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Application of Statistical Analysis in Assessment of Seasonal and Temporal Variations in Groundwater Quality

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ABSTRACT

Statistical analyses (Descriptive analysis and ANOVA test) were applied to groundwater quality data sets monitored for year 2006 to 2007 for four observations to check the seasonal and temporal variations in water quality. Changes in concentrations of various physico-chemical parameters such as temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), carbonates (CO_3^{2-}), bicarbonates (HCO_3^-), chlorides (Cl^-), sulphates (SO_4^{2-}), phosphates (PO_4^{3-}), fluoride (F^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+) and total hardness (TH) were observed using statistical techniques. Statistical analyses revealed that concentrations of variables were changing with seasonal variation but variations in three variables such as pH, HCO_3^- and TH were statistically more significant.

Keywords: *Statistical analyses, Descriptive, ANOVA test, groundwater, physico-chemical*

INTRODUCTION

Water pollution may be considered as a naturally induced alteration in water quality or conditions induced directly by anthropogenic activities which make it unsuitable for human health, food, industry, agriculture or leisure per suit [1, 2]. Groundwater in this region is one of the most important water sources. In this region spending of water for domestic, irrigation and industrial purposes are primarily dependants on groundwater sources. The main objective of our study was to test out the seasonal and temporal variations in water quality using statistical techniques i.e. descriptive statistics and ANOVA test. The basic reason of examining the variations among four different observations was to check the impact of seasonal variations on groundwater quality that is linked with changing climatic and hydrological conditions [3]. Various workers have linked the changed concentrations of various physico-chemical parameters with seasonal variations. Rajmohan and Elango [4] analyzed the concentrations of phosphate and potassium to understand spatial and seasonal variations in the shallow subsurface water of intensively irrigated region of the Palar and Cheyyar river basins. Of late, statistical techniques (i.e. correlation matrix and t-test) have been considered useful to check the seasonal and temporal variations in groundwater quality [5, 6]. A relationship has also been established between physico-chemical parameters concentrations of groundwater with seasonal variations using statistical methods. They have found that concentrations of various parameters were changed with change in season, while working in groundwater quality of Ghaggar Basin system. Mehta [7] emphasized on importance of public awareness and continuous monitoring of groundwater quality in careful management of groundwater resource in welfare of public.

MATERIALS AND METHODS

Description of study area

Groundwater samples were collected from different sources viz. tube wells, hand pumps, bore wells and open wells spreading over Haryana and Punjab regions along the Ghaggar River course in lower Siwaliks.

Data Preparation

The data sets of total 64 monitoring sites, which comprise 15 water quality parameters monitored for 2006 and 2007, were subjected to descriptive statistics and ANOVA test to check the seasonal variations in groundwater quality. Physico-chemical variables used for data sets are temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), carbonates (CO_3^{2-}), bicarbonates (HCO_3^-), chlorides (Cl^-), sulphates (SO_4^{2-}), phosphates (PO_4^{3-}), fluoride (F^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+) and total hardness (TH). For qualitative analysis, samples were collected

from sixteen stations for pre-monsoon and post-monsoon season observations. Sixteen groundwater samples were collected in May (pre-monsoon, 2006) and same stations were again sampled in September (post-monsoon, 2006), May (pre-monsoon, 2007), September (post-monsoon, 2007) to see the seasonal variations. All mathematical and statistical computations were carried out using Microsoft Office Excel 2003 and SPSS 11.5.

RESULTS AND DISCUSSION

To assess impact of seasonal variations on groundwater quality mean values were taken into the consideration as characteristic values to check the variations with seasonal variations as shown in Tables (1 and 2).

