ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Quality Assessment and Recharge Potential of Ground Water of Chasnala Coal Mines – A Case Study

Kumar G [1], Singh SK [1], Murari K, Pandey V[1], Om Prakash[1], Sinha BK[2], Prasad SK[3]

[1] BIT Sindri, P.O. Sindri Institute, Dhanbad – 828 123, Jharkhand, India
[2] SAIL – ISP, Chasnala, Dhanbad, Jharkhand, India
[3] Dept. of Biotechnology, BCET, Durgapur, India.

ABSTRACT

Ground water is a renewable resource subjected to periodic replenishment primarily through precipitation. Recharge is one of the key hydrological parameters for assessment, budgeting, management, and modeling of ground water resources. Although information and data regarding recharge rate is vital for recharge assessment of any region, determination of this parameter is neither easy nor straightforward. Groundwater is one of the important sources of potable water. This accounts for a significant water resource in India for domestic, irrigation and industrial needs. Over 80% of the rural domestic water supply and 45% of the irrigation water supply in the country are met by these valuable resources. Besides quantity, groundwater quality is a serious problem in the country. In the present context, when ground water table level which is depleting every year, the study of its availability assessment becomes necessary. This assessment may be quite helpful in restricting our water requirement and leads us for the water requirement audit. Groundwater occurrence and storage in study area are mainly controlled by the geological set up of the area. The ability of geological formation to store and transmit water is dependent on its formation parameters, such as porosity and hydraulic conductivity. In the mining area, the water levels are bound to be affected and disturbed. Rainfall is the principal recharge source to groundwater. Besides rainfall, the mine water discharge from the local mining areas and existing water bodies including water logged in abundant mine quarries are also contributed to the ground water recharge as return flow. The present work attempts to establish a hydrogeological framework for the understanding of natural groundwater recharge processes in relation to climate, landform, geology, and biotic factors. It begins with the concepts of groundwater flow systems, which form the basis for comprehending recharge processes. It then concentrates on the sources and mechanisms of groundwater recharge and stresses the importance of developing correct conceptualizations of recharge. The ground water recharge potential in the area was estimated by using rainfall-infiltration and water table fluctuation methods. The annual withdrawal of water for irrigational uses as well as domestic uses have been calculated and also the annual draft through mine discharge have been calculated. On the basis of these studies, net annual ground water availability assessment has been made. The present work also highlights the quality of Ground Water of the area which is mainly of category B as per the **IS: 10500.**

Keywords: Groundwater, Porosity, Hydraulic Conductivity, Hydrological, Mine Quarries.

***Corresponding author**
Email: drgkumar12@gmail.com

INTRODUCTION

Modeling of ground water recharge-potential principally aims at water-resource evaluation. Various techniques are available to assess recharge-potential, and their capability in estimating recharge for the quantitative estimation of recharge, few can be applied successfully in the field. All are characterized by major uncertainties [2]. When estimating groundwater recharge it is essential to proceed from a good conceptualization of different recharge mechanisms and their importance in the study area [3]. Besides this conceptualization the objectives of the study, available data and resources, and possibilities of obtaining supplementary data should guide the choice of recharge-estimation methods [4].

STUDY AREA

Chasnalla lies in the eastern extremity of Jharia Coalfield (JCF) in the Dhanbad district of Jharkhand state. It covers an area of 4.5 Km^2. The area is roughly defined by north latitudes $23^0$38'25'' and 23''40'00'' and East longitudes $86^0$27'12'' & 86^0 29'15''. It is included in the survey of India Topo sheet no.73 I/6 and in Sheet No.8 of the geological map of JCF. **Figure 1** show the regional location of the area.

