Quality Assessment of Surface and Groundwater of Taluka Daur, District Nawabshah, Sindh, Pakistan.

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Summary: In present work groundwater and surface water samples are analyzed from taluka Daur, district Nawabshah, Sindh. 38 water samples of the study area were examined. The physico-chemical parameters of the water samples were found in the following ranges pH 6.64-8.18, total dissolved salts (TDS) 188-26752 mg/L, HCO_3 27-5011 mg/L, total hardness (TH) 62-13200 mg/L, chloride 41-13953 mg/L, SO_4 23-5122 mg/L, ortho-phosphate (P) 0.09-0.144 mg/L, total phosphate (P) 0.097-0.925 mg/L, NO_2-N 0-0.662 mg/L, NO_3-N 0.02-1.993 mg/L and dissolved oxygen 1.1-10.0 mg/L. The concentration of essential metal ions (Na, Ca, Mg, and K) was found in the ranges of 18-4600 mg/L, 12-3610 mg/L, 4-1308 mg/L and 3-570 mg/L, respectively. Only ten samples were found suitable and rest of the samples were unsuitable for human consumption. The study shows that the groundwater of the major portion of study area is not suitable for drinking purpose.

Introduction

District Nawabshah is situated in the middle of Sindh province bounded between 25° -59 to 27 ° -15 north latitudes and 67° -52 to 68° -54 east longitudes. The District is bound on the north by Naushehro Feroze and Khairpur, south by Hyderabad District, east by Sanghar and Khairpur and the west by Indus River, Larkana and Dadu Districts. Nawabshah city, the capital of the district, is in fact, the exact center of the Sindh province. The total area of the District is 4502 km^2 (according to the figures of 1994-95) [1].This city is located at an elevation of about 50 meters above sea level. The population of the district comprises of 1071530 lives (census 1998). River Indus is running about 90 km along the western side of the district. The soil of the district is sandy with hard clay loams with a negligible exception where the soil is saline.

The climate of the district varied very sharply into northern and southern portion. The desert affects the northern portion and hence climatic conditions are extreme.

Taluka Daur has recently been given the status of taluka, formerly it was part of taluka Nawabshah. The taluka Daur is located at the northern part of the district and is partly fertile with some water logging deposits. Groundwater is the source of drinking water in villages of the taluka but water supply schemes are also available in Daur and Jam Sahab towns. Physico-chemical characteristics are vital for monitoring of water quality. Hence it is necessary to obtain information on the variation of physico-chemical characteristics of water resources in order to decide on the type of water treatment process to be adopted [2].

A lot of work has been carried out on the quality of groundwater of different parts of Pakistan [3-10], Majidano *et al.* [11], reported Physico-chemical parameters of surface and groundwater of taluka Nawabshah, district Nawabshah. The present work examines quality of groundwater of taluka Daur, district Nawabshah, Sindh. The results of analysis would create environmental awareness to the people of the study area.

Results and Discussion

Thirty eight water samples (Fig. 1) were collected from hand pumps, electric motors, tube wells and water supply schemes (Table-1). The contour diagram of the TDS contents of the water samples of the study area is shown in (Fig. 2). Results of physico-chemical parameters of water samples are summarized in Table-2a and 2b, which reveal the varying nature of the groundwater of the study area. The difference in the quality of groundwater may be due to topography of soil;

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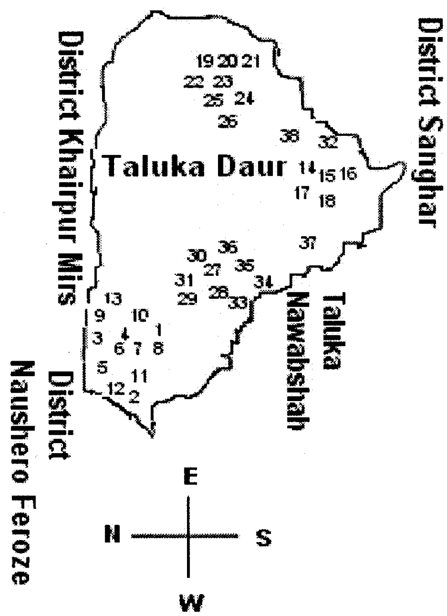

Fig. 1: Map of Taluka Daur (the numbers are indicating the sampling locations).

