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Monitoring the seasonal variation of groundwater chemistry and quality assessment for agricultural and industrial purpose of Athgarh basin, India

Rosalin Das

Department of Geology, Fakir Mohan University, Balasore, Odisha, India

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ABSTRACT

The groundwater chemistry of a region is sensitive to climate change and to change of agricultural practice of the surrounding region. The water quality is also largely governed by the litho hydrological character of the region. Hence monitoring the hydrochemistry of the groundwater with respect to climate change is vital for detecting its suitability for irrigation of cropland and industrial use. The present study area Athgarh basin, belongs to upper Gondwana has a varied lithology. The regional scale data can be statistically related to climate change. Moreover, seasonal variation of water quality has been monitored after systematic collection of groundwater samples and their methodical physicochemical analysis. 75 water samples were collected during pre-monsoon, monsoon and post-monsoon period of 2015-2016. The quality assessment is made through the estimation of physicochemical parameters, cations and anions. Based on these analyses, the irrigational parameters like salinity hazard, sodium absorption ratio (SAR), sodium%, residual sodium carbonate (RSC), potential soil salinity (PS), magnesium ratio (MR), corrosivity ratio (CR) and permeability index (PI) were calculated to determine the suitability of groundwater for irrigational and industrial purpose. The groundwater falling under (Doneen's) class-II is almost good for irrigation purpose whereas groundwater falling under class-III indicates poor water quality. The groundwater samples are excellent to good as per Wilcox diagram. From Gibb's diagrams, it can be established that the groundwater of the study area is mainly dominated by the lithology of aquifer of the concerned region.Various classifications show that present status of groundwater is suitable for irrigation purpose, except few locations, with a caution that it may deteriorate in near future.

Key words: *Athgarh basin, Irrigation, Wilcox, Doneen'spermebility index, Gibb's diagram*

Introduction

The water bodies are continuously subjected to dynamic state of change with respect to lithological characteristics and geo-climatic condition. For efficient management of these water resources, information regarding the water quality and its variability are required. The present study is to access the quality of water of the Athgarh basin and its suitability for agronomic and industrial purpose. The Athgarh basin has been considered as the northernmost extension of the east-coast Upper Gondwana sediment. The Athgarh basin is exposed to the north, northwest and southwest of Cuttack and Bhubaneswar (twin city). The study area covers an area about 800 sq.km. Geographically the area is situated between latitude $20^0 45'$N to 20^0N and longitude $85^0 30'$E to 86^0E. Some portion of the Athgarh sandstone is concealed by laterite and alluvium. However, Athgarh and stone has been encountered in the subsurface, i.e., in the offshore region of coastal Odisha in the Bay of Bengal (Kaila *et al*., 1987). The location of the study area is shown in Fig. 1. The analytical results and computed values of water samples of the study area are given in Table 1. The groundwater quality data interpretation for irrigation has been carried out as per guidelines given by Ayers (1977) and Christiansen *et al*. (1977).

Methodology

The chemical analysis of groundwater samples provides direct information about the present quality of the aquifer. One litre of each water sample was taken for hydrochemical analysis. Sampling was conducted at 75 sampling sites in the Athagarh basin three times during pre-monsoon, monsoon and post-monsoon of 2015-16 (Fig. 1). A comprehensive analysis of physico-chemical parameters of groundwaterwas undertaken by standard analytical procedures (APHA, 1992). Special care was taken to avoid the error. Each water sample was taken for analysis by using a double beam spectrophotometer, flame photometer, water analyser, etc. In order to achieve the aim of the research, to reveal the suitability of ground water for irrigation purposes, the study on the effect of mineral constituent of the water on both plant and soil is essential. The parameters such as Sodium Absorption Ratio (SAR), Sodium Percentage (Na%), Potential soil Salinity, Magnesium Ratio (MR) and Permeability Index (PI), corrosivity ratio were estimated to assess the suitability of water for irrigation and industrial purpose. To establish litho hydrological relationship, Gibb's diagram for anions and cations are plotted. The concentrations of the ions were interpreted and calculated from standard equations".

Results and Discussion

Groundwater Chemistry

The hydro-chemical parameters are analyzed and the computed values are interpreted for assessment of groundwater quality for irrigation and industrial purpose as per guidelines proposed by Ayers and Christiansen (1977). The analytical results and computed values of water samples of the study area are given in (Table 1,2,3). The suitability of water for irrigation depends upon salinity hazard and the sodium content in relation to the amounts of calcium and magnesium or Sodium Absorption Ratio (Alagbe, 2006). Quality requirements for industrial water may vary widely according to potential use. The assessment of groundwater suitability for industrial purpose can be done from the hardness, TDS and corrosivity ratio. As the concentration of total hardness and TDS are within the permissible limits during pre-monsoon, monsoon and post-monsoon periods, the water may use for industrial use.

Salinity Hazard

The salinity usually reported as Electrical Conductance (EC) affects the availability of water to crop.

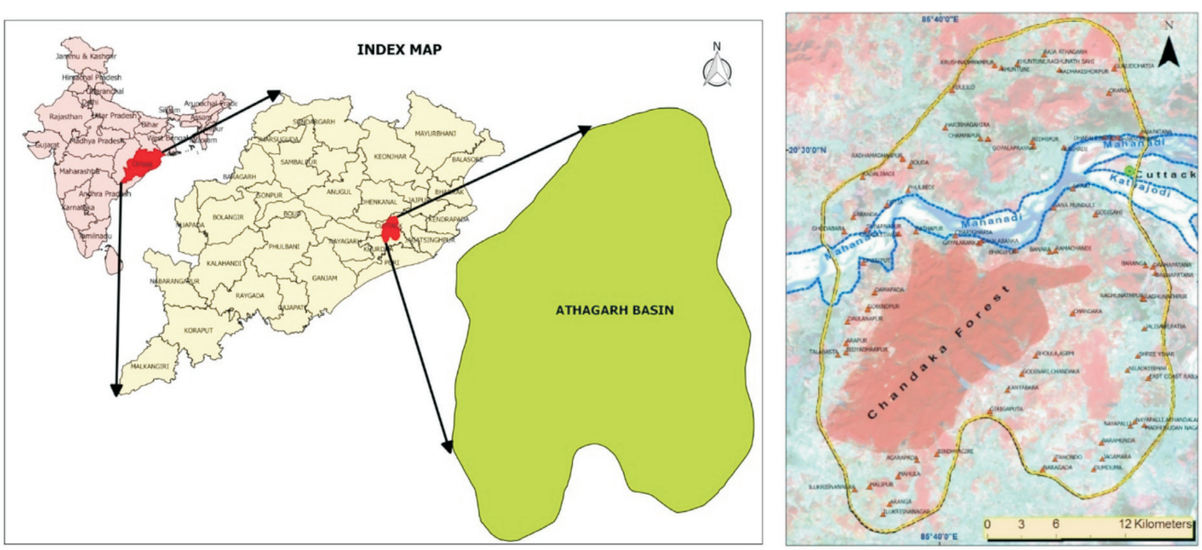


Fig. 1. Location Map of the study area.