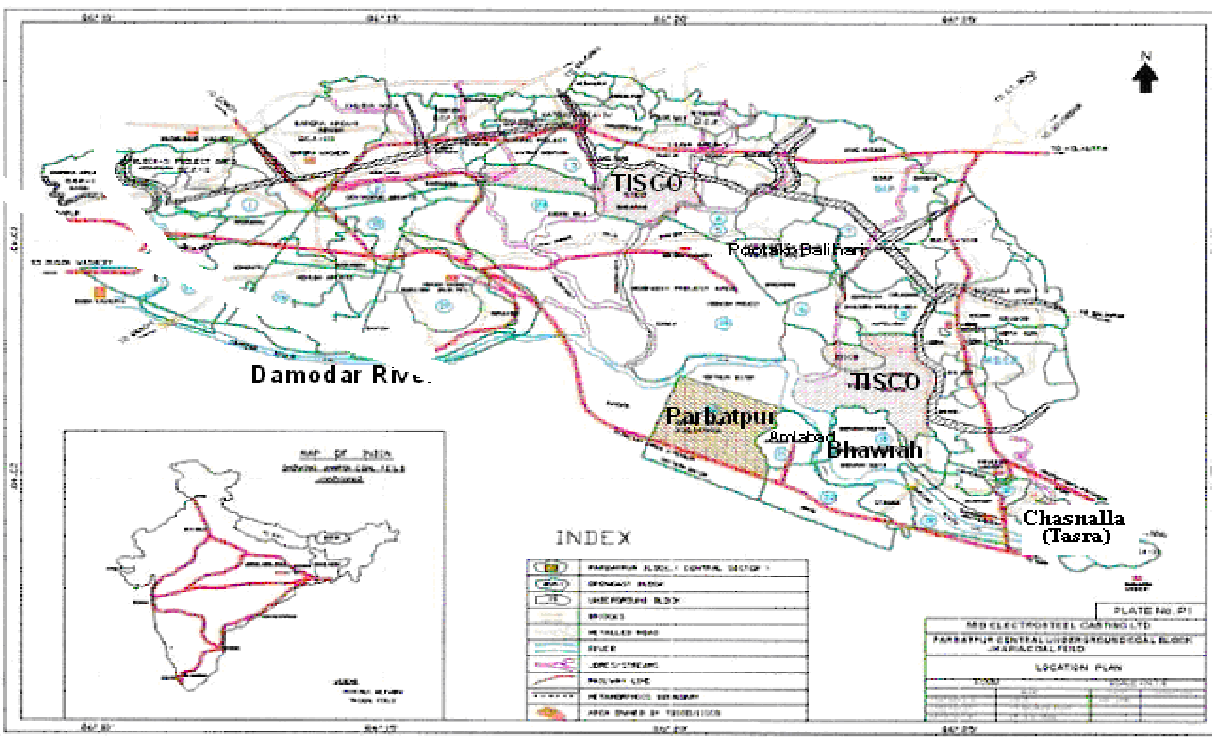

Fig 1: Location Map of the Jhaia Coalfield and Chasnala Coal Block.

Chasnala is located about 15 km from Jharia town and about 23 km from Dhanbad town. Dhanbad - Sindri Road passes through its northern boundary. The nearest Railway station of Eastern Railway is at Sindri at about 5 km from here. The nearest airstrip is at Dhanbad. There is also a landing strip at Burnpur about 80 Km away owned by the Indian Iron & Steel Co. Ltd. a subsidiary of SAIL.

PHYSIORAPHY, DRAINAGE AND CLIMATE:

The area has a flat to gently undulating topography with a general southerly slope towards Damodar River, which flows west to east beyond the southern boundary of the block. The highest ground elevation is about 149m. (Triangulation station T15) and the lowest elevation has been observed to be about 126m (B.H.No. TS-33). The local drainage of the area is controlled by the two jores draining in Damodar river viz., Domohani jore and Cilatu (also called Chetu) jore. The Domohani jore has been diverted into Cilatu jore in the central part of the block near bohrehole No. TS-19 in order to facilitate mining activity in Chasnalla colliery.

The area lies in the tropical region with fairly wide temperature variations between winter and summer. The climate of Jharia Coalfield is tropical monsoon type with maximum precipitation occurring in the months of June to September. The maximum temperature of the coalfield raises upto 44°C in May while it dips to 5° to 7°C in December/ January. The annual rainfall in Jharia Coalfield and adjacent regions varies from 1197 to 1380 mm.

