An assessment of groundwater quality at Lalganj block, Uttar Pradesh, India: A Water Quality Index approach

Pokhraj Sahu[1&2], Pramod Kumar Singh[2], Ganesh Chandra Kisku[1], Prashant Singh[3], and Vinay Kumar[1&2]
[1]Environmental Monitoring Laboratory, CSIR-Indian Institute of Toxicology Research, Vishvigyan Bhavan, 31, Mahatma Gandhi Marg Lucknow - 226 001, India.
[2] Environment Science Division, Department of Chemistry, Babu Banarashi Das University, Lucknow 226028 India.
[3]Central Pollution Control Board, Ministry of Environment, Forest and Climate Change, Government of India Parivesh Bhavan , Shahdara, Delhi- 110032.
***Corresponding author:** Dr. P K Singh, Department of Environmental Science, Babu Banarasi Das University Faizabad Road, Lucknow, Uttar Pradesh 226028

Abstract

Water quality assessment is most important to the human health and to take necessary action for management or control pollution of water bodies. Present investigation carried out to easily accessible the expanding demands of fresh water and besides to find out remedial methods for improvement of groundwater quality. Study area of Lalganj block of Raebareli District, Uttar Pradesh, India, is selected to discuss the impact of groundwater quality on vegetation and human health, where the agriculture is the main livelihood of rural people and the groundwater is the main source for irrigation and drinking. twenty groundwater samples were collected from each block and analyzed for pH, turbidity, total dissolved solids, total hardness, major anions (F^-, Cl^-, NO_3, HCO_3^- and SO_4^{2-}) and cations (Ca^{2+}, Mg^{2+} $Na^+$and K^+). Study results reveal that groundwater of the area is alkaline in nature and HCO_3^-, F^-, Mg^{2+}, Na^+ and total hardness are major contributing ions to the dissolved solids. Alkaline earth metals (Mg^{2+}) exceed alkalis (Ca^{2+} and Na^+) and weak acid (HCO_3^-) dominate over strong acids (Cl^- and SO_4^{2-}) in majority of the groundwater samples. Na-Mg-HCO_3 and Na-Mg-Cl-HCO_3 are the dominant hydro geochemical facies in the groundwater of the area. The calculated WQI ranged from 46.48 to 111.77 Lalganj block. The groundwater quality status of Lalganj block was found good category of water on the basis of calculated WQI. The concentration of TDS, HCO_3, F^-, and total hardness exceed the desirable limits of IS and WHO. The mean concentration of fluoride in groundwater of Lalganj block were 2.24 mg/L respectively, inhabitant of the area may be risk to dental and skeletal fluorosis.

Keywords: Groundwater, water quality index, special distribution, fluoride, fluorosis**.**

Introduction

Water pollution is a major global problem which requires ongoing evaluation and revision of water resource policy at all levels. More than 90% rural and just about 30% urban population of India utilized to groundwater for drinking and domestic requirements **(Jaiswal et al. 2003)**, where the population is widely dispersed and the infrastructures required for the treatment and transportation of surface water does not exist **(Jain et al. 2010)**. It has been suggested that it is the leading worldwide cause of deaths and diseases, and that it accounts for the deaths of more than 14,000 people daily. According to WHO organization, about 80% of all the diseases in human

beings are caused by water. WHO **(**2012) have reported worldwide 748 million peoples are still relied on unimproved drinking water sources, almost 27 nations and 200 million people across the global face issues of excess fluoride in drinking water and 66.64 million people in India. Ground water is one of the earth's renewable resources which occur as a part of hydrological cycle. Ground water comes from rain, snow, sleet and hail that socks into the ground. The water that moves down into the ground because of gravity passing between particles of sand, gravel or rock until it reaches a depth where it is filled with water is called saturated zone and the top of this zone is called the water table. The physical and chemical properties of fresh water bodies are characterized by the geochemical, climatic, geo-morphological and pollution condition **(Chaurasia and Pandey, 2007)**.

