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RESEARCH ARTICLE

QUANTITATIVE AND QUALITATIVE ASSESSMENT OF GROUNDWATER RESOURCES FOR DOMESTIC AND IRRIGATIONAL USES IN DIGAPAHANDI BLOCK OF ODISHA, INDIA

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ABSTRACT

Digapahandi block of Ganjam district is a chronically drought prone and economically backward area of Odisha. Optimum utilization and efficient management of ground water resources in the block will boost agricultural production and improve socio-economic condition of the people. The systematic and logical evaluation of groundwater resources both quantitatively and qualitatively is essential for sustainable development and management of groundwater in this area. Quantitative evaluation indicates that the net annual utilizable ground water resource of the block is 4118.36 HM. The net ground water draft is 852.95 HM (Unit draft method, based on 100% well census). The ground water balance of the block as on December 2015 is 3265.41 HM, out of which 326.50HM can be utilized for domestic and drinking purposes and 2938.91HM for additional irrigation purpose. At present, the stage of ground water development is 20.71% and falls under safe category. Hence, there is a vast scope for ground water development through suitable abstraction structures for development of agrarian economy. A total additional area of 3672 hect. and 2203 hect. can be irrigated during kharif and Rabi season respectively by utilizing the balance ground water. Quantitative assessment study revealed that comparison of the hydro chemical parameters with that of ISI (1983) standards ensures the potability and other domestic utility of the ground water of the block except very few locations. With respect to sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Total Dissolved Solid (TDS), Percent Sodium (%Na), Magnesium Hazard and Permeability Index (P.I), the ground water of both dug wells and bore wells falls within the good to excellent category for irrigation except very few cases.

INTRODUCTION

Digapahandi block of Ganjam district is a chronically drought prone and economically backward area of Orissa. The economy of the area is basically agrarian. The area experiences drought frequently because of erratic nature of rainfall over space and time. The agricultural lands which are mostly rain fed bear the adverse effects of drought resulting in loss of crops. Surface water irrigation is very limited and also not dependable due to vagaries of monsoon rainfall. Drinking water problem is very acute during summer as most of the wells go dry or yield less water. The development of agrarian economy demands stabilized agriculture and crops insurance against drought. The expansion of agriculture is inevitable. The area requires development of ground water through suitable structures to combat drought and to increase crop yield by covering more areas under irrigation. Drinking water problem is very acute during summer as most of the wells go dry or yield less water.

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Optimum utilization and efficient management of ground water resources in the block will boost agricultural production and improve socio-economic condition of the people..For a planned management and development of groundwater, it is essential to assess groundwater resources both quantitatively and qualitatively in the block.

Review of Literature

The literature available on ground water evaluation, development and management was reviewed in detail. Sikdar *et al*. (2007), Sankar and Venkatram (2002), Chauhan (2000) Rokade *et al*. (2007), Mahapatra *et al*. (2000), Patnaik(2003), Reddy *et al*.(2003), Sahu and Sahoo (2006) and Sahu (2008) in their study relating to ground water exploration and targeting potential ground water zone, have emphasized that integrated geological, geophysical, remote sensing and GIS techniques should be adopted for targeting potential ground water zones in hard rock areas. Reddy (1999) has emphasized the need to adopt modern know-how i.e. Remote sensing and GIS to evaluate the ground water potential in hard rock provinces. Josrotia and Singh (2007), Singh *et al*. (2007), Prasad (2007) and Pandian (2007) and Sahu (2003) studied on the hydrochemistry and ground water quality in different parts of the country and emphasized the need of qualitative evaluation for sustainable development of ground water resources.

STUDY AREA

Located on the east coast of India, Digapahandi block of Ganjam district, Orissa is bounded by $19^0$11'30" to $19^0$24'0" N Latitude and $84^0$19'50" to $84^0$41'24" E longitude (Fig.1) falling in the Survey of India Topo sheet Nos. 74A/7, 74A/8 and 74A/11 It has a geographical area of 422.18 sq. km. Digapahandi block is situated at a distance of 60 km from district headquarters Chatrapu6.82% and 32.83% respectively. Total no. of villages is 232. No. of households is 28855. About 80% of the population of the block is rural. The area enjoys a humid and sub-tropical climate characterized by cold winter and hot summer. The winter season starts from November and continues up to the end of February. December is the coldest month. The summer commences in March and continues till middle of June. It is fairly hot in Digapahandi area. May is the hottest month with mean daily maximum temperature of 36^0 C. South-West monsoon is the principal sources of rainfall in the area. The rainy season generally starts from middle of June and continues till the end of September. August is the wettest month of the year. The annual average rainfall is 1296 mm.

