGC), consisting rocks of Archean-Proterozoic period and non-lithified sediments of Quaternary period. Granites of different types, gneiss and migmatites intruded by dolerite constitute BGC. The alluvium, unconformably overlying BGC, is divided into Older Alluvium and Newer Alluvium. Older Alluvium comprises sediments of silt-clay with kankar and Newer Alluvium consists of sediments grey- sand, silt and clay and at some places grey micaceous sand. Banda Alluvium represents Older Alluvium of early Pleistocene age. It consists of silt, clay with kankar along with red quartzo- felspathic sand. The Newer Alluvium is represented by Channel Alluvium and Terrace Alluvium of Holocene age and consists of grey sand, silt and clay along with grey micaceous sand. The thickness of Alluvium varies from 125 to 155 metres. The older supracrustals of Archean age consists of Amphibolite. Two distinct physiographic regions near hamirpur in the study area are:

1. The southern part plain area. The region is underlain by thin alluvial cover.
2. The northern part flat topography.

Near, Chhatarpur district, the study area consists of Bundelkhand Gneissic Complex comprising varieties of granites, gneisses etc. these rocks overlain by Bijawar group of rocks which includes breccia, stromatolites and dolomites. The Bijawar group of rocks were overlain by Vindhyan Supergroup which consists of sandstone, limestone shales.

The Percolation of groundwater is not easy here, in addition to this storage of groundwater is rather difficult because of hard rock terrain and rugged topography. Usually, in hard rocks, weathering and resulting fractures enhance porosity and water percolation. The overburden of Kulpahar, Charkhari ranges from 8 to 34 m. It amplifies the retention time for rainwater to penetrate through these fractures.

4. Methodology

In order to study water quality parameters, the Birma watershed was delineated in ten sub watersheds . For hydrochemical analysis, fourteen groundwater samples were collected and analysed as per the standards procured by the American Public Health Association(APHA). The WQI, correlation and Physico-chemical parameters are the statistical techniques adopted for this study. A proper selection procedure was followed prior to sample collection to ensure that water sample were collected from appropriate location so as to cover the 2589.77 Km^2 Brima watershed. The samples were filter. The fourteen samples were collected from handpump in prewashed polyethylene bottles. The initially discharged water from handpump was discarded to avoid any anomalies arising due to interaction of groundwater with corrosive surface of metallic structure of pipe/pumpset. The sample bottles were sealed immediately ensuring that no air bubbles were present to avoid oxidation of sample collected. Parameters such as pH, Electrical conductivity(EC), TDS were determined using potable device; Alkalinity, Total Hardness, Ca^+, Mg^+, HCO_3^-,Cl^- were determined manually using volumetric titrations, Na^+, and K^+ were analysed using flame photometer model 129, nitrate, fluoride and sulphate were analysed using spectrophotometer. Spatial distribution maps of these parameters were generated through IDW interpolation method using ArcGis10.3 software. The correlation matrix was made using MS Excel using analysed groundwater quality is shown in table (3).

5. The Water Quality Index(WQI)

The water quality index(WQI) is means by which water quality data is summarized for reporting to the public in a consistent manner. It provides a single number that expresses the overall water quality.

The WQI were calculated using weighted arithmetic index method (Brown et al., 1972), proposed by Horton(1965). The selected parameter have standard limit prescribed by BIS(2012).

The unit weight of each water quality parameter is represented by (W_i) ; and is calculated by

$$W_i = K/S_n \qquad \text{.................(1)}$$

Where $K= \quad 1/[(1/S_1 + 1/S_2 + 1/S_3 \ldots\ldots 1/S_n)] = 1/\Sigma S_n \qquad \text{...............(2)}$

And S_n= is the standard nth value as prescribed by Bureau of Indian Standard

On summation of all selected parameters unit weight factors W_n= 1(unity).

In accordance with Brown et.,al (1972), the sub-index Q_n is calculated by following formula;

$$Q_n= [(V_n - V_o)]/[(S_n-V_o]*100 \qquad \text{.......(3)}$$

Where, V_n= mean concentration of the nth parameter

S_n = standard value of the nth parameter as prescribed by BIS

V_o= actual values of the parameter of sample collected ,

Generally V_o for most parameter is zero , except for pH and dissolved oxygen(DO). In **pH** the ideal value is **7.0** for drinking water and **14.0mg/L** in case of Dissolved Oxygen**(DO).**

Therefore, the weighted water quality index(WQI) is calculated as;

$$WQI= \Sigma W_n Q_n / \Sigma W_n \qquad \text{.............(4)}$$

The categorization of water quality based on WQI as put forth by Brown et.al (1972) is shown in table(1).

6. Result and discussion

The measured physicochemical analysis of water sample is shown in the form of spatial distribution map through inverse distance weightage (IDW) and converted into single WQI and weightage and relative weightage of each groundwater sample is shown in table (2). The standard prescribed by BIS(2012) of drinking and for agriculture have been used for reference purpose.

Table 1. Categorising Of WQI based upon Brown et.al(1972)

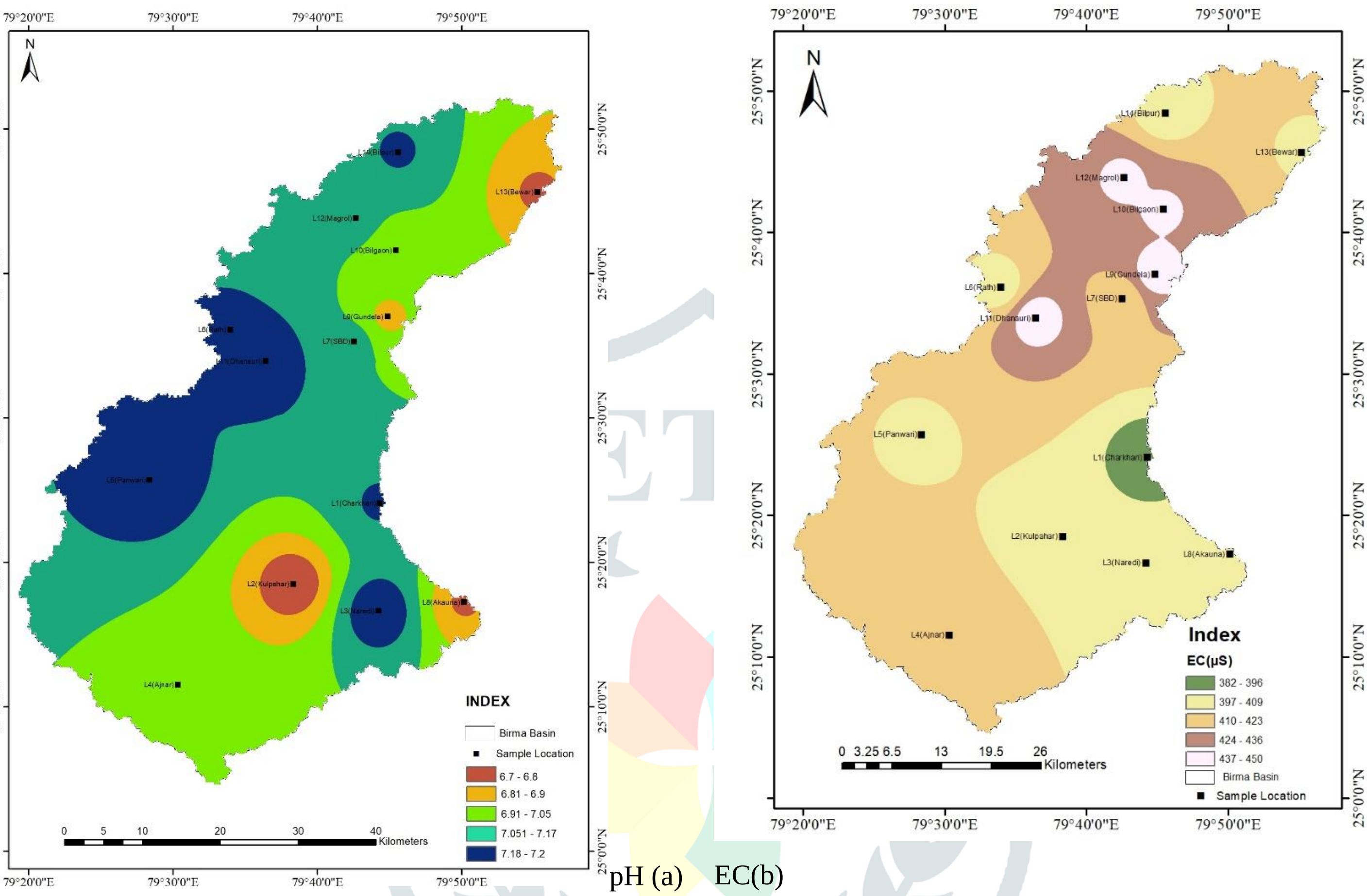
WQI	Water Quality Rating
≥100	Unsuitable
51-100	Poor
26-50	Good
≤25	Excellent

