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Assessment of Drinking Water Quality of Groundwater in Udhampur Industrial Zone of Jammu Province, J and K, India

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Abstract

The present study deals with the effect of industrial effluents on the groundwater quality of Udhampur industrial zone in Jammu province, J and K. The ground water from hand pumps and springs in the industrial area is used for drinking and other domestic purposes by the local inhabitants besides its use for various industrial processes. Monthly water samples were collected from two hand pumps and two springs in the study area and the water quality was assessed by analyzing various physicochemical parameters during a period of one year viz. April, 2011 to March, 2012.For the present study, mean values of various water quality parameters were taken to assess site wise and depth wise variations in these two ground water sources. The study indicated that the ground water in both hand pumps and springs belonged to the Ca^{2+}-HCO_3^- group with calcium and bicarbonate as dominant cation and anion. The collected primary data for various parameters has been analyzed statistically. Coefficient of correlation(r) within the parameters of both hand pumps and springs has indicated strong positive correlations between parameters such as EC,TDS and turbidity; calcium and total hardness and; BOD and phosphate and strong negative correlation between pH and free CO_2; free CO_2 and DO; and DO and BOD. The results of Paired t-test have revealed strong variations between the two groundwater sources in terms of parameters like water temperature, pH, turbidity, free CO_2, bicarbonate, BOD, chloride, magnesium, sodium, potassium, silicate, nitrate and sulphate. Water quality Index (WQI) has been calculated using twelve important water quality parameters and has shown water quality deterioration during monsoon season in both the ground water sources. The overall analysis of the data has revealed that most of the water quality parameters in both the ground water sources have exceeded the desirable limits but are within the permissible limit set by WHO and BIS. However, these may cross the permissible limits in future if proper preventive measures are not taken.

Keywords: Coefficient of correlation(r), ground water quality, paired t-test, physicochemical parameters, water quality index.

Introduction

Groundwater constitutes 97 per cent of global freshwater and is an important drinking water source particularly in areas having either limited or polluted surface water resources[1]. Besides it contributes in meeting the daily requirements of domestic, industrial and agricultural sectors. The rapid increase in agricultural development, industrialization and urbanization throughout the world has led to overexploitation and contamination of ground water, thereby, threatening its long-term sustainability. Groundwater quality variation of an area is a function of physical and chemical variations and is greatly influenced by geological formations and anthropogenic activities[2]. The study of chemical budget of major ions has gained importance in ground water quality monitoring as it explains the origin of the ions in water and the level of the contamination by natural as well as anthropogenic sources[3]. Discharge of untreated effluents and domestic waste water are considered to be the main anthropogenic factors responsible for ground water pollution and a number of research publications from various parts of the country are dedicated to the deteriorating ground water quality due to increasing industrial and waste water pollution[4-5]. Increase in concentration of various physicochemical parameters like BOD, COD, TDS, chloride, total hardness, sulphate, nitrate, iron and lead due to these activities not only pose serious threat to ground water but also to those using this water for drinking purposes[6,7]. There is an extensive literature stressing deterioration of water quality due to increased industrial activities[8-11], risk of water-borne diseases due to contamination[12-13] and the potential health hazards that may result from drinking contaminated water of the industries[14-15]. However, no such study has been carried out from this part of the country. Therefore, in the present study major ions have been determined so as to draw a conclusion on the natural or anthropogenic source of origin of these ions in the industrial area.

Material and Methods

Study Area: Udhampur is the fifth largest district of the J and K state situated in the southern part of the state and lies between $32^0 34'$ to $39^0 30'$ North Latitude and $74^0 16'$ to $75^0 38'$ East Longitude. Industrial area of Udhampur named as Integrated Infrastructure Development Project, comprises of more than 60 registered units comprising of cement factories, flour mills, oil refineries, petrochemicals etc.[16]. Most of the water supply for various industrial processes in the industrial area is through these ground water sources.

Water Sampling and analysis: Monthly water samples were collected from two hand pumps and two springs located in the industrial zone of Udhampur for a period of one year viz. April 2011 to March 2012. The water samples were collected in poly-propylene plastic bottles and analyzed in chemical laboratory within four hours of their collection. Physicochemical analysis of water samples was done using standard techniques[17]. Air and water temperature were measured using mercury bulb thermometer (^{0}C); electrical conductivity, TDS, pH were measured by Century water/ soil analyser kit (CMK 731); turbidity was observed by turbidity meter (model 331 E); free carbon dioxide, carbonate and bicarbonate, DO, BOD, chloride, calcium, magnesium were analyzed by titration method; sodium and potassium by flame photometry and phosphate, silicate, sulphate and nitrate by double beam spectrophotometer. Also, the statistical tool SPSS version 17.0 was used to calculate coefficient of correlation(r) within various parameters of the two ground water sources. Paired t-test was computed using Microsoft Excel-2007. Weighted arithmetic index method has been used to calculate the water quality index[18].

