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Groundwater Quality for Drinking and Irrigation Purpose in Damonjodi Area, Koraput District, Odisha, India

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Abstract: This study was conducted to evaluate factors regulating ground water quality in this area. Eighteen ground water samples have been collected from Damonjodi area of koraput district. The chemical constituents and values were compared with national and in the results of this analysis were compared with the water quality standard of BIS and WHO. In this area the various physicochemical parameters such as pH, electrical conductivity, turbidity, total dissolved solids, Cl^-, SO_4^{2-}, total hardness, total alkalinity, Na^+, K^+, Ca^{2+}, COD, BOD, DO, Sodium adsorption ratio, magnesium adsorption ratio, Kelly's ratio, permeability index, residual sodium bi-carbonate etc. were determined using standard procedures. The quality of ground water samples were discussed with respect to these parameters and thus attempt were made to ascertain the quality of ground water used for drinking, cooking and irrigation purposes in and around Damonjodi areas.

Key words: Evaluation · Irrigation water quality · SAR · Water quality standards

INTRODUCTION

Water is a universal solvent and is the elixir for all living beings. Ground water is about 20% of the world resources of fresh water and used in large amount for industry, irrigation and domestic activity. Water constitutes about 70% of the body weight of almost all living organism. Man's activities such as food production, nutrition are dependent on water availability in adequate quantities and good quality [1].water is the most common and wide spread chemical compound in nature which is a major constitute of all living creatures [1].The quality of water is of great importance as it is commonly consumed and used by households. Ground water which occurs beneath the earth surface is considered free from contamination. Naturally ground water recharged through rain water. The groundwater could be affected by urbanization, agriculture waste, applications of pesticides, fertilizers, utilization of wastewater for irrigation, leakage from waste water from septic tanks and industrial discharge [2-11]. Domestic wastewater is considered as a major source of pollution. It has been investigated that once pollutant enters the subsurface environment, it may remain dormant for a long period and get dispersed over wide areas of groundwater aquifer and thus rendering groundwater unsuitable for consumption and other domestic purposes [1].As Damonjodi area is famous for Asia's largest and world's seventh largest producer of aluminium plant is situated named as NALCO. This area water pollution is due to mainly bauxite mines ore and effluent produced by National Aluminium Company. Ground water in the study area is utilized for both agriculture and drinking purposes hence discussed in order to understand the concentration of the total dissolved constituents present in the ground water with respects to the standards of safe portable water.

Study Area: Damonjodi is a small town in the Koraput district in the Indian state of Odisha. Aluminium plant is situated at Damonjodi named as NALCO. Damonjodi is a valley situated among the panchpatmali hills.

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Panchapatmali mines means the mine is surrounded by five hills. It is situated at coordinates of 18° 82" N and 82° 72" E.

MATERIALS AND METHODS

The current study was designed to investigate the conditions of ground water contamination in study area. The hydro geochemistry study was undertaken by randomly collected 18 ground water samples from dug well as well and bore wells covering entire peripheral of Damonjodi area in month of pre monsoon may 2011. The water Samples were collected during the day time between 9 am to 12 am maintaining 1 km distance between two places. Samples were collected in one litre plastic bottles. Before sampling the plastic bottles were cleaned thoroughly to remove all surface contamination, rinsed with double distilled water and dried. The collected samples were properly brought to the laboratory without adding any preservative. Suspended matters if any in the samples were removed by filtering through what man filter paper No.41.Then it is stored in the refrigerator at 25°C till the analysis was over. The pH, EC, TDS was estimated by Cyber scan pH meter. Total hardness (TH) as $CaCO_3$ and Calcium (Ca^{2+}) were analysed titrimetrically using standard EDTA, Magnesium (Mg^{2+}) was calculated by taking the differential value between total hardness (TH) and calcium (Ca^{2+}) concentration. Chloride (Cl^-) was determined titrimetrically by standard $AgNO_3$ titration. The content of Sodium (Na^+), Potassium (K^+) and Calcium (Ca^{2+}) in ground water was estimated Elico flame photometer. Sulphate was determined by titrimetric method. Total alkalinity was determined by titrimetrically. DO was done by Wrinkle's titrimetric method. COD was done by COD Merck meter and BOD was done by BOD Merck meter

Parameters such as TDS, Alkalinity, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, COD, BOD, DO, Total Hardness were expressed ppm or milligrams per litre (mg/L) where as SAR, SSP, MAR, KR, RSBC, RSC, PI were expressed in mill equivalents per litre (meq/L), except pH (units) and Electrical conductivity (EC) is expressed in micro Seimen /cm (µS/cm) at 25°C.