Table 2. Weightage and Relative Weightage of Each Groundwater Parameters

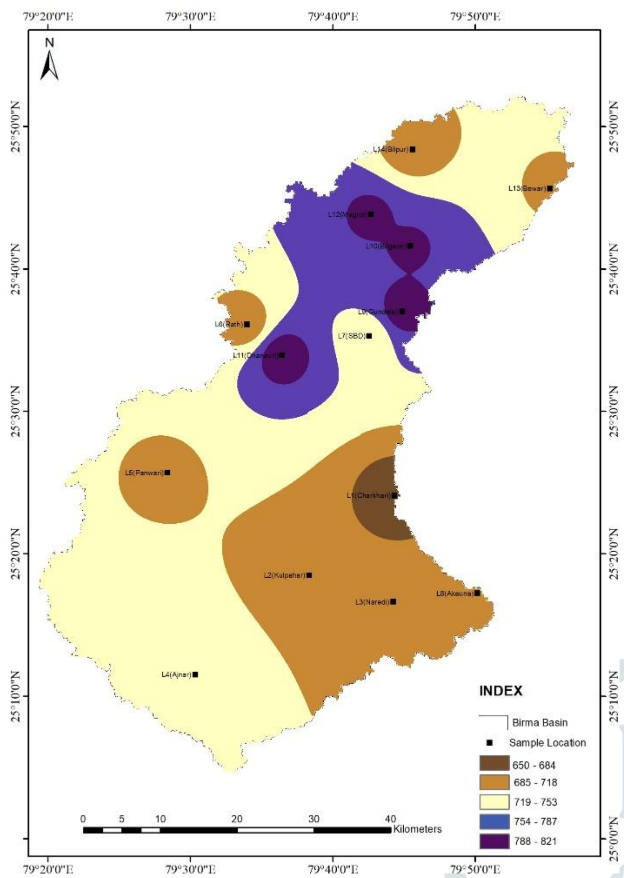
Parameters	Permissible limit	wi	Relative weight	(Wn)
pH(scale)	6.5-8.5	1	0.033333	0.001721
EC (µS/cm)	750–3000	2	0.66667	0.000036
Alkalinity(mg/L)	200–600	1	0.033333	0.000022
TDS(mg/L)	500-2000	1	0.033333	0.000049
Ca2+(mg/L)	75-200	1	0.033333	0.000049
mg2+(mg/L)	30-100	1	0.033333	0.000014
Na+(mg/L)		2	0.66667	0.000031
K(mg/L)		1	0.033333	0.000021
HCO3(mg/L)	300-600	1	0.033333	0.000044
SO4(mg/L)	200-400	1	0.033333	0.000036
NO3(mg/L)	45	3	0.033333	0.000201
TH(mg/L)	200-400	1	0.033333	0.0000103
Flouride(mg/L)	1-1.2	2	0.066667	0.105306
Iron(mg/L)	1	2	0.066667	0.035123
Chloride(mg/L)	250-1000	1	0.033333	0.401206
		Σwi=30	**ΣWir**= 1	**ΣWn**= 1

6.1 Potential of Hydrogen(pH)

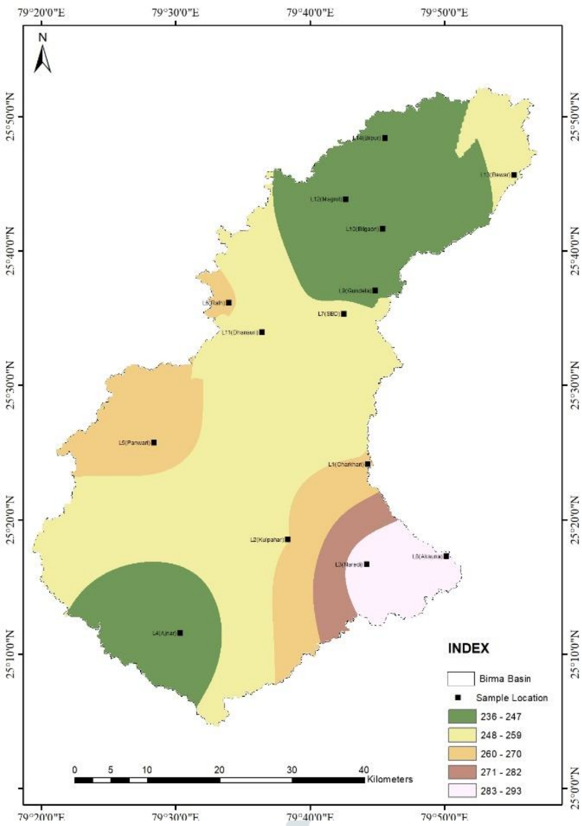
It represents the ratio of Hydronium ions(H_3O) to Hydroxide ion(OH) or negative logarithm of hydrogen ion concentration. It is one of the main parameter to analyse water quality in terms of acidity/alkalinity. The BIS(2012) standard for pH of drinking water ranges from 6.5-8.5. The pH of the water sample are under permissible limit and is safe for drinking purpose. Study result shows that sample collected from western half of Birma basin comprising localities such as Birpur, Rath, Dhanauri, panwari show highest values of Ph ~7.2-7.3 in the area, while samples of from eastern portion of basin such as Kulpahar, Akauna, Gundela, Bewar are more acidic in nature(pH ~6.3).