WQI in the present study is calculated from the following equation:

$$WQI = {}^{12}\sum_{n=1} W_i.q_i \,/\, {}^{12}\sum_{n=1} W_i$$

Where W_i is unit weight for the nth parameter and q_i is the quality rating[18].

Results and Discussion

The analytical results of mean monthly variations in physicochemical parameters of groundwater samples collected from hand pumps and springs of Udhampur Industrial Zone and their comparison with various national/ international standards have been tabulated in tables 1-3. The statistical analysis of various parameters of these two sites viz. coefficient of correlation (r), paired students t test and water quality index (WQI) are shown in tables 4-7.

Table-1
Mean monthly variation in water quality parameters of hand pumps in Udhampur industrial zone

Parameter	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Mean	SD
A.T. (^{0}C)	22	34	34	35	35.75	35.25	31	24	23.5	21.5	25	23	28.67	5.92
W.T. (^{0}C)	23	22.5	24	24.25	25	26	27.75	23.75	24	22.5	24	24	24.23	1.48
EC(µS/cm)	234.5	302.5	337.0	255.5	233.5	244.5	206.0	344.0	329.5	337.5	434.0	423.0	306.8	74.3
TDS (ppm)	142.2	184.5	204.7	155.4	141.7	148.6	125.1	206.7	199.8	205.4	260.9	256.4	185.9	44.55
Turb(NTU)	0.50	0.50	0.00	1.00	0.00	0.50	0.00	0.00	0.50	0.00	1.50	2.50	0.58	0.76
pH	7.44	7.64	7.39	7.30	7.35	7.19	7.34	7.63	7.67	7.57	7.41	7.04	7.41	0.19
FCO_2(mg/l)	14.50	13.16	14.71	35.70	18.41	20.79	14.62	19.73	18.18	16.01	18.40	29.41	19.46	6.68
DO (mg/l)	5.58	6.33	5.13	3.65	5.05	5.09	5.87	4.35	6.74	7.22	5.31	5.11	5.45	0.99
BOD (mg/l)	0.35	0.35	1.14	1.87	0.58	0.57	0.40	1.29	0.70	0.64	0.67	0.89	0.78	0.45
HCO_3^-(mg/l)	256.2	266.4	244.7	236.7	217.4	214.5	183.0	227.6	243.5	216.5	288.2	210.2	233.7	28.4
Cl^-(mg/l)	16.00	21.99	12.18	15.99	16.20	21.02	19.47	20.55	17.05	12.04	16.93	21.20	17.55	3.36
Ca^{2+}(mg/l)	69.01	62.06	70.10	63.74	49.41	52.71	50.24	50.48	43.71	59.77	49.76	68.55	57.46	9.14
Mg^{2+} (mg/l)	15.10	7.52	22.49	15.94	17.56	13.12	9.31	24.98	28.50	15.61	21.09	9.72	16.74	6.51
TH (mg/l)	245.8	163.4	244.4	194.7	195.2	176.7	183.7	221.8	244.6	203.5	227.9	211.2	209.4	27.95
Na^+ (mg/l)	20.50	27.00	29.45	30.05	27.45	27.80	16.45	23.40	22.65	16.85	24.10	25.35	24.25	4.53
K^+ (mg/l)	2.50	3.15	3.70	4.20	4.20	3.25	2.45	3.40	3.30	3.35	3.50	3.75	3.40	0.55
PO_4^{3-} (mg/l)	0.03	0.75	0.16	0.70	0.70	0.03	0.02	0.03	0.02	0.02	0.03	0.05	0.21	0.31
SiO_2^-(mg/l)	1.51	1.04	1.10	1.04	1.00	1.54	1.39	1.65	0.85	1.54	1.51	1.36	1.29	0.27
NO_3^-(mg/l)	1.13	1.35	1.11	1.43	1.51	1.15	1.79	1.14	0.53	1.06	1.09	1.91	1.26	0.37
SO_4^{2-}(mg/l)	1.60	2.30	2.20	2.15	1.60	1.75	1.35	1.95	0.65	1.60	1.20	1.25	1.63	0.48

Table-2
Mean monthly variation in water quality parameters of springs in Udhampur industrial zone