RESULTS AND DISCUSSIONS

The various physical and chemical parameters determined for the water samples were given in the table I and 2 respectively. From the analyzed results it was found that quality of water in study area varies from location to location.

pH: pH is one of the important factors of ground water. In the study area pH Varies from 5.99 to 7.11 with average (Table 1) indicates that ground water quality is slightly acidic nature. 38.89% samples were exceeds the permissible limit prescribed by BIS.

Electrical Conductivity (EC): Conductivity measure capacity of a substance to conduct electric current. Most of salts in water are present in their ionic forms and capable of conducting current and conductivity is a good indicator to assess ground water quality. Electrical conductivity is indication of the concentration of total dissolved solids and major ions in a given water body.

Electrical conductivity in groundwater in study area varies from 200 to 6820(µS/cm) with average of 1015 µS/cm

Classification of ground water from conductivity of water

Permissible	Conductivity Range	No. of Samples	percentage of Sample (%)
Permissible	<1500	16	88.89
Not permissible	1500-3000	1	5.56
Hazardous	>3000	1	5.56

Total Dissolved solids (TDS): Total dissolved solids concentration is the sum of the cations (positively charged) and anions (negatively charged) ions in the water. Total dissolved salts comprise inorganic salts i.e. calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates and some small amounts of organic matter that are dissolved in water. The total dissolves solids in all study area varies from 110 to 3370 mg/L with average value 503.38 mg/L and 27.78% samples were exceeding permissible limit prescribed 500 mg/L by the BIS. High values of TDS in the ground water are not harmful to human beings but high concentration of these may affect persons, who are suffering from kidney and heart diseases.Water containing high solid may cause laxative or constipation effects [12].

TDS level of drinking water for consumer ratings

Rating	TDS level (mg/L)	No. Samples	Percentage of Samples (%)
Excellence	<300	10	55.55
Good	300-600	6	33.33
Poor	600-900	1	5.55
Unacceptable	>1700	1	5.55

Table 1: Physico-Chemical parameters of bore well and hand pump in Damonjodi area koraput district.

Sample No/parameter	pH	EC	TDS	PhA	TA	Ca^{2+}	Mg^{2+}	TH	Temp (°C)
D-1	6.06	2420	1190	8	48	15	72	335	23
D-2	6.74	412	210	8	88	5	15	75	23
D-3	6.44	445	229	0	32	4	17	80	23.2
D-4	6.85	1113	553	24	144	8	45	205	23.8
D-5	7.11	1298	645	24	248	8	56	250	23.1
D-6	6.99	6820	3370	16	224	80	231	900	23.1
D-7	6.33	133	70	0	40	2	21	90	23.4
D-8	6.40	475	230	4	56	4	27	120	23.2
D-9	7.04	699	352	44	128	7	43	195	23.5
D-10	6.78	211	105	0	56	2.8	29	125	23.1
D-11	6.38	392	197	4	72	3.6	33	145	23.4
D-12	6.51	645	317	12	56	9	43	200	23
D-13	5.99	420	210	0	24	2.6	24	105	22.8
D-14	6.97	653	334	32	168	7.2	50	225	22.7
D-15	6.45	200	100	16	224	8.6	48	220	23
D-16	6.60	550	240	24	210	10.2	54	250	23.2
D-17	6.50	1100	600	24	200	16	73	340	22.8
D-18	6.73	220	110	12	88	7.6	75	330	23.1