Water quality refers to "the chemical, physical, and biological, characteristics of water*"*. As we all know, water has many uses, such as for drinking, fisheries, agriculture, industry and recreation. The natural chemical composition of ground water is influenced predominantly by depth of soils, sub-surface, geological formations through which ground water passes, atmosphere, surface water bodies and organic matter. Both ions can be present in the ground water, cations are Na+, K^{+}, Ca^{2+}, Mg^{2+},Al^{3+}, Fe^{2+}, Mn^{2+} and anions are CO_3^{2-}, HCO_3^{-}, Cl^{-}, F^{-}, NO_3^{-}, SO_4^{2-}. Cations present in the ground water and they are constitutional part of soil which are derived from minerals such as orthoclase ($KAlSi_3O_8$), albite ($NaAlSi_3O_8$,), epidote ($4CaO.3(AlFe)_2O_3.6SiO_2H_2O$), iron oxide (FeO), Magnetite (Fe_3O4), Manganese oxides (MnO_2), Calcium carbonate ($CaCO_3$) etc. About 35% of the volume of a typical soil consists of air filled pores. The quality of groundwater is worsening rapidly due to industrial and domestic wastes being discharged into the surrounding areas **(Shaji et al. 2009)**.

Sulphate originates from sedimentary rock sand igneous rocks, is oxidized in soil by bacteria and other organisms to sulphuric acid. Chloride is a major ion in ground water and key element in sea water, atmospheric moisture and mineral halite. The potassium is derived from silicate minerals like orthoclase, microcline, nepheline, leucite and biotite. The F- content of groundwater can originate from the dissolution of fluorine-bearing minerals in the bedrock. In other words, bedrock mineralogy is, in general, a primary factor for the variations in F- content of groundwater. Both, quality and quantity of groundwater is important to its owing to the suitability of water for various purposes **(Chidambaram et al. 2011)**. Fluoride Contamination of groundwater is functioning with many factors such as availability and solubility of fluorine-bearing minerals, temperature, pH, concentration of calcium and bicarbonate ions in water, etc. It is mainly derived from fluorite and fluorspar- CaF_2 (The rocks rich in fluoride are sedimentary rocks, lime stones, sand stones); Cryolite-Na_3AlFPO_6 (Igneous rocks, Granite); Fluorapatite-Ca_3 (PO) $2Ca(FCl)_2$.

The population explosion is increasing the water demand that is increasing to the developmental activity for supporting of population and surface and groundwater was extremely exploited for that activity **(Krishan et al., 2016)**. The water quality indexing is a mathematical tools for transforming physico-chemical data into a single numerical value which described overall level of groundwater quality. The WQI helps to land use planning and management of water resources for the specific area. The water quality index is unique, easily understandable and effective tools to represent the overall quality of water for its suitability of different using purposes **(Singh et al. 2013)**. Water quality assessment is fist steps of environmental management plan, keeping in views of above objective the drinking water quality assessment was conducted in groundwater of Lalganj Block, Uttar Pradesh,

India and developing water quality index for helping in management of water resources and land use planning of the study area.

Study design

Study area

Lalganj is a block of Raebareli District (UP), lies between 26º 09' 53.18"N latitude and 80º58'14.89"E longitude given in figure 1. Lalganj block Located at Ganga basin in 84 km distance from Lucknow (Capital of UP) to Raebareli road. Total 1, 62,941 numbers of populations inhabit in 29,592 households which spreading over 223.72 square kilometre area and the population of 0 to 6 year age group are 19,818 which contribute 10,423 numbers of male and 9,395 numbers of female. Climate of Lalganj is semi arid and average rainfall of 923 mm 0 to 6 year with mean maximum and minimum temperature of 44.2 ^{0}C and 8.3^{0}C.

Samples collection and analysis

For this study, 20 no. of water sample collected from Lalganj block during post-monsoon season 2016. Water sample was taken in pre-washed polypropylene plastic bottle (1000 ml). Standard methods (BIS-3025, APHA, 2012) will be used for water quality analysis. Sulphate, nitrate, were analyzed by spectrophotometer. Total hardness, bicarbonate and chloride were determined by titrimetric method. Fluoride was analyzed by Ion Selective Electrode (Fluoride Meter). TDS of water sample was finding out by gravimetric method. Calcium, magnisium, sodium, and potassium were determind by using emission mode in atomic absoption spectrometer. All reagents and calibration standards use for the experiment will analytical grade chemicals. Measured parameters will be compared with the guidelines for drinking water suggested by Bureau of Indian Standards (BIS-10500) and WHO.