The most common soil types in the block are red sandy soils, red loamy soils and alluvial soils. The soils are mainly neutral to mildly acidic in nature. Nitrogen content in soil is generally low, phosphorous content is very low, while potassium content is rather high. The fertility status of the soils of Digapahandi block is good to moderate. Digapahandi block shows wide variation in the pattern of land utilization. Nearly 75% to 80% of the geographical area is available for cultivation. The cultivation is mainly in the Kharif season. Rabi cultivation is restricted to areas with irrigation facilities. Agriculture is the principal sources of income of the people in the block. Paddy is the principal corp. Other crops grown in the block are pulses, oil seeds, vegetables, sugarcane etc.

DATA USED AND METHODOLOGY

Collection of secondary data like population, rainfall, ground water abstraction structures and irrigation potential. Collection of Toposheets, references etc. Remote sensing technique has been adopted. Hydro-geomorphological map, lineament and structure maps have been used fig no-2. Estimation of ground water resources using "water table fluctuation method" recommended by the Ground water Estimation Committee (GEC-1997) constituted by Govt. of India. In this method, the thickness of aquifer (T) is determined based on water table fluctuation recorded form the observation well. Specific yield(s) of each aquifer(s)/ formation are calculated by conducting pumping tests.

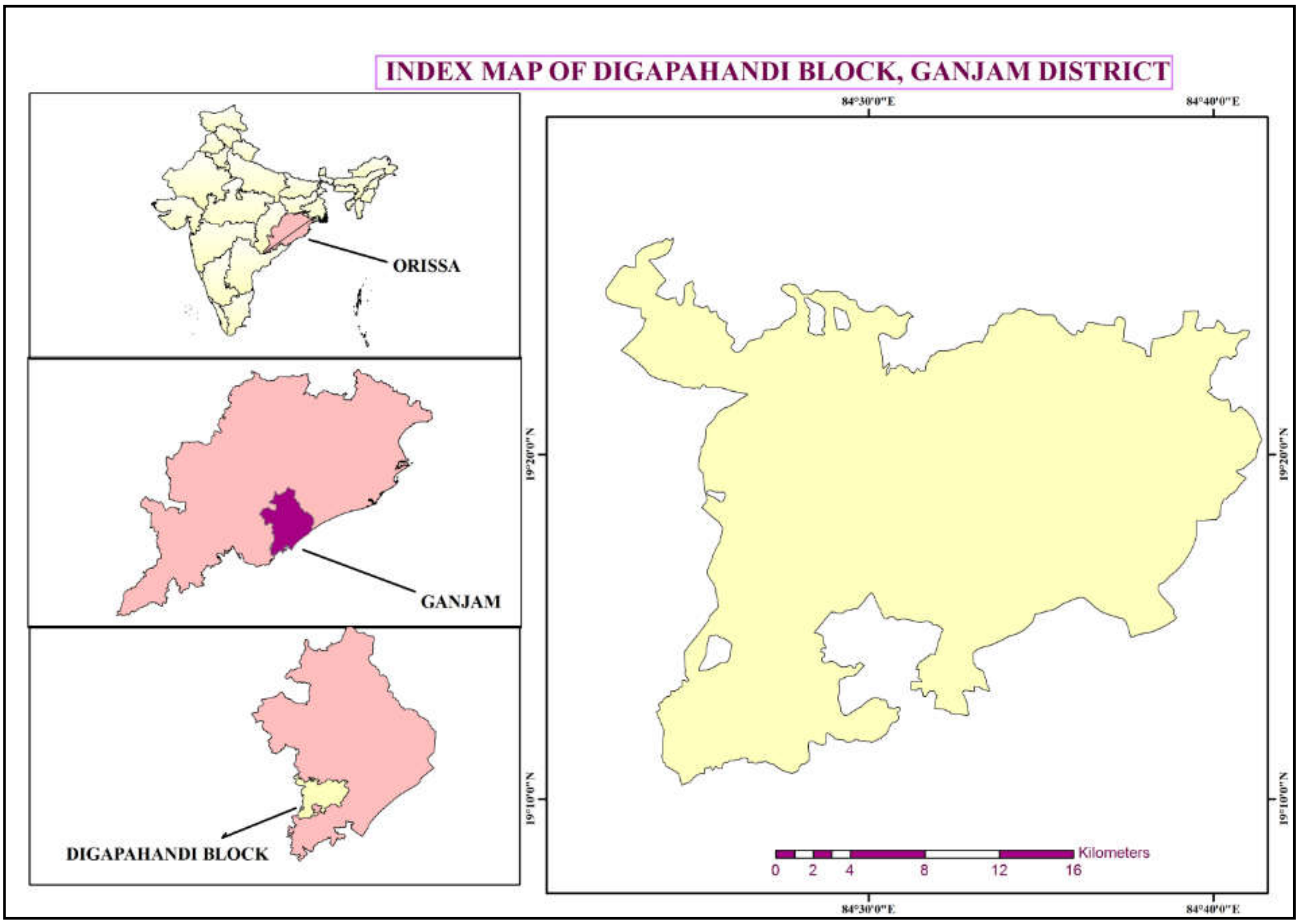

Figure 1. Location map of Digapahandi Block of Ganjam District