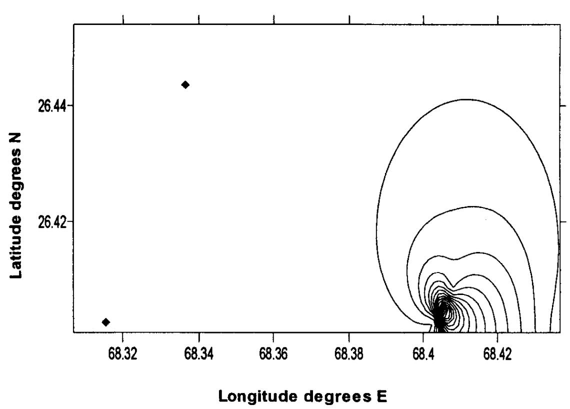

Fig. 2: Contour diagram of TDS contents of water samples collected from Taluka Daur.

different earth beds and effect of recharge sources (canals *etc*) on groundwater.

pH

The pH of water is very important parameter and may affect solubility and toxicity of metals in aqueous system [2]. All the samples analyzed indicated slightly alkaline pH, except two samples (10 and 20) were with slightly acidic pH (6.87 and 6.64 respectively). pH of water samples ranged as 6.64-8.18 (Table-2a). All samples showed pH within the safe guidelines of 6.5-8.5 prescribed by World Health Organization (WHO) for drinking water. Sample 2 (60th Mile road, Daur (Table 1)) showed maximum pH (8.18).

Total Dissolve Solids (TDS)

TDS varied in the range of 188-26752 mg/L. A lot of variation was observed in TDS of water samples, only eleven samples were observed within the limits of WHO. Out of these 11 samples 2 were taken from water supply schemes (surface water) and other 9 were ground waters. Out of these groundwater samples, seven were very near to the recharge sources (canals) where the surface water regularly recharges the groundwater putting in positive effects on the quality of these waters. The variation in TDS may be due to different earth beds and recharge sources. 27 water samples have high values of TDS than the prescribed value of 500 mg/L, making them unsuitable for drinking purpose. TDS of twelve samples was found above 4000 mg/L (Table-2a).

Bicarbonates and Total Hardness

The carbonates, sulfates and chlorides of the Ca and Mg in the water body produce temporary or permanent hardness [12]. The contents of bicarbonate and hardness fluctuated in the ranges of 27-5011 mg/L and 62-13200 mg/L respectively. A parallel behavior of bicarbonate with hardness was noted. Water with total hardness above 300 mg/L is classified as hard [13]. Nine samples (7, 14, 15, 16, 17, 18, 19, 21 and 22) were found soft with hardness below 300 mg/L. However, the hardness of 16 samples was within the safe limits of 500 mg/L prescribed by WHO for drinking water.

Chloride and Sulfate

Chlorides are relatively harmless to organisms except when changed to Cl_2, ClO^- and ClO_3^-, which are toxic. Elevated values of chloride give rise to taste in water and may produce corrosion [13]. The sources of chloride in waters are mostly human wastes. Chloride was found in the range of 41-13953 mg/L (Table-2a). Fourteen samples showed

Table-1: Sources and locations of water samples.