Sample No/Parameter	Na^{+}	K^{+}	DO	SO_4^{2-}	Cl-	SAR
S-1	69.8	2.4	6.15	48	206	1.660
S-2	28.8	1.0	7.14	38	289	1.446
S-3	14.6	2.5	6.94	46	209	0.710
S-4	24.2	8.4	5.75	38	233	0.735
S-5	2.0	4.0	6.44	40	265	0.055
S-6	52.2	8.3	7.83	41	502	0.757
S-7	3.5	1.9	5.04	41	259	0.160
S-8	11.8	1.4	4.28	41	226	0.469
S-9	32.5	1.6	5.14	38	131	1.013
S-10	4.1	0.8	5.90	26	204	0.159
S-11	15.4	1.2	5.52	36	143	0.556
S-12	9.6	1.8	3.42	38	180	0.295
S-13	24.1	1.0	6.94	48	208	1.024
S-14	12.2	3.2	6.09	36	211	0.354
S-15	10.2	2.9	6.30	200	360	0.299
S-16	7.8	3.7	5.98	121	110	0.214
S-17	45.3	2.5	4.78	220	135	1.069
S-18	20.2	3.6	5.75	60	240	0.484

Sample No/Parameter	SSP	MAR	KR	RSBC	RSC	PI
S-1	31.22	88.95	0.454	0.048	-5.63	40.35
S-2	45.51	82.69	0.835	1.182	0.209	89.15
S-3	28.45	87.49	0.397	0.324	-1.072	60.90
S-4	20.46	90.73	0.257	1.981	-0.931	50.32
S-5	1.713	92.39	0.017	3.685	-0.124	41.42
S-6	11.22	77.66	0.126	-0.340	-13.76	20.69
S-7	7.81	94.44	0.084	0.555	-1.140	49.36
S-8	17.65	91.66	0.214	0.718	-1.343	50.60
S-9	26.64	90.76	0.363	1.738	-0.327	53.94
S-10	6.67	94.39	0.071	0.778	-1.577	42.30
S-11	18.79	93.79	0.231	1.00	-1.579	49.28
S-12	9.47	88.74	0.104	0.468	-2.673	31.19
S-13	33.34	93.80	0.500	0.263	-1.701	53.30
S-14	10.56	91.99	0.118	2.394	-0.670	43.61
S-15	9.17	90.22	0.101	3.242	-0.185	48.81
S-16	6.366	89.80	0.067	2.933	-0.748	41.17
S-17	22.50	88.23	0.290	2.479	-2.707	43.17
S-18	11.77	94.24	0.133	1.063	-4.744	27.85

Statistical evaluation for different parameters in the bore well and deep well waters in and around Damonjodi area, Koraput district

S. No	Parameter	Range	BIS	WHO	Mean	SD	COV(%)
1	Temperature	23.7-24	28-30	28-30	24	10	110
2	pH	5.99-7.11	6.5-8.5	6.5-8.5	6.60	0.32	4.87
3	Conductivity	132-6820	1500	1500	1011.44	1549.11	153.15
4	TDS	69-1190	500	500	503.38	765.33	152.03
5	PhA	0-44	-	-	14	12.59	89.95
6	TA	24-248	200	200	117	76.88	65.71
7	Ca^{2+}	2-80	-	-	11.11	17.62	158.60
8	Mg^{2+}	15-170	-	-	49.74	35.40	71.17
9	TH	75-900	500	500	232.77	187.50	80.54
10	Na	2-52	-	-	21.57	18.40	85.33
11	K	0.8-8.3	-	-	2.9	2.21	76.22
12	Ca	4-150	75	75	28.67	33.36	116.37
13	DO	4.28-7.83	-	-	5.85	1.07	18.28
14	SO_4^{2-}	26-200	200	200	64.25	56.75	88.33
15	Cl-	110-502	250	250	228.47	91.56	40.07
16	SAR	0.05-1.66	-	-	0.63	0.45	71.78
17	SSP	1.71-31.22	-	-	17.73	11.63	65.57
18	MAR	77.66-92.39	-	-	90.10	7.31	4.79
19	KR	0.017-0.454	-	-	0.24	0.20	84.94
20	RSBC	-0.34-3.242	-	-	1.36	1.17	86.56
21	RSC	-5.63-0.209	-	-	-2.26	3.25	-143.99
22	PI	20.69-89.15	-	-	46.53	14.46	31.08

All values are ppm unit except EC is (iS/cm),TDS: Total dissolved Solids, Cl:Chloride, TH:Total Hardness, DO: Dissolved Oxygen, PhA:Phenolpthlein Alkalinity, TA:Total Alkalinity, Ca: Calcium,Mg:Magnesium,Na:Sodium,K:Potassium,SO4:Sulphate,SAR:Sodium Adsorption Ratio, SSP:Sodium soluble percentage, MAR:Magnesium Adsorption Ratio, RSC: Residual Sodium carbonate, PI: Permeability Index.