Based on porosity & hydraulic conductivity parameters, the rock formation of the area may be classified as hard and soft rocks. Hard rocks, mainly crystalline and consolidated sedimentary is characterized by very little porosity. Ground water in such rocks circulated to a limited extent through the secondary openings represented by joints, cracks, fissures and such other planes of discontinuity. Soft rocks represented by sandstone, pebbles and loose sand, posses higher degree of primary porosity and as such characterized by higher water storage capacity. As greater part of the study area is underlain by Precambrian crystalline rocks. The weathered residual of the hard rock's as well as the fractures, joints, fissures, faults and other zones of discontinuity are the principle repositories of ground water in the area. The weathered zone is usually of limited thickness, fractures and joints generally close up with depth. The thickness of weathered mantle in the hard rock zone of area is about 10-20 meter in the topographic lows. Ground water in the weathered and fracture zones of hard rock's occur under unconfined condition. Ground water circulating through fracture zone is sometimes held under pressure. Depth of the water table in the hard rock of the area generally ranges from 3.0 m to 10.0 m below ground level. The Gondwana sediments form the semi-consolidated formations and are better water potential zone. The splintery shales of Talchir and basal pebbles bed, the variegated Barren Measure shales and the sandstones are the major lithounits of the Gondwana Formations. Gondwana sandstones in general, are known to constitute good aquifers at many places. Ground water occurs under unconfined condition in the weathered mantles varying depths from 7-14m as observed in the dugwells and semiconfined condition in the deeper aquifers. Depth of water level for premonsoon period varies from 4-5m bgl around the Tasra block to some places it stretches to a deeper depth of 8-12m. The pre-monsoon water level rises due to recharge and becomes 3-6 m bgl around Tasra area during post-monsoon period.

WATER TABLE BEHAVIOUR IN THE AREA:

Total 30 dug wells were selected as observation points in the core and buffer zone for measuring the water levels in these wells during pre and post monsoon seasons. In the core and buffer zone the fluctuation of ground water level is given in **Table 1.**

Water table in ten monitored wells in core zone varies between 5.65–7.45 m in pre-monsoon and 2.98-4.07 m during post-monsoon. In the buffer zones, the water table ranges between 5.10 m to 9.33 m in pre-monsoon to 2.80 – 4.23 m in post-monsoon season. The average water table in core and buffer zone during pre-monsoon is 6.46 m and 7.19 m respectively, while in post-monsoon season, the average water table is measures 3.29 m and 3.45 m respectively for core and buffer zone. The average water table fluctuation in core and buffer zone varied between 2.50 - 4.29 m (avg. 3.16m) and 2.11 – 5.28 m (avg. 3.72 m) respectively. The average water table fluctuation between pre and post-monsoon season for the study area was observed as 3.53 m.

GROUND WATER RECHARGE POTENTIAL:

Rainfall is the principal recharge source to groundwater. The area experience an average annual rainfall of about 1330 mm and the highest annual rainfall was recorded as 2061 mm in 2006. The highest rainfall recorded within 24 hours was 40.0 mm. Besides rainfall, the mine water discharge from the local mining areas and existing water bodies including water logged in abundant mine quarries are also contributed to the ground water recharge as return flow.

In the study area, ground water is withdrawn usually by means of open dug wells and small diameter hand operated tube wells for domestic and irrigation purposes. The tube wells are most often deeper (19m–58m) than the dug wells and tap the aquifer below the weathered mantle. As the area is being located in the hot-tropical belt, the temperature regime is very high, the daily maximum reaches to over 44^0C. Due to excessive heat, the loss of moisture through evaporation is considerably high (60-65%). During the wet monsoon seasons, the net evaporation is less than the precipitation, resulting in surplus water which loss through either surface runoff or being part of the subsurface storage. The surface runoff and subsurface storage of water depends upon various factors including the amount of rainfall, topography of the area, land use pattern, soil type, slope, physiographic, drainage pattern and hydrogeomorphology of the catchment/sub-catchment. The study area is having gentle slope towards south and south east. Water received on the slopes, gets collected in low-lying area and is thus ultimately absorbed in the top soil cover and become part of the ground water flow according to the slope to form seasonal streams/nallas.

In the mining area, the water levels are bound to be affected and disturbed. The Jharia mining area is highly disturbed and the permeabilities of individual geological units are spatially variable and depend on lithology, fracturing and attenuation with depth. The porous and more open-jointed sandstone members tend to form aquifers, the shaly members are aquitards, which may be leaky but are poorly permeable and form the poor permeable barriers to the vertical groundwater movement. The ground water recharge potential in the area was estimated by using rainfall-infiltration and water table fluctuation methods. As reported in the GEC Report 1997 [4], for semi-consolidated sandstones and weathered and fractured hard rock terrains, a rainfall infiltration factor of 10-15 % of normal rainfall and for sandy areas infiltration factor of 20-25% may be undertaken for calculation of recharge potential.

