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ASSESSMENT OF GROUNDWATER QUALITY FOR IRRIGATION PURPOSE IN BADUA-CHANDAN SUB-BASIN IN BIHAR- A CASE STUDY

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ABSTRACT

India is an agricultural based country. The new strategy in agro-oriented economy demands, high degree of concentration in water management that is effective control of over utilization of water by irrigation sector. The major objective of the present study is to assess the groundwater for irrigation purpose. In this study thirteen locations are collected from tube wells/boreholes in the Badua-Chandan sub-basin in Bihar, India. The hydrochemistry of groundwater and the impact of major ions on its suitability for drinking water and agricultural purposes have been thoroughly examined through parameters like percentage of sodium, sodium absorption ratio, U S Salinity laboratory diagram and the Wilcox diagram. By analyzing samples, the Piper diagram indicates all samples belongs to calcium-magnesium-bicarbonate (Ca > Mg > HCO_3^-) type water. The results of Wilcox diagram indicates that, 23 percent samples come under Excellent to good category and 53.84 percent of groundwater samples fall into the Good to Permissible category, which means 76 percent of samples are used for agricultural purpose. However, in U S Salinity laboratory diagram, 77 percent of the groundwater samples come under $C_3 – S_1$ category which means high salinity and low sodium hazard are require proper leaching required for irrigation purpose.

Keywords: Sodium absorption ratio; U.S. Salinity laboratory diagram; Wilcox diagram

1. Introduction

Freshwater resources are extremely scarce, less than 1 percent of the water on earth is suitable for human consumption (Asadi et al. 2020 and Hashmi et al. 2009). Therefore, it is necessary to manage and preserve freshwater resources (FAO, 1994). One of the major priorities of local and national governments has been to regulate and limit freshwater usage for agricultural purposes in order to preserve this valuable resource for sustainable development (Venkateswaran et al. 2011; Khan et al. 2012; Jafar et al. 2013; Salahat et al. 2014). However, agriculture remains an important part of the global economy (Arumugam, K and Elangovan, K., 2009). For the economic growth and reliable supply of drinking water in both urban and rural areas, groundwater is a very valuable natural resource (Foster et al. 2002). The natural, physical, and chemical conditions of the water are considered to be its quality, as well as any variations that may have been carried through anthropogenic activity (Suresh et al. 2014).

In semi-arid regions, groundwater management is crucial for satisfying the water needs of the fast growing urban, industrial, and agricultural sectors. Ground water is the water found under the Earth's surface in soil pore pores and rock cracks. When a unit of rock or an unconsolidated deposit may provide a useful amount of water, it is called an aquifer. Some part of rainfall is returned back to the atmosphere as loss, and few parts of rainfall directly reach to the streams and rivers as runoff. In addition, the remaining part of rainfall goes down into the soil, and it is stored in the voids or inter-granular spaces between the soil particles and aggregates of grains. In continuous rainfall condition, the rain water retained in the voids moves down and down and gets stored over the impervious formation existing in the ground at some depth; and thus, develops the water storage in the ground and the same is called ground water. It is also called sub surface water.

Groundwater is properly managed for drinking and production both in quantity and quality if it is consistent source of water. However, this resource is now declining in many Asian cities because of uncontrolled and excessive withdrawal occurring due to socio-economic development (Praveen & Roy 2021a). Problems such as decreasing well yield, water table drawdown, land subsidence and salinity hazard have emerged as the results of over utilization of ground water. Ground water quality is caused by heavy metals and Coli-form. Such problems may incur the socio-economic losses (Samitra and Kumar, 2005).

Different types of dissolved inorganic chemical components exist in different quantities in ground water. Chloride, fluoride, nitrate, iron, and arsenic are inorganic pollutants that are essential in determining the appropriateness of ground water for drinking (Anthony et al. 2013). From groundwater chemistry data, chemical characteristics such as sodium absorption ratio (SAR), electrical conductivity, and sodium percentage were computed. With the aid of chemical parameters, the Wilcox Diagram and US Salinity Diagram were used to assess the groundwater quality for irrigation purpose (Praveen & Roy 2021b).