Water quality index (WQI)

Water Quality index (WQI) is defined as a technique of ranking which affords the composite influence of individual water quality parameter on the overall quality of water. WQI is one of the powerful tools to assess the status of drinking water suitability for human consumption. The average means concentration of the ten physico-chemical parameters such as pH, TDS, Turbidity, TA, TH, Cl^-, NO_3^-, SO_4^{2-}, F^-, Ca^{2+}, Mg^{2+}, Na^+, and K^+ was used for the calculation of WQI. The cumulative effects of different parameters can be calculated to evaluate the drinking water quality of an area. The critical pollution index considered unacceptable is 100. The steps are as follows:

In the first step,

The permissible values of different parameters as per Indian standard and WHO standard were observed to select the parameters for calculating the WQI (Table 1). Then among the total analyzed parameter, 13 parameters has been selected for assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (Table 4.3). The maximum weight of 5 has been assigned to the parameter like TDS, Cl^-, SO_4^{2-}, NO_3^- and F^- due to their major importance and these parameters are the mainly pollution indicating parameters

and TA, TH and K^+ which are given the minimum weight of 3 as these parameters are itself may not be harmful than previous ones.

In the second step,

The relative weight (Wi) is computed from the following equation

$Wi = wi / \sum wi$ ..... Eq. (1)

Where,

wi =assigned a weight

$\sum wi$ = sum of the weights of all the parameters considered in relative weight calculation table.

In the third step,

a quality rating scale, Qi, was computed for each parameter using following equation:

$Qi = (Ci / Si) x100$ ..... Eq. (2)

Here

Ci =the concentration of parameters present in the samples

Si= acceptable limits of WHO and Indian standard for each parameter, in mg/L.

Si Value for pH is considered as 7.

In the fourth step,

The water quality sub index, SI_i was then calculated for each parameter using Eq. (3).

$SI_i = Wi x Qi$ ..... Eq. (3)

In ending step,

WQI values Computed by means of-

$WQI = \sum SI_i$ ..... Eq. (4)

Computed WQI values are usually classified into five categories as follows (Sahu and Sikdar 2008):

≤50 excellent water, 50–100 good water, 100–200 poor water, 200–300 very poor water, >300 water unsuitable for drinking.

Results and discussion

The groundwater sample collected during the post-monsoon period 2016 and descriptive statistics of various physico-chemical parameters of shown in tables 1.

pH of the groundwater

The pH stands for "potential of hydrogen". The pH value is expressed as the negative logarithm of the hydrogen ion concentration. The concentration of hydrogen in a solution is important factor in maintaining the carbonate and bicarbonate levels in water. The mean values are recorded within the range from 7.68 to 8.61(8.04±0.04) in groundwater samples of Lalganj block show in table no. 1. 95 % samples of the study area found to be within the permissible limit of IS and WHO (6.5-8.5ppm). The variations in pH are relatively in small.

TDS (Total Dissolve Solid)

TDS is a measure of the amount of dissolved material in water. A high content of dissolved solids elevates the density of water, reduces utility of water for drinking, irrigation and industrial purposes. Its concentration beyond 500 mg/L, decreases palatability and may causes gastrointestinal irritation. TDS includes solutes such as sodium, calcium, magnesium, bicarbonate, chloride and others that remain as a solid residue after evaporation of water from the sample. The mean TDS values are found within the range from 675 to 1848 (1041±108.6) in groundwater samples Lalganj block. Most of the groundwater samples show the TDS values within the permissible limit of WHO (1500 ppm). High levels of TDS may aesthetically be unsatisfactory for bathing and washing.

Turbidity

Turbidity is a measure of the cloudiness or murkiness of water due to suspended particles dissolution from inorganic particles (silt, clay and natural chemical compounds like calcium carbonate and micro-organism). Water becomes poor quality, smell or taste due to Organic and inorganic particles in ground water. In present investigation mean value of turbidity in groundwater of Lalganj block were ranged from 1 to 6 NTU (3± 0.36). 95% sample was found well within the prescribed limits by regulatory bodies. The milky colure of water cause to turbid in water due to clay contamination **(Krishan et al., 2016)**

Alkalinity (Bicarbonate)

Total Alkalinity is the sum of hydroxide, bicarbonate and carbonate; carbonate and hydroxide alkalinity absent in groundwater of study area. Most of the alkalinity in natural water is formed due to dissolution of carbon dioxide in water; it's also called "neutralizing capacity of water". The Alkalinity were ranged 231 to 1146 mg/L in groundwater samples of all block and the mean value were 242 to 628 mg/L (437 ±21.45) in groundwater of Lalganj block exceeded the acceptable limits of total alkalinity for drinking water is 200 mg/L and under the permissible limit 600 mg/L of Indian Standard. However, in large quantities it imparts bitter taste to water.