Parameter	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Mean	SD
A.T. (^0C)	22.5	33.75	36	35.5	35.5	35	29	23	22	20	24	22.5	28.23	6.47
W.T. (^0C)	20.5	20.75	22	24.25	21.5	25.5	26	22.5	23	23	20.5	19.5	22.42	2.05
EC(µS/cm)	286.5	322.5	287.5	320.0	241.0	256.0	205.5	284.0	275.5	354.5	344.0	321.0	291.5	43.62
TDS (ppm)	173.6	195.6	175.6	193.7	146.2	155.3	125.7	172.4	164.8	216.0	207.7	186.8	176.1	25.96
Turb(NTU)	0.50	0.50	0.00	0.50	1.00	1.00	2.00	1.00	2.00	2.50	2.50	2.50	1.33	0.91
pH	7.15	7.45	6.86	6.35	6.40	6.89	7.17	6.80	7.11	7.02	6.87	6.91	6.91	0.31
FCO_2(mg/l)	42.49	25.08	55.43	93.31	88.74	31.81	24.87	34.86	31.37	43.40	47.88	51.77	47.58	22.57
DO (mg/l)	5.78	7.54	6.22	3.80	4.79	6.89	7.46	5.46	6.31	6.21	6.01	5.24	5.97	1.08
BOD(mg/l)	1.14	0.95	1.53	2.79	1.70	0.97	0.71	1.38	1.20	1.42	1.18	1.34	1.36	0.53
HCO_3(mg/l)	245.3	260.5	146.4	194.0	146.9	146.1	141.1	151.7	252.3	214.6	173.8	161.2	186.2	45.71
Cl^-(mg/l)	26.67	32.23	23.07	27.88	23.43	25.57	25.78	29.73	31.47	17.53	21.49	35.84	26.72	5.09
Ca^{2+}(mg/l)	108.00	73.90	100.60	74.34	79.04	49.42	43.73	44.92	42.76	49.61	48.38	47.76	63.53	23.08
Mg^{2+} (mg/l)	8.77	5.67	22.75	11.43	12.63	9.13	6.77	18.80	23.32	11.71	9.59	7.48	12.34	6.04
TH (mg/l)	305.9	208.0	344.7	232.7	249.4	161.0	137.1	189.4	202.5	172.0	160.2	150.1	209.4	64.06
Na^+ (mg/l)	21.90	37.10	34.20	31.00	30.35	33.40	19.90	25.35	23.95	21.25	25.25	25.45	27.43	5.62
K^+(mg/l)	2.35	3.40	2.95	3.15	2.90	3.15	2.45	2.55	3.40	2.55	3.40	2.75	2.92	0.39
PO_4^{3-}(mg/l)	0.05	0.56	0.07	1.02	0.97	0.03	0.02	0.03	0.03	0.03	0.02	0.02	0.24	0.38
SiO_2^-(mg/l)	1.76	1.20	0.99	1.20	0.98	1.99	2.25	1.70	1.53	1.54	1.31	1.85	1.52	0.40
NO_3^-(mg/l)	7.63	7.43	6.80	8.10	7.69	6.70	6.38	5.68	3.53	3.80	6.85	7.90	6.54	1.51
SO_4^{2-}(mg/l)	3.45	4.05	4.50	4.95	4.25	4.60	2.95	2.40	1.95	2.00	3.10	3.45	3.47	1.02

Table-3
Comparison of physicochemical parameters of two sites with various national and international standards

	Min	**Max**	**Min**	**Max**	**WHO Desirable**	**WHO Permissible**	**BIS Desirable**	**BIS Permissible**
A.T. (0C)	21.5	35.75	20	36	-	-	-	-
W.T. (0C)	22.5	27.75	19.5	25.5	-	-	-	-
E.C.(mS/cm)	206	434	205.5	354.5	-	1500*	-	3000
TDS (ppm)	125.05	260.85	125.7	215.9	600	1000	500	2000
Turbidity	0	2.5	0	0.1	-	-	5	10
pH	7.04	7.67	6.35	7.44	6.5-8.5	No relaxation	6.5-8.5	No relaxation
FCO_2(mg/l)	13.155	35.7	24.87	93.30	-	-	-	-
HCO_3^- (mg/l)	182.96	288.235	141.1	260.5	300*	600*	300	600
DO(mg/l)	3.65	7.22	3.79	7.54	-	5-7**	-	-
BOD(mg/l)	0.345	1.865	0.71	2.79	-	5**	-	-
Cl^-(mg/l)	12.035	21.99	17.5	35.8	250	600	250	1000
Ca^{2+}(mg/l)	43.71	70.1	42.76	108.0	100	300	75	200
Mg^{2+} (mg/l)	7.52	28.5	5.67	23.34	30*	150*	30	100
TH(mg/l)	163.35	245.82	137.1	344.7	100	500	300	600
Na^+ (mg/l)	16.45	30.05	19.9	37.1	50	200	-	-
K^+ (mg/l)	2.45	4.2	2.35	3.4	10*	12*	-	-
PO_4^{3-} (mg/l)	0.02	0.75	0.02	1.02	-	0.1**	-	-
SiO_2 (mg/l)	0.85	1.65	0.99	2.25	-	-	-	-
NO_3^- (mg/l)	0.53	1.91	3.53	8.10	50	-	45	100
SO_4^{2-} (mg/l)	0.65	2.3	1.95	4.95	250	400	200	400