Table 1. Quality parameters for irrigation and industrial purposes during pre-monsoon

Sl. No	Location	Well type	Na%	SAR	PI	PS	MR	CR
1	Agarapada	Tw	49.72	7.35	0.93	52.44	68.63	0.63
2	Aranga	Tw	39.69	6.93	1.73	32.80	25.68	0.89
3	Arapur	Tw	33.90	3.64	1.82	36.76	49.45	0.48
4	Banara	Tw	61.14	12.49	1.27	67.31	42.17	0.21
5	Baramunda	Dw +(12)	42.15	7.36	1.44	48.85	36.48	0.48
6	Baranga	Tw	53.20	7.03	2.46	57.18	51.90	1.67
7	Bhagipur	Tw	65.87	12.17	0.96	64.26	30.87	1.35
8	Bhoula, asbm	Tw	54.48	7.15	0.91	48.91	58.89	2.61
9	Bidyadharpur	Tw	42.64	10.19	1.66	52.20	23.37	0.14
10	Bidyadharpur, khordha	Tw	46.59	7.22	2.20	48.58	58.04	1.44
11	Bindhyagiri	Tw	64.03	13.40	1.48	71.03	66.74	0.33
12	Bouda	Tw	39.62	5.11	1.08	31.19	30.06	0.46
13	Chakuleswar	Tw	42.00	7.03	0.98	33.26	31.52	0.63
14	Champapur	Tw	24.46	3.01	1.33	20.41	35.04	0.49
15	Chandaka	Tw	66.49	12.91	1.22	67.56	53.85	1.01
16	Charigharia	Tw	75.03	22.50	2.31	74.21	50.52	1.13
17	Damapada	Tw	42.10	4.92	1.42	42.03	51.94	0.90
18	Darhapatana	Tw	61.19	9.94	1.61	55.08	34.84	1.13
19	Darhapatana	Dw(14)	34.06	3.73	1.78	39.46	38.26	0.79
20	Daulanapur	Tw	42.65	8.79	1.82	43.91	30.06	0.79
21	Dhabaleswar	Dw(17)	26.58	5.29	0.91	37.41	34.61	0.08
22	Dhabaleswar	Tw	46.77	7.36	1.39	57.61	48.66	0.14
23	Dumduma	Tw	14.76	2.29	1.90	14.76	34.92	0.77
24	East coast railway	Tw	25.47	4.80	1.06	20.19	20.33	1.90
25	Gayalabanka	Tw	48.32	5.56	1.41	58.03	40.50	0.46
26	Gayalabanka	Dw(20)	45.49	6.82	0.90	55.04	39.42	0.12
27	Ghasiput	Tw	30.84	3.89	1.23	32.08	43.92	0.24
28	Girigaputa	Tw	36.93	4.96	2.12	36.99	37.74	0.91
29	Gobindpur	Tw	31.77	3.95	1.13	35.42	28.07	0.41
30	Godisahi	Tw	41.83	8.22	1.69	45.61	16.96	0.46
31	Ghodabara	Tw	51.16	10.31	1.34	56.95	69.67	0.82
32	Godibari,chandaka	Tw	49.87	11.60	2.34	61.91	43.36	0.34
33	Gopalaprasna	Tw	35.66	8.82	1.47	41.38	27.82	0.19
34	Gurudijhatia	Tw	49.20	12.41	1.33	48.85	23.53	0.18
35	Harirhagahira	Tw	35.73	4.03	1.73	46.75	53.85	0.22
36	Ilukrisnanagar	Tw	40.18	12.43	2.38	46.51	62.35	0.59
37	Ilukrisnanagar	Dw(4)	62.77	15.25	1.61	60.67	56.06	2.66
38	Jagamara	Tw	44.37	3.48	3.37	38.57	48.79	1.13
39	Jalisahi,patia	Tw	38.97	6.94	2.85	51.40	29.27	0.48
40	Kadalibadi	Tw	40.06	5.27	3.76	42.40	60.49	1.44
41	Kantabara	Tw	48.04	5.36	1.47	68.34	60.93	0.76
42	Kakhadi	Tw	43.20	6.26	1.06	75.37	24.87	0.16
43	Khuntuni,raghunathsahi	Dw(20)	29.54	4.43	1.98	36.92	33.27	0.32
44	Khuntuni	Tw	56.17	19.30	3.58	58.17	55.64	1.05
45	Krushnashyampur	Tw	41.48	10.77	2.16	50.96	32.01	0.20
46	Kuleilo	Tw	51.52	7.30	1.35	49.85	28.19	0.50
47	Madhusudan nagar	Tw	58.09	9.39	1.49	55.02	42.81	2.79
48	Mahakalabasta	Dw(37)	64.25	8.72	1.19	90.03	48.32	0.07
49	Mahakalabasta	Tw	49.02	9.31	1.17	57.81	44.26	0.30
50	Mahula	Tw	49.36	7.77	0.84	50.83	45.25	0.52
51	Malipur	Tw	38.15	4.30	2.87	37.99	57.04	1.99
52	Naraj	Tw	63.85	8.17	1.10	73.05	52.90	0.42
75	Naragada	Dw(12)	55.72	9.21	1.31	56.70	48.01	0.50