Table 1: Ground Water Level Fluctuation in Core and Buffer Zone Area of Chasnalla (Pre and Post-monsoon of 2008)

Core/Buffer Zone	Sites	Well No.	Pre-monsoon (m)	Post-monsoon (m)	Fluctuation (m)
Core Zone	Tasra	W-1	6.33	3.24	3.09
		W-2	7.12	4.07	3.05
		W-3	6.45	3.11	3.34
		W-4	5.98	3.27	2.71
	Kandra	W-5	6.14	3.43	2.71
		W-6	5.78	3.22	2.56
		W-7	6.32	3.10	3.22
	Rohrabandh	W-8	7.45	3.16	4.29
		W-9	5.65	2.98	2.67
		W-10	7.34	3.36	3.98
Buffer Zone	Bhaghmara	W-11	5.76	3.50	2.26
		W-12	7.23	3.13	4.10
		W-13	8.13	3.98	4.15
		W-14	9.23	4.15	5.08
	Gosalla	W-15	7.25	3.22	4.03
		W-16	8.43	3.43	5.00
		W-17	7.15	3.15	4.00
	Bhojudih	W-18	6.67	3.41	3.26
		W-19	7.45	3.75	3.70
		W-20	9.33	4.05	5.28
	Digwadih	W-21	8.45	3.56	4.89
		W-22	7.76	3.36	4.40
		W-23	8.21	4.12	4.09
		W-24	9.13	4.23	4.90
	Damodarpur	W-25	6.12	3.43	2.69
		W-26	5.10	2.99	2.11
		W-27	5.34	3.22	2.12
	Joradih	W-28	5.12	2.83	2.29
		W-29	5.64	2.80	2.84
		W-30	6.33	3.11	3.22
Minimum			**5.10**	**2.80**	**2.11**
Maximum			**9.33**	**4.23**	**5.28**
Average			**6.95**	**3.41**	**3.53**

Here, we have considered an average 15% rainfall infiltration factor for calculating annual recharge potential of the area. The total annual ground water replenishable recharge (TARR) estimated for the areas are 74.119 million m^3 by rainfall infiltration factor. Following the GEC Report-1997 [5] prepared by CGWB, irrigation annual draft in the buffer zone was estimated as 3.664 million m^3**.** For calculating the domestic water consumption, population of 2,98,985 at the consumption rate of 70 liter per day per person was considered. The water withdrawal for domestic uses was estimated as 7.63 million m^3. The consumption by cattle population was projected as 10% of domestic consumption, amounting 0.763 million m^3. The total mine discharge into the area through different active and abundant opencast and underground mines was estimated as 17.338 million m^3. Of this about 20% (i.e. 3.467 million m^3) is estimated as return flow to the ground water system. Thus the net mine water discharge in the area was projected as 13.870 million m^3. The net ground water recharge and draft for buffer zone were estimated as 74.119 million m^3 and 25.927 million m^3 respectively. Thus the balance available groundwater resource projected as 48.192 million m^3.

GROUNDWATER STAGE DEVELOPMENT:

Except, for coal mining and some coal based industries, no major industrial development activity is located in the area. As per GEC-1997 [5], the total annual replenishable groundwater resource in the area is assessed as 74.119 million m^3 and total withdrawal from the area as 25.927 million m^3 and the calculated stage of ground water development as 35% and it falls within the category **"white"**. Summary of the water potential estimation is given in Table 2

.

(I) Total annual replenishable recharge (TARR) in million m^3/year

(A) By rainfall infiltration factor method:

TARR	=	Area x average rainfall x infiltration factor
Total geographical area	=	437.089 km^2
Average rain fall of the area	=	1330 mm
Infiltration factor	=	15%
TARR	=	437.089 km^2 x 1.330 m x 15%
	=	87.199 million m^3

Natural discharges & other losses (15% of Recharge) = (-) 13.08 million m^3

Net Annual Groundwater Recharge (TARR) = 74.119 million m^3

(B) By ground water table fluctuation method:

Total annual replenishable recharge (TAAR)
= Area x Average water table fluctuation x Specific Yield

Total Area = 437.089 km^2

Average water table fluctuation = 3.53 m
Specific Yield = P*Rg/HW*(P-Rs)

Where P is the annual rainfall, Rg is the annual groundwater runoff, Rs is the annual surface runoff and Hw is the water table fluctuation.