Sample No.	Source	Sampling Station	Sample No.	Source	Sampling Station
1	G W (HP)	Yasir Welding Shop, 60th MILE Road, Daur.	20	G W (HP)	Saith Gopaldas Shop, Gupchani Road, Jam Sahab.
2	G W (HP)	Ustad Abdul Latif Alvi, near Admore Perol Pump, 60th MILE Road, Daur.	21	WS	Water supply pond, Jam Sahab.
3	G W (HP)	Telephone Exchange Daur.	22	WS	Dargah Jam Sahab.
4	G W (HP)	Qadir Bux Khilji, Daur.	23	G W (HP)	Gh. Hussain Bugti, Cabin, Nawabshah Bus Stop, J. Sahab.
5	G W (HP)	Shehzad Pathan, Daur.	24	G W (HP)	Zulifaquar Ali Sher Cloth House, Nawabshah Bus Stop, J. Sahab.
6	G W (HP)	Ansar Rajput, Daur.	25	G W (EM)	Habibullah Pathan Hotel, Shahpur Chakar Road, J. Sahab.
7	G W (EM)	Muhammad Shahid Khanzada, Daur	26	G W (HP)	Police Station, Jam Sahab.
8	G W (HP)	Ali Gul Solangi, Daur.	27	G W (HP)	Ustad Ghulam Rasool Keerio House, Village Raees Kora Khan Rind/ Muhammad Ismail Rind (S.P).
9	G W (EM)	Rizwan Shah Cycle Workshop, Daur.	28	G W (HP)	Khan Muhammad Rind House, Village Raees Kora Khan Rind/ Muhammad Ismail Rind (S.P).
10	G W (EM)	Mechanic Saleem Jat, Daur.	29	G W (EM)	Mureed Husain Mashori, Village Muhammad Hashim Mashori.
11	G W (EM)	Mushtaque Arain Karyana Store, Daur.	30	G W (EM)	Zakir Husain Mashori, Village Muhammad Hashim Mashori.
12	G W (EM)	Garage of Mechanic Samiullah Jat, Daur.	31	G W (EM)	Ali Muhammad Mashori, Village Muhammad Hashim Mashori.
13	G W (EM)	Mechanic Muhammad Ashraf Mallah, Daur.	32	G W (HP)	Village Motoo Mal/ Gareebabad, Near 60TH MILE Road.
14	G W (HP)	Telecom. Builing, 60TH MILE town.	33	G W (HP)	House of Muhammad Younis Kamboh.
15	G W (HP)	Motoo Mal, 60TH MILE town.	34	G W (HP)	Dargah Sain Gohar Shah, Gajrawah Stop. West Side of Canal.
16	G W (HP)	Mustafa Rind Cycle Workshop, 60TH MILE Town.	35	G W (HP)	Dargah Sain Gohar Shah, Gajrawah Stop. East Side of the Canal.
17	G W (HP)	Hotel Muhammad Ismail Makurani, 60TH MILE Town.	36	G W (TW)	Tube Well, Near Village Muhammad Hashim Mashori.
18	G W (HP)	Workshop of Raees Ahmed Yousifzaee Pathan, 60TH MILE Town.	37	G W (HP)	Madrsa Al-Hakeem (Nigran Ashique Ali Shah).
19	G W (HP)	Taj Muhammad Jat House, Dahri Muhalla, Jam Sahab.	38	G W (HP)	Batho Stop/ Cotton Factory.

G W (HP) = Ground water (Hand Pump).
G W (EM) = Ground water (Electric Motor).
G W (TW) = Ground water (Tube Well).
WS = Water supply.

their chloride concentration within the regulations set by WHO (250 mg/L).

The high concentration of sulfate in drinking water causes diarrhea [14]. Sources of sulfate in surface and subsurface water are mainly calcium sulfate and sodium sulfate [10]. Sulfate was found between 23 and 5122 mg/L in water samples. Majority of the water samples (21 out of 38) indicated their sulfate contents above the limits of WHO (250 mg/L). 10 samples (2, 9, 10, 11, 20, 23, 24, 25, 26 and 36) indicated sulfate above 2000 mg/L (Fig. 3), may be due to topology of earth. These samples were collected from two towns Daur and Jam Sahab. The soil of both these towns is very saline but the groundwater of the former is more contaminated than that of latter one, which indicates the presence of high deposits of sulfate salts in the soil. A parallel trend was found in the concentrations of chloride and sulfate in water samples.

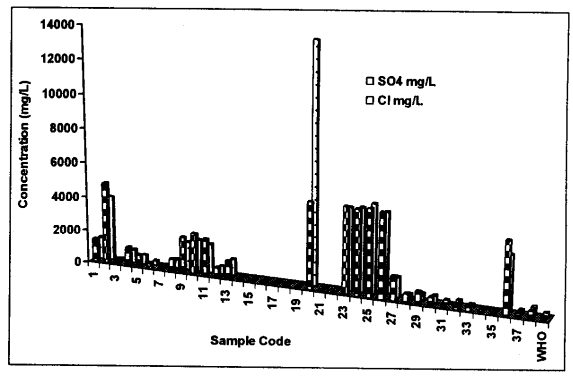

Fig. 3: Chloride and sulfate contents of water samples.

Phosphorus

Phosphorus in the form of orthophosphate (P) and total phosphate (P) in water may be due to

Table-2a: Physico-chemical parameters of water samples of the study area.