Table 1. *Continued ...*

Sl. No	Location	Well type	Na%	SAR	PI	PS	MR	CR
54	Nayapalli	Tw	58.36	15.30	1.17	67.01	48.51	0.16
55	Nayapalli, akhandalamani temple	Tw	55.95	13.20	1.90	62.61	29.98	0.36
56	Nidhipur	Tw	63.56	10.42	1.28	64.46	43.99	1.21
57	Niladribihar	Tw	64.62	7.85	0.97	55.09	39.38	1.78
58	Nuapatana	Tw	39.57	5.96	2.90	39.81	48.24	1.05
59	Oranda	Tw	47.55	10.42	1.80	46.33	25.65	0.37
60	Ostia	Tw	48.77	8.54	1.68	49.14	74.81	2.05
61	Pathapur	Tw	37.36	8.73	1.30	34.69	37.33	0.66
62	Phulbedi	Tw	38.20	6.90	1.20	37.31	34.76	0.21
63	Radhakishorpur	Tw	38.26	4.19	1.58	45.71	23.70	3.07
64	Radhamadhabpur	Tw	31.75	3.43	0.91	43.39	40.12	0.13
65	Radhamadhabpur	Dw(11)	46.61	5.83	1.13	66.08	44.51	0.39
66	Raghunathpur	Dw(16)	41.60	5.06	2.45	32.24	72.51	2.82
67	Raghunathpur	Tw	47.41	3.85	1.39	35.67	43.36	0.50
68	Raja athagarh	Tw	49.88	7.48	1.02	66.55	62.25	0.13
69	Ramachandi	Tw	50.75	7.60	3.19	50.61	40.50	2.91
70	Sana munduli	Tw	22.34	1.79	0.89	24.84	32.81	0.49
71	Saranda	Tw	32.32	5.38	1.61	36.04	43.10	0.65
72	Shree vihar	Tw	44.18	8.06	1.55	73.75	37.31	0.13
73	Subarnapur	Tw	47.89	8.68	1.60	57.42	33.79	0.34
74	Talabasta	Tw	28.11	2.76	3.16	25.30	67.84	1.44
75	Tamondo	Tw	56.30	9.84	1.50	64.40	25.66	0.41

Table 2. Quality parameters for irrigation and industrial purpose during monsoon

Sl. No.	Location	Well Type	Na%	SAR	PI	PS	MR	CR
1	Agarapada	TW	49.5	7.1	75.0	0.9	60.7	0.5
2	Aranga	TW	39.9	6.4	34.0	1.5	26.0	0.6
3	Arapur	TW	30.5	3.4	38.0	1.7	44.3	0.4
4	Banara	TW	59.0	12.0	69.0	1.2	34.9	0.2
5	Baramunda	DW(12)	42.5	7.3	49.0	1.4	36.0	0.5
6	Baranga	TW	52.6	6.9	63.0	2.5	48.3	1.0
7	Bhagipur	TW	66.9	12.0	71.0	1.1	18.5	0.5
8	Bhoula,asbm	TW	76.0	7.9	60.0	1.0	54.1	0.4
9	Bidyadharpur	TW	42.3	11.0	52.0	1.5	23.4	0.1
10	Bidyadharpur, khordha	TW	49.6	8.7	61.0	2.1	54.0	0.4
11	Bindhyagiri	TW	65.8	15.0	74.0	1.3	59.4	0.2
12	Bouda	TW	33.4	4.0	33.0	1.1	29.8	0.4
13	Chakuleswar	TW	41.2	6.3	35.0	1.1	26.9	0.5
14	Champapur	TW	19.5	2.5	21.0	1.8	36.5	0.6
15	Chandaka	TW	69.4	13.0	71.0	1.4	58.8	0.7
16	Charigharia	TW	74.5	22.0	79.0	2.5	44.0	1.3
17	Damapada	TW	39.7	4.3	47.0	1.1	58.1	0.4
18	Darhapatana	TW	58.4	9.0	59.0	1.9	25.4	0.8
19	Darhapatana	DW(14)	33.9	4.2	39.0	1.3	36.4	0.6
20	Daulanapur	TW	39.4	8.0	44.0	1.8	33.7	0.7
21	Dhabaleswar	DW(17)	22.2	4.0	36.0	0.8	33.8	0.1
22	Dhabaleswar	TW	48.1	8.2	57.0	1.3	44.5	0.1
23	Dumduma	TW	12.5	2.1	14.0	1.8	37.1	0.8
24	East coast railway	TW	21.5	4.1	23.0	1.4	21.9	0.8

Table 2. *Continued ...*

Sl. No.	Location	Well Type	Na%	SAR	PI	PS	MR	CR
25	Gayalabanka	TW	44.4	4.6	59.0	1.4	33.1	0.4
26	Gayalabanka	DW(20)	40.4	5.8	58.0	0.8	40.9	0.1
27	Ghasiput	TW	27.6	3.5	34.0	1.3	46.4	0.2
28	Girigaputa	TW	36.5	4.4	37.0	1.9	31.6	0.8
29	Gobindpur	TW	27.5	3.2	35.0	1.1	22.6	0.4
30	Godisahi	TW	42.9	9.0	46.0	1.6	15.4	0.5
31	Ghodabara	TW	75.3	11.0	59.0	1.4	68.0	0.6
32	Godibari, chandaka	TW	51.2	12.0	62.0	2.3	42.5	0.3
33	Gopalaprasna	TW	37.8	9.6	43.0	1.6	26.9	0.2
34	Gurudijhatia	TW	49.0	12.0	50.0	1.3	22.2	0.2
35	Harirhagahira	TW	31.1	3.5	48.0	1.6	47.2	0.2
36	Ilukrisnanagar	TW	42.6	13.0	51.0	2.3	55.7	0.2
37	Ilukrisnanagar	DW(4)	61.8	15.0	66.0	1.6	63.3	0.6
38	Jagamara	TW	44.8	3.4	42.0	3.0	48.5	2.6
39	Jalisahi,patia	TW	39.9	7.7	52.0	2.5	32.6	0.4
40	Kadalibadi	TW	38.6	5.5	49.0	2.9	64.4	1.0
41	Kantabara	TW	52.7	6.5	72.0	1.4	63.3	0.5
43	Khuntuni, raghunathsahi	DW(20)	26.3	3.3	37.0	1.9	29.0	0.2
44	Khuntuni	TW	56.8	18.0	61.0	2.8	32.0	0.3
45	Krushnashyampur	TW	39.5	11.0	52.0	2.1	58.8	0.3
46	Kuleilo	TW	50.8	6.5	75.0	1.5	35.7	0.2
47	Madhusudan nagar	TW	55.8	8.0	64.0	1.7	30.5	0.4
48	Mahakalabasta	DW(37)	65.3	10.0	90.0	1.5	41.4	0.9
49	Mahakalabasta	TW	52.2	11.0	59.0	1.4	55.6	0.1
50	Mahula	TW	48.6	6.8	54.0	0.8	42.4	0.3
51	Malipur	TW	29.5	3.1	43.0	2.3	44.3	0.3
52	Naraj	TW	64.6	7.3	78.0	1.0	61.5	0.9
53	Naragada	DW(12)	55.8	8.8	60.0	1.0	53.5	0.3
54	Nayapalli	TW	61.0	14.0	63.0	1.1	49.1	0.2
55	Nayapalli, akhandalamani temple	TW	54.3	13.0	63.0	1.9	47.3	0.3
56	Nidhipur	TW	62.9	9.1	67.0	0.9	25.0	0.4
57	Niladribihar	TW	62.6	6.7	62.0	0.9	45.5	0.6
58	Nuapatana	TW	37.5	5.1	41.0	3.0	47.9	0.7
59	Oranda	TW	43.3	9.0	47.0	1.7	48.4	1.0
60	Ostia	TW	50.8	9.4	54.0	1.4	22.9	0.3
61	Pathapur	TW	35.9	8.5	35.0	1.2	77.9	0.5
62	Phulbedi	TW	38.4	7.4	39.0	1.0	36.1	0.6
63	Radhakishorpur	TW	47.3	5.5	55.0	1.5	31.7	0.1
64	Radhamadhabpur	TW	32.1	3.6	43.0	1.0	17.0	0.8
65	Radhamadhabpur	DW(11)	43.7	5.1	66.0	1.0	39.7	0.2
66	Raghunathpur	DW (16)	36.8	4.5	41.0	2.1	25.4	0.4
67	Raghunathpur	TW	46.4	3.2	36.0	1.3	72.8	0.6
68	Raja athagarh	TW	47.7	6.7	69.0	1.2	37.1	0.5
69	Ramachandi	TW	49.9	7.2	57.0	2.5	56.1	0.1
70	Sana munduli	TW	13.8	0.6	26.0	1.2	33.8	1.0
71	Saranda	TW	28.4	4.7	36.0	1.5	42.5	0.6
72	Shree vihar	TW	44.1	7.4	74.0	1.8	36.9	0.6
73	Subarnapur	TW	56.1	8.1	56.0	1.7	32.2	0.2
74	Talabasta	TW	23.8	2.5	35.0	2.9	29.4	0.4
75	Tamondo	TW	54.8	9.8	65.0	1.7	69.5	0.8