*WHO (1997) standard, ** WHO (1992) standard

Water and Air Temperature: Water temperature in hand pumps and springs showed narrow annual variation and ranged between 22.5^0C to 27.75^0C and 19.5^0C to 25.5^0C, respectively, while air temperature observed wide annual fluctuations ranging from a minimum of 21.5^0C and 20^0C during winter to a maximum of 35.75^0C and 36^0C during summer in the two ground water sources. Atmospheric temperature followed seasonal pattern of summer increase and winter decrease as reported by earlier workers[19]. However, water temperature observed comparatively low variations with slight increase during post-monsoon (September-October) and decline during winter in both the ground water sources. Comparatively narrow annual variations in water temperature indicated thermostatic characteristics of ground water as it comes out from sub-surface rocks[20]. WHO has not set any range for water temperature but it must be acceptable.

Table 4
Coefficient of correlation(r) within parameters of handpumps in Udhampur Industrial Zone

	A.T. (^{0}C)	W.T. (^{0}C)	pH	EC (µS/cm)	TDS (ppm)	Tur B(NTU)	FCO_2(mg/l)	HCO_3^-(mg/l)	DO (mg/l)	BOD (mg/l)	Cl^-(mg/l)	Ca^{2+}(mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	TH (mg/l)	PO_4^{3-} (mg/l)	SiO_2^-(mg/l)	NO_3^-(mg/l)	SO_4^{2-}(mg/l)
A.T. (^{0}C)	1																			
W.T. (^{0}C)	0.63	1																		
pH	** -0.90	* -0.72	1																	
EC µS/ cm	** -0.94	** -0.84	** 0.92	1																
TDS (ppm)	** -0.94	** -0.85	** 0.91	** 0.99	1															
Turb (NTU)	** -0.35	** -0.82	0.28	0.60	0.59	1														
FCO_2 (mg/l)	0.64	-0.02	-0.28	-0.43	-0.43	-0.06	1													
HCO_3^- (mg/l)	-0.67	** -0.99	* 0.76	** 0.87	** 0.87	* 0.80	-0.01	1												
DO (mg/l)	** -0.83	-0.16	0.55	0.63	0.63	0.08	** -0.95	0.21	1											
BOD (mg/l)	0.27	-0.39	0.14	-0.02	-0.02	0.14	** 0.91	0.36	* -0.75	1										
Cl^- (mg/l)	0.20	* 0.75	-0.55	-0.45	-0.45	-0.41	-0.61	* -0.73	0.37	** -0.88	1									
Ca^{2+} (mg/l)	0.02	-0.52	-0.16	0.20	0.21	** 0.90	0.00	0.48	-0.12	0.03	-0.13	1								
Mg^{2+} (mg/l)	-0.64	-0.63	** 0.90	* 0.70	* 0.70	0.09	0.13	0.66	0.19	0.49	* -0.76	-0.33	1							
Na^+ (mg/l)	0.60	-0.24	-0.37	-0.31	-0.31	0.39	** 0.88	0.19	* -0.88	* 0.76	-0.54	0.52	-0.12	1						
K^+ (mg/l)	0.32	-0.39	0.07	-0.05	-0.05	0.20	** 0.92	0.36	* -0.79	** 0.99	** -0.86	0.12	0.42	** 0.82	1					
TH (mg/l)	** -0.86	** -0.93	** 0.89	** 0.98	** 0.98	0.68	-0.27	** 0.95	0.48	0.14	-0.59	0.30	* 0.72	-0.13	0.1	1				
PO_4^{3-} (mg/l)	0.63	-0.18	-0.33	-0.35	-0.35	0.23	** 0.94	0.13	** -0.94	** 0.85	-0.60	0.33	-0.01	** 0.97	** 0.9	-0.17	1			
SiO_2^- (mg/l)	-0.48	0.35	0.18	0.18	0.17	-0.37	** -0.90	-0.32	** 0.86	** -0.88	* 0.71	-0.41	-0.10	** -0.97	** -0.9	-0.01	** -0.98	1		
NO_3^- (mg/l)	** 0.91	0.55	** -0.97	** -0.85	** -0.84	-0.08	0.38	-0.59	-0.65	0.01	0.39	0.34	** -0.86	0.56	0.1	* -0.7	0.49	-0.3	1	
SO_4^{2-} (mg/l)	0.64	-0.11	-0.59	-0.39	-0.37	0.49	0.58	0.06	* -0.73	0.42	-0.20	* 0.74	-0.48	** 0.90	0.5	-0.23	** 0.80	-0.7	* 0.7	1

