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ASSESSMENT OF GROUNDWATER QUALITY IN THE SOUTH 24-PARGANAS, WEST BENGAL COAST, INDIA

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The suitability of groundwater quality for drinking and agricultural purposes was assessed in the South 24-Parganas district of West Bengal (India), based on various water quality parameters. The study area falls under a monsoon type of climate. For the present study forty-six representative groundwater samples were collected randomly from tube wells/bore wells to monitor the water chemistry of various ions. The results showed that the concentrations of these ions are above the permissible limits for drinking and irrigation purposes. The pollution with respect to chloride, nitrate and fluoride is mainly attributed to the extensive use of fertilizers and large-scale discharge of municipal wastes into the open drainage system of the area. Most of the groundwater samples of the study area fall into the U.S. Salinity Laboratory Classification C3-S1 (high salinity-low SAR). According to the Wilcox irrigation water classification, 46% of the water samples fall under good to permissible category and 37% under the permissible to doubtful category. A classification based on conductivity shows most of the groundwater samples fall in the "tolerable" to "safe" category. Based on a groundwater chloride classification, 54% of water samples are "safe" to "tolerable", and 22% of water samples fall under a "health hazard" category.

INTRODUCTION

Groundwater plays a pivotal role in human life and development. An understanding of the chemical quality of groundwater is essential in determining its usefulness for domestic, industrial and agricultural purposes. Good quality of water has the potential to cause better crop yields under good soil and water management practices. The suitability of irrigation water depends upon many factors including the quality of water, soil type, salt tolerance characteristics of plants, climate and drainage characteristics of soil (Michael, 1990). Groundwater always contains small amounts of soluble salts. The kind and quality of these salts depend upon the sources for recharge of the groundwater and the strata through which it flows. An excess of soluble salts can be harmful for many crops. Hence, an understanding of the chemistry of groundwater is essential to properly evaluate groundwater quality for drinking and irrigation purposes.

Presentation of geochemical data in the form of graphical charts such as the U.S. salinity diagram and Wilcox salinity diagram help to recognize various hydrogeochemical types in a groundwater basin. Analysis of the chemical constituents of groundwater also sheds light on the geochemical evolution of groundwater, as well as identification of recharge areas. The present study has been undertaken with the objective of (a) chemical characterization of groundwater of the study area and (b) evaluation of the suitability of groundwater in the study area for drinking and irrigation purposes.

The northern portion of the study area (which is a part of Bengal delta) has features of a mature delta and was formed earlier than the southern portion. The delta building process is still going on in the southern part of the study area, which is covered by the Sundarban forest.

The morphological features in the district include the levees along the rivers Hooghly, Malta and Bidyadhari, and marshes bordering the levees and the islands. The district is drained by the Hooghly, Malta, Bidyadhari, and Thakuran rivers and their many tributaries and distributaries, which form a network of rivers and tidal creeks, especially in the Sundarbans region. Thick sequences of quaternary sediments cover the entire district. Soils vary from deep fine loamy to deep fine clayey soils. In the southern part, the soil is saline in nature.

The climate is characterized by hot summers, cool winters, high humidity, and heavy rainfall during the monsoon. The average rainfall is 1,722 mm. Mean annual temperature ranges from 25^{o}C to 27.5^{o}C. Mean summer maximum temperature is around 40^{o}C and mean winter temperature is around 10^{o}C.

The study area is rich in mangrove forest resources, with total forest cover in the district about 1,706 sq. km. The Sundarbans mangrove forest harbors a wide diversity of flora and fauna. It is the only mangrove tiger habitat on earth.

The population is predominantly rural and agriculture is the main occupation. Net area available for cultivation is 3,928 sq. km. Rice is the main crop followed by vegetables and pulses. Orchards and gardens are localized in and around Baruipur. Only 15% of the total geographical area is under irrigation. Important industrial centers are Bata, Budge Budge, Birlapur, Falta, Sonarpur and Baruipur. Main industries are cotton and jute textile, engineering, metallurgical, plastic and polyethylene, leather, drugs and pharmaceutical products.