Total Hardness

Hardness is defined as the concentration of multivalent metallic cations in solutions. The principle hardness causing cations are divalent calcium, magnesium, stronsium, iron, manganese and anions are bicarbonate, sulphate, chloride, nitrate and silicate. Hardness when caused because of bicarbonates and carbonates of these cations is called temporary hardness which can be removed by boiling. Sulphates and chlorides of these cations caused permanent hardness which is not removed simply by the boiling. Permanent hardness is also called Total hardness which is generally caused by the presence of chloride and sulphate of calcium and magnesium.

In general, surface water is softer than ground water. The hardness of water reflects the nature of geological formation with which it has been in contact. Determination of hardness serves as a basis for routine control of

softening process. Water is commonly classified in terms of the degree of hardness, as follows soft (0 – 75 mg/l) → moderately hard (75 – 100), hard (150 – 300), very hard (>300). The mean TH values were range of 26-497 mg/L and mean value was 292 ± 27.62 mg/L. TH mean values were exceeded acceptable limit of WHO and Indian Standard while within the permissible limit in groundwater samples of study area.

Chloride

Chloride is a widely distributed element in rocks and its shows high affinity with sodium; as a result, its concentration is high in ground waters. The mean chloride content of all blocks was found to be well within the permissible levels. The chloride content ranges from 13 to 375 mg/L. It eliminates the growth of microorganisms and reduces taste, odor and colour of the water and widely distributed as salts of calcium, sodium and potassium in water. The major taste producing salts in water are sodium chloride and calcium chloride.

Nitrate

Nitrate is the highest oxidable form of nitrogen and occurs in trace quantity in surface water but may attain high levels in some ground water. In ground water, nitrates may find through leaching from soil and at times by contamination. The main contributor for nitrate in ground water is the nitrogenous fertilizers of both animal and chemical origin and also sewage and industrial waste. The values of nitrate were observed within the range of 4 to 84 mg/L. Nitrate values are within the permissible limit of WHO in 75 % groundwater samples. Suppose high nitrate concentrations (<45 mg/l) in groundwater could pose blue baby disease to infant health.

Sulphate

Sulphate occurs naturally in water as result of leaching from gypsum and other common minerals. More than 250 mg/L of sulphate concentration in ground water is objectionable. Beyond this limit the sulphate concentration causes gastro-intestinal irritation. The sulphate are found in the range of 11-451 mg/L with mean values was 144 mg/L. The mean values of sulphate are within the permissible limit of WHO (250 mg/L).

Fluoride

Fluorides are more common in ground water compare to surface water because of ground water contact with different fluoride bearing rocks and minerals. It is derived from fluorite- the principal fluoride mineral of igneous rocks and mineral specially the fluorospar. The maximum permissible limit of fluoride in drinking water is recommended to be 1.5 mg/L by WHO. Due to its strong electro negativity, fluoride is attracted to positive charged calcium in teeth and bones and enters in our body. Leaching of fluoride depends on the alkalinity of the groundwater. In alkaline environment, leaching of fluoride minerals from the aquifer matrix will be more. The mean concentrations of fluoride found 2.24 mg/L and significant number of water sample has found to be fluoride content. Average fluoride concentration of groundwater was found to more than 49 % exceeded than prescribed standard of WHO and population of this block have extremely risk to dental and skeletal fluorosis.