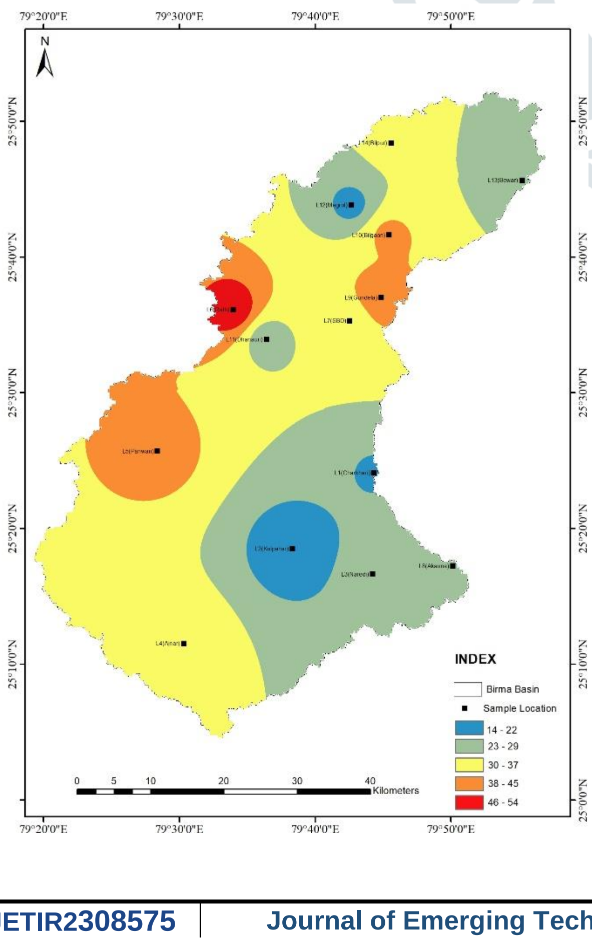
pH (a) EC(b)



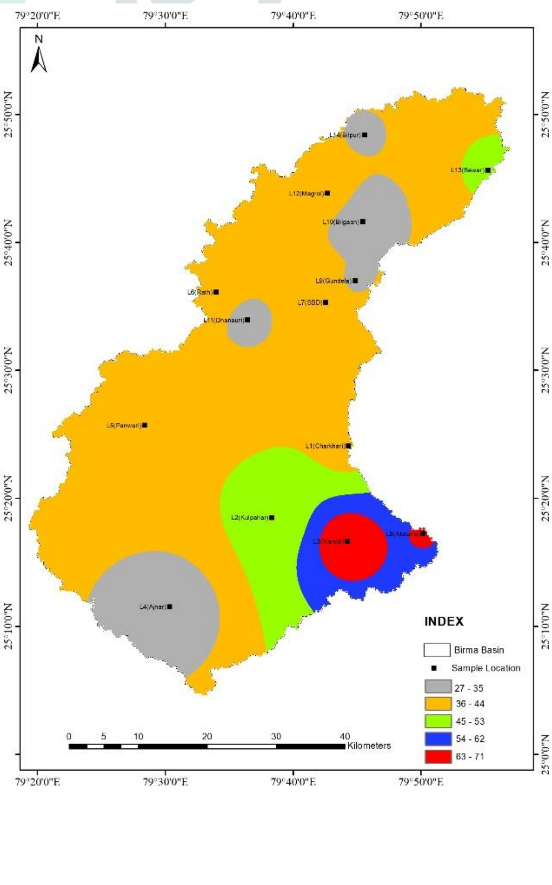
TDS (c)



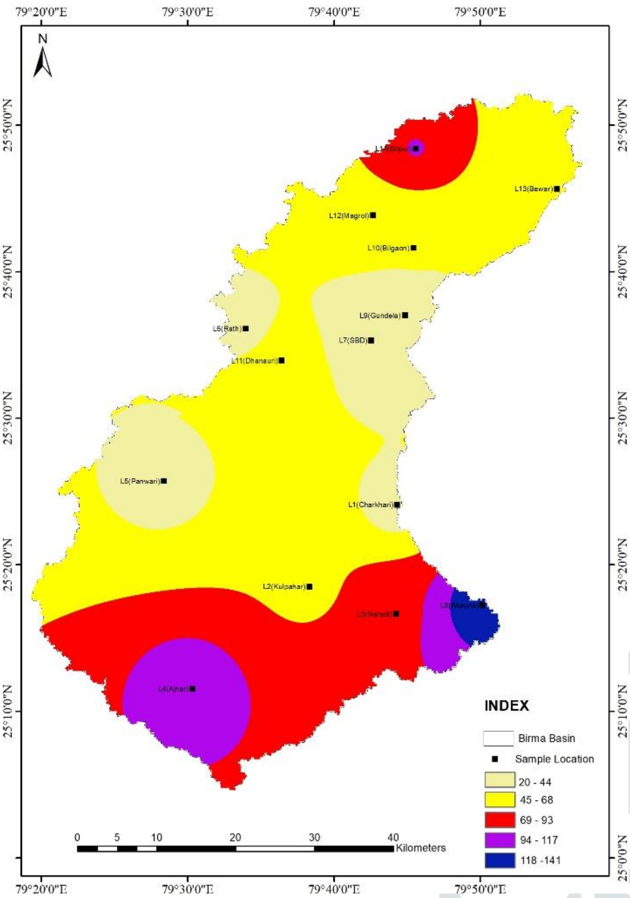
TH (d)

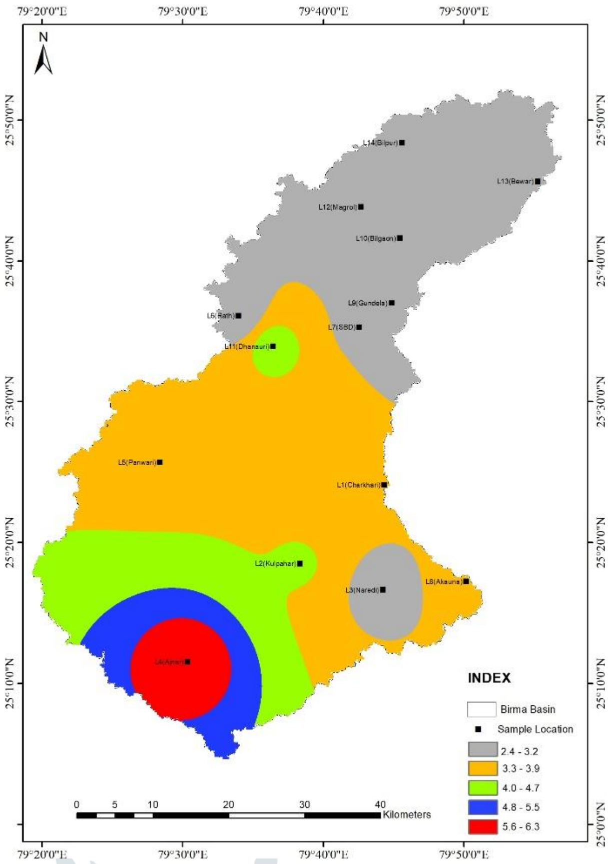


Ca^{2+}(e)



Mg^{+} (f)


79°20'0"E
79°30'0"E
79°40'0"E
79°50'0"E
25°50'0"N
25°40'0"N
25°30'0"N
25°20'0"N
25°10'0"N
25°0'0"N
N
L13(Bewar)
L12(Magrol)
L10(Bilgaon)
L9(Gundela)
L6(Rath)
L7(SBD)
L11(Dhansuri)
L5(Panwari)
L1(Charkhari)
L2(Kulpahar)
L3(Naredi)
L4(Ajnar)
INDEX
Birma Basin
Sample Location
20 - 44
45 - 68
69 - 93
94 - 117
118 -141
0 5 10 20 30 40
Kilometers
Na^{+} (g)