*Significant at 0.05 level; **Significant at 0.01 level

Table 5
Coefficient of correlation(r) within parameters of springs in Udhampur Industrial Zone

	A.T. (^{0}C)	W.T. (^{0}C)	pH	EC (µS/cm)	TDS (ppm)	Turb(NTU)	FCO_2(mg/l)	HCO_3^-(mg/l)	DO (mg/l)	BOD (mg/l)	Cl^-(mg/l)	Ca^{2+}(mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	TH as CaCO3 (mg/l)	PO_4^{3-} (mg/l)	SiO_2^-(mg/l)	NO_3^- (mg/l)	SO_4^{2-}(mg/l)
A.T. (^{0}C)	1																			
W.T. (^{0}C)	0.38	1																		
pH	-0.60	-0.03	1																	
EC (µS/cm)	-0.62	** -0.91	0.0	1																
TDS (ppm)	-0.62	* -0.90	-0.01	** 0.99	1															
Turb (NTU)	* -0.76	0.29	0.46	0.06	0.08	1														
FCO_2 (mg/l)	0.58	-0.24	** -0.90	0.18	0.18	-0.66	1													
HCO_3^- (mg/l)	-0.64	-0.95	0.20	** 0.96	** 0.96	0.01	0.03	1												
DO (mg/l)	-0.36	0.39	** 0.90	-0.39	-0.40	0.52	** -0.96	-0.23	1											
BOD (mg/l)	0.45	-0.32	** -0.93	0.30	0.31	-0.56	** 0.98	0.13	** -0.99	1										
Cl^-(mg/l)	0.03	-0.62	0.41	0.27	0.25	-0.56	-0.12	0.48	0.14	-0.16	1									
Ca^{2+} (mg/l)	0.45	-0.65	-0.33	0.33	0.32	** -0.91	0.61	0.39	-0.56	0.56	* 0.71	1								
Mg^{2+} (mg/l)	-0.67	-0.59	-0.17	** 0.86	** 0.87	0.39	0.20	* 0.73	-0.44	0.35	-0.24	-0.07	1							
Na^+ (mg/l)	* 0.79	-0.26	-0.49	-0.08	-0.10	** -0.99	0.68	-0.05	-0.54	0.58	0.52	0.90	-0.3	1						
K^+ (mg/l)	-0.01	-0.39	-0.78*	0.56	0.58	-0.11	* 0.78	0.35	** -0.90	** 0.86	-0.39	0.23	* 0.7	0.1	1					
TH (mg/l)	0.25	** -0.80	-0.37	0.56	0.55	* -0.79	0.65	0.58\	-0.67	0.65	0.64	** 0.96	0.2	* 0.7	0.4	1				
PO_4^{3-} (mg/l)	* 0.70	-0.12	** -0.95	0.03	0.03	* -0.71	** 0.98	-0.17	** -0.91	** 0.95	-0.12	0.60	0.1	* 0.7	0.6	0.6	1			
SiO_2^- (mg/l)	-0.14	0.69	0.69	-0.66	-0.66	0.52	** -0.85	-0.55	** 0.93	** -0.90	-0.13	-0.69	-0.5	-0.5	** 0.8	** -0.8	* -0.76	1		
NO_3^- (mg/l)	** 0.85	-0.12	-0.46	-0.23	-0.23	** -0.98	0.62	-0.18	-0.45	0.50	0.49	** 0.83	-0.5	** 0.9	0.1	0.7	0.69	-0.4	1	
SO_4^{2-} (mg/l)	** 0.96	0.12	-0.53	-0.43	-0.44	** -0.91	0.62	-0.41	-0.43	0.50	0.28	0.67	-0.6	** 0.9	0.1	0.5	* 0.73	-0.2	** 0.9	1

*Significant at 0.05 level; **Significant at 0.01 level

Table 6
Paired Sample t-test for difference in concentration of various parameters of two sites