Cations (Sodium, Potassium, Calcium and Magnesium)

The higher value is mainly attributed due to the abundant availability of lime stone in the area. In present investigation, concentration of sodium, potassium and calcium in the all sampling stations was found under limits but magnesium was beyond the limits. The concentration of magnesium may be very high due to dissolution of magnesium from calcite, gypsum and dolomite with ground water. Results indicated that the average concentration of calcium in the groundwater of the Lalganj was found 49 mg/L were found within the acceptable limit as IS and WHO given in table 1. The effect of high calcium in water is development of scales in the water supply pipes which checks the water conducting volume of the same. IS suggested that the desirable limit of magnesium in water for drinking purpose is 30 mg/L and in the study area average concentration found more than the IS, it ranged from 34 to 147 mg/L with mean value 68 mg/L . High concentration of magnesium ions is responsible for scaling of water in pipes. Magnesium bearing minerals in the rocks of the study area are dolomite ($CaMg(CO_3)_2$) and clay minerals, they contribute magnesium to the groundwater. Sodium contents present in water combined with chloride and sulphate that make the water salty in taste and unfit for human consumption. Sodium naturally occurs in water up to 200 mg/L (Todd 1980) and the WHO (2008) has also recommended this as permissible limit of sodium to be present in water for drinking purposes. The concentration of sodium in the groundwater samples of Lalganj was 194 mg/L which is well within the WHO guideline and about 65% of samples have under the prescribed limit of WHO. Potassium plays critical role in various metabolic and physiological activities in plants and animals (Lewis, 1997) its intoxication is rare as it is rapidly excreted in absence of pre existing kidney damage (Gosselin et al., 1984 and Gennari, 2002). The value of potassium ranged from 5 to 43 mg/L in the study area and the average mean 16 mg/L.

Water quality index (WQI)

The water quality indexing is a mathematical technique that provides single numerical value which is classifying the overall quality of the data. The water quality index was calculated in the groundwater sample of Lalganj block, Raebareli District, Uttar Pradesh (India) based on the above equation 1 to 4 and necessary parameter was shown in the table 2. The calculated WQI values for Lalganj block was ranged from 49.55 to 111.77. Average WQI value was found below 67.75, which shown that the status of water quality of the study area is good. The minimum WQI values were fall under category of “Excellent” and maximum value under category of “Poor”, which is shown in table 3. In this investigation results revealed that majority of the groundwater samples (80%) were under “Good” category and 10-10% samples were “Excellent” and “Poor” category. The “Poor” quality of groundwater is need to treatment or filtration before using in consumption purpose. Bicarbonate, total hardness, chloride, sulphate and nitrate were found beyond the permissible limits of drinking water quality standard that also increased total dissolved solids, which causing Poor category of groundwater. The above physico-chemical parameter found at higher concentration may due to natural process (weathering of minerals, ion-exchange

process) and anthropogenic process (house hold activities, exploitation of groundwater, excessive uses of agrochemicals and fertilizers). It is evident from special distribution of WQI in groundwater of Lalganj Block shown in figure 2 that the water quality is good in all direction except north-western parts of the study area. The groundwater needs to treatment in the north-western parts of the study area.

Conclusion

In this investigation, the status of groundwater quality of Lalganj block were found "Good" category of water in 80 % samples on the basis of calculated water quality index (WQI). A comparison of groundwater quality parameters with prescribed limits for drinking water of WHO and IS shows that mean concentrations of TDS, HCO_3, F^-, Mg^{2+} and total hardness exceed the desirable limits of IS in groundwater of Lalganj block. The surplus concentration of fluoride in drinking water may be creating incurable effect like dental and skeletal fluorosis in population of Lalganj block. Further the study emphasis the keep on seasonal monitoring of groundwater quality is suggested. Governments should install water treatments technique such as activated carbon, ion-exchange, and coagulant-precipitation or Nalgonda technique in study area. Public awareness program needed for water quality management of study area.