By multiplying the aquifer thickness (T) with specific yield(s) of the formation and the rechargeable area (A) occupied by it, the gross ground water resource is worked out. For estimation of ground water draft, unit draft method based on 100% well inventory has been utilized. The concept of ground water balance was introduced by the world bank. The ground water balance refers to the net ground water resources available for development in a given area, which is computed by subtracting the net ground water draft from the net utilizable. Systematic collection of ground water samples from shallow and deeper aquifers during pre and post monsoon period and chemical analysis for ions like Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4, NO_3 and other parameters like pH, Temp., TDS, EC etc. are measured in the field. . Hydro-geochemical evaluation based on studies established by Doneen (1964), Richards (1954) etc. have been carried out.

RESULTS AND DISCUSSIONS

For a planned management and development of groundwater, it is essential to compute quantitatively ground water resources in the block. The systematic and logical evaluation of groundwater resources is needed to guard against the over-exploitation of the available ground water resources. The net annual utilizable ground water resource of Digapahandi block is 4118.36 HM. The net ground water draft based on 100% well census is 852.95 HM. The ground water balance as on December 2015 of Digapahandi block is 3265.41 HM out of which 326.50 HM can be utilized for domestic and drinking propose and 2938.91 HM for additional irrigation purpose. The stage of ground water development of the block is 20.71% and comes under White/ Safe category Table 1.