79°20'0"E
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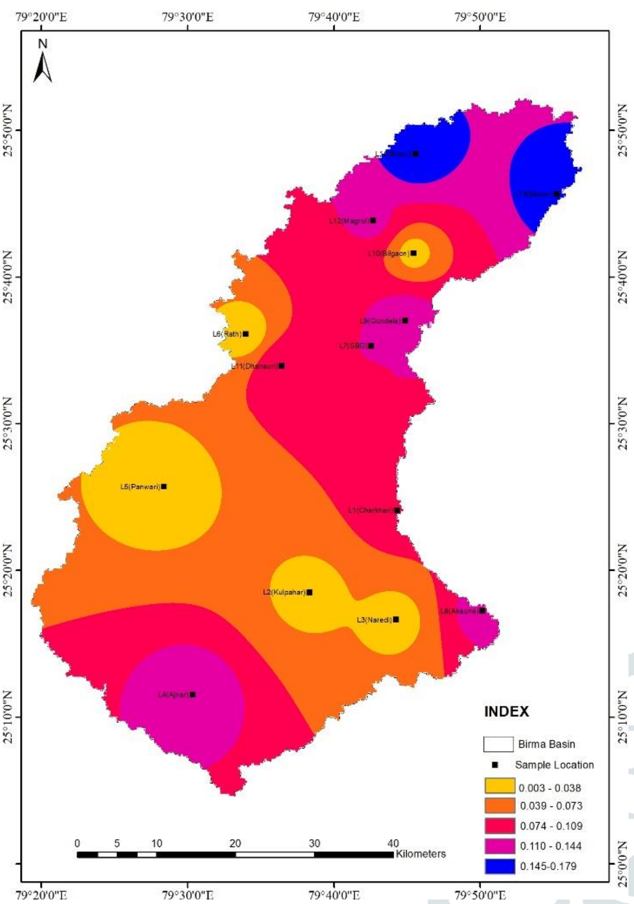
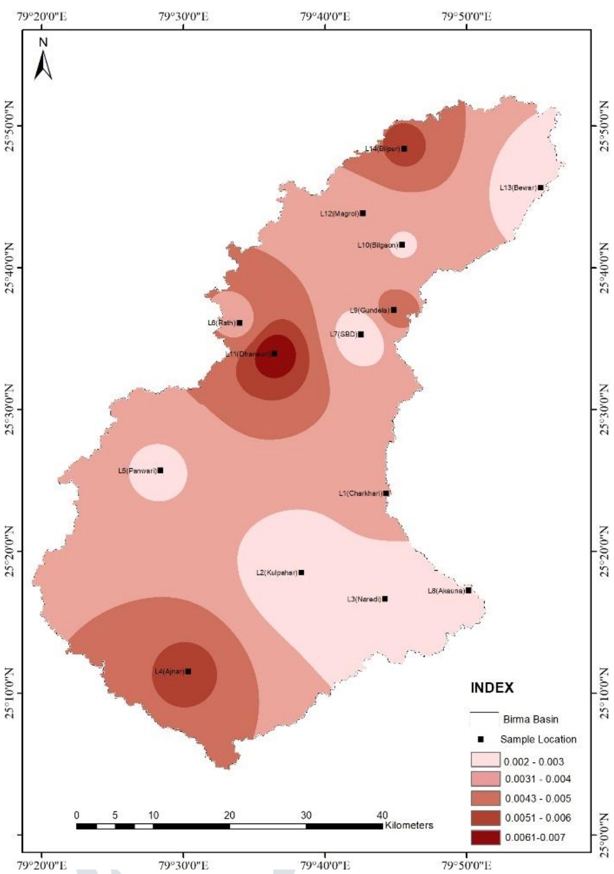
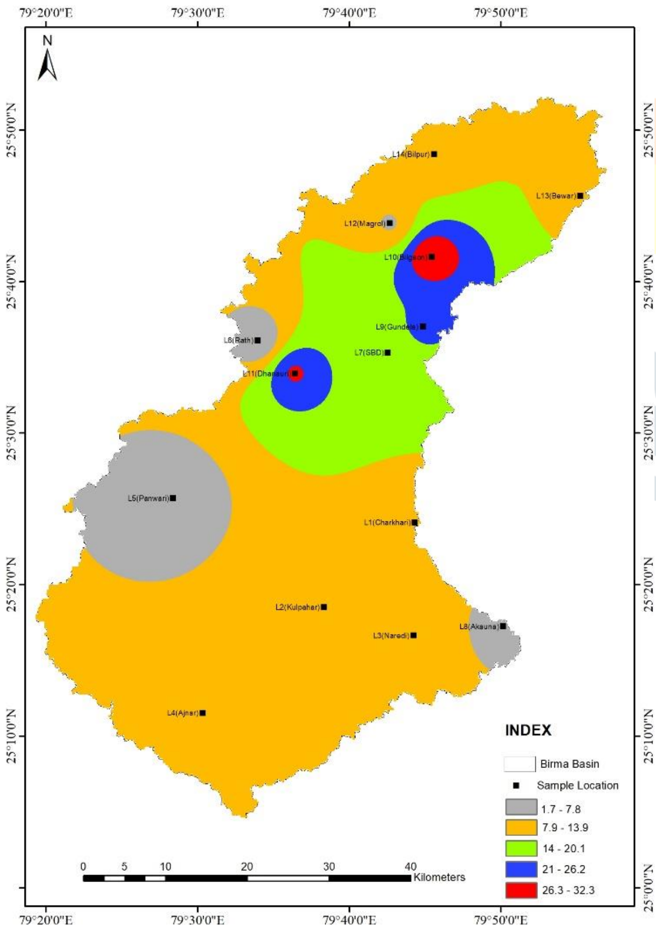
25°50'0"N
25°40'0"N
25°30'0"N
25°20'0"N
25°10'0"N
25°0'0"N
N
L14(Bilpur)
L13(Bewar)
L12(Magrol)
L10(Bilgaon)
L9(Gundela)
L6(Rath)
L7(SBD)
L11(Dhansuri)
L5(Panwari)
L1(Charkhari)
L2(Kulpahar)
L8(Akauna)
L3(Naredi)
L4(Ajnar)
INDEX
Birma Basin
Sample Location
2.4 - 3.2
3.3 - 3.9
4.0 - 4.7
4.8 - 5.5
5.6 - 6.3
0 5 10 20 30 40
Kilometers
K^{+} (h)



Fe (i)