Calcium (Ca^{2+}): Calcium is a naturally present in water. It is major constituent of igneous rocks. The calcium presents in ground water in form of soluble calcium carbonate, sulphide and rarely chloride. Calcium content in the ground water varies from 2 ppm to 80.40 ppm with average value is 11.11 mg/L. All samples in study area were within maximum permissible limit prescribed by the BIS.

Total Hardness (TH): Hardness is soap consuming property of water. Hardness is concentration of magnesium and calcium ion. When hard water is heated scale forms much faster. This creates an insulation problem inside the boilers, water heaters and hot water lines and increases water heating cost. The degree of hardness considered objectionable depends on the degree of hardness to which consumers have become accustomed as described as

In Study area 5.5% is soft, 33.34% is moderate, 38.89% is hard and 22.23% is very hard water.

Total hardness is varies in study area varies in 90 mg/L to 900 mg/L with average value is 232.11 mg/L, which may

due to presence of calcium (Ca^{2+}) and magnesium (Mg^{2+}).The study concluded that 22.22% samples were exceeding maximum permissible limit prescribed by BIS.

Ground water quality according to Total hardness.

Ratings	TH as CaCO3	No. of Sample	Percentage of Sample
Soft	0-75	1	5.55
Moderate	75-150	6	33.33
Hard	150-300	7	38.88
Very Hard	>300	4	22.22

Alkalinity: Alkalinity of water is the capacity to neutralize acidic nature and the presence of carbonates, bicarbonates and hydroxides are the main cause of alkalinity of water. An increase in alkalinity causes a loss of colour, which is directly proportional to the alkalinity of the water sample and is usually close to its hardness value. The value of alkalinity in study area varies from 40 to 240mg/L with mean value is 117.00 mg/L. The studies conclude that 27.77 % were exceeding maximum permissible limit prescribed by BIS. High alkalinity in drinking water leads to sour taste and salinity.

Chloride (Cl^-): Chlorides originates from sodium chloride which gets dissolved in water from rocks and soil. It is good indication of groundwater quality and its concentration in groundwater will increase if it mixed with sewage or sea water. The chloride content in study area has shown variation from 110 mg/L to 450.20 mg/L and 27.77% of samples were exceeding maximum permissible limit prescribed by BIS.

Sodium (Na): Sodium is the sixth most abundant element in Earth's crust. Sodium occurs as major cation in water samples. Sodium bearing minerals like albite and other members of plagioclase feldspars, nephelene etc. Most of sodium salts are readily soluble in water. The sodium content in study area varies from 2 mg/L to 52.2 mg/L. Hence all samples site were within permission limit of BIS.

Potassium (K): Potassium is a minor element in ground water as compared to sodium.This is due to the fact that the potassium minerals are resistant to decomposition by weathering. The main sources of potassium in ground water weathering of potash silicate minerals and use of potash fertilizers. The potassium content in study area ranging from 0.8 ppm to 8.4 ppm which is below the maximum permissible limit 10 ppm as per European Economic Community. High potassium values may cause nervous and digestive disorder.

Dissolved Oxygen (DO): The level of dissolved oxygen in water is used as an indication of pollution and its potability. This thus forms a key test in water pollution control activities and waste treatment process control. The value of dissolved oxygen varies in study area 4.28 mg/L to 7.83 mg/L with mean value is 5.85 mg/L.

In the present investigation the ground water samples from different part of study area revealed that there is marked variation in ground water quality.

Correlation of Physicochemical parameters of ground water: Correlation is the mutual relationship between two variables. In order to find out the relationship amongst physiochemical parameters of the water samples, correlation coefficients were carried out and a large no of significant correlations were obtained. It is a simply measure used to exhibit how well one variable predicts the other. The high positively correlated values were found between EC and TDS (0.99), Total hardness and EC (0.92), Ca and EC (0.96), Ca and TDS (0.96), Total hardness and TDS (0.92) and negative correlation between EC and Sulphate (-0.96).This provides a means for easier and faster monitoring of water quality in a location.