Table 3. Quality parameters for irrigation and industrial purposes during post-monsoon

Sl. No.	Location	Well Type	Na%	SAR	PI	PS	MR	CR
1	Agarapada	TW	39.7	5.2	43.9	0.9	31.0	0.5
2	Aranga	TW	20.3	4.1	20.5	1.6	12.6	0.5
3	Arapur	TW	43.4	5.9	50.8	1.6	39.5	0.3
4	Banara	TW	31.6	4.4	36.5	1.2	38.8	0.2
5	Baramunda	DW (12)	40.4	8.1	47.7	1.6	32.2	0.6
6	Baranga	TW	39.8	5.2	42.9	2.1	42.4	0.7
7	Bhagipur	TW	33.6	5.4	33.9	1.1	22.9	0.4
8	Bhoula, Asbm	TW	38.0	5.7	43.6	1.2	20.8	0.5
9	Bidyadharpur	TW	26.7	6.0	32.8	1.6	3.6	0.1
10	Bidyadharpur, Khordha	TW	32.2	5.4	39.9	2.1	25.8	0.3
11	Bindhyagiri	TW	39.6	8.7	39.2	1.5	11.4	0.2
12	Bouda	TW	11.3	1.9	11.7	1.3	4.2	0.4
13	Chakuleswar	TW	20.8	4.0	19.8	1.1	20.0	0.4
14	Champapur	TW	14.9	2.6	15.8	1.3	5.0	0.4
15	Chandaka	TW	45.0	7.2	48.9	1.3	49.2	0.6
16	Charigharia	TW	61.3	12.9	64.4	2.3	38.0	1.0
17	Damapada	TW	41.9	6.3	50.1	1.2	34.7	0.4
18	Darhapatana	TW	35.4	5.2	40.2	1.7	15.4	0.4
19	Darhapatana	DW(14)	32.8	5.2	37.6	1.3	33.3	0.6
20	Daulanapur	TW	38.1	9.0	46.8	1.5	30.4	0.5
21	Dhabaleswar	DW(17)	14.3	2.8	20.3	0.6	7.8	0.0
22	Dhabaleswar	TW	17.1	3.3	23.5	1.3	9.6	0.1
23	Dumduma	TW	12.2	2.1	12.4	1.5	11.6	0.6
24	East Coast Railway	TW	11.3	2.2	11.4	1.2	9.3	0.5
25	Gayalabanka	TW	45.4	6.3	52.2	1.4	31.0	0.4
26	Gayalabanka	DW(20)	17.2	2.7	24.8	1.3	8.9	0.1
27	Ghasiput	TW	20.4	3.5	24.5	1.3	39.6	0.2
28	Girigaputa	TW	33.0	4.7	33.3	2.1	30.2	1.0
29	Gobindpur	TW	24.2	3.3	31.7	1.0	17.5	0.4
30	Godisahi	TW	39.5	8.8	41.9	1.6	15.5	0.5
31	Ghodabara	TW	42.6	7.1	43.3	1.3	45.0	0.5
32	Godibari, Chandaka	TW	51.9	13.9	62.2	2.0	40.5	0.3
33	Gopalaprasna	TW	26.6	6.4	34.5	1.2	10.6	0.1
34	Gurudijhatia	TW	20.9	4.2	26.5	1.3	21.9	0.1
35	Harirhagahira	TW	30.7	4.2	45.8	1.7	29.0	0.2
36	Ilukrisnanagar	TW	42.2	9.2	60.6	2.3	21.0	0.1
37	Ilukrisnanagar	DW(4)	60.5	11.2	72.6	1.6	45.0	0.4
38	Jagamara	TW	32.5	3.8	33.0	3.1	41.0	2.2
39	Jalisahi,Patia	TW	34.9	7.4	46.1	2.6	27.8	0.4
40	Kadalibadi	TW	64.6	10.7	74.5	3.3	32.3	1.0
41	Kantabara	TW	37.6	4.3	48.5	1.3	31.0	0.3
43	Khuntuni,RaghunathSahi	DW(20)	20.5	2.7	26.8	1.8	22.0	0.1
44	Khuntuni	TW	51.4	11.6	63.7	2.9	24.8	0.3
45	Krushnashyampur	TW	31.3	6.1	42.0	1.9	23.4	0.1
46	Kuleilo	TW	33.1	4.0	42.2	1.1	17.9	0.1
47	Madhusudan Nagar	TW	48.7	5.8	51.4	1.3	25.9	0.2
48	Mahakalabasta	DW(37)	35.1	5.1	49.5	1.5	31.5	0.6
49	Mahakalabasta	TW	36.1	8.0	43.6	1.5	12.0	0.1
50	Mahula	TW	39.3	5.1	37.8	0.7	40.5	0.2
51	Malipur	TW	39.3	5.1	37.8	0.7	35.7	0.3
52	Naraj	TW	49.3	6.4	59.9	1.0	13.5	0.2
53	Naragada	DW(12)	41.9	6.2	44.5	1.2	36.0	0.2
54	Nayapalli	TW	55.2	9.0	75.3	1.0	27.7	0.3