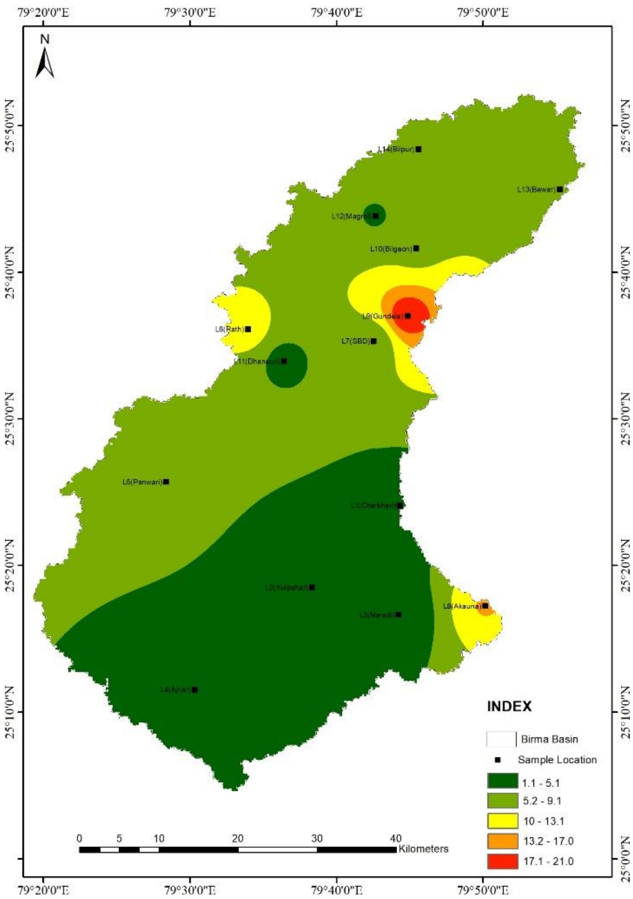


Mn (j)



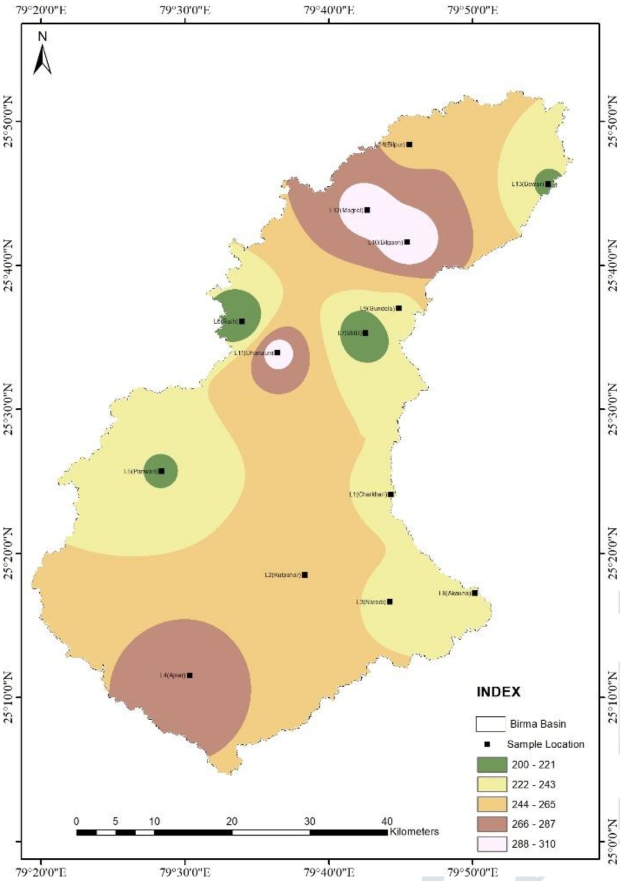
NO_3^-

(k)



(l)

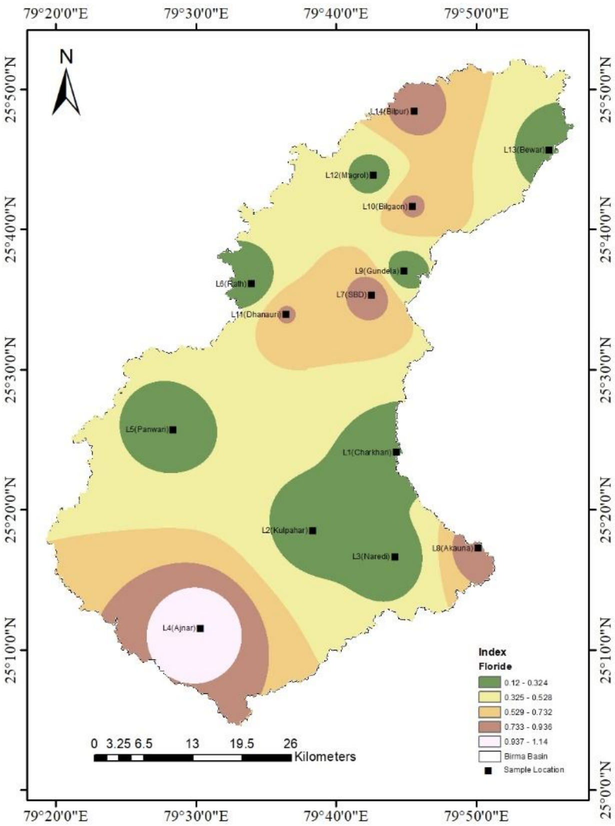
SO_4^-

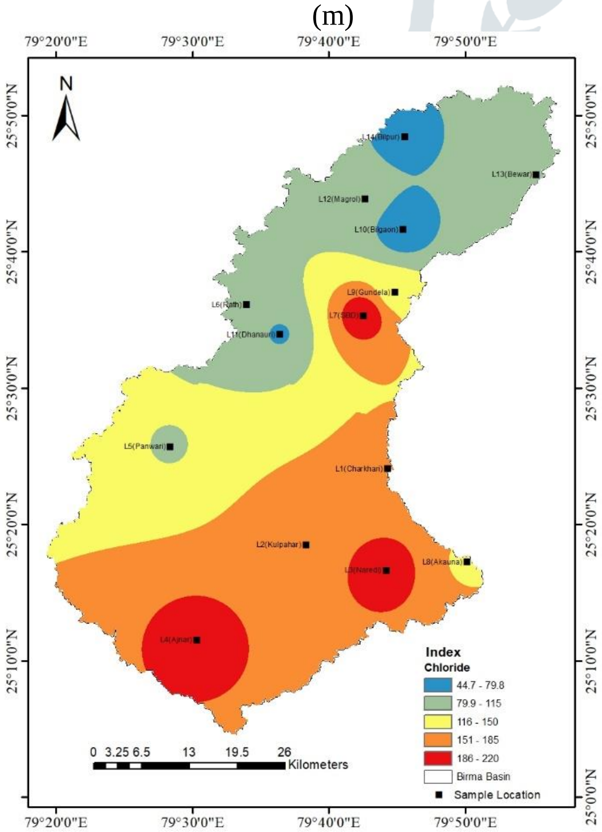


ALK

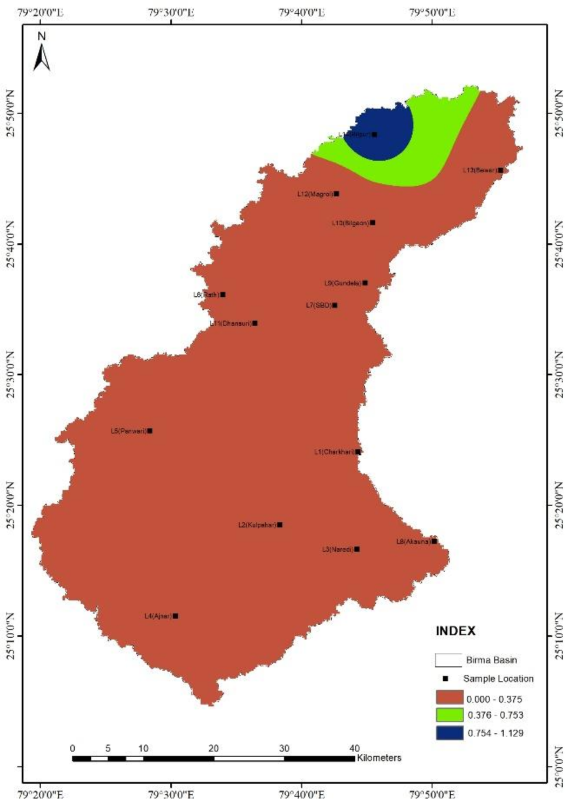
(m)