2. Materials and Methods

A total nineteen groundwater samples were collected from the Badua-chandan sub basin in south Bihar. The groundwater samples are collected in clean 1000 ml polyethylene bottles. The polyethylene bottles were completely cleaned three times with the same samples when groundwater samples were collected (Praveen and Roy, 2022). Hand pumps and open wells were used to collect the all-groundwater samples. After five minutes of pumping, groundwater that had been kept in the well was drawn out and samples were taken from the hand pump. A portable field kit was used to measure the pH, EC, and Total Dissolve Solids at the time the sample was collected. Consequently, these factors change as storage duration increases (WHO, 1996). At Central

Groundwater Board (CGWB), Patna, performed the laboratory experiments. The main cations Na, Ca, Mg, and K values were determined using a flame photometer. Thermo-Orion bench top ion electrode is used to determine fluoride. Titration was used to measure the bicarbonate and overall hardness. To analyze chemicals, the APHA (1995) Standard method is employed.

2.1 The Study Area

The study area spreads over 3,693 sq kms and forms part of the Badua Chandan sub-basin in the South Bihar Plains (SBP) of the total study area, 2450 sq km falls in the Bhagalpur district and 1243 sq km lies in the Banka district. Administratively, the area covers 9 Blocks of Bhagalpur district and 6 Blocks of Banka district. On the basis of the geological set-up, the area can be divided into the following two prominent units. The geo-morphological map of the study area is shown in figure-1.

- Alluvial Plains which is divided into the younger and the older alluvium
- Hard-rocks (constituting the Chottanagpur Granite Gneiss suite of rocks)

Groundwater in the study area occur under two distinct geological environments. In the alluvial part, groundwater occurs under unconfined or phreatic condition in the shallow aquifers while in the deeper aquifers it occurs under confined condition. Groundwater, here, occurs in the inter granular spaces within the sediments.

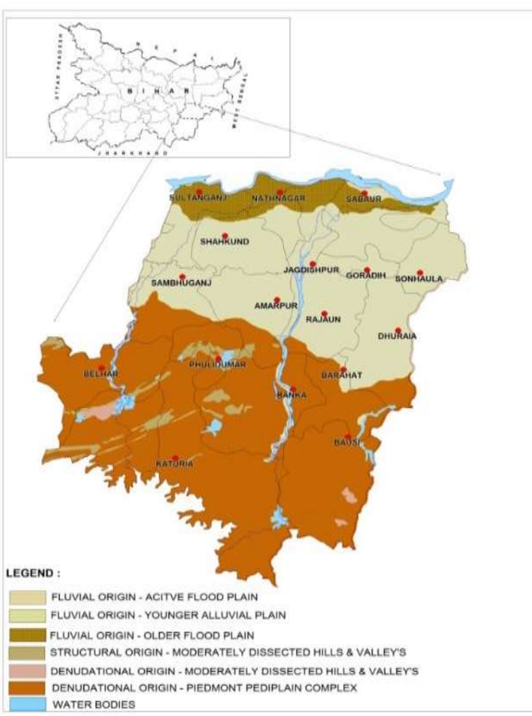


Figure 1. Geo-morphological Map

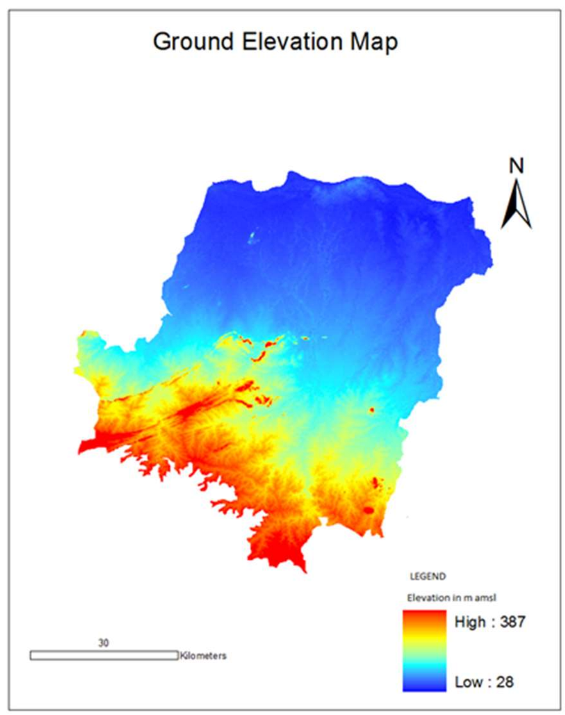


Figure 2. Ground Elevation Map

The soil in the study area is composed of alluvial soils which are partly derived from older alluvium and partly by newer alluvium. The alluvium plain soil colour is light grey to Dark grey. This soil is generally somewhat heavy and texturally fine. The land use of the study area is 52.8% of total Geographical area is under cultivation.