Regional disparity in development is very prominent in this district. While the northern and northeastern parts, i.e., the area adjacent to Calcutta, have experienced marked development, the Sundarbans region shows very low level of development in all respects.

MATERIALS AND METHODS

Groundwater samples were collected from the tube wells/ bore wells and analyzed for various chemical parameters as described by the American Public Health Association (APHA, 1995). Figure 1 shows the geographical location of the study area. These parameters include pH, electrical conductivity, total dissolved solids, and important cations such as calcium, magnesium, sodium and potassium as well as anions such as carbonates, bicarbonates, chlorides, nitrates, sulfates and fluorides (Table 1). The pH and electrical conductivity (EC) were measured in the field by means of a pH meter and digital conductivity meters, respectively. Sodium and potassium were determined by flame photometer. Total hardness (TH) as $CaCO_3$, calcium (Ca^{2+}), magnesium (Mg^{2+}), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and chloride (Cl^-) were analyzed by volumetric methods. Nitrate (NO_3^-) and fluoride (F^-) were determined using ion analyzer. Sulfates (SO_4^{2-}) were estimated by

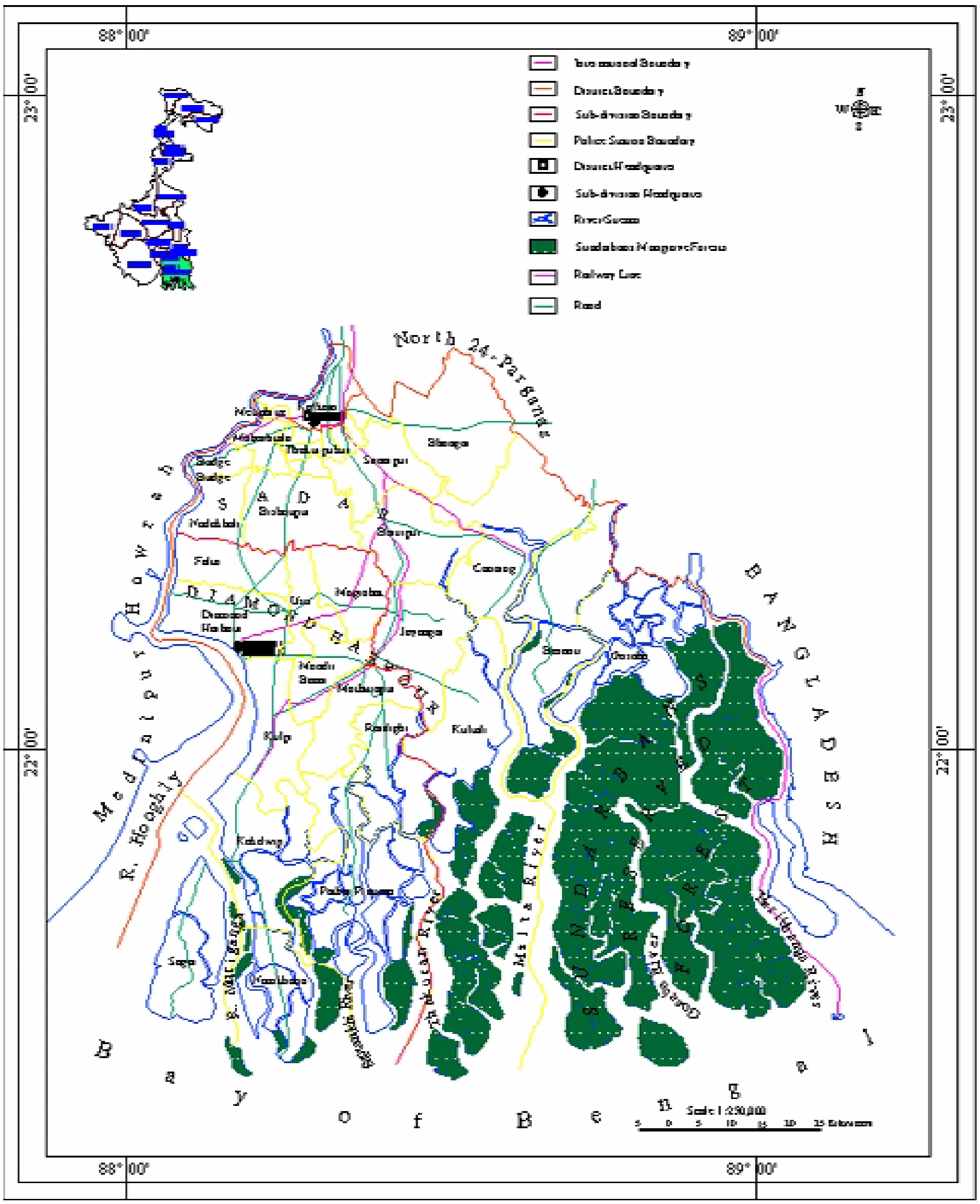

Figure 1. Administrative divisions of South 24-Parganas District.

Table 1. Analytical Results of Groundwater Samples at Different Locations in South 24-Parganas District