Coefficient correlation between quality parameter in study area:

EC	TDS	pH	TH	TA	Cl-	SO_4^{2-}	Na^+	K^+	Ca_2^+	DO
EC	1									
TDS	0.999	1								
pH	0.253	0.254	1							
TH	0.924	0.925	0.326	1						
TA	0.377	0.379	0.579	0.535	1					
Cl^-	0.658	0.657	0.231	0.602	0.306	1				
So_4^{-2}	-0.962	-0.087	-0.179	0.122	0.512	-0.049	1			
Na^+	0.620	0.625	-0.160	0.562	0.034	0.178	0.111	1		
K^-	0.655	0.654	0.462	0.685	0.565	0.518	0.009	0.250	1	
Ca^{2+}	0.966	0.969	0.246	0.925	0.390	0.652	0.011	0.698	0.6801	
DO	0.438	0.435	0.147	-0.336	0.236	0.553	-0.091	0.256	0.333	0.454 1

Irrigation Water Quality: Groundwater is the main source of irrigation in entire study area. The adequate amount of water is very essential for proper growth of plants but the quality of water used for irrigation purpose should also be within the permissible limit otherwise it could adversely affect the plant growth. The quality of irrigation water depends primarily on the presence of dissolved salts and their concentration. Parameters such as EC, pH, Sodium Adsorption Ratio (SAR), Sodium Percentage (SP), Residual Sodium Carbonate (RSC), Chlorides and Sulphate were used to assess the suitability of water for irrigation purposes [13-18].

According [19],Sodium Adsorption ratio (SAR) is expressed as

$$SAR = \frac{Na^{+}}{\frac{\sqrt{Ca^{+2} + Mg^{+2}}}{2}}$$

According [20], Soluble sodium percentage (SSP) is expressed as

$$SSP = \frac{Na^{+} + K^{+}}{Ca^{+2} + Mg^{+2} + Na^{+} + K^{+}} * 100$$

According [21] expressed Residual Sodium Bicarbonate (RSBC)

$RSBC = HCO3^{-} — Ca^{+2}$

According [22] defined permeability index (PI) as

$$PI = \frac{Na^{+} + \sqrt{HCO3 -}}{Ca^{+2} + Mg^{+2} + Na^{+} + K^{+}} * 100$$

Magnesium adsorption ratio (MAR) [23] is expressed as

$$MAR = \frac{Mg^{+2}}{Ca^{+2} + Mg^{+2}} * 100$$

Kelley's ratio (KR) [24] is described as

$$KR = \frac{Na^{+}}{Ca^{+2} + Mg^{+2}}$$

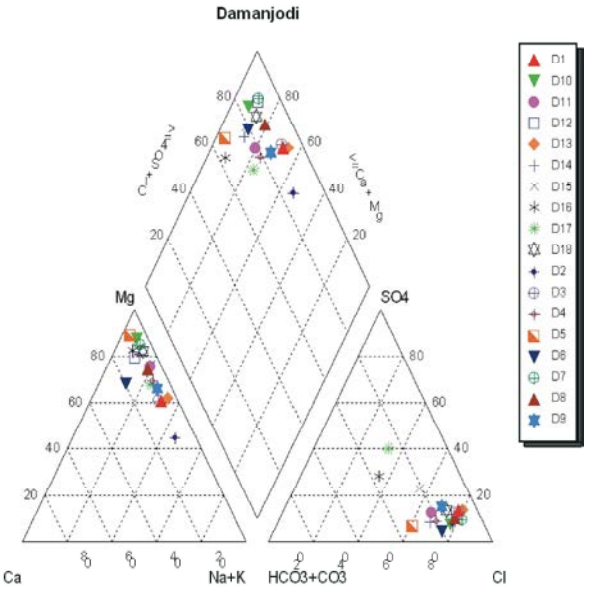
According to [23-25], Residual sodium carbonate is expressed as

$RSC = (Co_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$

RESULTS AND DISCUSSIONS

pH: The Values of ground water ranges from 5.99 to 7.11 with an average value of 6.6 indicated very slightly acidic in nature (table 1).The lowest value is observed in the sample no.13 and the highest value in the sample no 5.