Sample No.	pH (25 °C)	TDS mg/L	DO mg/L	TH mg/L	HCO_3 mg/L	SO_4 mg/L	Cl mg/L
1	7.03	5139	1.1	3000	630	1373	1262
2	8.18	22912	1.2	13200	4750	4814	3847
3	7.24	919	1.9	336	270	303	115
4	7.22	3277	4.5	595	350	1099	745
5	7.28	2266	3.3	630	367	730	525
6	7.41	1030	3.0	336	220	302	242
7	7.34	474	8.1	210	125	110	96
8	7.93	2490	8.1	525	550	754	507
9	7.38	5754	7.2	1208	450	2121	1631
10	6.87	8806	3.5	3150	1100	2448	1844
11	7.46	7354	5.0	2205	450	2174	1667
12	7.13	1754	1.4	399	450	576	459
13	7.17	3443	3.1	840	350	1056	957
14	7.88	409	2.4	103	115	115	77
15	7.87	487	1.6	125	205	72	75
16	7.12	338	1.5	71	120	96	47
17	7.71	257	1.3	62	102	73	47
18	7.52	361	1.5	96	115	185	59
19	7.13	472	3.9	162	190	75	70
20	6.64	26752	2.7	4774	1000	5101	13953
21	8.05	192	9.3	139	180	43	41
22	8.08	188	10.0	69	160	23	41
23	7.15	24640	3.1	4200	4769	5073	4850
24	7.07	24448	2.6	4800	4697	5020	4921
25	7.01	25472	2.2	5300	4977	5122	5201
26	7.10	25280	2.5	5040	5011	4990	4813
27	7.47	4058	4.2	1600	400	1416	1148
28	7.51	1466	4.1	1080	312	518	288
29	7.06	1984	4.0	1360	500	720	392
30	7.19	1683	9.9	1880	408	480	377
31	7.11	1053	3.3	840	270	200	226
32	7.21	1453	2.0	720	70	331	283
33	7.68	934	3.6	294	190	302	160
34	7.73	301	2.6	160	50	95	65
35	7.70	202	1.7	108	27	65	41
36	7.14	19968	1.6	8520	4513	4212	3233
37	7.77	1299	3.0	344	456	274	230
38	7.13	2029	1.9	880	520	490	471
WHO	6.5-8.5	500	6.5-8.5	500	-----	250	250

Table-2b: Physico-chemical parameters and metal contents of water samples of the study area.

Sample No.	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	$O\text{-}PO_4\text{-}P$ mg/L	$T\text{-}PO_4\text{-}P$ mg/L	$NO_2\text{-}N$ mg/L	$NO_3\text{-}N$ mg/L
1	610	398	514	248	0.1	0.116	0.038	1.516
2	2467	498	2100	1308	0.099	0.119	0.662	0.518
3	111	50	82	49	0.132	0.134	0.024	0.124
4	336	17	298	208	0.114	0.117	0.514	1.801
5	251	31	242	118	0.117	0.126	0.414	1.482
6	131	18	104	49	0.111	0.126	0.094	1.125
7	62	10	30	20	0.144	0.144	BDL	0.611
8	327	12	264	120	0.124	0.142	0.267	1.993
9	1094	24	521	412	0.12	0.925	0.292	1.184
10	1162	52	928	575	0.112	0.149	0.203	0.48
11	1081	52	638	402	0.12	0.117	0.172	1.698
12	246	8	236	75	0.116	0.122	0.208	0.854
13	412	12	328	206	0.117	0.117	0.409	1.866
14	46	6	42	36	0.111	0.122	0.058	0.312
15	60	15	50	38	0.134	0.134	0.023	0.05
16	42	5	29	25	0.111	0.124	0.018	0.022
17	37	8	18	28	0.1	0.112	0.018	0.03
18	46	4	40	30	0.102	0.126	0.064	0.092
19	53	11	50	41	0.094	0.097	0.061	0.518
20	4600	570	3610	955	0.1	0.12	0.535	0.316
21	37	3	55	4	0.104	0.11	0.038	0.408
22	18	4	12	7	0.1	0.131	0.044	0.316
23	3820	440	2914	795	0.118	0.131	0.04	0.866
24	3915	412	2971	786	0.105	0.117	0.051	0.539
25	4206	500	3005	815	0.101	0.115	0.11	0.433
26	3914	491	2910	750	0.097	0.113	0.032	0.791
27	754	32	454	264	0.099	0.117	0.03	1.853
28	230	27	125	60	0.1	0.154	0.052	0.144
29	382	5	174	181	0.1	0.134	0.211	0.048
30	268	9	149	154	0.11	0.141	0.02	0.045
31	138	5	101	74	0.104	0.144	0.043	0.045
32	193	63	112	76	0.107	0.111	0.295	1.835
33	136	5	68	56	0.111	0.154	0.027	0.871
34	51	5	24	19	0.09	0.151	0.041	0.134
35	36	5	18	10	0.102	0.121	0.023	0.082
36	2477	103	1995	1224	0.107	0.136	0.025	0.473
37	223	18	90	86	0.119	0.121	0.018	0.02
38	230	17	198	142	0.12	0.122	0.018	0.165
WHO	200	12	200	150	-----	-------	1.0	10