S.No	Location	pH	EC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3	HCO_3^-	SO_4^{2-}	Cl^-	NO_3^-	F	TDS	Na%	SAR	PI	RSC
		units	units	ppm											Meq/l			
SP 1	Kakdwip	7.7	982	26	17	110	3	Bdl	360	1.30	127	6.40	0.23	651	64.33	3.88	67.93	3.20
SP 2	Diamond harbour	7.8	1723	45	21	295	2	Bdl	361	1.20	376	3.50	0.28	1105	76.43	6.61	77.79	1.94
SP 3	Namkhana	7.8	938	20	7	186	2	Bdl	447	1.30	74	1.30	0.71	739	83.80	5.37	87.01	5.75
SP 4	Baruipur	7.9	880	46	35	107	3	Bdl	491	20.00	28	5.30	0.10	735	47.76	3.53	49.68	2.87
SP 5	Raidighi	8	1230	18	15	238	2	Bdl	471	1.40	174	9.10	0.09	929	82.99	6.17	84.87	5.59
SP 6	Budge budge	7.3	990	64	28	101	1	Bdl	473	22.00	42	0.70	0.21	732	44.57	3.19	47.56	2.26
SP 7	Barisha	7.6	1370	94	40	134	7	Bdl	608	15.00	123	55.00	0.23	1076	42.95	3.59	43.81	1.98
SP 8	Kulpi	7.9	1230	26	11	226	2	Bdl	409	1.30	202	3.30	0.26	881	81.78	5.89	83.74	4.50
SP 9	Bhangar	7.7	1200	104	27	108	5	Bdl	415	1.20	202	0.30	0.23	863	39.44	2.99	42.16	-0.61
SP 10	Falta-dw	7.6	4120	101	98	685	2	Bdl	1080	17.00	812	7.20	0.18	2802	69.50	10.10	70.05	4.60
SP 11	Sargana	7.5	1540	76	12	238	50	Bdl	377	16.00	302	7.00	1.60	1080	70.88	5.51	70.60	1.40
SP 12	Jaynagar	7.9	1040	26	15	112	3	Bdl	506	1.30	99	8.20	0.13	771	66.16	3.92	70.26	5.76
SP 13	Herobhanga	7.7	1930	68	36	318	5	Bdl	541	65.00	345	8.50	0.13	1387	68.72	6.67	70.09	2.51
SP 14	Ramdhan	7.6	2230	104	40	341	6	Bdl	409	110.00	495	6.70	0.23	1512	63.86	6.63	64.98	-1.78
SP 15	Padmajola	7.5	2160	106	53	301	15	Bdl	636	35.00	395	6.30	0.70	1548	58.28	6.11	58.96	0.77
SP 16	Dhosa	7.7	970	16	6	231	1	Bdl	559	34.00	57	13.00	0.80	918	88.63	6.10	91.05	7.87
SP 17	Ambikanagar	8	980	14	7	226	1	Bdl	515	33.00	64	14.00	0.05	874	88.55	6.06	91.71	7.17
SP 18	Dakshin barasat	7.9	1080	46	21	167	4	Bdl	485	35.00	108	7.30	0.23	874	64.68	4.70	67.03	3.93
SP 19	Radhakantpur	7.8	1420	10	6	345	3	Bdl	672	1.60	138	15.00	0.21	1191	93.83	7.62	97.01	10.02
SP 20	Usti	7.8	1270	40	26	215	3	Bdl	408	1.20	228	4.30	0.18	926	69.52	5.55	71.32	2.55
SP 21	Bishnupur-tw	7.7	1440	104	40	180	3	Bdl	415	23.00	267	22.20	0.23	1054	48.25	4.34	48.66	-1.68
SP 22	Kashipur	7.6	820	120	26	30	1	Bdl	453	1.30	51	1.10	0.21	684	14.07	0.97	15.50	-0.70
SP 23	Langalbena	7.7	1120	136	38	22	14	Bdl	521	10.00	103	6.30	0.09	850	11.71	0.69	11.60	-1.37
SP 24	Ramnagar	7.8	770	88	23	43	2	Bdl	385	16.00	35	1.20	0.60	594	23.42	1.50	25.55	0.03