The study area is drained by several peninsular rivers having their origin in the hills of Santhal Parganas and Munger. Chandan and Badua are the dominant streams in the district. Kudar, Orni Panchkatia is the main tributaries of Badua. Major rivers contain very little surface water in dry season. The ground elevation map for the study area is shown in Fig 2. The drainage map of the study area is shown in Fig 3. In this drainage map the water in the study area flows from south to north.

The main Kharif crops are rice, maize, pulses and oilseeds while Rabi crops are wheat, maize, oilseeds, pulses, potatos etc. The area falls under the Chandan-Badua canal command area. The irrigation scenario can be revealed by the fact that areas irrigated by different sources e.g. canals, tube wells, dug wells and other constitute 45% of the total cultivated area. Canals are the most important source for irrigation which constitutes 61% of the total irrigated area while ground water structure are supplementary sources for irrigation in the southern part of the study area falling in Banka district and in the northern part falling in Bhagalpur district. The share of groundwater irrigation increases to 30%. The groundwater sample collected locations are given in Table - 1.

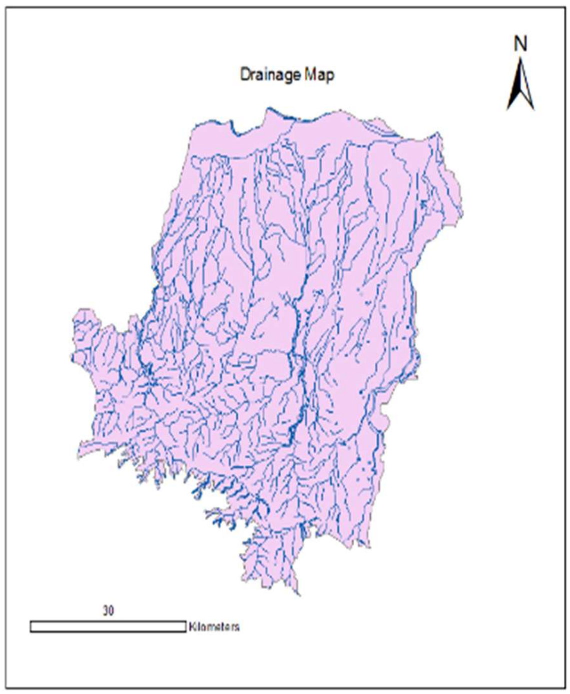


Figure 3 Drainage Map of the Study Area

Table 1. Groundwater Sample Collected Locations

S.No	Place/Location	long-X	lat-Y
1	Amarpur	86.9042	25.0542
2	Banka	86.9208	24.8958
3	Barahat	87.0208	24.8833
4	Baunsi	87.025	24.8083

5	Rajaun	86.9792	25.0083
6	Rampur	86.8611	25.0528
7	Shambhuganj	86.916	24.883
8	Sultanganj	86.7433	25.2402
9	Akbarnagar	86.833	25.233
10	Bhagalpur	86.952	25.248
11	Sabaur	87.0458	25.2458
12	Jagdishpur	86.9833	25.1625
13	saino	86.974	25.143
14	rajaun	86.989	25.001
15	Warshabad	86.802	25.046
16	Rudpai	86.744	25.071
17	Champanagar	86.945	25.249
18	Barehpura	86.975	25.184
19	Mahesi	86.8	25.25

2.2 **Methodology**

Since the country is to face water storage in future which is evident from Table-2 and 3, it is being focused to develop and utilize the groundwater resource to its maximum capacity. Keeping this in view, the methodology adopted for the present study area discussed below.

Table 2. Groundwater Potential in Bihar and India (GEC, 1997)
(In Cubic kilometers per year as in 1982)

State/Country	Utilizable Resources	Draft	Potential available for future development	Stage of Groundwater Development in %
Bihar	28.60	5.90	22.70	21
All states	418.27	97.58	320.69	23.3
All Union Territories	4.59	2.585	2.01	56.8
Total for the country	422.86	100.165	322.70	23.7

Table 3. Annual Requirement of Fresh Water in km³(CGWB, 1995)

Sl. No.	Water Use	2000			2025		
		Surface water	Ground water	Total	Surface water	Ground water	Total
1.	Irrigation	420	210	630	510	260	770
2.	Other uses	80	40	120	190	90	280