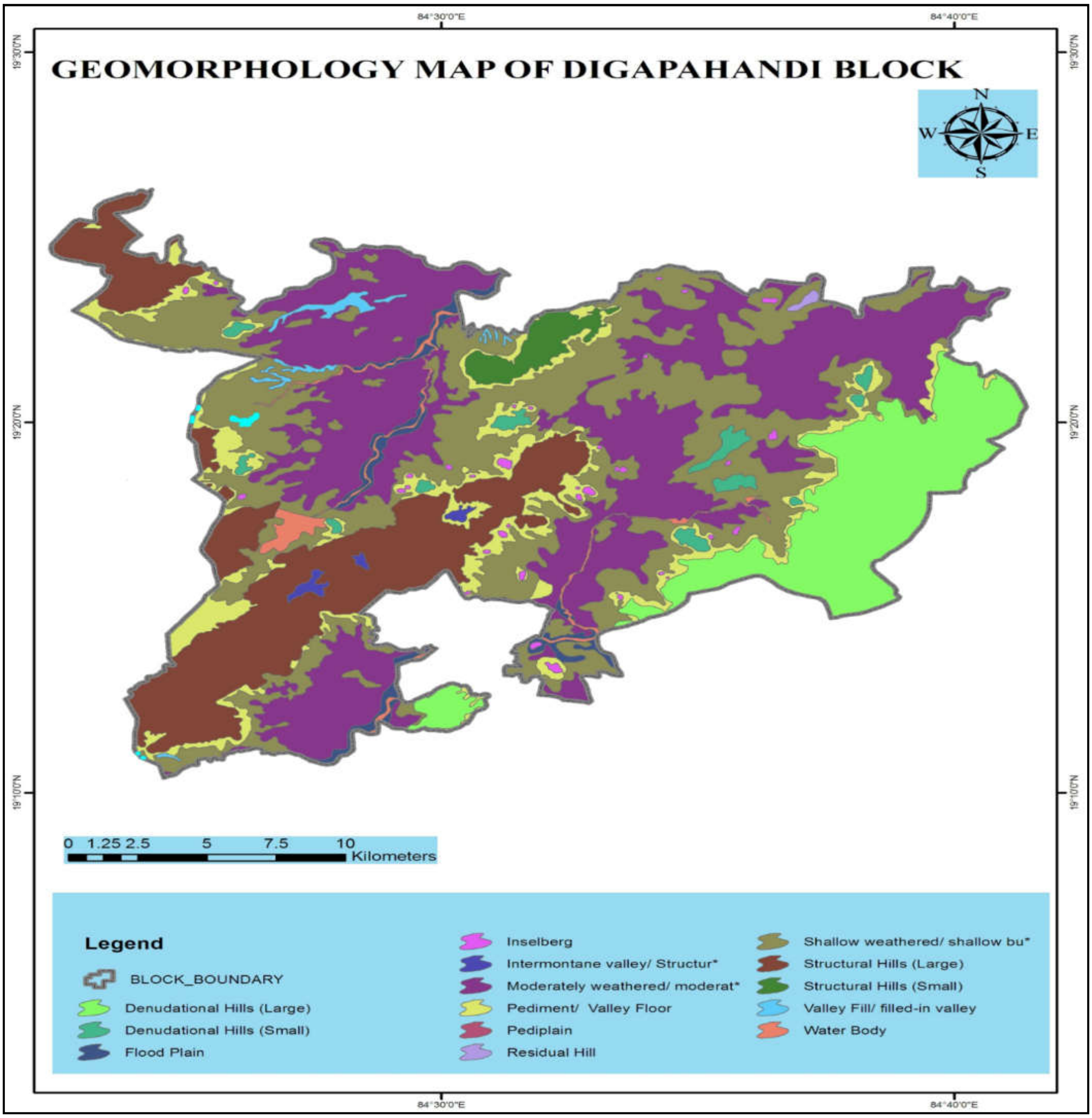

Figure 2. Geomorphology map of Digapahandi Block, Ganjam District

Table 1. Groundwater Resource Estimation and Budgeting of Digapahandi Block for the year 2015

Ground water resources estimation (water table fluctuation method)					
Lithology	Land form	Area in Hect.	Specific yield	Water table fluctuation (m)	Unitwise resource estimation in HM (3x4x5)
1	2	3	4	5	6
Alluvium	Flood plain	1930	0.065	4.0	501.93
	Deeply Weathered Buried Pediplain	13822	0.050	4.8	3117.28
	Shallow Weathered Burried Pediplain	10759	0.025	6.0	1613.90
	Pediment	3088	0.015	8.5	393.72
	Inselberg	514	-	No water table	-
	Structural Valley	257	0.040	5.5	56.54
	Structural Hill	7207	-	No. water table	-
Granite gneiss					
Charnockite and Khandalite	Denudational Hill	4633	-	No water table	-
Gross Ground water Resources – 5883.37 HM					
Net Utilisable Resources (70% of gross) – 4118.36 HM					

The groundwater development in the study area is low which needs further development through different feasible abstraction structures. The balance ground water resource of the block allocated for additional irrigation purpose i.e. 2938.91 HM, can safely sustain installation of 2938 numbers of additional standard dug wells with pump sets in addition to the existing ground water structures. It has been estimated that a standard dug well with Tenda can irrigate an average area of 0.5 hect. for Kharif crops and 0.24 hect. for Rabi crops. Similarly a standard dug well with pump set can irrigate an average area of 1.25 hect. for Kharif crops and 0.75 hect. for Rabi crops. So, a total additional area of 3672 hect. and 2203 hect. can be irrigated during Kharif and Rabi season respectively.