SP 25	Dhamua	7.6	1180	40	22	220	3	Bdl	512	53.00	167	7.20	0.23	1024	71.71	5.63	73.01	4.59
SP 26	Katalia	7.7	1240	110	35	99	5	Bdl	373	5.20	242	0.70	0.22	870	34.64	2.75	37.25	-2.25
SP 27	Chandipur	7.6	980	80	34	72	4	Bdl	471	1.30	57	5.50	0.02	725	32.27	2.35	33.35	0.93
SP 28	Athaarobanki	7.8	3110	26	23	660	5	Bdl	506	1.20	823	1.20	0.21	2046	90.04	10.48	90.64	5.10
SP 29	Nalmun	7.4	1270	146	33	70	3	Bdl	412	10.00	206	9.50	0.09	890	23.79	1.89	25.35	-3.25
SP 30	Bhojerhat	7.8	1250	120	34	92	4	Bdl	451	11.00	173	4.80	0.21	890	31.84	2.53	33.16	-1.39
SP 31	Bodra	7.8	1120	46	36	138	3	Bdl	612	1.40	74	3.30	0.33	914	53.63	4.17	55.30	4.77
SP 32	Padmapukur	7.7	1220	92	34	126	4	Bdl	608	33.00	71	1.30	0.36	970	43.04	3.45	44.33	2.58
SP 33	Hariharpur	7.7	970	68	32	97	5	Bdl	453	3.00	88	5.50	0.05	752	41.91	3.06	42.57	1.40
SP 34	Srirampur	7.6	920	60	30	93	4	Bdl	459	8.00	60	0.30	0.20	715	43.16	3.05	44.69	2.06
SP 35	Kamalgazi	7.7	1030	136	13	41	2	Bdl	477	20.00	64	0.80	0.11	754	18.93	1.22	21.67	-0.04
SP 36	Nonajagadishpur	7.6	1310	124	33	93	5	Bdl	472	9.20	174	0.70	0.05	911	31.92	2.53	32.27	-1.17
SP 37	Subhasgram	7.7	1380	60	26	240	2	Bdl	636	7.00	135	0.30	0.46	1107	67.15	5.70	68.92	5.29
SP 38	Kumarhat	7.4	850	112	24	33	1	Bdl	415	1.10	46	6.70	0.70	640	16.19	1.08	17.35	-0.76
SP 39	Burarghat	7.6	1390	68	35	216	3	Bdl	675	52.00	137	5.70	0.17	1192	60.16	5.25	61.83	4.79
SP 40	Nungi	7.5	753	80	31	25	38	Bdl	436	18.00	60	0.60	0.12	689	23.94	0.97	18.29	0.60
SP 41	Dulalpur	7.8	1800	116	35	240	3	Bdl	534	68.00	275	21.00	0.72	1293	54.82	5.18	56.27	0.08
SP 42	Mathurapur	8.1	1350	36	24	227	4	Bdl	381	35.00	246	7.80	0.46	961	72.57	5.78	74.43	2.47
SP 43	Mandir bazar	7.8	1290	32	21	234	5	Bdl	406	12.20	235	5.30	0.37	951	75.61	5.93	77.73	3.33
SP 44	Andhamanitala	7.9	1190	38	25	168	6	Bdl	446	87.00	99	11.40	0.20	881	65.37	4.82	68.33	3.36
SP 45	Jalaberia	7.7	1180	30	26	246	4	Bdl	451	72.00	148	9.30	0.22	987	74.82	6.13	74.64	3.76
SP 46	Sonakhali	7.9	2490	16	18	497	2	Bdl	538	12.00	543	4.00	0.05	1630	90.48	9.13	90.46	6.54
	Avg	7.7	1363.2	68.1	27.7	193.2	5.5	0.0	493.9	21.4	195.0	7.1	0.3	1012	56.1	4.6	57.6	2.4
	SD	0.2	622.2	39.5	14.9	144.3	8.8	0.0	121.3	25.5	179.9	8.8	0.3	393.8	23.2	2.3	23.6	3.0
	Max	8.1	4120.0	146.0	98.0	685.0	50.0	0.0	1080	110.0	823.0	55.0	1.6	2802	93.8	10.5	97.0	10.0
	Min	7.3	753.0	10.0	6.0	22.0	1.0	0.0	360.0	1.1	28.0	0.3	0.0	593.8	11.7	0.7	11.6	-3.2