F-





Cl-



Zn

Figure 1 . Spatial Distribution Maps of Groundwater Quality Parameters of Birma Basin

6.2 Electrical Conductivity(EC)

It is a computation of dissolved material in a water sample and is associated with material' ability to generate electric current through water sample. BIS (2012) set the desirable limit for drinking water as 750 µS/cm. Study results shows that EC ranges from 300- 450 µS/cm. When the EC is high, it probably suggests that there is mixing of sewage with groundwater which is due to urbanisation.

6.3 Alkalinity

It is the ability of water to neutralize its acid nature which is due to the presence of carbonates, bicarbonates and hydroxyl ions. Desirable limit set by BIS(2012) is 200mg/L beyond which it changes its nature to acidity. In the study area, water sample shows alkalinity ranges gradually from 200 to 310 mg/L which is within permissible limit. If there would have been a sudden change in alkalinity range, it would have been due to industrial and municipal wastes discharge.

6.4 Total Dissolved Solid(TDS)

It is related to dissolved minerals/salts in groundwater. These dissolved minerals/salts includes cations, anions, chlorides & fluorides in groundwater. The TDS is dependent upon resident time of cations & anions of an aquifer, geological setup , industrial discharge etc (Syed et al. 2002). Anthropogenic reasons for TDS in water mainly due to municipal & industrial wastewater discharge and results in bitter or salty taste in water , dental problems etc. In potable water, TDS is directional proportional to electrical conductivity of the water. In the study area, TDS ranges from 650- 822 Mg/L which is within the permissible limit set by BIS(2012). Therefore, water is suitable for drinking purpose.

6.5 Calcium

Apart from bicarbonates, Ca^{+} ions is the most important constituent for potable water which is mainly due to dissolution of calcium bearing minerals. Though its essential for plants and human as its deficiency can leads to osteoporosis in human and been in surplus amount leads to hypercalcemia. In water excess of Ca^{+} ions makes it hard. Sometimes, hard water helps in strengthening of bones due to its high calcium concentration only if human body is undergoing through its deficiency. In the study area, Ca^{+} ions ranges from 14.2- 53.3 mg/L which is within the permissible limit set by BIS(2012).

6.6 Magnesium

Calcium and Magnesium are two parameter responsible for hardness of water. In the study area, the concentration of Mg^{+} ranges 28.6 to 71.2 mg/L which is within the permissible limit. Though at few places, value is slightly more than the desirable limit, but it is safe for drinking and irrigation purposes.

6.7 Sodium(Na^{+})

After Ca^{+} & Mg^{+} , it is one of the most abundant cation present in groundwater. The natural augmentation of Na^{+} ions in groundwater is often by dissolution of silicate minerals such as sodic plagioclase/alkali feldspar. In the study area, it ranges from 20.6- 110.7 mg/L which lies well within permissible limit.

6.8 Potassium(K+)

It is present in most of the rocks and is readily soluble in water. In some cases, excess of potassium causes hyperkalemia in human. In the study area, potassium ions ranges from 2.4-6.4 mg/l which is within permissible limit.

6.9 Nitrate

Nitrate ions is common is groundwater yet its considered serious major problem. The reason for the dissolution in groundwater is due to the extensive use of nitrogen based fertilizers for agricultural practises to upsurge crop production. Its overapplication causes Methaemoglobinaemia in infants. In study area, it is within permissible limit i.e 45 Mg/L , however in Bilgaon it is bit higher with a value of 32.4 Mg/L. This needs a constant check , as slight increase in NO_3 ions causes cancer and different health hazards to children. The study area, is a hard rock terrain (granite-gneiss) , in which atmospheric nitrogen is mixed in soil in the form of ammonia through plants & animals remains, bacterial actions by the process of ammonification in soil. Granitic rocks contain nitrogen concentrations up to 250 mg Nkg−1with ammonium partitioned into the orthoclase feldspar to a greater extent than muscovite or biotite (Boyd et al. 1993).

6.10 Iron

The dissolution of iron in groundwater is due to weathering of iron bearing minerals. Presence of iron in soluble state does not cause any health hazard as such. In this present study, the concentration of iron range from 0.1- 0.23 mg/l which is within permissible limit.

6.11 Sulfate

The sources responsible for concentration of sulphate in water are gypsum, airborne sulphate compounds originated from sea and from dust, gaseous sulphur oxide, decaying organic matter, volcanic exhalations and the weathering products of some. magmatic rocks. The maximum permissible limit for sulphur concentration in drinking water is 200 ppm. Water with high sulphur concentration causes diarrhea. In the study area, the concentration of sulphur is in the range of 1.11-21.1ppm which is within permissible limit.

6.12 Chloride

The concentration of chloride in natural water varies widely. When present in large amount, it is an indicator of pollution due to chemical origin. Higher levels of chloride cause variation in taste of water An upper limit of 250 mg/l has been set for chloride as per IS: 10500 (BIS 1991) . The concentration of chloride in the study area ranges from 44.6- 220.4 mg/l, which is within permissible limit. Though , it is higher in the sample collected from Swami Bramhanad dam 220.4 mg/l , but still it is within permissible limit.

6.13 Fluoride

Fluoride present in groundwater is of soil origin. It is one of the most reactive element along with lightest halogen(Kaminsky et al. 1990). The groundwater percolates through fluoride bearing minerals, acts as a solvent and infiltrates fluoride rich water to the aquifer units. The study comprises of granite, granitic gneiss, which contain calcium fluoride as an accessory mineral (Ozsvath 2006; Saxena and Ahmed 2003) and hence fluoride is present in the study area. In the study area, F- is within permissible limits.

6.14 Copper (Cu): Copper is an essential element is human metabolism. Nutritional problems are common in infants due to deficiency in copper. The detectable range of copper varies from 1 to 5 ppm and imparts peculiar taste to water. The presence of copper in small amounts does not cause health hazard but large amount can cause sickness and may damage liver. The permissible limit of Cu 1.0ppm . The concentration of copper is within permissible limit.

6.15 Zinc: It is an essential element for plants, animals and man as it has an important role in the functioning of various enzymes. The prescribe zinc concentration for drinking water supplies (BIS, 1991, WHO. 1971) is 5 ppm as higher desirable limit and 15 ppm as maximum permissible limit Water appears milky and produces metallic or stringent taste on boiling when level of zinc in water in very high. A nutritional deficiency of zinc in animal causes impaired growth, testicular atrophy and fibrotic changes in the esophagus, while excessive levels can damage kidneys, renal tubular injury proteinuria, anemia and hypertension. The range in which the zinc concentration in study area is within permissible limit.

