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Journal of Advanced Studies in Agricultural, Biological and Environmental Sciences (JABE) www.jabe.in

A Peer Reviewed & Refereed, International Open Access Journal

Vol.4.Issue.4.2017 (Oct-Dec) **ISSN:2455-0221(P), 2394-2606(O)**

AN ASSESSMENT OF GROUNDWATER QUALITY AT TETULIA UPAZILA UNDRE PANCHAGARH DISTRICT FOR CROP PRODUCTION

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ABSTRACT

An investigation was carried out to assess the quality of ground water collected from TetuliaUpazila of Panchagarh District of Bangladesh. To study the various physicochemical andmicrobiological parameters groundwater samples from TetuliaUpazila, smaller administrative unit of Bangladesh, were collectedand analyzed. The statistical methods of sampling were used for collecting samples. The collected samples were analyzed for thefollowing parameters: pH, electrical conductivity (EC), total dissolved solids (TDS), transparency, acidity, dissolvedcarbon dioxide, total alkalinity, total hardness, chloride, ammonia-N, hydrogen sulfide, sulphate-S,o-phosphate-P, biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate-N, iron, manganese, copper, calcium, magnesium, sodium,potassium,Sodium adsorption ratio(SAR), Soluble sodium percentage (SSP), Residual sodium carbonate (RSC), permeability index (PI), Kelly's ratio, potentialsalinity, Gibbs ratio and Total hardness($_H$T) using the procedure outlined in the standardmethods. The pH values indicated that the waters were mostly acidic in nature. Among the chemical budget of ions, magnesium and chloride were found to be the most predominant ions. The average amount of Ca, Na, K and HCO_3 were safe for crop production. The mean values of TDS and SAR indicated the excellent category for irrigation. Based on SSP all waters were excellent classes. In respect to hardness, water had moderately hard to very hard class. Based on the total hardness, most ground waters were moderately hard. All waters were free from RSC and belong to the suitable category. Most of the major ionic constituents were detected below the acceptable level for drinking and Fe, Zn, Mn, Cu and Cl were within the safe limit for irrigating agricultural crops. Iron and Manganese exceeded the drinking standard in some waters.

Keywords: Physicochemical assessment, Groundwater resources, Water quality, Electrical conductivity, Sodium adsorption ratio(SAR).

1. INTRODUCTION

Water is the most vital element among the natural resources, and is crucial for the survival of all living organisms. The environment, economic growth and development of Bangladesh are all highly influenced by water - its regional and seasonal availability, and the quality of surface and groundwater. Spacitial and seasonal availability of surface and groundwater is highly responsive to the monsoon climate and physiographic of the country. Unfortunately about 3.4 million people die each year from different illnesses such as cholera, dysentery, and malaria associated with contaminated water. Although access to safe drinking

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water is a fundamental human right and providing such a facility is also an important national goal in Bangladesh like other developing countries, ironically many populations in both urban and rural areas of Bangladesh have been facing difficulties in getting such quality water Water-borne diseases namely diarrhoea and cholera are still the major killers of infant and child mortality in this populous nation consisting of approximately 145 million populations living in 145,000 square kilometers only. Until around the 1970s, people of Bangladesh used to use surface water for drinking and cooking purposes. As that water was highly polluted by many sources including micro-organisms, both infant and child mortality was very high, mostly attributed to water-borne diseases such as diarrhea, cholera, and dysentery. Water abstraction from groundwater and surface water for agricultural production, mining, industrial production, power generation, and forestry practices can lead to deterioration in water quality and quantity that impact not only the aquatic ecosystem but also the availability of safe water for human consumption. Water quality would be determined by the weathering of bedrock minerals, by the atmospheric processes of evapo-transpiration and the deposition of dust and salt by wind, by the natural leaching of organic matter and nutrients from soil, by hydrological factors that lead to runoff, and by biological processes within the aquatic environment that can alter the physical and chemical composition of water. Global average concentrations of the four major cations (calcium, magnesium, sodium, and potassium) and the four major anions (bicarbonate, carbonate, sulphate, and chloride) in surface water tend to approach patterns in which calcium concentrations dominate the cations and bicarbonate and/or carbonate concentrations dominate the anions.In Bangladesh, there is a common expression "paniropornamjibon", which means water is life. All across Asia as well as the rest of the globe, clean water is necessary for human health and livelihood as well as being interwoven into many cultures. Today, water quality is a critical issue for many Asian countries, with a rise in water demand paralleled with a decrease in the amount of usable water, due to degraded water quality. Sound management requires clear and timely information on water quantity and quality, information which now is severely lacking across the Asian region. Irrigated agriculture is dependent on adequate water supply of usable quality. Water quality concerns have often been neglected because good quality water supplies have been plentiful and readily available. For irrigation, the quality of water determines if optimum returns from the soil can be obtained as the quality affects soil, crop and water management. In most irrigation situations, the primary water quality concern is salinity levels, since salts can affect both the soil structure and crop yield. Surface water contributes the major share of irrigation coverage. Low lift pumps of various capacities are used to utilize surface water. Groundwater replenishes surface source during dry period since the underground flow directions are towards rivers, as indicated by different studies. The generally accepted view is that in most parts of Bangladesh, the present levels of surface water abstraction for irrigation during dry season are very close to the accepted maximum limits. Irrigated agriculture in Bangladesh has already started showing problems regarding water quality and fertilization. Groundwater resources support urban and rural communities in Bangladesh. As industrial and agricultural development of Bangladesh increases, the demand for water also steadily grows. In some parts of the country, the current rate of groundwater extraction is depleting the resource faster than it is being recharged. In contrast, suitability of groundwater for drinking, irrigation and industrial purposes depends upon its quality. The utilization of water from groundwater sources atTetuliaUpazillain the District of Panchagarh, Bangladesh is gradually increasing for irrigation, domestic and industrial purposes.