TABLE 1: DESCRIPTIVE STATISTICS FOR FOUR OBSERVATIONS OF 2006-07

		N	Mean	Std. Deviation	Std. Error
Temp	1st season	16	24.7500	2.37346	.59337
	2nd season	16	23.2938	1.86743	.46686
	3rd season	16	24.8875	2.07810	.51953
	4th season	16	24.4375	2.30850	.57712
	Total	64	24.3422	2.20633	.27579
pH	1st season	16	7.2938	.37854	.09463
	2nd season	16	7.0500	.22804	.05701
	3rd season	16	7.3875	.43493	.10873
	4th season	16	7.3000	.23094	.05774
	Total	64	7.2578	.34678	.04335
EC	1st season	16	761.0000	225.19976	56.29994
	2nd season	16	716.3125	284.58150	71.14537
	3rd season	16	658.7500	209.75716	52.43929
	4th season	16	752.1875	321.31318	80.32830
	Total	64	722.0625	260.87672	32.60959
TDS	1st season	16	499.0000	154.84444	38.71111
	2nd season	16	463.5625	187.80130	46.95033
	3rd season	16	424.6875	141.30710	35.32677
	4th season	16	497.8125	223.00380	55.75095
	Total	64	471.2656	177.88049	22.23506
CO_3^-	1st season	6	15.0000	12.24745	5.00000
	2nd season	5	14.0000	5.47723	2.44949
	3rd season	6	17.5000	11.29159	4.60977
	4th season	4	28.7500	20.96624	10.48312
	Total	21	18.0952	13.08398	2.85516
HCO_3^-	1st season	16	31ND0	52.91503	13.22876
	2nd season	16	391.8750	107.79417	26.94854
	3rd season	16	322.1875	67.08126	16.77032
	4th season	16	352.5000	98.33616	24.58404
	Total	64	344.1406	88.44133	11.05517
Cl^-	1st season	16	79.0437	39.48951	9.87238
	2nd season	16	127.3875	74.92052	18.73013
	3rd season	16	84.1063	51.48033	12.87008
	4th season	16	111.4250	59.38640	14.84660
	Total	64	100.4906	59.81251	7.47656
SO_4^{2-}	1st season	16	128.2500	160.43212	40.10803
	2nd season	16	145.7500	168.16837	42.04209
	3rd season	16	132.1875	153.65599	38.41400
	4th season	16	151.3750	174.05243	43.51311
	Total	64	139.3906	160.58490	20.07311
PO_4^{3-}	1st season	15	6.0133	3.36173	.86800
	2nd season	15	8.4333	5.22312	1.34860
	3rd season	16	6.1250	4.91318	1.22829
	4th season	15	7.8600	5.84280	1.50860

	Total	61	7.0918	4.91329	.62908
F^-	1st season	16	.3275	.19223	.04806
	2nd season	15	.3140	.15347	.03963
	3rd season	16	.3775	.20440	.05110
	4th season	16	.3981	.25116	.06279
	Total	63	.3549	.20209	.02546
Na^+	1st season	16	187.0563	194.59063	48.64766
	2nd season	16	208.5313	236.11870	59.02968
	3rd season	16	177.6187	174.39213	43.59803
	4th season	16	180.8563	193.72161	48.43040
	Total	64	188.5156	196.50341	24.56293
K^+	1st season	16	6.5688	3.09424	.77356
	2nd season	16	7.0563	2.95837	.73959
	3rd season	16	6.2625	5.43493	1.35873
	4th season	16	5.2250	5.35830	1.33957
	Total	64	6.2781	4.32312	.54039
Ca^{2+}	1st season	16	86.7063	27.93680	6.98420
	2nd season	16	107.1625	32.43845	8.10961
	3rd season	16	89.6563	30.45946	7.61486
	4th season	16	104.1937	41.50996	10.37749
	Total	64	96.9297	33.87465	4.23433
Mg^{2+}	1st season	16	24.6963	10.76107	2.69027
	2nd season	16	28.7438	11.74115	2.93529
	3rd season	16	18.7750	12.19888	3.04972
	4th season	16	29.4000	17.11518	4.27879
	Total	64	25.4038	13.55531	1.69441
TH	1st season	16	318.1250	91.00247	22.75062
	2nd season	16	386.5000	100.45629	25.11407
	3rd season	16	301.0000	92.03912	23.00978
	4th season	16	388.0625	138.89731	34.72433
	Total	64	348.4219	112.05566	14.00696