6.16 Manganese(Mn) : It is naturally present in groundwater and is widely dependent upon ionic composition of rainwater, hydro geochemistry of groundwater, aquifer properties, etc. In the study area, Mn is present within permissible limits , i.e., 0.3mg/l.within permissible limits.

7. Water Quality Index

The water quality Index map is composed using ArcGIS by considering the selective parameters of groundwater quality in order to classify them as excellent, good , poor, unsuitable (as shown in table 3) at each hydrostation particularly for drinking purposes. The WQI map of the study area shows that major area shows good quality of groundwater (L3,L5,L6, L7, L9, L12, L13, L14), some have poor quality as well. The map clearly shows that Charkhari block has excellent quality of groundwater and is completely suitable for human consumption.

There is actually moderate fluctuation in groundwater in NE parts of the basin , and in eastern part of the block as well ranging from excellent, poor, good. There is no significant change in groundwater except in some parts i.e , Bilgaon, Dhanauri areas. In Swami Bramhanand dam, the change is evident and deterioration in quality class can be easily seen in areas around dam. The overall quality of basin is good and poor and major portion of the area is suitable of human consumption.

Table 3 . WQI Of Birma River Basin

Sample No.	WQI	Category
L1	19.814	Excellent
L2	52.37	Poor
L3	35.59	Good
L4	53.39	Poor
L5	44.86	Good
L6	30.03	Good
L7	47.19	Good
L8	74.3	Poor
L9	37.39	Good
L10	69.47	Poor
L11	69.72	Poor
L12	32.044	Good
L13	29.57	Good
L14	47.86	Good

8. Spatial Distribution Interpretation.

The spatial distribution map of the chemical parameters of Birma river basin is generated by IDW interpolation in Spatial analyst tools. The study area shows minor amount of fluctuation in pH. The pH value range from 6.7 to 7.3. This implies that the groundwater condition is more or less neutral, ranging from weakly acidic to weakly basic. Weakly acidic pH values are seen towards eastern margin of basin which includes Bewar(L13), Gundela(L9), Akauna(L8).apart from south central part of basin also has similar pH conditions which include Kulpahar(L2). Contrary to this , the areas along the western margin of basin show weak alkaline groundwater conditions i.e, Panwari, Dhanauri, Rath, Bilpur. The study shows a distinct trend in increase in acidity of groundwater from west to east. The acidic and alkaline nature of groundwater is plays a major role for fluoride accumulation in water. Acidic conditions, tends to adsorbed fluoride, while alkaline nature tends desorbed fluoride (Rafique et al. 2009; Saxena and Ahmed 2003). The NE part of the basin shows high TDS i.e., >750mg/l dur to weathering and leaching of rock and soil. Similarly , same parts of the basin shows high EC as well. This shows that TDs and EC shows positive correlation which is further cross checked in correlation matrix. Spatial pattern of alkalinity clearly shows that in northern part of basin i.e in Bilgaon, Magrol shows decreasing outward trend. Usually, bicarbonates amplifies alkalinity of groundwater. In the study area, the majority of groundwater is more or less neutral, therefore, the carbonates doesn't dissolve in the form bicarbonates. The correlation matrix as shown in table . clearly shows positive correlation between fluoride and alkalinity subsequently responsible for fluoride in groundwater but it is within permissible limit. The Ca^{2+} spatial distribution pattern of basin specifically and clearly shows decreasing outward trend in NE part of the trend , and present in scattered patches throughout the basin due to the presence of orthoclase in granitic rocks. Likewise, Mg2+ concentration shows high pattern in SE part of basin whereas the majority of basin ranges 36-44 mg/L in Mg concentration which is within permissible limit. The spatial distribution pattern of groundwater suggests that water is hard in the basin.

The reason for presence of Ca2+ , Mg2+ is by percolation of water which dissolves minor amounts minerals and hold them in solution. From the correlation matix , it is clear that fluoride shows that positive correlation with Ca, and negative with Mg, which indicates high content of fluoride as compared to Mg. The correlation matrix shows positive correlation TDS, EC, alkalinity, TH and Mg, which is quiet evident from their spatial distribution maps.(Table 3). Spacial distribution pattern, of Na+ ions , shows concentration is high in eastern and southern most part of the basin , and a small patch in northern part of the basin which can be seen in TDS and alkalinity spatial distribution pattern. The K+ ions shows evenly distribution in spatial pattern throughout the basin i.e, decreasing outward pattern from south to north of the basin.(Figure 1(h)) due to weathering of alkali feldspar in granitic rocks.this pattern doesn't show any conformance neither with TDS or Na+ . the bicarbonates HCO3- doesn't show any positive correlation with many ions but still shows slightly positively correlated with TDS, Mg+ ions. SO4- shows strong positive correlation with Ca2+ ions (>0.5) which evidently seen in spatial pattern (Figure 1 c, f, l). The presence of SO4- ions is within permissible limit in the study area.

Cl- in present in scattered patches in the basin and is high in southern part of the basin. It is present below desired limit in throughout the basin. The reason for this may be absence of halite minerals.

F- ions is an important parameter in groundwater quality . it can be seen that in study area, it is present in scattered patches throughout the basin. In the southern part of the basin , in Ajnar F- ions the concentration of F- is higher than usual areas but it is also within permissible limit. The presence of NO3 ions is mainly due to landfills, municipal wates, excessive use of nitrate fertilizers etc. (Chapman 1996). The is study area, the presence of NO3 ions is high at certain places like Bilgaon , Dhanauri , but that too within permissible limits. The terrain of the study area is granite-gneiss which has fixed atmospheric nitrogen and added as ammonia in soil through, bacteria in soil and plants roots. Moreover , animal faeces, plants remain undergoes the process of nitification which results in formation of ammonia in soils. Poor drainage management , lack of proper management of domestic wastes may be the reason due to high nitrate ions in the study area.

In the view of metals concentration in the study area, there is no significant traces of Cu seen in study area. Arsenic is below desired limit throughout the Birma basin. Zn doesn't show remarkable trace in study area. Mn is present in very minor amount in basin. Traces of Fe can be seen in everywhere.

	pH	EC	TDS	Alkalinity	Ca2+	Mg2+	Na+	K	TH	HCO3	SO4	Cl	F	NO3	Fe
pH	1.00														
EC	0.03	1.00													
TDS	-0.02	0.93	1.00												
Alkalinity	-0.02	0.45	0.63	1.00											
Ca2+	0.27	0.06	0.12	-0.30	1.00										
Mg2+	-0.05	-0.36	-0.49	-0.45	-0.35	1.00									
Na+	-0.18	-0.12	-0.12	0.34	-0.33	0.32	1.00								
K	-0.07	0.29	0.16	0.34	-0.15	-0.31	0.43	1.00							
TH	0.11	-0.35	-0.44	-0.64	0.22	0.84	0.14	-0.41	1.00						
HCO3	-0.03	-0.01	0.06	-0.03	0.00	0.15	-0.15	-0.51	0.15	1.00					
SO4	-0.26	0.13	0.27	-0.22	0.58	-0.09	-0.08	-0.33	0.24	0.40	1.00				
Cl	-0.16	-0.17	-0.35	-0.39	-0.27	0.42	0.10	0.34	0.29	-0.26	-0.30	1.00			
F	-0.05	0.20	0.17	0.31	0.07	-0.29	0.51	0.50	-0.27	-0.25	0.00	0.04	1.00		
NO3	-0.10	0.58	0.65	0.53	-0.03	-0.40	-0.23	-0.06	-0.44	0.28	0.06	-0.24	0.22	1.00	
Fe	-0.26	0.30	0.31	0.43	-0.12	0.02	0.31	0.16	-0.05	0.18	0.13	-0.29	0.29	0.46	1