using the calorimetric technique. Groundwater quality for drinking purposes was analyzed by considering the WHO (1971) and ISI (1983) standards. The quality parameters like salinity (EC), permeability index (Doneen's Permeability Index, Doneen, 1964), toxicity due to chloride and sodium (SAR), and parameters causing miscellaneous problems to soil-water-plant relationships (bicarbonate, RSC, sulfate) were determined to assess the irrigation suitability of the groundwater. The data was also plotted on a Wilcox diagram and a U.S. Salinity Laboratory diagram (USSL Staff, 1954).

RESULTS AND DISCUSSION

Suitability of ground water for drinking purpose

The analytical results of different parameters of groundwater in the study area are given in Table 1. The pH values of groundwater in the study area range from 7.3 to 8.1, indicating an alkaline type of groundwater. The electrical conductivity (EC) values range from 753 to 4120 micromhos/cm. The larger variation in EC is mainly attributed to anthropogenic activities and to geochemical processes prevailing in this region. Total dissolved solids (TDS) in the study area vary in the range 594-2802 mg/l. TDS values obtained in the study area are beyond the desirable limits, but only two samples have TDS values more than the permissible limits (ISI, 1983), making the water unsuitable for various domestic activities. The groundwater in the study area falls under fresh (TDS<1000 mg/l) to brackish (TDS>1000 mg/l) types of water (Freeze and Cherry, 1979). In the study area, the sodium concentration in groundwater ranges from 22-685 mg/l. The concentration of calcium in the study area ranges from 10-146 mg/l. The major source of magnesium in the groundwater is due to ion exchange of minerals in rocks and soils by water, and the samples of the study area vary in the range of 6-98 mg/l. The concentration of potassium varies from 1 mg/l to 50 mg/l.