Table 3. *Continued ...*

Sl. No.	Location	Well Type	Na%	SAR	PI	PS	MR	CR
55	Nayapalli, Akhandalamani Temple	TW	40.9	10.0	45.7	1.6	45.0	0.3
56	Nidhipur	TW	44.8	3.8	39.4	1.3	16.5	0.3
57	Niladribihar	TW	36.4	4.8	38.4	1.1	43.4	0.8
58	Nuapatana	TW	44.1	5.3	49.2	2.3	30.4	0.4
59	Oranda	TW	25.2	4.9	28.2	1.6	49.2	0.5
60	Ostia	TW	52.8	9.4	60.0	1.6	17.7	0.2
61	Pathapur	TW	21.9	5.3	22.3	1.1	55.1	0.5
62	Phulbedi	TW	14.5	3.4	16.3	1.2	10.2	0.5
63	Radhakishorpur	TW	36.5	3.8	41.8	1.5	9.3	0.2
64	Radhamadhabpur	TW	17.4	2.4	26.7	0.9	45.0	0.6
65	Radhamadhabpur	DW(11)	39.4	5.1	45.4	1.1	36.0	0.1
66	Raghunathpur	DW(16)	35.8	3.5	37.8	2.2	36.4	0.4
67	Raghunathpur	TW	44.3	5.4	38.5	1.4	29.0	0.5
68	Raja Athagarh	TW	14.0	2.7	19.4	1.1	34.6	0.5
69	Ramachandi	TW	37.8	6.8	48.0	2.7	8.0	0.1
70	Sana Munduli	TW	21.9	3.3	31.4	0.9	22.8	0.4
71	Saranda	TW	21.3	4.0	26.4	1.7	32.7	0.5
72	Shree Vihar	TW	16.9	3.2	23.3	1.5	21.4	0.7
73	Subarnapur	TW	34.1	4.7	35.1	1.6	13.3	0.1
74	Talabasta	TW	33.6	3.5	44.2	2.8	15.7	0.4
75	Tamondo	TW	51.0	9.6	61.9	1.5	52.1	1.0

The Electrical conductivity (EC) depends upon temperature, concentration and types of ions present in the water (Hem, 1991) (Das *et al*., 2011, 2015, 2016). The Electrical Conductivity varies from 28 to 1451 µmhos/c in pre-monsoon, ranges from 30 µmhos/c to 1524 µmhos/c in monsoon and between 56 µmhos/c to 2084 µmhos/c in post-monsoon. The effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water. The higher the EC, the less water is available to plant. Maximum EC in water is marked in sample location of Bidyadharpur, Khorda. The difference between the values reflects the wide variations in the activities and chemical processes prevailing in the region.

Sodium Adsorption Ratio (SAR)

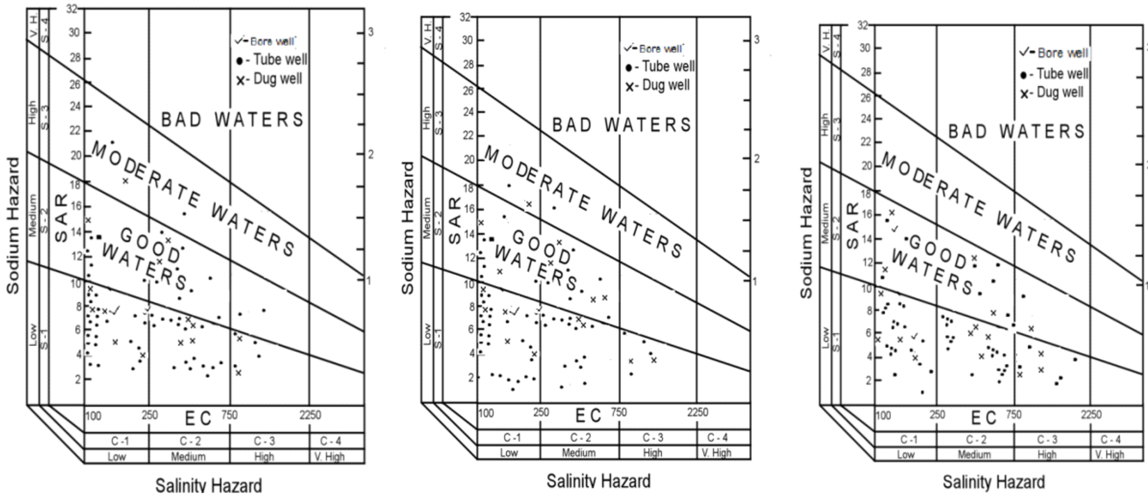
The most common measure to assess sodicity in water and soil is called the Sodium Absorption Ratio (SAR). Itis determined by the absolute and relative concentration of cations and isproposed by the U.S. Salinity Laboratory diagram,where EC (Electrical Conductivity) plotted against SAR. (Richards, 1954). SAR is expressed as

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

Where concentrations are expressed in equivalent per million (epm). According to the salinity hazard classification (Anbazhagan and Nair, 2004), there is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. The calculated values of SAR in the study area ranges from 0.658 to 20.584 in pre-monsoon, 1.025 to 22.365 in monsoon and 2.258 to 23.56 in post-monsoon. In the U.S. Salinity Laboratory diagram (Fig. 2) based on Sodium Absorption Ratio (SAR) Vs specific conductance values, it is evident that in pre-monsoon 58 samples are of excellent water, 14 are good water and 03 samples show medium water quality for irrigation purpose. In monsoon 56 samples show excellent, 16 are good, 03 samples are of medium quality and in post-monsoon 64 samples show excellent and 11 are good. (Table 4) From US salinity diagram it is evident that most of the water shows excellent quality for agricultural practice leaving few exceptions.