Figure 2 Correlation Matrix of Physico Chemical Parameter of Birma Basin

9. The Hydrochemical Facies

The ions analysed are more or less evenly distributed , in Hill Piper Trilinear diagram as shown in figure (2). The diagram have cation in left side, and anions in right side , with diamond shaped centre to show significant ions responsible for groundwater quality. This diagram is categorise as Ca-HCO3, Na-Cl , Mixed Ca-Mg-Cl, Mixed Ca-Na-HCO3, Na-HCO3, Ca-Cl type. Critically evaluating the diagram shows that most of the sample falls under Ca-HCO3 type, one sample falls under Na-Cl type and one is of the mixed Ca-Mg-Cl type. The samples are evenly distributed throughout the diagram reflecting higher absorptions of calcium and sodium minerals in groundwater. While analysing the hydrochemistry of samples collected from the basin shows that the major cations are present in order $Ca^{2+} > Na^{+} > Mg^{2+} > K^{+}$ of average abundance whereas anions are present in order of $HCO_3^{-} > Cl^{-} > SO_2^{-} > NO_3$ shows in Figure (2). This shows that sodium, chloride and bicarbonate are dominant ions concentration in the groundwater due to weathering of rocks and minerals along with infiltration of water through fissures and fractures of these rocks.

10. Conclusion

- The consequence of this research in hard rock terrain of Bundelkhand granitic rocks shows that groundwater quality of the study area is needs proper management and attention as its quality is declining in certain places by both natural and anthropogenic process.
- Owing to the lithology of Birma basin which includes, granite, granitic gneiss, is responsible for various ions like chlorides, fluorides etc.
- The presence of silt-clay with kankar in northern part of the basin is vast , but its thickness is not that profound, to block the concentration of TDS , HCO3 in groundwater due to poor fluxing.
- Many factors, like poor water management, negligible sewage tank management, no proper dumping of domestic , municipal wastes leads to poor quality of groundwater in certain places. Most the places of Birma river basin has good to poor quality of groundwater. The study area, is a hard rock terrain (granite-gneiss) , in which atmospheric nitrogen is mixed in soil in the form of ammonia through plants & animals remains, bacterial actions by the process of ammonification in soil.
- In Hill Piper Trilinear diagram most of the sample falls under Ca-HCO3 type, one sample falls under Na-Cl type and one is of the mixed Ca-Mg-Cl type.
- The WQI map of the groundwater shows that it is good and safe for drinking purpose ,except, in few places like Dhanauri , Akauna. These places show high WQI values due to certain chemical parameters which requires immediate attention.at is also within permissible limit. Cr also doesn’t present in remarkable traces in basin.

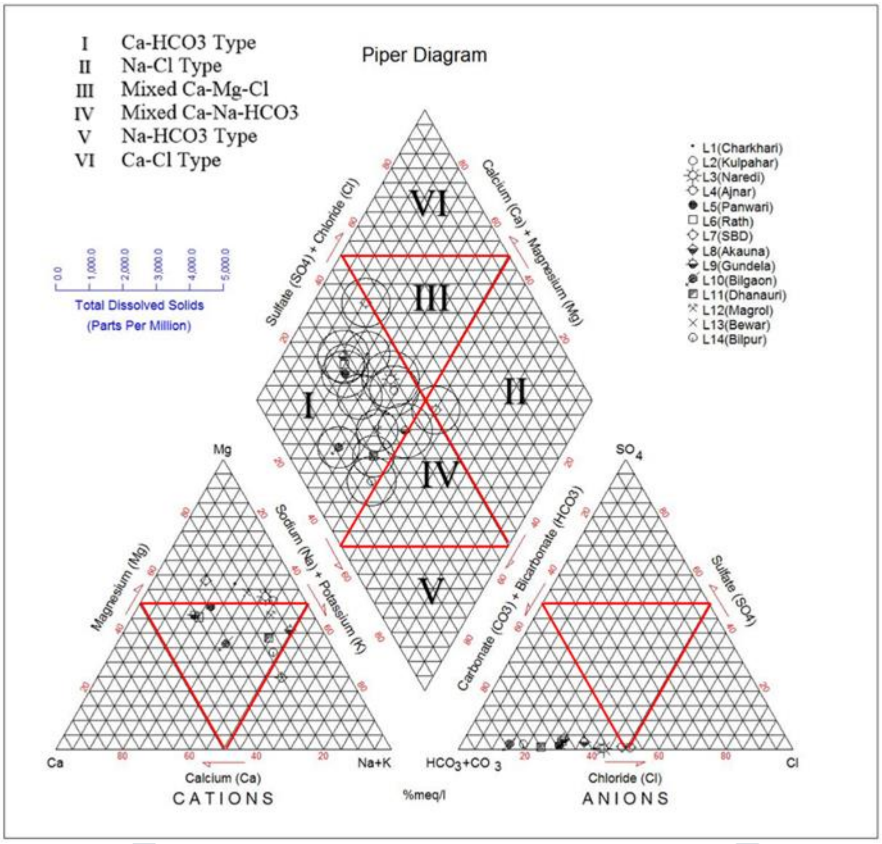


Figure 3 Piper Trilinear Diagram of Birma Basin

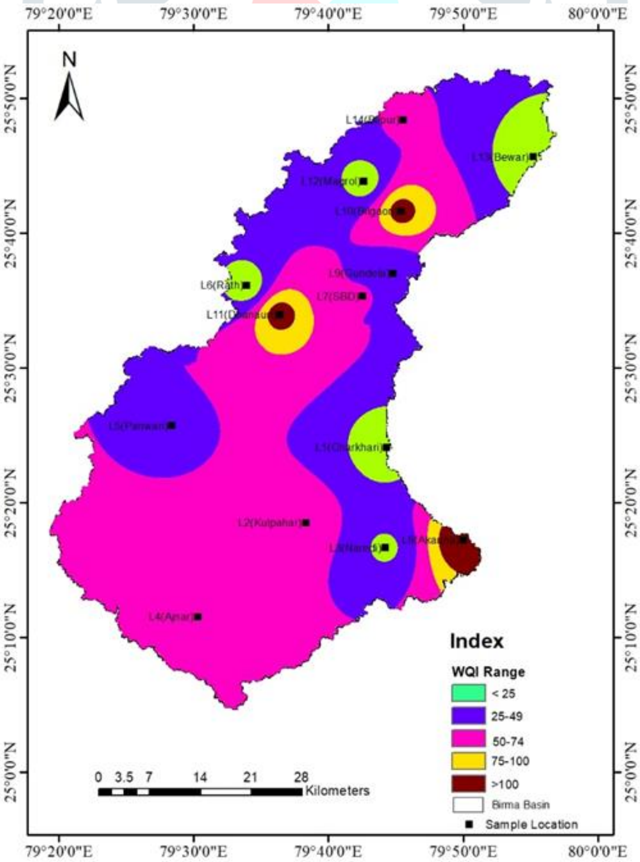


Figure 4 Water Quality Index of Birma Basin

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