geological reasons. Ortho and acid hydrolysable phosphate varied in the ranges of 0.09-0.144 mg/L and 0.097-0.925 mg/L, respectively (Table-2b).

Nitrites and Nitrates

Commonly known forms of nitrogen are ammonia, nitrites, nitrates and organic nitrogen. The presence of nitrogen in water is caused by the decomposition of proteinous compounds in wastewater [13]. Seepage from agricultural land is also one of the sources of nitrogen compounds in water. The presence of nitrogen in water from mineral sources is rare. Microbiological transportation of NO_3 under anaerobic conditions leads to the production of more toxic NO_2 and ammonium ion making nitrate undesirable in water [15]. Nitrates in drinking water could become a cause of cyanosis (Mathaemoglobinaemia) in babies [16]. Nitrite nitrogen and nitrate nitrogen varied in the ranges of 0-0.66 mg/L and 0.02-1.99 mg/L, respectively (Table-2b). Nitrite and nitrate nitrogen of all the samples analyzed were within the WHO threshold and indicate that groundwater is not contaminated with organic materials in the study area.

Dissolved Oxygen (DO)

Dissolved oxygen (DO) in the water body is required to prevent odor and is suitable for use by aquatic plants and other life in water. The water samples showed their dissolved oxygen contents in the range of 1.1-10 mg/L (Table-2a). Thirty three samples showed their DO contents below the permissible limits of WHO may be because of underground water, had minimum contact with air. The DO decreases by increase in temperature due to decrease in solubility of oxygen in water and the fact that the biochemical reactions increase at high temperature, which utilize the DO at higher rate [15].

Cation Chemistry

High concentration of essential as well as non essential elements can cause morphological abnormalities; reduce growth, increase mortality and mutagenic effects [13]. Concentrations of major metal ions (Na, K, Ca and Mg) ranged as Na 18-4600 mg/L, K 3-570 mg/L, Ca 12-3610 mg/L and Mg 4-1308 mg/L, respectively (Table-2b). High concentration of Na leads to cardiovascular diseases and high blood pressure [17].

The high concentration of Ca and Mg in water is good sign for its quality. These metals do not have any significant adverse health effects but add to dietary needs of the body, however, very high concentrations may cause slight health problems. The Na in 16 samples, K in 17 samples, Ca in 21 samples and Mg in 22 samples, respectively was found to be within the permissible limits of WHO.

The concentration of major metal ions followed following decreasing order: (Figs. 4 and 5) Na > Ca > Mg > K

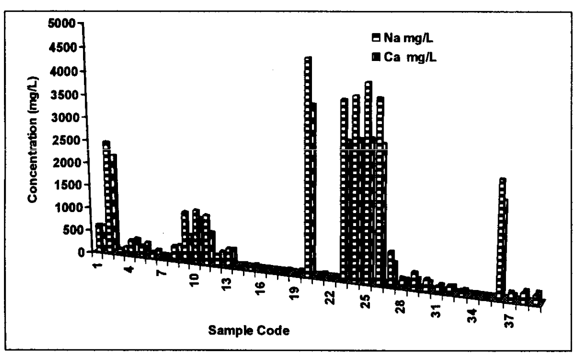

Fig. 4: Essential metal ions (Na and Ca) concentration of water samples.