TABLE 2: ANOVA TEST FOR FOUR OBSERVATIONS OF 2006-07

		Sum of Squares	Df	Mean Square	F values	Sig.
Temp	Between Groups	25.152	3	8.384	1.787	.159
	Within Groups	281.524	60	4.692		
	Total	306.676	63			
pH	Between Groups	1.009	3	.336	3.074	.034*
	Within Groups	6.567	60	.109		
	Total	7.576	63			
EC	Between Groups	103442.875	3	34480.958	.494	.687
	Within Groups	4184126.875	60	69735.448		
	Total	4287569.750	63			
TDS	Between Groups	59244.672	3	19748.224	.613	.609
	Within Groups	1934167.813	60	32236.130		
	Total	1993412.484	63			
CO_3^-	Between Groups	597.560	3	199.187	1.198	.340
	Within Groups	2826.250	17	166.250		
	Total	3423.810	20			
HCO_3^-	Between Groups	63935.547	3	21311.849	2.982	.038*
	Within Groups	428842.188	60	7147.370		
	Total	492777.734	63			
Cl^-	Between Groups	25142.698	3	8380.899	2.511	.067
	Within Groups	200242.116	60	3337.369		
	Total	225384.814	63			
SO_4^{2-}	Between Groups	5761.047	3	1920.349	.071	.975
	Within Groups	1618852.188	60	26980.870		
	Total	1624613.234	63			
PO_4^{3-}	Between Groups	68.249	3	22.750	.940	.428

	Within Groups	1380.177	57	24.214		
	Total	1448.426	60			
F^-	Between Groups	.075	3	.025	.602	.616
	Within Groups	2.457	59	.042		
	Total	2.532	62			
Na^+	Between Groups	9282.607	3	3094.202	.077	.972
	Within Groups	2423373.457	60	40389.558		
	Total	2432656.064	63			
K^+	Between Groups	28.788	3	9.596	.501	.683
	Within Groups	1148.641	60	19.144		
	Total	1177.429	63			
Ca^{2+}	Between Groups	5038.378	3	1679.459	1.498	.224
	Within Groups	67253.596	60	1120.893		
	Total	72291.974	63			
Mg^{2+}	Between Groups	1145.064	3	381.688	2.196	.098
	Within Groups	10430.960	60	173.849		
	Total	11576.024	63			
TH	Between Groups	99008.922	3	33002.974	2.861	.044*
	Within Groups	692048.688	60	11534.145		
	Total	791057.609	63			
* Significant at the 0.05 level						

Mean values of various variables of four different observations of 2006 and 2007 were taken into consideration. A significant seasonal variation in pH of groundwater was observed, at the 0.05 level of significance. The comparison of mean values shows higher pH in pre-monsoon season (2006) and lower in post-monsoon season (2006). pH mean value changes from 7.2938 (pre-monsoon) to 7.05 (post-monsoon) with standard deviation of 0.378 and 0.228, respectively. Bicarbonates also showed impact of monsoon because changes in groundwater quality were statistically more significant with seasonal variations. Bicarbonates showed higher mean value (391.88) in post-monsoon season (2006) than the pre-monsoon season (2006) with mean value of 310. The variations in chloride concentration are also significant at the 0.05 level of significance as its mean value changed from 79.04 to 127.39 with standard deviation of 39.49 and 74.92, respectively. These occurred changes in groundwater quality are linked with seasonal and temporal variations.

Similarly, mean values of EC, TDS, carbonate, bicarbonate, chloride, sulphate, phosphate, fluoride, sodium, calcium, magnesium and TH were higher in post-monsoon (2007). In pre-monsoon season (2007) only three parameters viz. temperature, pH and K^+ showed mean values higher than the post-monsoon season (2007). A significant change was observed in TH concentrations, at the 0.05 level of significance. The mean value of TH varied from 301.01 (pre-monsoon, 2007) to 388.1 mg/l (post-monsoon, 2007). The variation in standard deviation value of TH was noticeably high as it varied from 92.04 in pre-monsoon (2007) to 138.90 in post-monsoon (2007).

From the ANOVA test, it is concluded that there are changes in almost all the parameters but changes in three parameters viz. pH, HCO_3^- and TH were significant with temporal variation and in other parameters changes are non-significant.

CONCLUSION

Hence, it was summarized that there were changes in almost all the analyzed parameters with seasonal and temporal variations but changes in three parameters values including pH, bicarbonates and total hardness (TH) were more significant. Changes in other parameters values were also evident but they were not significant.

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