Sodium Percentage (Na %)

Percentage of sodium content in natural water is an imperative parameter to assess its suitability foragricultural use. (Wilcox, 1948). Sodium percentage can be defined in terms of epm of the common cations.



Pre-monsoon monsoon Post-monsoon

Fig. 2. U.S. Salinity diagram for classification of Irrigation Water Salinity Hazards

$$Na\% = \frac{(Na^{+} + K^{+})100}{Ca^{++} + Mg^{++} + Na^{+} + K^{+}}$$

The concentrations of cations are in meq/l. In pre-monsoon the sodium percentage (Na%) in the study area ranges from 10.29% to 58.16%. In monsoon the value ranges from 11.03% to 69.23%. In post-monsoon, it ranges between 11.06 % to 79.78%. Plot of analytical data on Wilcox diagram (Wilcox, 1967) relating electrical conductivity and sodium percentage shows different water classes for irrigation and are reflected in the Table 5. Excellent to good and good to permissible water can be used for irrigation purpose. The highest percentage of sodium is found in the dug well water sample of Bouda. The minimum value of Na% is located in the tube well water sample of Talabasta.

Doneen'sPermeability Index (PI)

The permeability index (PI) is obtained by considering the ions (epm) which influence permeability of soil (Domenico and Schwartz, 1990). Permeability Index is defined as,

$$PI = \frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na} * 100$$

The concentration of cations and anions are in epm. According to Doneen's chart (Domenico and

Table 4. Quality of water based on SAR value

Water classes for irrigation	SAR value	Out of 75 water samples		
		Pre-monsoon	Monsoon	Post-monsoon
Excellent	Up to 10	58	56	64
Good	10-18	14	16	11
Medium	18-26	3	3	Nil
Bad	>26	Nil	Nil	Nil

Table 5. Quality of water based on Na%

Water class for irrigation	Na%	Out of 75 water samples		
		Pre-monsoon	Monsoon	Post-Monsoon
Excellent	Up to 20	18	36	32
Excellent to Good	20-40	35	16	19
Permissible	40-60	14	20	19
Permissible to Doubt full	60-80	8	3	5

Schwartz, 1990). Most of the groundwater samples of the study area fall in class-I and class-II of Doneen's chart (Table 6). It is inferred on the basis of the permeability index that the ground water of the study area is of good quality for irrigation purposes. The groundwater samples under class –I was due to dilution and subsequent lower values of permeability index. And the increased percentage of groundwater samples in class-II indicated the higher concentration of sodium in the respective.

Potential soil Salinity (PS)

The potential soil salinity (PS) is given by the concentration of chloride and half of the sulphate ions,

Table 6. Water class based on permeability index

Water classes	Out of 75 water samples		
	Pre-monsoon	Monsoon	Post-monsoon
Class I	26	27	25
Class II	47	45	45
Class III	2	3	5

$$PS = Cl(epm) + \frac{1}{2} * SO_4(epm)$$

The potential soil salinity (PS) of groundwater varies from 0.023 epm to 3.367 epm in pre-monsoon, 0.2134 epm to 2.8675 epm in monsoon and from 0.3245 epm to 2.8698 epm in post-monsoon period. From the PS classification (Table 7), it is cleared that all the water samples fall under excellent to good soil potential.

Magnesiumratio

Generally, calcium and magnesium maintain a state of equilibrium in water. More Mg^{2+} present in water will adversely affect the soil quality converting it to alkaline and decreases crop yields.

The magnesium ratio can be expressed as

$$MR = \frac{Mg*100}{Ca+Mg}$$ (All ions are expressed in epm)