2. MATERIALS AND METHODS

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2.1 Location

Panchagarh is situated in the extreme northern part of Bangladesh with an area of 1404.62 square km(542.00 sq.miles), is bounded on three sides by 288 kmlong Indian border, having Darjeeling district on the north, Jalpaiguri and Cooch Behar district on the northeast , west Dinajpur district and Purnea district on the west. Dinajpur and the Thakurgaon districts on the south, Nilphamari district on the east.Its soil is sandy, alluvial and bears close affinity with the soil of the old Himalayan basin.It is 150 feet (46 m)high from the sea level.Panchagarh has 16 rivers.Among them some main rivers areKaratoya, Atrai, Tista, Mahananda, Tangon, Dahuk, Pathraj, Bhulli, Talma, Nagar, Chawai, Kurum, Versa, Tirnoi, Chilka.

2.2 Chemical analysis

The collected surface water samples were analyzed for pH, electrical conductivity, total dissolved solids, the cations, such as nitrogen, calcium, magnesium, potassium, sodium; the anions, viz., carbonate, bicarbonate, chloride, sulphate, phosphate and borate according to the standard methods and techniques (Jackson, 1967). The water quality determining indices, such as Sodium Adsorption Ratio (SAR), Residual Sodium Bicarbonate (RSBC), Soluble Sodium Percentage (SSP), etc. were calculated by using the following recommended relationships.

Sodium Adsorption Ration (SAR)

$$SAR = \frac{\text{Na}+}{\sqrt{\dfrac{\text{Ca}^{2+}+\text{Mg}^{2+}}{2}}} \text{..........} \text{..........} (1)$$

Soluble Sodium Percentage (SSP) was calculated by the following equation (Todd, 1980):

$$\text{SSP} = \frac{\text{Soluble Na concentration (meq/L)}}{\text{Total cation concentration (meq/L)}} \times 100 \text{..........} \text{........}(2)$$

The Residual Sodium Bi-carbonate (RSBC) was calculated according to Gupta and Gupta (1987):

RSBC= HCO_3-Ca^{+2}

The Permeability Index (PI) was calculated according to Doneen (1962) by the following equation:

$$PI = \frac{(Na+\sqrt{HCO3})}{\text{Ca}+Mg+Na} x100 \text{...........} 3$$

Total Hardness (TH) was calculated by the following equation (Raghunath, 1987):

TH= (Ca^{+2}+Mg^{+2})x50.................4

The Kelly's Ratio was calculated using the equation (Kelly's 1963 as:

$$KR=\frac{Na}{Ca+Mg} \text{......................} 5$$

Where, all the ionic concentrations are expressed in milli-equivalents per litre (meq/L). Although all these indices were evaluated in this study, the SAR is probably the only one in current use and is generally considered an effective evaluation index for most water used in irrigated agriculture (Ayers and Westcot, 1985).

3. RESULTS AND DISCUSSION

The average temperature of the water samples of the study area was approximately 18.9^{o}C. The chemical compositions of the collected ground water samples are presented in Table 1. The results of the water quality parameters are discussed below:

Table 1. Chemical composition of ground water samples in the study area

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					Cation contents								Anion contents			
	pH	EC	TDS	Hardness	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cu^{2+}	Fe^{2+}	Mn^{2+}	Zn^{2+}	Cl^-	HCO_3^-	SO_4^{2-}	PO_4^{3-}
Sample ID	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		(μScm^{-1})	(mg L^{-1})	(mgL^{-1})	($meqL^{-1}$)	($meqL^{-1}$)	($meqL^{-1}$)	($meqL^{-1}$)	mg L^{-1})	mg L^{-1})	mg L^{-1})	mg L^{-1})	($meqL^{-1}$)	($meqL^{-1}$)	($meqL^{-1}$)	($meqL^{-1}$)
1	6.9	122	55	65	0.13	0.06	0.48	0.84	0.01	0.01	0	0.004	0.02	0.01	0.16	0.0008
2	7	112	62	66	0.13	0.06	0.52	0.81	0.03	0.01	0.004	0.002	0.04	0.04	0.11	0.001
3	6.5	175	79	82	0.09	0.06	0.88	0.77	0.02	0.01	0.004	0.003	0.03	0.05	0.01	0.0003
4	6.4	89	51	60	0.13	0.1	0.4	0.81	0.01	0.01	0.006	0.002	0.02	0.02	0.07	0.0005
5	6.8	91	42	58	0.09	0.1	0.4	0.77	0.01	0.09	0.007	0.003	0.04	0.06	0.02	0.0014
6	6.1	92	45	66	0.09	0.06	0.44	0.89	0.02	0.01	0.008	0.003	0.03	0.05	0.01	0.0012
7	6.4	149	67	79	0.17	0.06	0.72	0.87	0.04	0.01	0.008	0.002	0.04	0.02	0.24	0.0003
8	6.8	129	50	96	0.13	0.13	0.8	1.13	0.04	0.01	0.009	0.003	0.03	0.05	0.02	0.0002
9	6.3	177	80	112	0.13	0.22	1	1.26	0.02	0.01	0.008	0	0.04	0.01	0.15	0.0002
10	6.8	168	75	98	0.09	0.1	0.76	1.22	0.03	0.01	0.009	0	0.03	0.02	0.12	0.0002
11	6.9	122	55	64	0.17	0.06	0.48	0.81	0.02	0.01	0.008	0.003	0.01	0.02	0.09	0.0004
12	7.1	125	64	64	0.13	0.1	0.52	0.77	0.01	0.06	0.009	0.003	0.03	0.01	0.07	0.0012
13	7.2	122	55	66	0.13	0.06	0.52	0.81	0.03	0.01	0.01	0.003	0.03	0.01	0.18	0.0014
14	6.7	120	53	54	0.13	0.06	0.4	0.69	0.02	0.01	0.01	0.003	0.04	0.01	0.14	0.0003
15	6.5	76	34	48	0.13	0.06	0.36	0.61	0.03	0.01	0.01	0.003	0.03	0.02	0.11	0.0007
16	6.3	90	39	60	0.13	0.06	0.44	0.77	0.03	0.01	0.01	0.002	0.04	0.02	0.12	0.0007
17	6.2	121	54	62	0.13	0.06	0.44	0.81	0.02	0.11	0.01	0.002	0.03	0.02	0.12	0.0009
18	6.4	115	60	60	0.13	0.1	0.4	0.81	0.02	0	0.01	0.004	0.01	0.02	0.11	0.0025
19	6.7	120	54	62	0.09	0.06	0.48	0.77	0.02	0.01	0.01	0.003	0.03	0.02	0.1	0.002
20	6.8	128	55	60	0.17	0.06	0.52	0.69	0.02	0	0.01	0.002	0.03	0.01	0.08	0.0003
21	6.5	101	45	24	0.17	0.06	0.44	0.04	0.07	0.01	0.013	0.002	0.03	0.02	0.25	0.0005
22	6.6	100	61	36	0.13	0.06	0.36	0.37	0.01	0.15	0.006	0.004	0.02	0.01	0.18	0.0021
23	6.9	102	46	56	0.13	0.06	0.44	0.69	0.01	0.01	0.006	0.007	0.06	0.01	0.18	0.0019
24	5.9	107	55	58	0.09	0.13	0.44	0.73	0.03	0.01	0.007	0.005	0.02	0.01	0.17	0.001
25	6.4	101	45	58	0.09	0.06	0.4	0.77	0.02	0.01	0.007	0.005	0.02	0.01	0.13	0.0009
26	6.8	100	50	58	0.09	0.06	0.44	0.73	0.12	0.01	0.009	0.001	0.03	0.01	0.11	0.001
27	5.4	100	45	54	0.13	0.06	0.48	0.69	0.03	0.01	0.007	0.004	0.02	0.01	0.12	0.0013
28	6.5	99	63	52	0.13	0.06	0.52	0.65	0.01	0.02	0.01	0.004	0.05	0.01	0.1	0.0013
29	6.7	101	45	54	0.09	0.06	0.88	0.69	0.04	0.01	0.006	0.005	0.05	0.02	0.17	0.0016