TDS: The Total dissolved solid ranges from 69 to 3370 mg/L. The standard for dissolved solids is up 500 mg/L and maximum permissible limits for irrigation is 2000 mg/L [13]. A water containing TDS less than 1000 mg/L can be considered to be fresh water for irrigation use and will not affect the osmotic pressure of soil solution[26].The TDS values of all sample area were suitable for irrigation except sample no.6 (3370mg/L)



Hydrochemical Facies: The geochemical evolution of groundwater can be understood by plotting the concentrations of major cations and anions in the piper tri-linear diagram [27].The plot shows that most of the groundwater samples fall in the field of mixed Mg-Cl type water except In sample station D2 is Cl-HCO_3^{-} type water, D16 is Mg-HCO_3^{-} type water and D17 is Mg^{2+}-SO_4^{2-} type water. From plot Mg^{2+} and Ca^{2+} significantly exceed the alkalis of Na^{+} and K^{+} while acids of Cl^{-} and HCO_3^{-} exceed the acids of SO_4^{2-}.

Sample station no.	Water Type.
D1	Mg-Na-Cl
D10	Mg-Cl-HCO3
D11	Mg-Cl-HCO3
D12	Mg-Cl
D13	Mg-Cl
D14	Mg-Cl-HCO3
D15	Mg-Cl-SO4-HCO3
D16	Mg-HCO3-Cl-SO4
D17	Mg-SO4-Cl-HCO3
D18	Mg-Cl
D2	Cl-HCO3
D3	Mg-Cl
D4	Mg-Cl-HCO3
D5	Mg-Cl-HCO3
D6	Mg-Ca-Cl
D7	Mg-Cl
D8	Mg-Cl
D9	Mg-Na-Cl

The Salinity Indicator: Electrical conductivity as an indicator of TDS is a useful tool to evaluate the purity of water and a good measure of salinity hazard to agriculture. Electrical conductivity (EC) values of groundwater samples range between 132 to 6820µS/cm (table).The results shows that almost all the values of the water samples are within irrigation permissible limit [23] except sample no.1 with EC value 2420 µS/cm and Sample no.6 with EC value 6820 µS/cm. High value of conductivity is caused by high level of Ca^{2+}, Mg^{2+}, Na^{+} (150ppm, 170ppm, 52.2 ppm) respectively.

Excess Electrical conductivity reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil [28].

Groundwater quality for irrigation water based on Electrical Conductivity.

Water class	Water quality	No	Percentage	EC (µS/cm)
Excellent	Low salinity	4	22.23	<250
Good	Medium salinity	9	50.00	250-750
Permissible	High salinity	3	16.67	750-2250
Unsuitable	Very high salinity	2	11.12	>2250

SAR Indicator: The suitability of the well water samples was evaluated by determining the Sodium Adsorption Ratio (SAR) value and they were categorized under different classes on the basis of salinity and alkalinity harards.The sodium adsorption ratio parameter evaluates the sodium concentration with respect to calcium and magnesium concentrations. The sodium adsorption ratio is used to predict the potential for sodium to accumulate in the soil. U.S salinity Lab. Proposed in sodium Adsorption Ratio (SAR) as more reliable criteria for evaluating Na hazard in irrigation water. The SAR values varied from 0.055 to 1.660 with an average of 0.637.The data revealed that all of the water samples fall in the low sodium class (S1) Table 5.If the SAR values is greater than 6 to 9,the irrigation water will cause permeability problems on shrinking and swelling types of clayey soils [28].A high value implies a hazard of sodium (alkali) replacing Ca^{2+} and Mg^{2+} in the soil through a cation exchange process that damages soil structures, mainly permeability and affects the fertility status of the soil and reduce crop yield [29].

U.S salinity proposed four classes of Na hazard based on SAR of irrigation water.