Sodium Adsorption Ratio (SAR)

Calcium, magnesium and sodium are the most important elements in the water in the form of salts. Sodium is the most important component for soil structure and water permeability. However the contents of this element alone do not supply enough

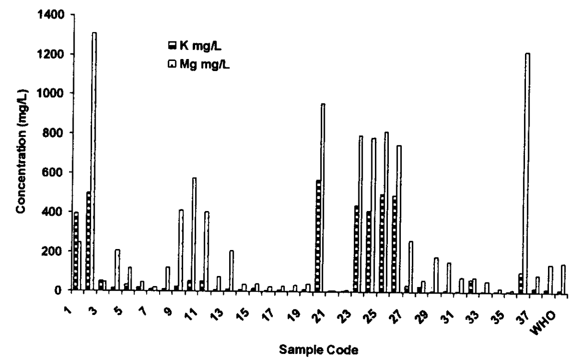

Fig. 5: Essential metal ions (Mg and K) concentration of water samples.

information about water quality and its effects on soil. Calcium and magnesium in large enough quantity will counter the effect of sodium and help to maintain good soil properties. Waters with high sodium content may be of good quality provided the calcium and magnesium contents are also significant. Thus, the ratio of sodium to calcium and magnesium usually expressed as SAR (Sodium Adsorption Ratio) enables the classification of water into different kinds [18]. Sodium adsorption ratio (SAR) was calculated to check the suitability of the waters to be used for irrigation purpose. The results revealed that 23 samples (2 surface water and 21 groundwater) were suitable for irrigation with SAR values below 6 and remaining 15 samples were unsuitable for irrigation with SAR values above 6, all these samples were underground water samples.

Salinity and Alkalinity Hazards

Thirteen samples (3, 7, 14, 15, 16, 17, 18, 19, 21, 22, 33, 34 and 35) indicated their TDS below 1000 mg/L and are classified as fresh waters, eighteen samples (1, 4, 5, 6, 8, 9, 10, 11, 12, 13, 27, 28, 29, 30, 31, 32, 37 and 38) are observed as brackish with TDS values within 1000-10000 mg/L and rest of the seven samples (2, 20, 23, 24, 25, 26 and 36) are found as saline waters with TDS contents above 10000 mg/L [19].

Classification of Irrigation Water Based on Electrical Conductivity (EC)

The water with electrical conductivity (EC) below 250 µS/cm is classified as excellent, none of the samples of study area can be placed in this class, however, ten samples (7, 14, 16, 17, 18, 19, 21, 22, 34 and 35) are classified as good with EC between 250 and 750 µS/cm, four samples (3, 6, 31 and 33) are found as permissible with EC values between 750 and 2000 µS/cm. Four samples (12, 28, 30 and 32) are classified as doubtful with EC 2000-3000 µS/cm and nineteen samples (1, 2, 4, 5, 8, 9, 10, 11, 13, 20, 23, 24, 25, 26, 27, 29, 36, 37 and 38) are classified as unsuitable for irrigation purpose with EC above 3000 µS/cm [19].

Sodium Percentage (Na %)

Sodium percentage was calculated by the formula:

Na % = (Na +K) × 100/(Na + K + Mg + Ca). All the concentrations were used in milli equivalents. The irrigation water is classified into four classes; excellent (Na% <20), good (Na% 20-40), permissible (Na% 40-60), doubtful (Na% 60-80) and unsuitable (Na% >80). Nineteen water samples (2, 4, 5, 6, 8, 10, 12, 13, 14, 15, 16, 17, 18, 19, 21, 30, 31, 36 and 38) of the study area fall into good category (Na% 20-40) and rest of the nineteen samples (1, 3, 7, 9, 11, 20, 22, 23, 24, 25, 26, 27, 28, 29, 32, 33, 34, 35 and 37) fall into permissible category (Na% 40-60) [19].

Permeability Index (PI)

Permeability Index (PI) was calculated by the following formula.

$$PI = (Na + \sqrt{HCO_3}) \times 100 / (Ca + Mg + Na).$$

All the concentrations were used in milli equivalents. Permeability Index (PI) is important parameter to check the water suitability for irrigation purpose. High concentration of sodium in irrigation water reduces the permeability [20, 21]. The sodium ions replace Ca^{+2} + Mg^{+2} and result in the poor internal drainage, eventually damage the quality of irrigation water. The water samples of the area are classified into class I, class II and class III, according to Doneen's chart [22]. In present study, PI of water samples ranged between 36.4 and 131. Only one sample (no. 22) fall into class I, two samples (no. 7 and 21) fall into class II and rest of the 35 samples fall into class III.