30	6.9	90	49	54	0.13	0.1	0.36	0.73	0.09	0.01	0.01	0.005	0.03	0.02	0.15	0.0036
31	6.5	101	45	56	0.09	0.06	0.4	0.69	0.02	0.01	0.01	0.005	0.02	0.01	0.01	0.0017
32	6.2	127	48	58	0.13	0.06	0.44	0.69	0.03	0.01	0.01	0.005	0.03	0.01	0.02	0.0037
33	5.1	102	46	60	0.09	0.06	0.44	0.73	0.01	0.01	0.01	0.004	0.03	0.01	0.02	0.0026
34	6.9	100	49	62	0.17	0.06	0.4	0.81	0.02	0.02	0.01	0.005	0.02	0.01	0.03	0.0007
35	5.2	107	48	66	0.13	0.06	0.48	0.77	0.02	0.01	0.01	0.001	0.03	0.02	0.15	0.002
36	6.8	101	51	56	0.13	0.06	0.6	0.73	0.02	0.02	0	0.005	0.04	0.02	0.16	0.0013
37	6.5	101	46	56	0.13	0.1	0.44	0.69	0.02	0.01	0.01	0.005	0.03	0.02	0.12	0.0016
38	6.3	100	50	62	0.13	0.13	0.44	0.69	0.03	0.01	0.01	0.003	0.03	0.01	0.1	0.0028
39	6.2	110	49	72	0.13	0.06	0.48	0.77	0.04	0.01	0.01	0.006	0.03	0.01	0.14	0.0023
40	6.5	112	61	108	0.17	0.06	0.52	0.93	0.03	0.01	0.01	0.004	0.02	0.01	0.14	0.0007
41	5.6	160	73	76	0.09	0.06	0.96	1.22	0.01	0.01	0.01	0.004	0.06	0.04	0.13	0.0027
42	6.5	154	52	64	0.13	0.06	0.68	0.85	0.02	0.01	0.01	0.005	0.02	0.04	0.06	0.0005
43	6.9	122	55	64	0.09	0.03	0.52	0.77	0.02	0.02	0.01	0.002	0.02	0.02	0.07	0.0002
44	6.3	138	59	68	0.13	0.06	0.48	0.81	0.02	0.02	0.01	0.004	0.03	0.01	0.09	0.0003
45	6.7	120	54	62	0.13	0.16	0.52	0.85	0.01	0.03	0.01	0.005	0.04	0.01	0.16	0.0003
46	6.3	119	54	60	0.13	0.06	0.44	0.81	0.06	0.02	0.01	0.001	0.03	0.01	0.17	0.0007
47	6.3	120	54	74	0.17	0.06	0.44	0.77	0.06	0.02	0.01	0.005	0.01	0.01	0.01	0.0007
48	6.8	100	55	64	0.17	0.1	0.64	0.85	0.02	0.01	0	0.005	0.03	0.02	0.01	0.0009
49	6.7	121	55	72	0.17	0.1	0.48	0.81	0.02	0.02	0.01	0.006	0.03	0.01	0.02	0.0013
50	6.2	100	54	66	0.17	0.06	0.52	0.93	0.02	0.01	0.01	0.004	0.03	0.01	0.16	0.0015
51	6.9	120	54	68	0.13	0.06	0.52	0.81	0.02	0.01	0.01	0.003	0.03	0.01	0.11	0.0002
52	7.2	102	54	64	0.13	0.06	0.56	0.81	0.01	0.01	0.01	0.005	0.02	0.01	0.11	0.001
53	6.4	120	54	88	0.17	0.13	0.48	0.81	0.02	0.01	0.01	0.006	0.06	0.01	0.12	0.0002
54	5.9	121	44	64	0.13	0.1	0.92	0.85	0.02	0.01	0.01	0.006	0.02	0.02	0.01	0.0005
55	6.1	122	54	88	0.13	0.06	0.48	0.81	0.02	0.04	0	0.002	0.02	0.01	0.06	0.0006
56	6.8	112	49	86	0.13	0.06	0.84	0.93	0.03	0.02	0.01	0.004	0.03	0.01	0.15	0.0003
57	6.6	180	81	68	0.17	0.06	0.92	0.81	0.03	0.01	0.01	0.006	0.02	0.01	0.07	0.0002
58	6.7	158	39	70	0.13	0.06	0.44	0.93	0.03	0.01	0.01	0.002	0.03	0.02	0.05	0.0004
59	6.3	120	54	68	0.13	0.06	0.48	0.93	0.03	0.02	0.01	0.007	0.03	0.02	0.11	0.0001
60	7.1	122	46	56	0.17	0.16	0.52	0.85	0.01	0	0.02	0.004	0.03	0.01	0.12	0.001
Mean	6.5	117.2	53.5	65.4	0.13	0.006	0.52	0.79	0.026	0.017	0.008	0.003	0.029	0.018	0.103	0.001
Max	7.2	179.7	80.6	111.8	0.17	0.01	1	1.25	0.117	0.154	0.023	0.006	0.056	0.059	0.244	0.0036
Min	5.1	76.2	34.3	24	0.08	0.03	0.36	0.04	0.006	0.002	0	0.006	0.014	0.007	0.006	0.0001
CV%	6	19.5	18	22.1	22.1	39	30.6	217	71	145	38	71	33	62.7	56.5	80