Water Class	No.	Percentage	SAR value	Class of Water	Suitability
Excellent	18	100	<10	S1	Can be used on all soils
Good	0	0	10-18	S2	can be used on textured soil
Doubtful	0	0	18-26	S3	Ordinary unsuitable water
Unsuitable	0	0	>26	S4	ordinary Unsuitable water

SSP Indicator: The Sodium percentage ranges from 1.71 to 45.51 % with averaging 17.74 % is tested sample in study area. The principle cations present in irrigation water are Ca^{2+}, Mg^{2+} and Na^{+} and with very low quantity of K^{+}. The alkaline hazard involved is mainly related with the soluble and relative concentration of the cation in irrigation water. If the proportion of Na is more the alkaline hazard is high and conversely, if Ca^{2+} and Mg^{2+} predominate, the hazard is low. Alkali soils are formed by accumulation of exchangeable Na^{+} and often characterized by poor physical conditions and low permeability. According [25] proposed Na % as a basis for evaluating irrigation water quality for Na hazard. The salts, besides affecting the growth of the plants directly, also affect sil structure, permeability and aerations, which indirectly affect plant growth [30].The Wilcox diagram relating sodium percentage and total concentration shows that most of the ground water samples fall on the field of excellent to good permissible quality.

Quality of irrigation water based on Na (%)

Water class	No.	Percentage	Sodium (%)
Excellent	11	61.12	<20
Good	6	33.34	20-40
Permissible	1	5.55	40-60
Doubtful	0	0	60-80
Unsuitable	0	0	>80

RSC Indicator: In addition to the SAR and Na%, the excess sum of carbonate and bicarbonate in ground water over the sum of calcium and magnesium also influences the suitability of ground water for irrigation. The Residual Sodium Carbonate value varies from -13.75 to 0.20 $meqL^{-1}$ with average value -2.26 $meqL^{-1}$ in study area. Most of the samples (94.45%) show negative values which indicated that dissolved calcium and magnesium contents were higher than carbonate and bicarbonate contents. Table indicates that (94%) of the samples have good water qualities.

Ground water quality for irrigation based on RSC

Water class	No.	Percentage	RSC (meqL-)
Good	18	100	<1.25
Doubtful	0	0	1.25-2.5
Unsuitable	0	0	>2.5

PI Indicator: The Permeability Index (PI) value is used to evaluate the sodium hazards of irrigation water.From the environmental point of view, a high permeability index, in association with subsurface structural features would facilitate widespread contamination of ground water. Accordingly, waters are can be classified as class I, class II and class III. Class I and Class II waters are categorized

as good for irrigation with 75% or more of maximum permeability. Class III waters are unsuitable with 25% maximum permeability.

The PI varies in study area from 20.69 to 89.15% with average value is 46.53 which fall under class I and Class II of Doneen's chart [31].

Ground water quality for irrigation based on PI

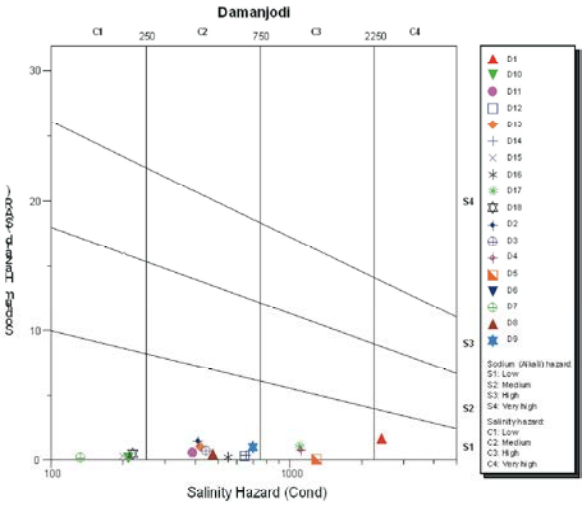
Water class	No.	Percentage	PI
Excellent	1	5.56	>75
Good	16	88.75	25-75
Unsuitable	1	5.56	<25

KR Indicator: The level of Na^+ measured against Ca^{2+} and Mg^{2+} is known as Kelley's ratio, based on which irrigation water can be rated [24][32] Kelley's ground water having less than one is considered as good for irrigation. The KR value varies in study area from 0.017 to 0.835 with average value 0.242.

Ground water quality is distinguished as per KR value

Water class	No.	Percentage	KR
Good	18	100	<1
Bad	0	0	>1

MAR Indicator: Magnesium present in water would adversely affect the soil quality for cultivation. Magnesium ion concentration plays an important role in productivity of soil, so that it is used to determine whether the water was suitable for irrigation [33].The MAR values varies in study area from 77.66 to 94.44 with average value 90.11. If Magnesium hazard if found more than 50, if less than 50 it is safe and suitable for irrigation. Therefore none of the sample found is suitable for irrigation. High concentration of magnesium can be attributed to dolomite, sandstone and siltstone [34].