Coefficient of Determinations among the Physico-chemical Parameters of Groundwater

The coefficient of determination among all parameters studied of the groundwater of the study area was calculated to find their possible sources. Negative correlation of pH was obtained with all parameters (Table-3). Negative correlation of TDS, TH, HCO_3, SO_4, Cl, Na, K, Ca and Mg each was obtained with O-PO_4-P, T-PO_4-P, NO_2-N and NO_3-N. Other parameters which indicated negative correlation among each other are O-PO_4-P with NO_2-N, T-PO_4-P with NO_2-N and NO_3-N. The negative correlation among these parameters indicates their different source points.

The positive correlation was obtained among; TDS with TH, HCO_3, SO_4, Cl, Na, K, Ca, and Mg; TH with HCO_3, SO_4, Cl, Na, K, Ca, and Mg; HCO_3 with SO_4, Cl, Na, K, Ca, and Mg; $SO_4$with Cl, Na, K, Ca, and Mg; Cl with Na, K, Ca, and Mg; Na with K, Ca, and Mg; K with Ca, and Mg; and Ca with Mg. TDS indicated comparatively greater correlation with majority of the parameters. However, maximum correlation (r^2 = 0.99) was found between Na and Ca

Table-3: Coefficient of determinations among physico-chemical parameters of groundwater.

	pH	TDS	TH	HCO_3	SO_4	Cl	Na	K	Ca	Mg	O-PO_4-P	T-PO_4-P	NO_2-N	NO_3-N
pH	1.00													
TDS	-0.025	1.00												
TH	-0.009	0.684	1.00											
HCO_3	-0.013	0.826	0.691	1.00										
SO_4	-0.03	0.974	0.672	0.775	1.00									
Cl	-0.025	0.738	0.362	0.308	0.69	1.00								
Na	-0.027	0.972	0.527	0.734	0.94	0.78	1.00							
K	-0.019	0.822	0.559	0.616	0.77	0.68	0.81	1.00						
Ca	-0.026	0.981	0.57	0.746	0.94	0.80	0.99	0.82	1.00					
Mg	-0.023	0.858	0.877	0.712	0.90	0.50	0.74	0.55	0.76	1.00				
O-PO_4-P	-0.196	-64.1	-65.0	-67.0	-58.5	-71.3	-65.8	-70.6	-66.8	-58.9	1.00			
T-PO_4-P	-0.003	-0.93	-0.96	-1.02	-0.76	-1.01	-0.92	-1.08	-0.98	-0.77	0.0266	1.00		
NO_2-N	-0.035	-0.31	-0.35	-0.40	-0.23	-0.03	-0.25	-0.37	-0.24	-0.21	-0.01	-0.17	1.00	
NO_3-N	-0.011	-0.73	-0.77	-0.82	-0.58	-0.85	-0.76	-0.80	-0.78	-0.64	0.0243	-0.37	-0.59	1.00

(Table-3) which is indicating their common source into the groundwater of the study area.

In the light of above results it is assumed that the dissolved salts in the groundwater of the area may be the HCO_3, SO_4 and Cl of the metals (Na, K, Ca and Mg). However the salts of Na and Ca are in greater concentration than the salts of rest of the two metals.

The Contamination Index C_d

The contamination index (C_d) developed by Backman *et al.,* [23] examines the quality of water by calculating the degree of contamination. The C_d is calculated separately for the each sample analyzed and is based on the sum of the factors obtained from the parameters exceeding the upper permissible level. The factors which were within permissible level were not used in calculation of C_d. The upper permissible levels used for the calculation of C_d were recommended levels of World Health Organization (WHO). The C_d combines different quality parameters considered harmful to household water.

The results of C_d are summarized in Table 4. The samples may be classified in three categories based on the observed values of C_d [23]. Eleven samples indicated low contamination with $C_d < 1$, three samples medium contamination with $C_d < 3$ and 24 samples high contamination with $C_d > 3$. The groundwater samples collected from Jam Sahab (except sample No.19 which was located near to water supply pond) indicated very high values of C_d ranging between 162 and 220, which indicate the area as highly contaminated zone.