Table 2: Acceptable range in drinking water

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Vol.4.Issue.4.2017 (Oct-Dec) ISSN:2455-0221(P), 2394-2606(O)

Parameter	Symbol	Unit	Standard	Remarks
pH	pH	-	6.5-8.5[a]	<6.5 and >8.5 not permissible
Phosphate	PO_4	mg/l	6[a]	>6 mg/l not permissible
Sulphate	SO_4	mg/l	400	>400 mg/l not permissible
Conductivity	-	µS/cm	500	>500 mg/l not permissible

Source: [a]Department of Environment, Bangladesh Government (1997); [b]World Health Organization(1971).

Table3: Irrigation water classification on the Basis of EC and SSP (Wilcox, 1955)

Water class	Percent sodium	Electrical conductance (EC), µS cm^{-1}
Excellent	<20	<250
Good	20-40	250-750
Permissible	40-60	750-2000
Doubtful	60-80	2000-3000
Unsuitable	>80	>3000

3.1 pH, EC, TDS

The range of the pH value of the ground water is 5.1 to 7.2 with the average value of 6.5, which are within the permissible limit (Table 2) for irrigated agriculture.[a]Department of Environment, Bangladesh Government (1997); [b]World Health Organization(1971). The Electrical Conductivity (EC) value of the ground water samples of the study area varied from 76.2 to 179.7 mS cm-1 with an average value of 117.2 mS cm-1, which are according to Wilcox, 1955 irrigation water quality classification 'excellent to good' for irrigation. The Total Dissolved Solids (TDS) value of ground water samples of the study area ranged from 34.3 to 80.6 mg L^{-1} with an average value of 53.5 mg L^{-1} .which are within the highest permissible limit (Table 9) according to (WHO, 1971).

Table4: Irrigation water classification based on SAR (Todd, 1980)

Water class	Sodium adsorption ratio (SAR)
Excellent	<10
Good	10-18
Fair	18-26
Poor	>26

Table5: Irrigation water classification based on RSBC (Eaton, 1950)

Suitability of the water	Residual sodium carbonate (RSBC), me L^{-1}
Suitable	<1.25
Marginal	1.25-2.50
Unsuitable	>2.50

Table 6: classification of irrigation water based on hardness (Sawyer and McCarty, 1967)

Water class	Hardness mg L^{-1}, as $CaCO_3$
Soft	0-75
Moderately hard	75-150
Hard	150-300
Very hard	>300

Table 7: Recommended maximum of trace elements in irrigation water

Elements	Symbol	For waters used continuously on all soils

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Vol.4.Issue.4.2017 (Oct-Dec) ISSN:2455-0221(P), 2394-2606(O)

Bicarbonate	HCO_3	1.50 me L^{-1}
Chloride	Cl	4.0 me L^{-1}
Copper	Cu	0.20 mg L^{-1}
Iron	Fe	5.00 mg L^{-1}
Manganese	Mn	0.20 mg L^{-1}
Phosphate-phosphorus	PO_4-P	0-2.0 mg L^{-1}
Potassium	K	0-2.0 mg L^{-1}
Sulphate	SO_4	0-20 mg L^{-1}

Source: Ayers, R.S. and Westcot, D.W. 1976. Water Quality for Agriculture, FAO Irrigation and Drainage Paper 29, p.81

Table 8. Quality classification of water samples for irrigation

						Water class based on					Alkalinity
Sl. No	EC	TDS	SAR	SSP	RSBC	EC	TDS	SAR	SSP	RSBC	Salinity class
1	122	55	0.16	8.5	-1.30	Ex	Fre	Ex	Ex	Suit	C1S1
2	112	62	0.16	8.3	-1.29	Ex	Fre	Ex	Ex	Suit	C1S1
3	175	79	0.11	7.1	-1.60	Ex	Fre	Ex	Ex	Suit	C1S1
4	89	51	0.16	8.9	-1.19	Ex	Fre	Ex	Ex	Suit	C1S1
5	91	42	0.11	8.9	-1.11	Ex	Fre	Ex	Ex	Suit	C1S1
6	92	45	0.11	8.5	-1.28	Ex	Fre	Ex	Ex	Suit	C1S1
7	149	67	0.21	6.9	-1.57	Ex	Fre	Ex	Ex	Suit	C1S1
8	129	50	0.16	5.8	-1.89	Ex	Fre	Ex	Ex	Suit	C1S1
9	177	80	0.16	4.9	-2.24	Ex	Fre	Ex	Ex	Suit	C1S1
10	168	75	0.11	5.9	-1.96	Ex	Fre	Ex	Ex	Suit	C1S1
11	122	55	0.21	8.3	-1.27	Ex	Fre	Ex	Ex	Suit	C1S1
12	125	64	0.16	8.1	-1.28	Ex	Fre	Ex	Ex	Suit	C1S1
13	122	55	0.16	8.3	-1.32	Ex	Fre	Ex	Ex	Suit	C1S1
14	120	53	0.16	9.8	-1.08	Ex	Fre	Ex	Ex	Suit	C1S1
15	76	34	0.16	10.7	-0.95	Ex	Fre	Ex	Ex	Suit	C1S1
16	90	39	0.16	9.0	-1.19	Ex	Fre	Ex	Ex	Suit	C1S1
17	121	54	0.16	8.2	-1.23	Ex	Fre	Ex	Ex	Suit	C1S1
18	115	60	0.16	8.8	-1.19	Ex	Fre	Ex	Ex	Suit	C1S1
19	120	54	0.11	9.1	-1.23	Ex	Fre	Ex	Ex	Suit	C1S1