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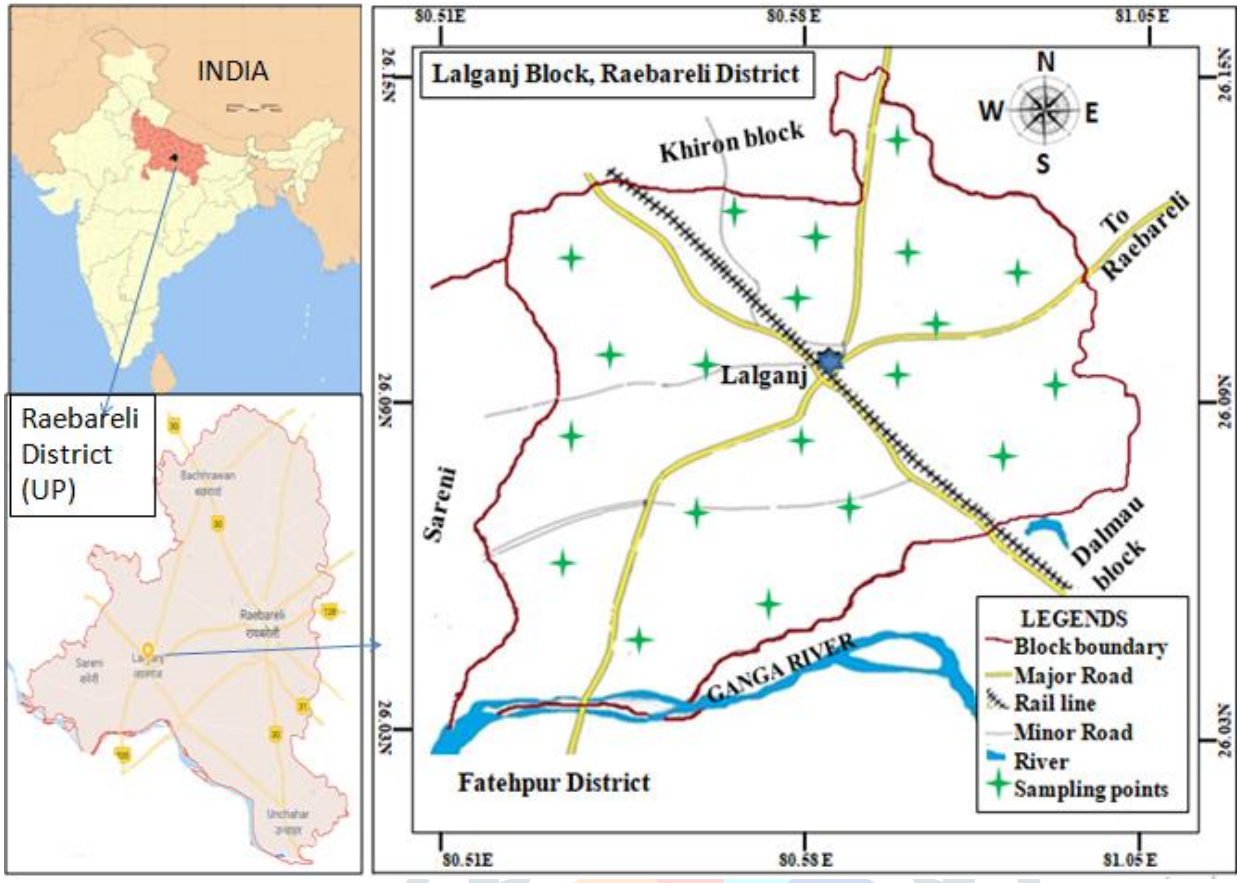

Figure 1: Geographical representation of Lalganj Block and groundwater sampling station