Table-4: Values of contamination index (C_d) of groundwater samples.

Sample Code	C_d	Sample Code	C_d
1	59.3	20	220.8
2	171.9	21	0
3	4.2	22	0
4	12.2	23	162.0
5	10.9	24	164.3
6	1.8	25	178.0
7	0	26	171.9
8	8.0	27	24.0
9	33.8	28	5.7
10	51.7	29	8.3
11	42.1	30	6.9
12	5.1	31	1.8
13	14.7	32	7.1
14	0	33	1.1
15	0.3	34	0
16	0	35	0
17	0	36	117.9
18	0	37	2.3
19	0	38	6.2

Experimental

Thirty eight water samples were collected from different parts of taluka Daur of district Nawabshah. Some water samples were also taken from water supply scheme of the Jam Sahab town.

Different physico-chemical parameters of water samples were measured at the field and in the laboratory. The homogenized sample was transferred to a clean 1.5 L clean plastic bottle. The temperature of air one meter above the surface of water was recorded with mercury thermometer, conductivity, salinity and total dissolved solids (TDS) were measured with Orion 115 conductivity meter at the field. pH was recorded with Orion 420A pH meter. Hardness, chloride and alkalinity were determined by titration with standard EDTA, silver nitrate, and hydrochloric acid, respectively. The dissolved oxygen was determined by Wrinkler method [24]. Nitrate nitrogen, nitrite nitrogen, orthophosphate (P) and total phosphate (P) were determined by spectrophotometric techniques. Orthophosphate (P) was determined by reducing phosphomolybdic acid formed with ascorbic acid to molybdenum blue. Total phosphate (P) was determined by persulfate acid digestion method. Nitrate-N was determined after derivatizing with brucine sulfate. Nitrite-N was analyzed using N-naphthyl ethylenediamine as derivatizing reagent [24]. Sulfate was determined by turbidimetry as $BaSO_4$ using double beam Hitachi 220 spectrophotometer.

The essential metal ions (Na, K, Ca, and Mg) were determined with Varian Spectr AA-20 atomic absorption spectrometer with standard burner head and air acetylene flame. The analysis was carried out in triplicate with integrate time of 3 seconds and delay time of 3 seconds. The concentration of metal ions (Na, K, Ca, and Mg) was determined after appropriate dilution of the sample containing 1 mL concentrated nitric acid per 250 mL.

Sodium Adsorption Ratio (SAR)

SAR was calculate using the formula

$SAR = Na/(Ca+Mg)^{1/2}/2$

Concentrations of Na, Ca, and Mg were used in milli equivalents.

The Contamination Index C_d

The contamination index C_d [23] is calculated for each sample, which is the sum of contamination factors of every parameter of a single sample exceeding the World Health Organization (WHO) limits set for drinking water, using following formula:

$$C_d = \sum_{i=1}^{n} C_{fi}$$

where

$C_{fi} = [(C_{Ai} / CN_i)]$
C_{fi} = contamination factor for the i-th component
C_{Ai} = analytical value for the i-th component
CN_i = upper permissible concentration for the i-th component

Contour Diagram

Longitudes/latitudes were noted with GPS Magellan Explorist 100, No. 0706, San Dimas CA 91773 USA, a product of Thales Navigation China, at the sampling sites and the Contour diagram was made with Golden Software, Inc., Surfer, version 8.0.20.0 on the computer.

Conclusion

The analysis revealed that a number of groundwater samples showed their majority of parameters above the respective permissible limits prescribed by WHO. Only 10 water samples (7, 14, 16, 17, 18, 19, 21, 22, 34, and 35) were found suitable for drinking purpose (on the basis of physico-chemical parameters). All the rest of the sampling sites were found highly contaminated. Therefore the groundwater of taluka Daur, district Nawabshah may not be considered as safe to be used for dinking purpose. However, the surface water may be used for drinking, on the other hand, 23 samples (2 surface water and 21 groundwater) were suitable for irrigation with SAR values below 6. It is assumed that the pollution sources of the groundwater of the area are non point. Special measures should be made in the field of water management.

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