EC and Na^+ play a vital role in suitability of water for irrigation [35].Soil containing a lesser proportions of Na^+ with HCO_3^- or Cl/SO_4^{2-} are turned acidic soil respectively. Lesser salt content in irrigation water causes an increase in soil solution osmotic pressure. Since plant roots extract water through osmosis, the water uptake of plant increases. The osmotic pressure is proportional to the salt content or salinity hazard. The salts, besides affecting the growth of plants directly, also affect soil structure, permeability and aeration, which indirectly affect the plant growth. High content of Na^+ content can cause displacement of exchangeable Ca^{2+} and Mg^{2+} from the clay mineral of soil [36].For irrigation purposes total concentrations of soluble salts classified into low(C1), medium(C2), high(C3) and very high (C4) salinity zones based on EC.These zones (C1 to C4) have values of EC of <250 ìS/cm,250 to 750 ìS/cm,750 to 2250 ìS/cm and >2250 ìS/cm respectively [35]. According to this classification 4 sampling station points low saline water, 9 sampling station points are medium saline water while 3 sampling station points are high saline water and 2 sampling station points are very high saline water. Average RSBC of the study area varies from -0.340 to 3.242 meq/L and the average PI are found varies 20.69 to 89.15 meq/L.A positive RSBC value indicates that the contents dissolved Ca^{+2} and Mg^{2+} ions is less that of CO_3^{2-} and HCO_3^- [37]. For irrigation purposes RSBC value <5 mg/L [21] and according to Donen's chart PI<1 [23].

Salinity of water and SAR, adsorption of Na^+ by soils and clay minerals is greater at higher Mg^{2+}: Ca^{2+} ratios. This is because the bonding energy of Mg^{2+} is less than that of Ca^{2+}, allowing more Na^+ adsorption and it happens when the ratio exceed 4.0 [38].Ayers and West cot also reported that soil containing high levels of exchangeable Mg^{2+} causes an infiltration problem. In the study area, the ration of Ca^{2+} and Mg^{2+} for all the samples are less than 1which is varies from 0.09 to 0.42, which maintains a good structure and tilth condition with no permeability problem of the soil for all sample station. However considering Na^+: Ca^{2+}, the presence of excessive Na^+ in irrigation water promotes soil dispersion and structure breakdown when Na^+ to Ca^{2+} ratio exceeds 3:1.Such a high Na^+: Ca^{2+} ration (>3:1) results in sever water filtration problems., mainly due to lack of sufficient Ca^{2+} to counter the dispersing effect of Na^+. Excessive Na^+ also creates problems in crop water uptake, poor seedling emergence, lack of aeration, plant and root diseases. In the study area Na^+: Ca^{2+} ratio in sample station no. D1, D2, D3, D9, D11, D13 which are greater than 3:1 so it is not suitable for irrigation purposes.

The US Salinity Laboratory's diagram is used widely for rating irrigation water where SAR is plotted against EC [17].Here SAR is an index of sodium hazard (S1) and Electrical conductivity is an index of salinity hazard (C1). From 18 places the SAR and Salinity hazard C1-S1 is low while the value of C1-S1 value is slightly medium at the sample station no.D1.The water of this area is most suitable for irrigation purposes according to US Salinity Laboratory's diagram. The water of Damonjodi area is also safe for irrigation and drinking purpose.

CONCLUSION

Interpretation of hydro chemical analysis reveals that the ground water in Damonjodi area of koraput district is fresh to brackish and acidic nature. In respect of all evaluating criteria, groundwater of that area could safely be used for long term irrigation and drinking purposes except the sample no. 6 for drinking purposes. Water of Damonjodi area is safe for drinking and irrigation purpose in respect of SAR, SSP, EC, PI, KR, MR and physico-chemical properties of water. Generally the water in these study areas is not harmful to human beings. So it is highly important to take periodical monitoring of the ground water quality in this region for our future sustainability. Hardness of study area is high on most of places. For drinking and cooking purposes water should purify by some anionic exchange resin to remove hardness and also primarily water should be boiled and cooled then use.

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