= 1330 x 199.5/3530 x (1330-292.6)

= 265335/3662022 = 0.072

The different parameters for the estimation are as follows:

Parameters		% of Rainfall	Values in Million m^3
Total Areas	437.089 km^2		
Total Rainfall	1330 mm	100 %	581.328
Evapo-transpiration	837.9 mm	63%	366.2366
Total Runoff	292.6 mm	22 %	127.892
Ground Water Recharge	199.5 mm	15%	87.199

Total annual replenishable recharge (TAAR) by ground water fluctuation method

= 437.089 km^2 x 3.53 x 0.072

= **111.09 million m^3**

(II). Annual Ground Water Withdrawal:

(A) Annual water withdrawal for irrigation uses:

(i) Net irrigation draft derived from the total irrigation land of 312.46 km^2

= 4.58 million m^3

(ii) Return flow from irrigation to ground water (-20%) = -0.916 million m^3

(iii) Net irrigation use (i-ii) = **3.664 million m^3**

(B) Domestic withdrawal =

(i) Annual domestic consumption = Population x 70 Liter x 365 days

= 2,98,985 x 70 liter x 365 days = 7.63 million m^3

(ii) For cattle population (10% of the domestic uses) = 0.763 million m^3

Total domestic water withdrawal (i+ii) = 8.393 million m^3

(C) Estimated annual draft through mine discharge =

There are number of mines of the East Jharia, Lodna, Bastacola, Kustore, ISCO and TISCO mining areas working in the studied area.

(i) The estimated mine water discharge for the buffer area is estimated to be 17.338 million m^3.

(ii) 20% return flow of the mine water discharges in the area = 3.467 million m^3
(iii) Net annual mine water discharges (i-ii) = 13.870 million m^3

Net Annual Groundwater Daft (A+B+C)
= 3.664 + 8.393 + 13.870 = 25.927 million m^3

Net Annual Ground Water Availability (I-II) = (74.119 – 25.927)
= 48.192 million m^3

Table 2: Summary of Water Potential Estimation

a) Range of water table (m bgl)	
Pre-Monsoon (April, 2008) ❖Core Zone ❖Buffer Zone	 6.46 m 7.19 m
Post-Monsoon (October, 2008) ❖Core Zone ❖Buffer Zone	 3.29 m 3.45 m
b) Total annual replenishable recharge (TARR)	
• By rainfall infiltration factor method (million m^3/year) • By groundwater table fluctuation method (million m^3/year)	74.119 111.09
c) Annual draft excluding estimated draft through mine discharge (million m^3/year)	12.057
d) Estimated draft through mine discharge (million m^3/year)	13.870
e) Net annual ground water availability (million m^3/year)	48.192
f) Stage of ground water development in %	34.98

DRINKING WATER QULAITY OF THE STUDY AREA (CORE ZONE):

The water samples from the core zone were collected and analysed as per **IS:10500** standards. Results of ground water analysis have been given in the Table 3. Concentration of some ions like SO_4 and Cl and value of TDS are relatively high in some ground water samples but well within the permissible limits. In general all the measured values are found well within the threshold limit as specified in test parameters of drinking water [6], [7]. However, the sodium absorption ration and the Coliform Org. count are more than the threshold values which make these water less suitable for the irrigation purpose & domestic water supply directly. The overall category of the water belongs to Class B, i.e. more suitable for all beneficial uses except domestic water supply. But with proper treatment, this can also be used for domestic water supply.

ISSN: 0975-8585

Table 3: Drinking Water Quality of the Study Area – Core Zone (Ground Water)