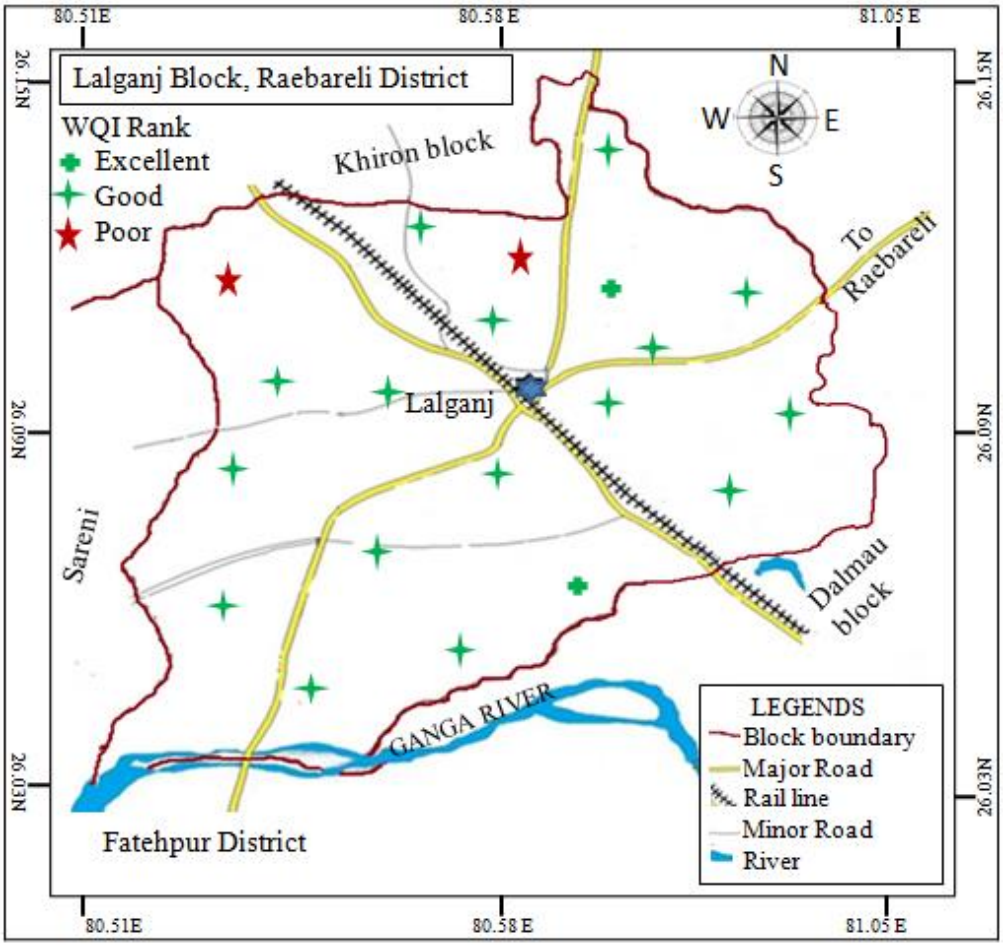

Figure 2: Special distribution of WQI in groundwater of Lalganj Block

Table 1 Statistical representation on data of physico-chemical parameter of groundwater quality at Lalganj block.

Block	Statistics		pH	TDS	Turbidity	BiC	TH	Cl^-	NO_3^-	SO_4^{2-}	F^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	
Lalganj	Mean		8.04	1041	3	437	292	91	27	144	2.24	49	68	194	16	
	Min		7.68	675	1	242	26	13	4	11	0.61	16	34	131	5	
	Max		8.61	1848	6	628	497	375	84	451	4.63	115	147	316	43	SEM
		0.04	108.6	0.36	21.45	27.62	20.28	5.45	28.31	0.23	4.95	6.67	11.60	2.47		
IS : (2012)		a	6.5	500	1	200	200	250	-	200	1	75	30	-	-	
		b	8.5	1000	5	600	600	1000	45	400	1.5	250	100	-	-	
WHO (2008)		a	6.5	-	5	-	200	200	-	200	-	75	50	-	-	
		b	8.5	1500	15	-	600	600	45	400	1.5	200	150	200	-	

SEM *Standard Error Mean, Data in mg/L except* **Turbidity** *(NTU) and pH,* **a** *acceptable limit,* **b** *permissible limit except pH*

Table 2 Groundwater quality parameters with their unit weights

Sl.No.	Parameter	Standard (Si)	Weight (Wi)	Relative Weight (Wi/∑Wi)
1	pH	7	4	0.074
2	TDS	500	5	0.093
3	Turbidity	5	4	0.074
4	TA	200	3	0.056
5	TH	200	3	0.056
6	Cl^-	250	4	0.074
7	NO_3^-	45	5	0.093
8	SO_4^{2-}	250	5	0.093
9	F^-	1	5	0.093
10	Ca^{2+}	75	5	0.093
11	Mg^{2+}	30	4	0.074
12	Na^+	200	4	0.074
13	K^+	10	3	0.056
		∑Wi	54	

Table 3 Water Quality Index Rating in groundwater of Lalganj block.

Sl. No	Lalganj	Sl. No	Lalganj
1	55.48	11	74.07
2	69.54	12	55.00
3	53.92	13	71.35
4	56.76	14	50.17
5	111.77	15	78.44
6	49.55	16	67.93
7	58.35	17	64.10
8	52.53	18	86.19
9	46.48	19	108.65
10	59.39	20	84.54

Average WQI = 67.76

Table 4 Rating of WQI and classified categories of water quality status. (Sahu and Sikdar 2008).

Rating of Water Quality Index	Water Quality Status	Number of location Lalganj
≤50	Excellent	2
50–100	Good	16
100–200	Poor	2
200–300	Very poor	-
>300	Unsuitable for drinking	-