Ground Water Budgeting

Resources	5883.37 HM
1. Gross Ground water Resources	4118.36 HM
2. Net Utilisable Resources (70% of gross)	
Draft (Unit draft method, 100% well census)	
1. Gross Ground Water Draft (Annual)	1218.50 HM
2. Net Ground water Draft (70% of Gross)	852.95 HM
Ground Water Balance	3265.41 HM
Stages of Development	20.71%
Category	Safe/White
Allocation	
1. Domestic and Drinking (10% of Balance)	326.50 HM
2. Available for irrigation	2938.91 HM

Groundwater Quality Evaluation

Based on the chemical analysis of water samples collected during hydrogeological survey, the quality of ground water of both shallow and deeper aquifers of Digapahandi block has been assessed. In major parts of the block, the ground water is neutral to slightly alkaline in nature with specific conductance ranging from 254 to 1500 µs/cm at 25^0C except in pockets where higher values are noticed i.e. S.Tikarapada, Pentha, Kusapada, Balijodi and Basudevpur. The ground water is characterized by low chloride, usually less than 500 mg/l. In a few localized pocket, the concentration is ranging from 500 to 920 ppm have been found (S.Tikarapada, Kusapada and Basudevpur). The concentration of NO_3, SO_4, HCO_3 in ground water ranges from nil to 37 ppm, 9 to 105 ppm and 21 to 238 ppm respectively. The concentration of Ca, Mg, Na and K in the ground water ranges from 18 to 22 ppm, 0.3 to 99 ppm, 9 to 289 ppm and 2 to 87 ppm respectively.

The general range of chemical constituents in the ground water of the block is presented in table-2.

Table 2. Range of Chemical constituents in groundwater of the block

Chemical Parameters	Concentration
pH	7.1 – 8.8
TDS	162-1442 (ppm)
TH	108-975 (ppm)
TA	58-378 (ppm)
Ca	18-228 (ppm)
Mg	0.3-99 (ppm)
Na	9-289 (ppm)
K	2-87 (ppm)
CO_3	Nil-27 (ppm)
HCO_3	21-238 (ppm)
Cl	20-920 (ppm)
SO_4	9-105 (ppm)

Water Quality for Domestic Use

The present study envisages the quality criteria of ground water from shallow and deeper aquifers and their comparison with ISI standards to assess its suitability for domestic purpose. Standards for drinking water is given in Appendix-V. Comparison of the drinking water standards (ISI, 1983) with the various water quality parameters of ground water of the block is presented in table-03. From the chemical data it is evident that with some exception, the ground water from both the shallow and deeper aquifers come under potable category with respect to maximum permissible limit, as proposed by ISI (1983). It is also a general observation that the water from deeper aquifers have better quality than that of the shallow aquifers.

Table 03. Comparison of Ground water of the Block with ISI Standards

Chemical Parameters	Total No. of sample Analysed	Total No. of Sample within permissible limit	(percentage)
PH	80	80	100
TDS	80	80	100
TH	80	78	97.5
Ca	80	79	98.75
Mg	80	80	100
Cl	80	80	100
NO_3	80	80	100
SO_4	80	80	100

Table 04. Agricultural Indice

Sl. No.	Indices	Equation	Reference
1	SAR	Na/ √ (Ca+Mg)/2	U.S. Salinity Laboratory staff, 1954
2	% Na	(Na +K) / (Ca+ Mg+ Na+K)	Wilcox, 1948
3	PI	Na+ √ HCO_3 / (Ca+ Mg+ Na) X 100	Doneen, 1964
4	R.S.C	(CO_3 + HCO_3) – (Ca+ Mg)	U.S. Salinity Laboratory Staff, 1954
5	Magnesium Hazard	Mg X 100 / (Ca+ Mg)	--

Therefore, from the quality point of view of drinking purposes, the water from deep bore wells is most suitable. The higher concentration of ions are normally observed in villages like S.Tikarapada, Samantarapur, Pentha, Ankorda, Kusapada, Baligudi and Basudevpur.

Quality Criteria for Irrigational use

Water used for irrigation purpose always contains some amount of dissolved constitutes (salts) which are the products of weathering of rocks and dissolution of minerals. The salts present in irrigation water affect the soil structure, permeability and aeration which ultimately affect the plant growth. Several factors such as Total Dissolved Solids (TDS), Percent Sodium (% Na), Residual Sodium Carbonate (RSC), Sodium Adsorption Ratio (SAR) and Permeability Index (PI) affect the suitability of water for irrigation, which are presented in Annexure-VI. The formulae used for calculating agricultural indices are given in table-04.

Salinity Hazard

The TDS content which determines the specific electrical conductance indicates salinity hazard to irrigation. Besides salinity hazard, excessive sodium content in water renders it unsuitable for soil containing exchangeable calcium and magnesium ions. The classification of well water from the study area with respect to salinity hazard is given below (table: 5).