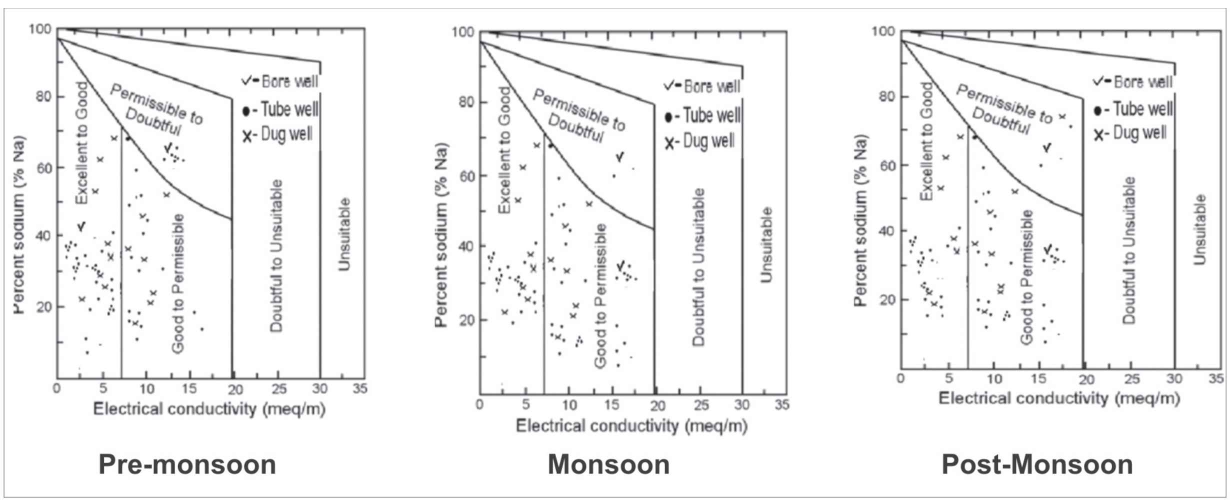


Fig. 3. Wilcox diagram for Classification of Groundwater based on EC and Na%

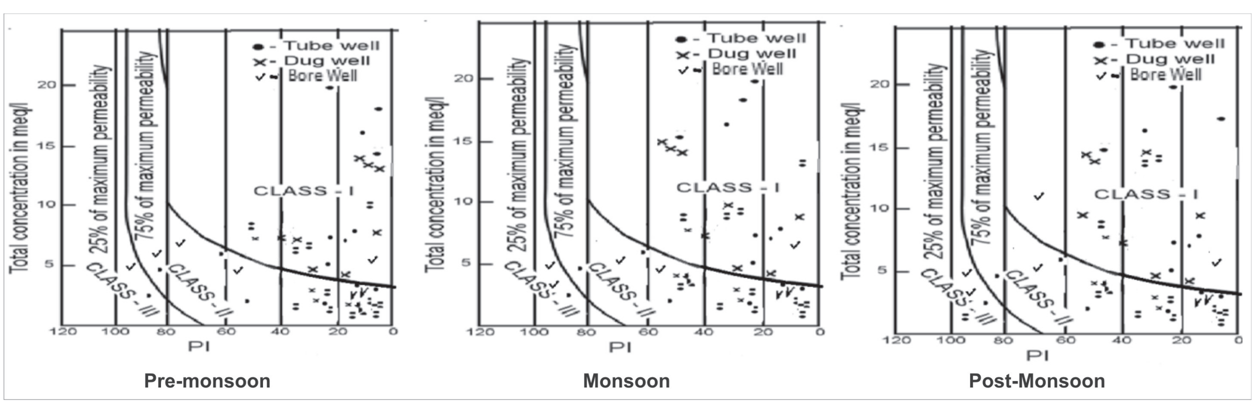


Fig. 4. Plotting of Permeability Index diagram (Doneen, 1962)

Table 7. Potential soil salinity (PS) classification of the study area

P. S	Class	Out of 75 water samples		
		Pre-monsoon	Monsoon	Post-monsoon
<5	Excellent to Good	75	75	75
5-10	Good to Injurious	Nil	Nil	Nil
>10	Injurious to Satisfactory	Nil	Nil	Nil

The magnesium ratio of groundwater varies from 15.97 epm to 77.38 epm in pre-monsoon and 17.04 epm to 72.94 epm in monsoon and from 4.76 epm to 55.65 epm in post-monsoon. Maximum value is marked in the sample location of Ostia. Except four locations, the magnesium ratio in almost all the investigated areas of pre-monsoon, monsoon and post-monsoon period is below 50, which depicts that the water can be used for agriculture purpose.

Corrosivity ratio (CR)

The corrosivity ratio is the susceptibility of groundwater to corrosion. It is expressed as ratio of alkaline earths to saline salts in groundwater. The corrosivity ratio is defined by the formula,

$$CR = \frac{\frac{Cl}{35.5} + \frac{2*(SO_4)}{96}}{\frac{2*(HCO_3+CO_3)}{100}}$$

Where all the ions are expressed in ppm of groundwater. The effect of corrosion is less dependent on hydraulic capacity of pipes. During pre-monsoon 5 samples having CR more than 1 and in monsoon and post-monsoon 3 and 2 samples have CR more than 1 respectively. Most of the area is found to be in the safe zone, except southwestern parts where a few isolated patches are marked in the unsafe zone in both the seasons. Water samples having corrosivity ratio below 1, signifies, all the water samples are safe for industrial use. Aravindan *et al.* (2004); Das *et al.,* (2012, 2013). In the area, where groundwater has Corrosivity Ratio (CR) more than 1, Polyvinyl Chloride (PVC) pipes should be used.

Litho Hydrological Relationship (Gibb's Diagram)

Based on aquifer lithology, the mechanism controlling chemical relationship of groundwater had been studied by Gibb's diagram. Three kinds of fields are recognized namely, precipitation dominance, evaporation dominance and rock-water dominance. Two diagrams are made,one on the basis of the Gibb's ratio plotted for anion $Cl^-/(Cl^-+HCO^{2-}_3)$ against relative values of Total dissolved solids (TDS). And the other made on the basis of the ratio of anion $(Na^++K^+)/(Na^++K^++Ca^{2+})$ of the water sample plotted against relative value of total dissolved solids. Gibb's Diagram for Cations shows 45, 43 and 40 water samples are pointed towards the field of rock dominance during pre-monsoon, monsoon and post-monsoon respectively, which reflects the influence of the chemistry of aquifer lithology vis-à-vis groundwater. Rests of the samples are in the field of precipitation dominance. The Gibb's Diagram for anion, shows 67, 43 and 66 water samples are pointed towards the field of rock dominance and the rest are in the field of precipitation dominance and evaporation dominance during pre-monsoon, monsoon and post-monsoon respectively (Table 8).

Hence from both the diagrams of Gibb (Fig. 5), it can be established that the groundwater of the study area is mainly dominated by the lithology of aquifer of the concerned region.

Conclusion

This research aims at assessment of potential irrigation water quality impairment that may affect suitability for cropping system and industrial use. Seasonal baseline data are important for setting guidelines for water quality standards and for establishing an aquatic management. The most influential water quality on crop productivity is water salinity haz-

Table 8. Quality of Water According to Gibb's Diagram (Gibbs, 1970)

	Pre-monsoon		Monsoon		Post-monsoon	
	Cation	Anion	Cation	Anion	Cation	Anion
Rock dominance	60%	90%	57.7%	57.3%	56%	89%
Precipitation dominance	33.4%	6.6%	32%	30.6%	33.4%	6.6%
Evaporation crystallisation dominance	6.6%	4%	4%	4%	2.6%	4%