Bicarbonate is the dominant anion, followed by chloride and sulfate. Bicarbonate in the study area ranges from 360-1080 mg/l, the source of most of the bicarbonates in the water being sewage and various human activities. Water with a high concentration of bicarbonates, if used for irrigation, may cause white deposits on fruits and leaves, which is undesirable (Subrahmanyam and Yadaiah, 2001). The concentration of chloride ranges from 28-823 mg/l; the large variation is attributed to geochemical processes, and to contamination by sewage wastes. Groundwater samples 10, 28 and 46 showed extraordinary high values of chloride. Nitrate concentration in the study area varies in the range of 0.3-55 mg/l, and all samples fall below the desirable limits, except for sample 7. The main source of nitrate in the groundwater is attributed to decaying organic matter, sewage wastes, and increased usage of fertilizers (Karanth, 1989). Sulfate varies from 1.1-110 mg/l. The fluoride content in the groundwater shows a range of 0.05-1.6 mg/l. The occurrence of low fluoride concentration in the groundwater may be either due to absence of fluoride containing minerals in the strata through which the groundwater is circulating. It could be also due to too rapid freshwater exchange, with the result that the normal process of concentration through evaporation or evapotranspiration is not very effective in raising the fluoride content of the groundwater to high values prevalent in some parts of the study area.

Suitability of groundwater for irrigation purposes

Irrigation water containing a high proportion of sodium will increase the exchange of sodium content of the soil, affecting the soil permeability and texture. This makes the soil difficult to plough and unsuitable for seeding emergence (Triwedy and Goel, 1984). If the percentage of sodium is high in irrigation water, calcium and magnesium exchange with sodium, thus causing deflocculation and impairment of the tilth and permeability of soils (Karanth, 1987). A sodium percentage of more than 60% is considered unsafe for irrigation. The values for the percent sodium in the study area range from 12-94%. Based on conductivity classification (Table 2) 52 % groundwater falls in “tolerable” (1000-1500 micromhos/cm) and 28 % under “safe” (<1000 micro mhos/cm) category. For groundwater classified on chloride (Table 3), 37 % of water sample is “safe”, 17 % is “tolerable” and 22 % of water samples fall under the “health hazard” category.

A more detailed analysis, however, with respect to the irrigation suitability of the groundwater, was made by plotting the data as shown in Figure 2 (SAR and salinity hazard) according to the diagram of the US Salinity Laboratory of the Department of Agriculture (US Salinity Laboratory Staff, 1954) and Wilcox classification (Figure 3). According to the Residual Sodium Carbonate (RSC) concentration, groundwater sample falling under different categories is given in the Table 4.

According to this classification, low-salinity water (<200 mg/l) may be used for all types of soils. Most of the groundwater samples of the study area fall into the category of the good to moderate (C3-

Table 2. Classification of Groundwater According to Conductivity (micro mhos/cm)

Conductivity range	Quality	Sample no.	Percentage of sample
<1000	Safe	1,3,4,6,16,17,22,24,27,33,34, 38,40,	28.26 %
1000-1500	Tolerable	5,7,8,9,12,18,19,20,21,23,25, 26,29,30,31,32,35,36,37,39, 42,43,44,45	52.17 %
1500-2000	Tolerable to some extent	2,11,13,41	8.69 %
2000-2500	Intolerable	14,15,46	6.52 %
>2500	Health hazard	10,28,	4.35 %

Table 3. Classification of Groundwater According to Chloride

Chloride range (mg/l)	Quality	Sample no.	Percentage of sample
<100	Safe	3,4,6,12,16,17,22,24,27,31, 32,33,34,35,38,40,44,	36.95 %
100-150	Tolerable	1,7,18,19,23,37,39,45	17.39 %
150-200	Tolerable to some extent	5,25,30,36,	8.69 %
200-250	Intolerable	8,9,20,26,29,42,43,	15.21 %
>250	Health hazard	2,10,11,13,14,15,21,28,41, 46	21.74 %