3.	Domestic & Live stock	28.70	28.70	40.00	40.00
4.	Industrial	30.00	30.00	120.00	120.00
5.	Thermal Power	3.30	3.30	4.00	4.00
6.	Miscellaneous	58.00	58.00	116.00	116.00
	Total	750.00	750.00	1050.00	1050.00

Wilcox diagram

Wilcox (1955), as shown in Fig. 4, uses sodium percentage and specific conductance to assess the appropriateness of ground water for irrigation. The ratio of sodium to total cat ions determines the sodium percentage via sodium, potassium, magnesium, and calcium. The concentrations are all given in milli equivalents per litre.

$$\text{Sodium percentage (Na \%)} = \frac{\text{Na}}{\text{Ca+Mg+Na+K}} \times 100 \quad (1)$$

Sodium Adsorption ratio (SAR)

The relative concentration of cat ions defined in terms of SAR determines the quantity of sodium present in ground water for irrigation. The sodium adsorption ratio (SAR) is recommended by the US Department of Agriculture's salinity laboratory because it has a direct relationship with sodium adsorption by soil.

$$\text{Sodium Adsorption ratio (SAR)} = \frac{\text{Na}^{+}}{\sqrt{\frac{\text{Ca}^{++}+\text{Mg}^{++}}{2}}} \quad (2)$$

U.S. Salinity Laboratory Diagram (1955)

The graphical classification of SAR and conductance by the United States Salinity Laboratory. It provides the two most important sodium and salinity dangers for irrigation operations. This investigation determines the quality of irrigation water and the salinity of the soil solution, as well as the salinity hazard and sodium hazard for this diagram.

Piper Diagram

Piper (1953) devised a tri linear diagram that is one of the most useful graphs for displaying and comparing water quality data. The Piper diagram depicts the chemistry of water samples in a visual format. It is divided into three sections. The anions and cations are shown separately in the ternary figure. The cations calcium (Ca), magnesium (Mg), and sodium plus potassium (Na+K) are shown at the apexes of the lower left triangle. Similarly, the anions sulphate, chloride, carbonate (CO3), and hydro carbonate are shown at the apex of the bottom right triangle (HCO3). Cations are shown as a single point on the lower left triangle and are reported as a percentage of total cations in milli equivalents per litre. Anions are sometimes represented in milli equivalent per litre as a proportion of total anions. On the lower right triangle, it maps as a single point. These two points are projected parallel to the centre diamond's top edges in the centre diamond shaped region (Alexander, 1972).

Stage of Ground Water Development

The stage of groundwater development is defined by the following equation:

$$\text{Stage of groundwater Development (\%)} = \frac{\text{Existing gross groundwater draft for all uses}}{\text{Net annual groundwater availability}} \times 100 \quad \ldots\ldots\ldots \textbf{(4.13)}$$

Table 4. Categorization of Stage of Ground-water Development (SOD)

SN	SOD	Categorization
1.	<70%	Safe
2.	70 - 90%	Semi critical
3.	90 - 100%	Critical
4.	>100%	Over Exploited

3. Result and Discussion

Piper diagram was used to analyze the ground water samples. It was discovered that alkaline earths outnumber alkalies, alkalies outnumber alkaline earths, weak acids outnumber strong acids, and carbonate hardness surpasses 50% in the research region, implying that alkaline earths and weak acids dominate the chemical characteristics of the water, as shown in Fig-4. All groundwater samples come under Zone-III, which means Calcium-Magnesium-Bicarbonate type water.