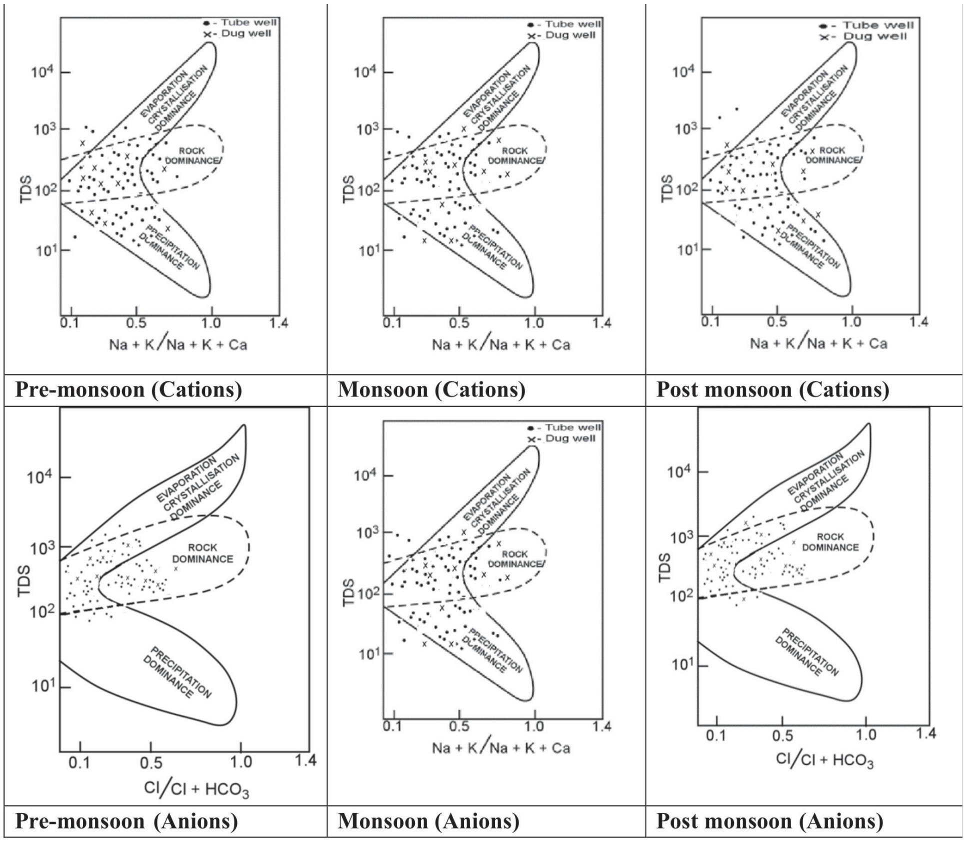


Fig. 5. Gibb's Diagram (Cations and Anions)

ard, measured by electrical conductivity (EC) and Total dissolve solid (TDS). The SAR assesses the potential for infiltration problems due to sodium imbalance in irrigation water.From US salinity diagram it is evident that most of the water samples fall under excellent category for agricultural practice excluding a few. The aim of this research work is to analyse the quality of irrigation water available to farmers and other irrigators of the study area and to interpret the physico chemical parameters to demonstrate the suitability for irrigation and industrial purpose. Also, to establish the litho hydrological character of the study area by plotting the anions and cations ratio against total dissolve solids (Gibb's diagram). Hence from both the diagrams of Gibb, it can be established that the groundwater of the study area is mainly dominated by the lithology of aquifer of the concerned region. From Doneen's permeability index diagram, it is evident that most of the groundwater falls under class-I and could be treated as good for agricultural purpose. The Wilcox classification shows most of the samples come under good to permissible zone. From the PS classification, it is cleared that all the water samples fall under excellent to good soil potential. Except four locations, the magnesium ratio in almost all the investigated areas of pre-monsoon, monsoon and post-monsoon period is below 50, which depicts that the water can be used for agriculture purpose. Maximum value is marked in the sample location of Ostia. From corrosivity ratio it is evident that most of the area are in the safe zone, except southwestern parts where a few isolated patches are marked in the unsafe zone in both the seasons. Water samples show corrosivity ratio below 1, signifies safe for industrial use. Various classifications show that present status of groundwater is suitable for irrigation purpose, except few locations, with a caution that it may deteriorate in near future.

References

Alagbe, S.A. 2006. Preliminary evaluation of hydrochemistry of the Kalambaina Formation, Sokoto Basin, Nigeria. *J. of Environmental Geology*. 51: 39-45.

Anbazhagan, S. and Nair, A.M. 2004. Geographical Information system and groundwater quality mapping in panvelbain, Maharatra, India. *Environ. Geol.* 45 : 753-761.

APHA, 2005. *Standard Methods for the Examination of the Water and Wastewater*. APHA (American Public Health Association), AWWA, WPCF, 21st edition, 1134 p.

Aravindan, S. 2004. Groundwater quality in the hard rock area of the Gadilam River Basin, Tamilnadu. *Geol. Soc. India.* 63 : 625-635.

Ayers, R.S. 1977. Quality of Water for Irrigation. *J. Irrigation and Drainage Div., ASCE*. 103 (IR2) : 135-154.

Christiansen, J.E., Olsen, E.C. and Willardson, L.S. 1977. Irrigation Water Quality Evaluation. *J. Irrigation and Drainage Div., ASCE.* 103 (IR2) : 155-169.

Das, R., Das, M. and Goswami, S. 2012. Groundwater quality assessment around Talabasta area, Banki Sub-Division, Odisha, India. *International Journal of Earth Sciences and Engineering.* 5 (6) : 1609-1618.

Das, R., Das, M. and Goswami, S. 2013. Groundwater quality assessment for irrigation uses of Banki Subdivision, Athgarh Basin, Odisha, India. *Journal of Applied Geochemistry.* 15 (1) : 88-97.

Das, R., Das, M. and Goswami, S. 2016. Groundwater quality Assesment for drinking and industrial purpose of Rourkela, Sundergarh District, Odisha, India. *International Tournal of Earth Science and Engineering*. (6) : 314-321.

Das, R. 2011. Hydrogeochemistry of Banki Sudivision, Cuttack district Orissa. *The Bioscan*, pp-35-428.

Das, R. 2015. Hydrochemistry and groundwater quality assessment for driking and industrial purpose in and around Rayagada Town, Odisha, India. *Asian Journal of Water Environment and Pollution.* (12) (4) : 35-42.

Domenico, P.A. and Schwartz, F.W. 1990. *Physical and Chemical Hydrogeology*. John Wiley and Sons, New York. pp. 410-420.

Doneen, L.D. 1962. The influence of crop and soil on percolating water. *Proc. 11961 Biennial Conference on Groundwater Recharge*, pp. 156-163.

Gibbs, R.J. 1970. Mechanism controlling world water chemistry. *Science*. 170 : 1088-1090.

Hem, J.D. 1991. Study and interpretation of the chemical characteristics of natural waters. U.S. Geological Survey Professional Paper 2254, 3rd ed. Scientific Publishers, Jodhpur, 263p.

Kaila, K.L. 1987. Crustal structure and delineation of Gondwana basin in the Mahanadi delta area, India from deep seismic soundings. *J. Geol. Soc. India*. 29 (3) : 201-308.

Richards, L.A. 1954. Diagnosis and improvement of saline and alkaline soils U.S. U.S. Salinity Laboratory (USSL), U.S. Deptt. Agri. Hand Book, Washington D.C., Vol. 60, : 1-160.

Wilcox, L.V. 1948. The Quality of water for irrigation, Use U.S. Dept. of Agriculture, Tech, Bull, 1962, Washington, D.C., 19p.

Wilcox, L.V. 1967. Classification and use of irrigation water. USDA circ.969, Washington D.C., 19p.