Table no 5. Salinity Hazard

Salinity Category	TDS (mg/l)	No. of wells in each category	Percentage
Low	< 200	4	5.00
Medium	200-500	50	62.50
High	500-1500	26	32.50
Very High	>1500	Nil	--

Well waters falling under low salinity category can be safely used for irrigation purpose without any salinity control technique. Water falling under medium to high salinity classes can be used for irrigation purpose using some salinity control techniques for growing plants. The salt tolerant crops such as wheat, sunflowers etc. and vegetables such as cabbage, carrot, onion can be grown.

Sodium Concentration

The sodium content of water is very important for its quality assessment for irrigation, Sodium, by the process of base exchange, replaces calcium from soil which ultimately reduces the permeability of soil. This is known as "Sodium/ Alkali Hazards", because the degradation process helps in the formation of alkali soil. An alkali soil has an unfavourable structure, puddles easily and restricts the aeration.

The Percent Sodium (% Na) is less than 60% in 95% of the water samples of the block collected. According to ISI standards, a maximum percent sodium of 60 is recommended for irrigational purpose. Thus, water from most of the wells are suitable for irrigation from Percent Sodium point of view. Further,the sodium alkali hazard in irrigated water is indicated my Sodium Adsorption Ratio (SAR) expressed by the relation.

$$SAR = \frac{Na}{\sqrt{(ca + mg)/2}}$$

Where

all the concentrations are expressed in epm. The classification of well water of the block with respect to SAR is as follows.

SAR	Class	No. of wells in each class	Percentage (%)
<10	Excellent	79	98.75
10-18	Good	-	-
18-26	Fair	01	1.25
>26	Poor	-	-

The above classification shows that the groundwaters of almost all the wells are excellent for irrigational use from SAR point of view. The suitability of groundwater for irrigational purpose has been evaluated with the help of US. Salinity Diagram (Richards, 1954) (figure no 03). A study of the data indicates that generally the ground water falls in C_2S_1 and C_3S_1 class which are good and moderately good for irrigation respectively. The classification of irrigation of water based on the US salinity diagram is presented as follows.

Classification of Irrigation water based on USSL diagram

SAR	Grade	No. of Samples	Percentage
C_1S_1	Good	-	-
C_1S_2	Moderately good	-	-
C_1S_3	Unsuitable	-	-
C_1S_4	Highly Unsuitable	-	-
C_2S_1	Good	52	65%
C_2S_2	Moderately good	-	-
C_2S_3	Unsuitable	-	-
C_2S_4	Unsuitable	-	-
C_3S_1	Moderately good	26	32.50%
C_3S_2	Moderately good	-	-
C_3S_3	Unsuitable	-	-
C_3S_4	Unsuitable	01	1.25%
C_4S_1	Un suitable	01	1.25%
C_4S_2	Un suitable	-	-
C_4S_3	Un suitable	-	-
C_4S_4	Un suitable	-	-

Magnesium Hazard

A ratio of (mg X 100) / (Ca+Mg) was used as an index of Magnesium Hazard of irrigation water. All the well waters are excellent from magnesium hazard point of view as the ratio is less than 50 in all water samples.

Residual Sodium Carbonate

Well respect to RSC values the groundwater of the block can be classified as follows.

RSC	Class	No. of wells in each class	Percentage
<1.25	Good	79	98.75
1.25-2.5	Medium	01	1.25
> 2.5	Bad	-	-

All most all the water samples have values less than 1.25 and falls under good category.