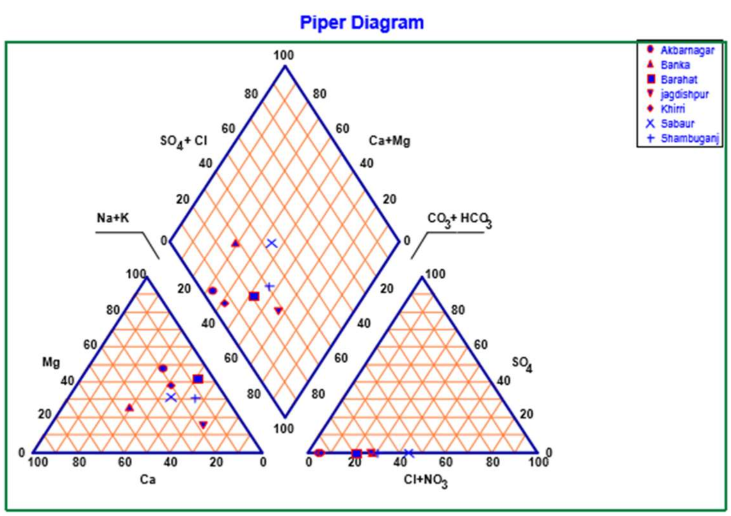


Figure 4. Piper Diagram of the Ground Water Samples

The ground water samples are classified according to the **Wilcox diagram interpretation (1955)** as shown in Fig-5. In this classification it was found that 53.84 % of the ground water samples come under the "**Good to Permissible**" category, 23.07% come under the "**Excellent to good**" category and 23.07% come under the "**Poor to Doubtful**" category. This poor to doubtful state is because of the effect of industries and domestic sewage directed into the river.

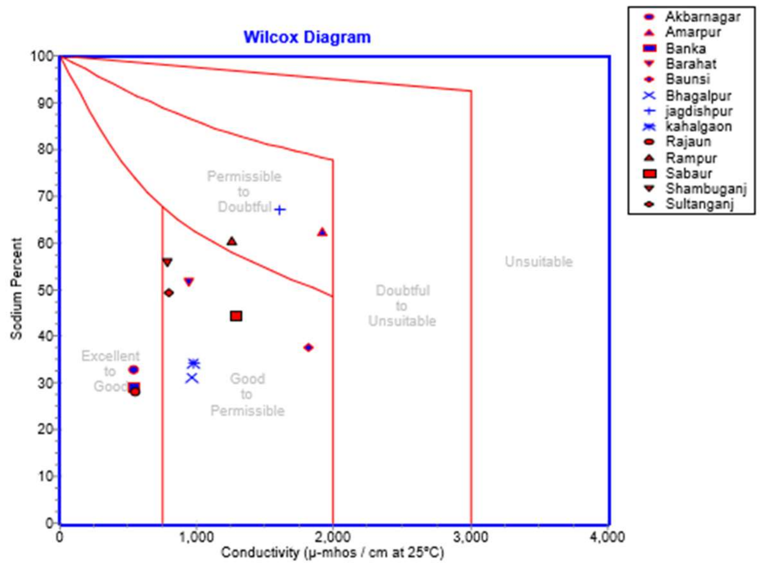


Figure 5. Plotting of ground water samples in Wilcox diagram

Table 5. Classification of Groundwater sample locations Based on Wilcox Diagram

S. No.	Category	Sample Locations	Percentage
1.	Excellent to Good	Akbarnagar, Banka, Rajaun	23.07
2.	Good to Permissible	Bhagalpur,Kahalgaon,Sabaur,Bharahat,Shambuganj, Sulthanganj,Amarpur	53.84
3.	Permissible to Doubtful	Rampur, Amarpur, Jagdishpur	23.07
4.	Doubtful to Unsuitable	-	-

These ground water samples were categorized using the U.S. Salinity Laboratory Diagram (1954), and it was discovered that 76.92 percent of them fall into the C3-S1 (high salinity – low sodium) group are shown in figure 6. This category is important in the research region and, as a result, it is appropriate for irrigation.

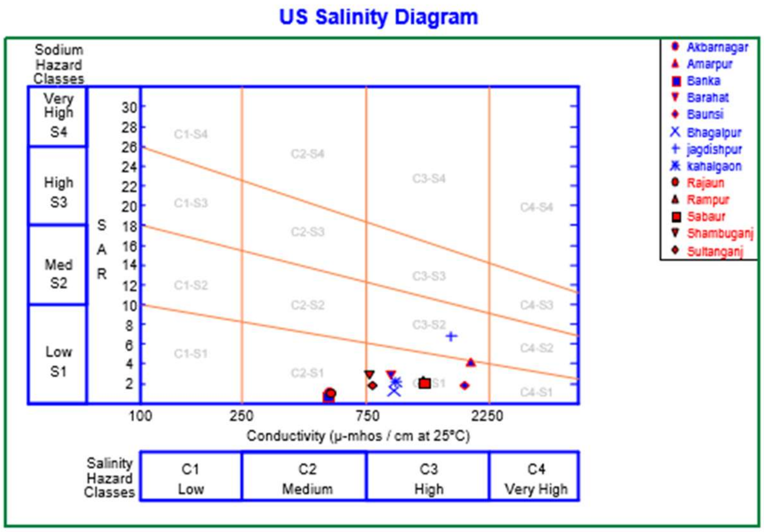
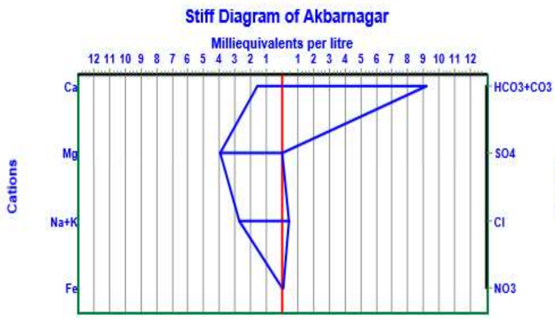