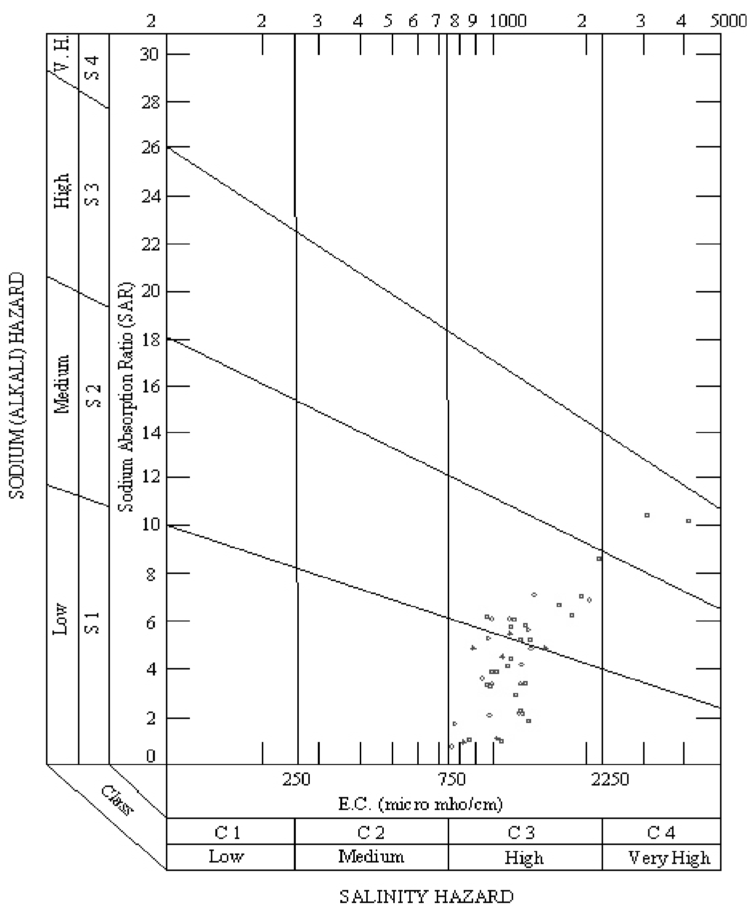

Figure 2. U.S. salinity diagram for classification of irrigation water (after Richards' 1954).