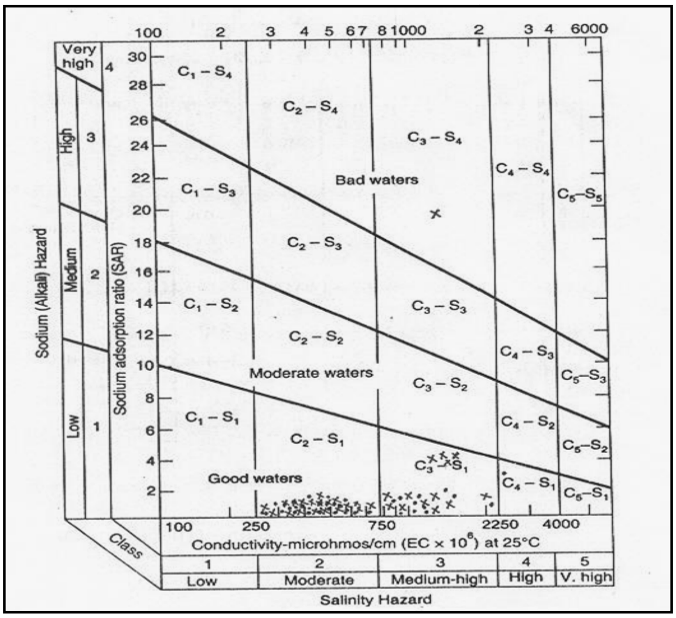

Figure 4. Classification of Irrigation Water

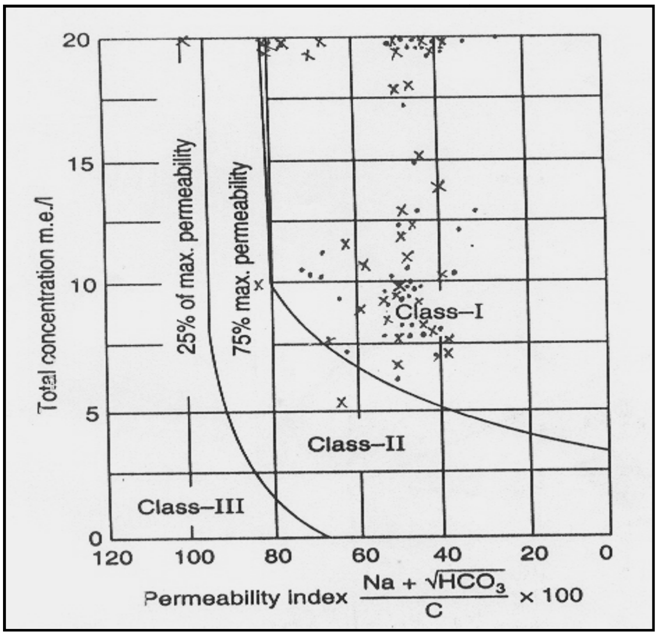

Figure 5. Classification of Irrigation Water based on P.I

Permeability Index

Doneer (1964) developed a criterion for assessing suitability of water of irrigation based on Permeability Index (PI). According to Doneen (1964) chart (Fig.05) majority of well waters (98.75%) fall under class I and class II and the rest (1.25%) under class III category. From the above discussion it is evident that with respect to SAR, TDS, Percent Sodium, RSC values, Permeability Index (PI) and Magnesium Hazard, all the ground water samples fall within the excellent to good category for irrigation except very few cases.

Conclusion

The groundwater in the investigated area shows limited seasonal variation in quality. Comparison of the hydrochemical parameters results of the study area with that of ISI (1983) standards ensures the potability and other domestic utility of the ground water of the block except very few locations. With respect to sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Total Dissolved Solid (TDS), Percent Sodium (%Na), Magnesium Hazard and Permeability Index (P.I), the ground water of both dug wells and bore wells falls within the good to excellent category for irrigation except very few cases. The net annual utilizable ground water resource of the block is 4118.36 HM. The net ground water draft is 852.95 HM (Unit draft method, based on 100% well census).

The ground water balance of the block as on December 2007 is 3265.41 HM, out of which 326.50HM can be utilized for domestic and drinking purposes and 2938.91HM for additional irrigation purpose. At present, the stage of ground water development is 20.71% and falls under safe category. Hence, there is a vast scope for ground water development through suitable abstraction structures for development of agrarian economy. A total additional area of 3672 hect. and 2203 hect. can be irrigated during kharif and Rabi season respectively by utilizing the balance ground water. Rain water Harvesting (RWH) and Artificial Recharge structures such as percolation pond, check dam, gully plug, contour bund and vegetative measures may be taken up by government agencies for serving dual purposes of improving the health of ground water sanctuary and solving geo-environmental problems like land degradation by soil erosion. This activity may generate additional employment opportunity for rural youth. The study emphasizes on:

- The need for scientific well siting on the basis of the result of the present hydro geological studies aided by remote sensing and GIS techniques.
- Large-scale development of ground water for sustainable growth of rain fed agriculture and mitigating drinking water problem, since the present stage of ground water development in the block only 20%.
- Site-specific suitable ground water structure such as dug wells, dug well-cum-bore wells, and bore wells may be taken up.
- Suitable steps for revitalization of old and defective wells and rain-water harvesting structures may be undertaken.

- The existing dug wells, which go dry during summer, may either be deepened or bore well can be drilled to meet the water requirement.
- Horizontal bores may be drilled for increasing the well yields.

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