Figure 6. Plotting of Groundwater Samples in U S Salinity diagram

Table 6. Classification of Groundwater sample locations Based on U S Salinity diagram

S. No.	Category	Ground Water Sample Locations	Percentage (%)
1.	C2-S1	Banka, Rajaun	15.38
2.	C3-S1	Amarpur, Barahat, Baunsi, Bhagalpur, Khalgaon, Rampur, Sulthanganj, Shambuganj, Akbarnagar, Sabaur	76.92
3.	C3-S2	Jagdishpur	7.69

The stiff diagram (H A Stiff, 1951) is used to represent concentration ratios for individual samples. The shape of the diagram makes it easier to compare samples, especially when placed on maps. On the horizontal axis, concentration in meq/l is displayed, with cat ions on the left and anions on the right. A polygon is formed by connecting all of the points. The stiff diagram of Akbarnagar and Sultanganj location ground samples are shown in figure 7 and figure 8.



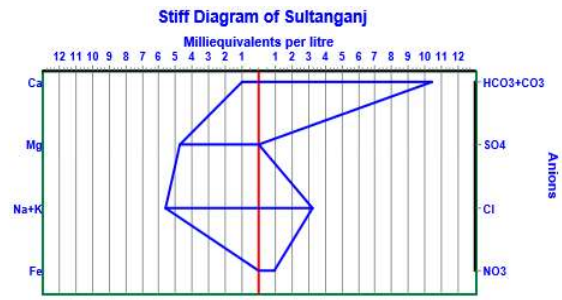


Figure 7. Stiff Diagram of Akbarnagar **Figure 8.** Stiff Diagram of Sultanganj

Stage of Ground-water Development (SOD) in the Study Area

The values of SOD are given in Table-6. After analyzing the values of SOD it was found that all blocks in the study area is come under the safe category which means that SOD is less than 70%. Therefore, these blocks have no significant long-term decline of Pre or Post monsoon ground water levels.

Table 7. SOD data of the Study Area (In hectare meters)

SN	Block	Net Annual Ground Water Availability (hec-meter)	Stage of Ground Water Development (%)	Recommended for development upto 70% source of development (hec-	Existing Gross Ground Water Draft For all Uses (hec-meter)	Allocation for Domestic and Industrial Requirement supply upto year 2025	Recommended for Irrigation Purpose (hec-meter)	Percentage of Recommended for Ground-water per year Irrigation Purpose
1	Amarpur	4471	50	3129	2236	616	277	8.85
2	Banka	3512	46.4	2458	1629	447	382	15.54
3	Bausi	2593	32.5	1815	844	384	587	32.34
4	Katoria	5909	33.5	4136	1981	382	1773	42.86
5	Rajun	5464	30.9	3824	1686	423	1715	44.84
6	Sambhuganj	5250	33.8	3675	1776	369	1530	41.63
7	Sabour	3143	31.8	2200	1000	298	902	41
8	Shahkund	5003	55.8	3502	2791	418	293	8.36
9	Sulthanganj	5890	30	4123	1766	561	1796	43.56
10	Total Bihar state	2570156	47	1799109	1192755	250523	355831	19.77

4.Conclusions

The stage of ground water development (SOD) is determined by using the methodology of GEC, 1997 of Government of India. After analyzing that data with classification of SOD it was found that the study area comes under the safe category.

According to the Wilcox categorization, 53.84 percent of ground water samples fall into the "Good to Permissible" category. However, salinity of ground water in this study area was classified as a "growing concern" in 76.92 percent of the ground water samples. The majority of ground water samples fall into the C_3-S_1 (high salinity – low sodium) group under the "suitable zone," according to the Richards U.S. Salinity laboratory diagram. The majority of ground water samples in this study have a high salinity. Hence, the ground water has high to very high saline water; soil must be permitted with sufficient drainage facilities for adequate crop growth.

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