Parameter	Pair	Mean	N	Std. Dev	D.f	T calculated	P<0.05	Remarks
Air Temp ^oC	Site 1	28.667	12	5.922	11	1.39	0.193	NS
	Site 2	28.229	12	6.470	11			
W Temp ^oC	Site 1	24.229	12	1.479	11	4.18	0.002	S
	Site 2	22.417	12	2.046	11			
pH	Site 1	7.412	12	0.192	11	5.96	0.000	S
	Site 2	6.911	12	0.309	11			
EC (µS/cm)	Site 1	306.792	12	74.302	11	0.98	0.350	NS
	Site 2	291.500	12	43.619	11			
TDS (mg/l)	Site 1	185.925	12	44.555	11	1.01	0.334	NS
	Site 2	176.100	12	25.958	11			
Turbidity (N.T.U.)	Site 1	0.583	12	0.764	11	-2.83	0.016	S
	Site 2	1.333	12	0.913	11			
FCO_2 (mg/l)	Site 1	19.465	12	6.679	11	-5.038	0.000	S
	Site 2	47.582	12	22.568	11			
Bicarbonate (mg/l)	Site 1	233.735	12	28.397	11	4.17	0.002	S
	Site 2	186.146	12	45.713	11			
DO (mg/l)	Site 1	5.451	12	0.988	11	-2.09	0.060	S
	Site 2	5.973	12	1.076	11			
BOD (mg/l)	Site 1	0.785	12	0.449	11	-6.91	0.000	S
	Site 2	1.357	12	0.527	11			
Chl (mg/l)	Site 1	17.549	12	3.361	11	-8.928	0.000	S
	Site 2	26.721	12	5.087	11			
Calcium (mg/l)	Site 1	57.460	12	9.138	11	-1.14	0.279	NS
	Site 2	63.535	12	23.075	11			
Magnesium (mg/l)	Site 1	16.743	12	6.508	11	5.20	0.000	S
	Site 2	12.335	12	6.044	11			
Sodium (mg/l)	Site 1	24.254	12	4.525	11	-3.96	0.002	S
	Site 2	27.425	12	5.615	11			

Parameter	Pair	Mean	N	Std. Dev	D.f	T calculated	P<0.05	Remarks
Potassium (mg/l)	Site 1	3.396	12	0.549	11	3.14	0.009	S
	Site 2	2.917	12	0.387	11			
TH (mg/l)	Site 1	209.414	12	27.954	11	0.00	1.000	NS
	Site 2	209.410	12	64.059	11			
Phosphate (mg/l)	Site 1	0.208	12	0.307	11	-0.692	0.503	NS
	Site 2	0.236	12	0.384	11			
Silicate (mg/l)	Site 1	1.292	12	0.270	11	-2.45	0.032	S
	Site 2	1.523	12	0.400	11			
Nitrate (mg/l)	Site 1	1.264	12	0.365	11	-14.07	0.000	HS
	Site 2	6.538	12	1.511	11			
Sulphate (mg/l)	Site 1	1.633	12	0.480	11	-7.81	0.000	S
	Site 2	3.471	12	1.022	11			

Note- S= Significant, NS= non-significant,

Table 7
Seasonal water quality index values for the two sites under study

WQI	Handpumps	Status	Springs	Status
Summer	50.97	Moderately polluted	49.67	Moderately polluted
Monsoon	58.27	Moderately polluted	51.29	Moderately polluted
Post monsoon	45.98	Fit for human consumption	41.13	Fit for human consumption
Winter	51.98	Moderately polluted	45.92	Fit for human consumption

pH and free CO_2: In the present study, low pH value in spring water (6.35-7.45) as compared to hand pumps (7.04-7.67) may be due to high free CO_2 concentration in spring water. Seasonally, pH showed increase during summer (April-May) in both the ground water sources with monsoon (July-August) decline in spring water and summer (March) decrease in hand pumps. Strong negative correlation of pH with free CO_2 in spring water (r=-.948; p<0.01) indicates inverse relationship between the both the parameters which is already on record[19]. High free CO_2 concentration in spring water may also be attributed to pollution caused by anthropogenic activities as these are open water sources and people use it for bathing, washing clothes and carry it for other domestic uses. The low pH in springs can also be related to presence of a cement factory nearby and also use of acid producing fertilizers like ammonium sulphate and super phosphate of lime as manure in the agricultural fields located in the catchment of these springs[21]. pH value in spring water was below the WHO[22] recommended limit of 6.5 - 8.5 during monsoon.

Electrical conductivity (EC), Total dissolved Solids (TDS) and Turbidity: Electrical conductivity/TDS varied between 206µS/cm/125.1mg/l (October) to 434µS/cm/260.9mg/l (February) in hand pumps and 205.5 µS/cm/125.7mg/l (October) to 354.5 µS/cm/216mg/l (January) in spring water. Seasonally, these parameters observed similar seasonal fluctuations throughout the year with winter (December-February) increase and post-monsoon (September-October) decline in both the groundwater sources. EC has shown direct relationship with TDS and direct relationship between EC and TDS is already on record[23]. This is further supported by strong positive correlation of EC with TDS in both the groundwater sources (r= 0.99, r=0.99; p<0.01). Turbidity varied between nil-2.5 NTU in both the ground water sources and observed winter increase similar to EC and TDS. Overall analysis of EC, TDS and turbidity for both the sites is well within the permissible limit of WHO[24,25] and BIS[26].