S. No.	Parameters	Station Code										IS : 10500
		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	
1	Colour (Hazen units)	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5-25
2	Odour	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO
3	Taste	A	A	A	A	A	A	A	A	A	A	‘A
4	BOD (5days at 20^{o} C)	4.3	3.9	4.1	4.6	3.6	4.5	4.8	3.3	4.3	4.4	‘30
5	Turbidity (NTU)	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5-10
6	pH	8.13	7.36	7.83	8.10	8.10	8.05	7.92	8.00	8.10	8.12	6.5-8.5
7	Total H (as $CaCO_3$)	198	210	238	225	253	222	228	234	244	236	300-600
8	Iron (as Fe)	0.10	0.19	0.13	0.18	0.25	0.18	0.16	0.22	0.24	0.25	0.3-1.0
9	Chloride (as Cl^-)	27.6	53.2	43.2	36.0	15.4	28.4	27.8	26.9	29.5	32.5	250-1000
10	Boron (as B)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	‘1
11	Residual Free Chlorine	<0.1	0.10	0.11	<0.1	0.12	0.14	0.12	0.14	0.12	0.14	0.’2
12	TDS	430	549	460	533	735	550	622	580	588	592	500-2000
13	Calcium (as Ca)	41.5	49.1	69.1	57.8	85.5	60.2	68.5	73.7	76.2	78.5	75-200
14	Magnesium (as Mg)	21.9	19.7	33.7	29.5	29.8	30.4	22.5	28.8	26.6	27.8	30-100
15	Copper (as Cu)	0.04	0.02	0.03	0.03	0.02	0.04	0.02	0.03	0.03	0.02	0.’07-1.5
16	Manganese (as Mn)	0.07	0.07	0.04	0.06	0.07	0.07	0.07	0.04	0.06	0.07	0.1-0.3
17	Sulphates (as SO_4^{--})	36.8	101.6	75.6	52.5	212.4	33.8	141.6	75.6	58.5	152.4	‘150
18	Nitrate (NO_3)	1.28	3.32	5.89	1.46	0.84	1.20	6.32	5.98	1.66	1.44	45-100
19	Fluorides as (F^-)	0.23	0.26	0.29	0.39	0.24	0.25	0.28	0.33	0.36	0.44	0.6-1.2
20	Phenolic com. (C_6H_5OH)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.’001
21	Mercury (as Hg)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.’001
22	Cadmium (as Cd)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.’01
23	Selenium (as Se)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.’001
24	Arsenic (as As)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.’07
25	Cyanide (as CN^-)	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.01	<0.02	0.’07
26	Lead (as Pb)	0.07	0.03	0.02	0.06	0.02	0.06	0.05	0.05	0.08	0.05	0.’1
27	Zinc (as Zn)	0.11	0.09	0.’07	0.11	0.13	0.11	0.19	0.17	0.21	0.23	0.’5
28	Sodium absorption Ratio	35	39	56	38	34	59	33	36	53	60	‘26
29	Coliform Org. (MPN /100 ml)	312	187	200	192	184	192	232	188	198	182	‘200
	Classification	**C**	**B**	**B**	**C**	**B**	**B**	**C**	**B**	**B**	**B**	

Note: Parameters expressed in mg/l except pH& Colour. As per classification of inland surface water (CPCB standard) ; A : Agreeable ; CL : Colorless ; BDL - Below Detection Limit.

CONCLUSIONS

Assessing the potential zone of groundwater recharge is extremely important for the protection of water quality and the management of groundwater systems [8], [9]. Various techniques are available to assess recharge-potential, and their capability in estimating recharge is also variable. It is difficult to determine the properties of large aquifers, such as transmissivities, storage coefficients and similar parameters, in sufficient resolution [10]. Modelling large aquifers seems an almost hopeless task. But the essential information for water availability is the information on fluxes in and out of the storage. In this paper, total annual replenishable recharge (TARR) in million m^3/year has been calculated by rainfall infiltration factor method by ground water table fluctuation method whereas for the annual ground water withdrawal 3 major sub units such as (i) Annual water withdrawal for irrigation uses (ii) Domestic withdrawal & (iii) Estimated annual draft through mine discharge have been taken into account and on the basis of these results, Net Annual Ground Water Availability has been estimated as 48.192 million m^3 which seems to be quite high and is sufficient to meet the requirement of the people.

In general all the measured values are found well within the threshold limit of drinking water. However, the sodium absorption ration and the Coliform Org.count [11] are more than the optimum values which make these water less suitable for the irrigation & domestic water supply directly. The overall category of the water belongs to Class B, i.e. more suitable for all beneficial uses except domestic water supply [12].

REFERENCES

[1] Bhuiyan C, Singh RP and Flugel WA. A GIS approach Env Earth Sc 2009; 59(4):929–38.
[2] Germann PF and Beven K. Water Resources Research 1985; 21(7):990–996.
[3] Kinzelbach W, Bauer P, Siegfried T and Brunner P. Scientific Problems and Tools Episodes 2004; 4:125-131.
[4] Molden D and Sakthivadivel R. Int J Water Resources Development 1999; 15(1 & 2):55–71.
[5] GEC Report 1997. http://cgwb.gov.in/groundwater/hard_rock_chap3.htm.
[6] ICMR. Manual of Standard Quality of Ground Water Supplies. ICMR, ND, India 1975.
[7] Indian Standards IS: 10500: Drinking Water Specifications 1992.
[8] Sophocleous MA and Perkins SP. J Hydrology 2000; 236:185–201.
[9] Oki T and Kanae S. Science 2006; 313(5790):1068-1072.
[10] Raju KCB. J Geological Society of India 1998; 51:429–454.
[11] WHO. Report of WHO Sc Gr Tech Report Series 778, Geneva, Switzerland 1989.
[12] Sinha BK, Kumar G, Singh SK and Prasad B. Int J Earth & Engg 2010; 3(6):24 – 31.