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20	128	55	0.21	8.8	-1.20	Ex	Fre	Ex	Ex	Suit	C1S1
21	101	45	0.21	16.0	-0.46	Ex	Fre	Ex	Ex	Suit	C1S1
22	100	61	0.16	11.9	-0.71	Ex	Fre	Ex	Ex	Suit	C1S1
23	102	46	0.16	9.6	-1.12	Ex	Fre	Ex	Ex	Suit	C1S1
24	107	55	0.11	9.1	-1.16	Ex	Fre	Ex	Ex	Suit	C1S1
25	101	45	0.11	9.5	-1.16	Ex	Fre	Ex	Ex	Suit	C1S1

Table 8.(Contd.)

						Water class baed on					Alkalinity
Sl. No	EC	TDS	SAR	SSP	RSBC	EC	TDS	SAR	SSP	RSBC	Salinity class
26	100	50	0.11	9.7	-1.16	Ex	Fre	Ex	Ex	Suit	C1S1
27	100	45	0.16	10.1	-1.08	Ex	Fre	Ex	Ex	Suit	C1S1
28	99	63	0.16	10.0	-1.04	Ex	Fre	Ex	Ex	Suit	C1S1
29	101	45	0.11	9.1	-1.07	Ex	Fre	Ex	Ex	Suit	C1S1
30	90	49	0.16	10.1	-1.07	Ex	Fre	Ex	Ex	Suit	C1S1
31	101	45	0.11	9.4	-1.08	Ex	Fre	Ex	Ex	Suit	C1S1
32	127	48	0.16	9.7	-1.12	Ex	Fre	Ex	Ex	Suit	C1S1
33	102	46	0.11	8.7	-1.16	Ex	Fre	Ex	Ex	Suit	C1S1
34	100	49	0.21	8.8	-1.20	Ex	Fre	Ex	Ex	Suit	C1S1
35	107	48	0.16	8.3	-1.23	Ex	Fre	Ex	Ex	Suit	C2S1
36	101	51	0.16	9.3	-1.31	Ex	Fre	Ex	Ex	Suit	C1S1
37	101	46	0.16	9.0	-1.11	Ex	Fre	Ex	Ex	Suit	C1S1
38	100	50	0.16	8.7	-1.12	Ex	Fre	Ex	Ex	Suit	C1S1
39	110	49	0.16	7.5	-1.24	Ex	Fre	Ex	Ex	Suit	C1S1
40	112	61	0.21	5.5	-1.45	Ex	Fre	Ex	Ex	Suit	C1S1
41	160	73	0.11	7.3	-2.14	Ex	Fre	Ex	Ex	Suit	C1S1
42	154	52	0.16	8.9	-1.50	Ex	Fre	Ex	Ex	Suit	C1S1
43	122	55	0.11	8.5	-1.27	Ex	Fre	Ex	Ex	Suit	C1S1
44	138	59	0.16	7.6	-1.28	Ex	Fre	Ex	Ex	Suit	C1S1

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45	120	54	0.16	8.5	-1.36	Ex	Fre	Ex	Ex	Suit	C1S1
46	119	54	0.16	8.4	-1.24	Ex	Fre	Ex	Ex	Suit	C1S1
47	120	54	0.21	7.2	-1.20	Ex	Fre	Ex	Ex	Suit	C1S1
48	100	55	0.21	8.1	-1.48	Ex	Fre	Ex	Ex	Suit	C1S1
49	121	55	0.21	7.5	-1.28	Ex	Fre	Ex	Ex	Suit	C1S1
50	100	54	0.21	8.3	-1.44	Ex	Fre	Ex	Ex	Suit	C1S1

Table 8.(Contd.)

						Water class based on					Alkalinity
Sl. No	EC	TDS	SAR	SSP	RSBC	EC	TDS	SAR	SSP	RSBC	Salinity class
51	120	54	0.16	8.1	-1.32	Ex	Fre	Ex	Ex	Suit	C1S1
52	102	54	0.16	8.0	-1.36	Ex	Fre	Ex	Ex	Suit	C1S1
53	120	54	0.21	6.4	-1.28	Ex	Fre	Ex	Ex	Suit	C2S1
54	121	44	0.16	8.4	-1.76	Ex	Fre	Ex	Ex	Suit	C1S1
55	122	54	0.16	6.4	-1.28	Ex	Fre	Ex	Ex	Suit	C1S1
56	112	49	0.16	6.4	-1.76	Ex	Fre	Ex	Ex	Suit	C1S1
57	180	81	0.21	8.1	-1.72	Ex	Fre	Ex	Ex	Suit	C1S1
58	158	39	0.16	7.8	-1.35	Ex	Fre	Ex	Ex	Suit	C2S1
59	120	54	0.16	7.4	-1.40	Ex	Fre	Ex	Ex	Suit	C1S1
60	122	46	0.16	7.3	-1.36	Ex	Fre	Ex	Ex	Suit	C1S1