DO and BOD: Dissolved Oxygen varied between 3.65 to 7.22mg/l in hand pumps and 3.79 to 7.54 mg/l in spring water. Seasonally, DO observed an increase during post-monsoon (September-October) in both the ground waters with winter (December-January) decrease in hand pumps and monsoon (July-August) decline in spring water. Monsoon decline in DO may be due to infiltration of waste water of various industries units along with rainwater into the ground causing oxygen depletion. Dilution effect due to increase in subsurface discharge after monsoon during September-October may explain comparatively high DO record. Reduced microbial activity and high oxygen solubility at low temperature during winter may also explain December and January rise in DO. DO has shown an inverse relationship with free CO_2 in the present study which is further supported by its strong negative correlation with both hand pump water (r= -.95; p<0.01) as well as spring water(r= -.96; p<0.01). Spring water showed higher BOD concentration (0.71-2.79mg/l) as compared to hand pumps (0.34- 1.86mg/l) as these are open water sources and are more prone to pollution. Seasonally, BOD observed high concentration during monsoon (July-August) and remained low during summer (April-May). Monsoon high record of BOD in spring water may be due to monsoon showers, when large quantities of dead organic matter infiltrate from top soil[27]. BOD is the indicator of organic load in a water body which is also confirmed by high concentration of phosphate in both the sites which also indicates anthropogenic pressures in water body. Strong positive correlation is observed between BOD and phosphate in the present study (r=0.85, r=0.95; p<0.01). Overall analysis indicates that BOD range for hand pumps and springs is well within the permissible limit of 5 mg/L as prescribed by WHO[24] for drinking water.

Cations: Among various cations, calcium showed dominance (43.71-70.1mg/l; 42.76-108 mg/l) followed by sodium (16.45-30.05mg/l; 19.9-37.1mg/l), magnesium (7.52-28.50 mg/l; 5.67-23.32 mg/l) and potassium (2.45-4.2mg/l; 2.35-3.4mg/l) in hand pumps and springs. In hand pumps, calcium, magnesium and total hardness almost paralleled in their seasonal pattern of increase and decrease and observed increase during summer (May-June) and declined thereafter upto October and again increased in winter with slight variations. In springs, only calcium and total hardness observed similar seasonal fluctuations with summer (June) peak and decline upto March. Magnesium, however, observed winter (November-December) increase. Hand pump water remained moderately hard (163.33-245.82mg/l). However, spring water was observed to be very hard during summer. In springs, calcium showed strong positive correlation with total hardness (r = 0.96; p<0.01). Seasonally, sodium observed post monsoon (September-October) decline in both the ground water sources. Conservative nature of potassium may explain its low seasonal variation[21]. Sodium showed moderate degree of correlation with total hardness and potassium in springs (r= 0.77, r= 0.73; p<0.05). Industrial and domestic wastes increase sodium and potassium concentration in ground water which otherwise are naturally occurring elements of groundwater. Increase in concentration of sodium and potassium as compared to earlier reports of NIH[28] from Udhampur is therefore attributed to the increase in industrial units releasing effluents in the study area. Calcium and total hardness have exceeded the permissible limits of WHO[25] in spring water.

Anions: Anionic spectrum of groundwater showed dominance of bicarbonate (182.96-288.24 mg/l)/ 141.15 to 260.48 mg/l followed by chloride (12.035 mg/l to 21.99 mg/l)/ (17.53 mg/l to 35.84 mg/l), sulphate (0.65-2.3) and (1.95-4.95), silicate (0.85-1.65mg/l) / (0.99 to 2.25mg/l), phosphate (0.02-0.75mg/l)/ / (0.02-1.02mg/l), in hand pumps/ spring water, respectively. Hand pumps recorded lower nitrate concentration (0.53 to 1.91mg/l) as compared to spring water (3.53-8.1mg/l). High nitrate concentration in spring water during monsoon (July-August) may be attributed to the application of urea as a major inorganic fertilizer in the agricultural fields in the upper catchment of the spring which infiltrate along with surface runoff[29]. Variations in depth of hand pump and spring water may account for low nutrient concentration like nitrate and phosphate in hand pumps having allochthonous input which generally decreases with increasing depth. The present range of nitrate is well within the maximum permissible limit of 45 mg/L as has been set by WHO[25] and BIS[26] for drinking water supplies. Phosphate values have exceeded the permissible limits in springs during most part of the year. Phosphate values reflected strong positive correlation with BOD, sodium and potassium in hand pumps (r_{BOD}=0.85, r_{Na}= 0.97, r_K= 0.90; p<0.01) while in springs it showed strong positive correlation with BOD (r_{BOD}= 0.95; p<0.01). Comparatively high record of bicarbonate during maximum part of the year may be attributed to continuous absence of CO_3^{2-}. Rise of bicarbonate with absence of CO_3^{2-} is already on record[19]. The dissolved bicarbonate in the groundwater originates mainly from the biologically active layers of the soil where carbon dioxide is generated by root respiration and decay of humus that in turn combines with rainwater to form bicarbonate[30]. Bicarbonate showed strong positive correlation with total hardness in hand pumps (r= 0.95; p<0.01) while weak positive correlation in springs (r=0.58). Silicate observed irregular trend of increase and decrease in hand pumps and springs, respectively. Sulphate was recorded higher during summer season and lower in winter months in both the groundwater sources. All the cations and anions in the present study have shown an increase as compared to earlier studies conducted by NIH[28] on various springs and wells located in the residential area of the town.