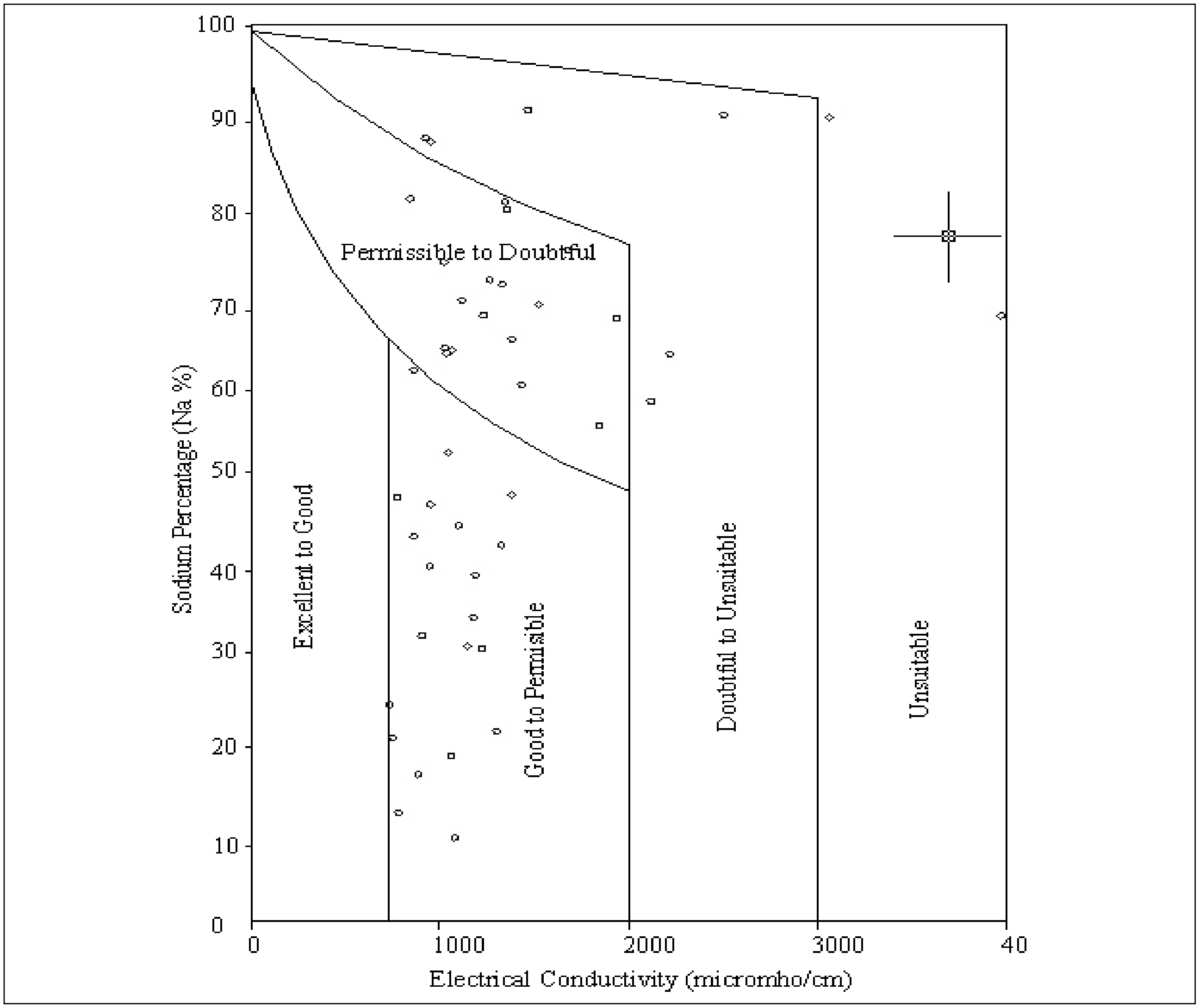

Figure 3. Wilcox diagram for irrigation of the water.

Table 4. Classification of Irrigation Water on the Basis of Residual Sodium Carbonate (RSC) (USSL Staff, 1954)

Category	RSC (meq/l)	Sample no.	Percentage of sample
Safe	< 1.25	9,14,15,21,22,23,24,26,27,29,30, 35,36,38,40,41	34.78 %
Marginal	1.25-2.5	2,6,7,11,33,34,42	15.21 %
Unsuitable	>2.5	1,3,4,5,8,10,12,13,16,17,18,19, 20,25,28,31,32,37,39,43,44,45,46	50 %

S1) (59%) and 37 % under C3-S2 category. According to the Wilcox irrigation water classification scheme, the majority of the water samples (46 %) fall under a “good to permissible” category and 37 % under a “permissible to doubtful” category.

CONCLUSION AND RECOMMENDATIONS

Groundwater quality in the South 24-Parganas is analyzed to classify the groundwater into different categories for the drinking and irrigation purposes. The water quality in the study area is alkaline in nature. The overall groundwater quality of the study area is suitable for drinking purposes, as well as for irrigation purposes. The ground water quality does not show any clear-cut regional trend in any direction (South-North or East-West). It is recommended to carry on the analytical work on ground water quality in greater detail and covering additional areas. Groundwater samples should be collected from many more sites to establish physicochemical variations and trends in the study area. A GPS-based ground water sampling strategy will be useful for accurate correlation of chemical signatures with subsurface hydrogeology.

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