Notes: Fre=Fresh water, Ex=Excellent,Suit=Suitable

Table 9: Standards for chemical quality of drinking water (WHO, 1971)

Chemical	Highest desirable	Maximum permissible
pH	7.0-8.5	6.5-9.2
TDS (mg L^{-1})	500	1500
HT as $CaCO_3$ (mg L^{-1})	100	500
Calcium (mg L^{-1})	75	200
Magnesium (mg L^{-1})	<30 if SO_4 is 250 mg L^{-1}, Up to 150 mg L-1 if SO_4 is <250 mg L^{-1}	150
Iron (mg L^{-1})	0.05	1.5
Manganese (mg L^{-1})	0.1	1.0
Copper (mg L^{-1})	0.05	1.5
Zinc (mg L^{-1})	5.0	15.0

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Chloride (mg L^{-1})	200	600
Sulphate (mg L^{-1})	200	400

3.2 Cation content

The sodium (Na+) content of the ground water samples ranged from 0.08 to 0.17meq l-1 with an average value of 0.13meq l-1. The potassium (K+) content of the surface water samples ranged from 0.03 to 0.01meq l-1 with an average value of 0.006meq l-1 . The calcium (Ca2+) content of the study area ranges from 0.36 to 1.0meq l-1 with an average value of 0.52meq l-1. The magnesium (Mg2+) content ranges from 0.04to 1.25meq l-1 with an average value of 0.79meq l-1. It is evident that all the values of Mg2+ in the ground water of the study area are much lower than the recommended limits(Table 7) (Ayers, R.S. and Westcot, D.W. 1976) and can be used without restrictions.

3.3 Anionic content

The bicarbonate (HCO^{3-}) content of the surface water samples ranged from 0.007 to 0.059meqL^{-1} with an average value of 0.018meqL^{-1}. The chloride (Cl^-) content of the surface water samples ranged from 0.014 to 0.056meq$L^{-1}$with an average value of 0.029meqL^{-1}. The range of Cl^- content of the irrigation water sample was far below (Table 7) the recommended limits (Ayers, R.S. and Westcot, D.W. 1976. The sulfate ($SO4^{2-}$) content of the groundwater samples ranged from 0.006 to 0.0244 mg $L^{-1}$with an average value of 0.103 mg L^{-1}. Although the $SO4^{2-}$ concentrations in the study area vary considerably, all the $SO4^{2-}$ values fall within acceptable limits (Ayers, R.S. and Westcot, D.W. 1976). The phosphate ($PO4^{3-}$) content ranges from 0.0001 to 0.0036 mg $L^{-1}$with an average value of 0.001 mg L^{-1}. The values obtained from all the water samples of surface waterfall were within acceptable limits (Ayers, R.S. and Westcot, D.W. 1976).

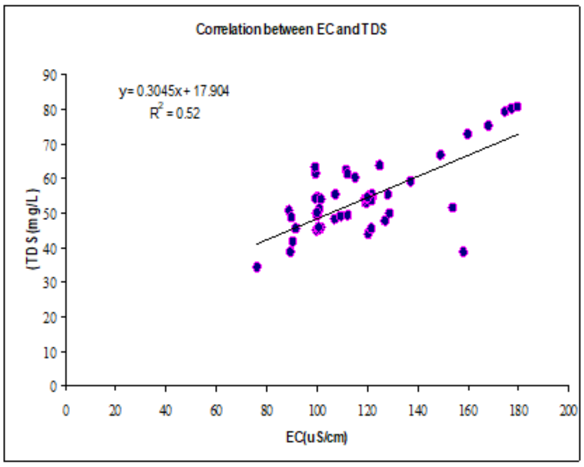

Fig. 1. Relationship between EC and TDS

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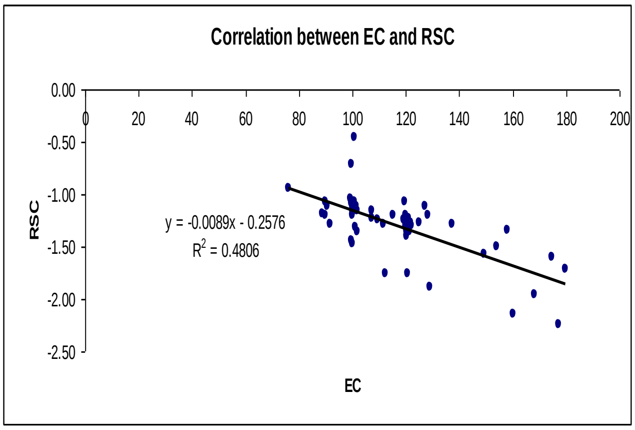