Paired Student t test: Statistical analysis using paired sample student t test has reflected significant site wise variation between similar parameters of hand pumps and springs like water temperature, pH, turbidity, free CO_2, bicarbonate, BOD, chloride, magnesium, sodium, potassium, silicate, nitrate and sulphate which have their calculated values ($t_{calculated}$) greater than the tabulated values at $p<0.05$ (table-6). The percolation of water into the soil is normally accompanied by filtration and the higher values of parameters like turbidity, BOD, chloride, nitrates and sulphate in spring water as compared to hand pumps may be due limnocrene nature of springs making them more prone to contamination from anthropogenic sources including both industrial and domestic.

Water Quality Index (WQI): Twelve parameters viz., pH, TDS, total alkalinity, chloride, calcium, magnesium, total hardness, DO, BOD, sodium, potassium and nitrate were used for the calculation of WQI. Based on arithmetic WQI, ground water has been categorised into four categories[18] viz. fit for human consumption (<50), moderately polluted (50-80), excessively polluted (80-100) and unfit for drinking (>100). In the present study, WQI was observed to be high during monsoon season followed by winter, summer and post-monsoon in both hand pumps and springs (figure-1). The water quality index varied from moderately polluted to fit for human consumption during different seasons. Water quality index observation was high for springs as compared to hand pumps indicating more anthropogenic pressure on them resulting in their deteriorating water quality.

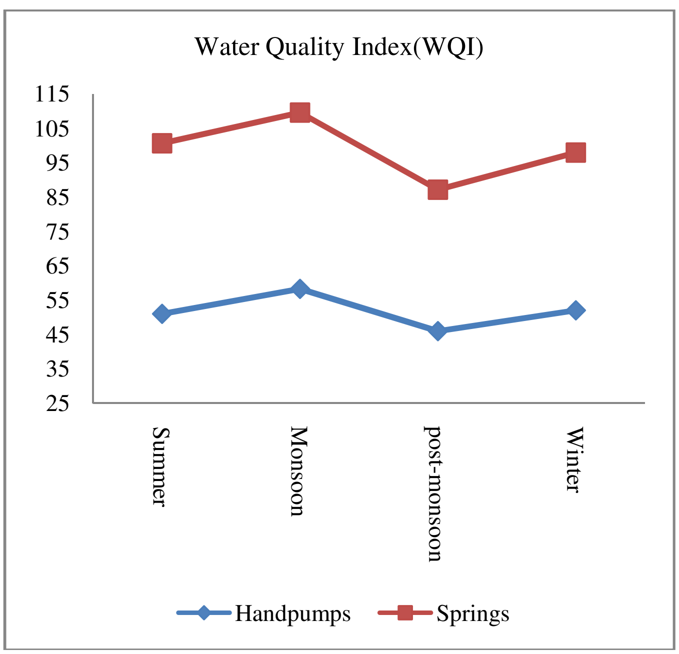

Figure 1
Seasonal water quality index (WQI) variations at two sites

Conclusion

The results of the analysis revealed that most of the parameters including various cations and anions in the present study have shown an increase as compared to the earlier studies conducted by NIH[28] on various springs and wells located in the residential area of the Udhampur town. This clearly indicates that industrial growth in Udhampur has started affecting these ground water sources. Even though all the parameters have not crossed the permissible limits as per World Health Organisation[22,24-25] guidelines but they have almost reached the desirable limits and with the present pace of increase in industries in the study area they may soon cross the permissible limits if proper preventive measures are not taken. Seasonally, more contamination was observed during monsoon season which is in accordance with the studies conducted by earlier workers in different industrial areas. Also, these parameters have higher mean values at spring site as compared to hand pumps which may be due to open nature of these springs. This is also supported by results of paired sample t-test results which have revealed significant variation at the two sites among parameters such as water temperature, pH, turbidity, free CO_2, bicarbonate, BOD, chloride, magnesium, sodium, potassium, silicate, nitrate and sulphate. Water quality Index has indicated moderate pollution in ground water which may become unfit for drinking in the near future. Therefore, the authorities should take appropriate steps to check the ground water contamination in Udhampur Industrial area.

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