Fig. 2. Relationship between EC and RSC

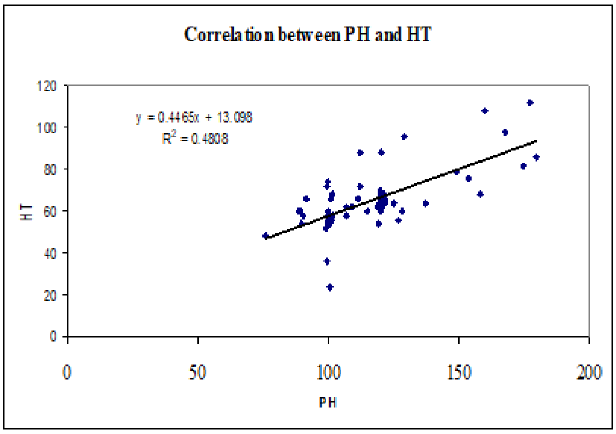

Fig. 3. Relationship between P^H and H_T

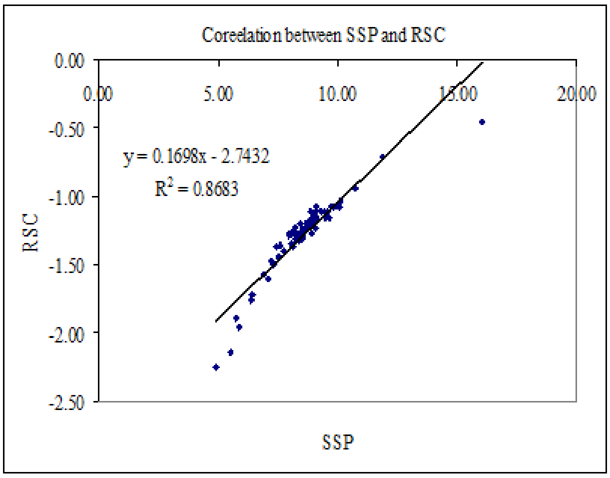

Fig. 4. Relationship between SSP and RSC

4. Quality determining indicates for irrigation water

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4.1. Sodium adsorption ratio (SAR)

The computed sodium adsorption ratio (SAR) of groundwater samples were within the range of 0.10 to 0.21 with the mean value of 0.16 and the standard deviation was 0.36 (Table 8).Considering this classification, all the ground waters were 'excellent' for irrigation (Table 4). The irrigation water with SAR less than 10.00 might not be toxic for agricultural crop (Todd, 1980)

4.2. Soluble sodium percentage (SSP)

The calculated SSP values of all water samples were varied from 4.9 to 16.0 with the mean value of 8.4 and the standard deviation was 1.6 (Table 4). Wilcox (1955) categorized the water as 'excellent' (SSP = <20), 'good' (SSP = 20-40), 'permissible' (SSP = 40-60), 'doubtful' (SSP = 60-80) and 'unsuitable' (SSP = >80).(Table 3).

4.3. Residual sodium Bi-carbonate (RSBC)

The calculated RSBC values of all water samples were varied from -2.24 to -0.46 with the mean value of -1.28 and the standard deviation was 0.33 (Table 8). Among samples, all samples were in 'suitable' grade following the categorized by Eaton (1950)

4.5. Total hardness (H_T)

The calculated H_T values of all water samples varied from 24 to 111.89 mg L^{-1} with the mean value of 65.41 mg L^{-1} and the standard deviation was 14.7 (Table 1).). Sawyer and McCarty (1967) suggested a classification for irrigation water based on hardness. Waters were classified as 'hard' (H_T = 150-300 mg L^{-1} as $CaCO_3$) for winter season and were 'moderately hard' (H_T = 75-150 mg L^{-1}) class for monsoon season. Out of 60 samples, 50 samples were in 'soft', 10 samples were in 'moderately hard' classes.

6. Correlation between quality factors and major ionic constituents of groundwater

The relationship of water quality factors in computed regression line recorded among the pH-EC, pH-SAR, pH-SSP, pH-RSC, EC-SAR, EC-SSP, EC-RSC, SAR-SSP, SAR-RSC and SSP-RSC demonstrated the positive relation (Fig.1-Fig.4).

7. CONCLUSION

From the study results and discussions it may be concluded that the ground water in the study area has no salinity or toxicity problem. On the basis of SAR, SSP and RSC values, no infiltration problem exists in the selected locations and water management in the area can be done with a desirable limit of SAR. Finally, the ground water of the study area is suitable or almost excellent for being used for irrigation and this quality investigation may be a useful guide to the quality of water in that area.All most all water samples were found suitable for drinking and industrial purposes. All the waters under test may be recommended for irrigation all types of agricultural crop in the study area. The present investigation indicated that the analysis of groundwater is important for proper understanding of the irrigation and drinking water quality and its impact on crop production and human health. It is suggested that irrigation water should be analyse systematically for understanding the impact of irrigation water towards the healthy crops in the entire irrigated area of the country.

It is concluded that some acid loving crops can be grown successfully in the study area.

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