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Assessment of Ground Water Quality of Dera Ismail Khan, Pakistan, Using Multivariate Statistical Approach

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Abstract: The current study was carried to determine the ground water quality of three tehsils of Dera Ismail Khan District. Water sampling was carried out, using standard protocols from various sources of water, i.e., Tubewells and Hand-pumps. The collected water samples were analyzed for 13 water quality parameters, employing standard methods. Spatial variability and source identification was done, using the integrated approach of multivariate analysis. It was observed that some of the water quality parameters, such as, total dissolved solids (TDS), sulfate, fluoride and arsenic, were beyond WHO guideline values. Cluster analysis (CA) was found an ideal tool in determining the spatial variability among different sites. The principal component analysis (PCA) determined the most influential parameters regulating the hydrochemistry of ground water. Water of the study area was dominated by salts of sodium, calcium and magnesium. Hydrochemistry of the study area was found to be significantly influenced by water rock interactions and by agricultural activities. Strong correlation was noted between certain physico-chemical parameters. Regular monitoring programs for ground water quality are the dire need of hour to suggest remedial and management strategies in order to safeguard the health of local masses.

Key words: Water management, Principal component analysis, Arsenic, Cluster analysis, Hydrochemistry.

INTRODUCTION

Water is one of the most essential resources and is the elixir of life. Besides, the human activities, like agriculture, industry, power and recreation, also depend on water. Pakistan is one of the most prone countries to water pollution where access to safe drinking water is a major problem (Azizullah *et al.,* 2011; Amin *et al.,* 2017). The rate at which access to safe and clean water being provided is very slow as compared to the speedy growth of the population. According to an approximation, the annual per capita availability of water has decreased from 5800 cubic meter in 1951 to about 1100 cubic meter in 2006 and it will decrease to 1066 cubic meter in 2010 (Habib, 2008). Pollution of water has become a severe dilemma in Pakistan and most of the health problems are because of water pollution (Muhammad *et al.,* 2017). Public health experts have a strong opinion that the provision of safe water is a prerequisite and is of great importance to public health. WHO reported that approximately 85% citizens have no access to secure and safe drinking water in Pakistan (PCRWR, 2008). The quality of drinking water of different reservoirs in the country has been contaminated by constant effects of various human, industrial and agricultural activities. The quality of water is affected by a number of factors; the most important being exponential growth of population and economic development (Walsh, 2000).

Pollutants, such as, microbes, harmful chemicals substances, manufacturing wastes, pesticides, heavy metals pollution, municipal wastewater, etc., make water unfit for drinking and other domestic uses. Similarly, a huge amount of waste is produced by the anthropogenic sources, like domestic, industrial, agricultural, hospital, etc. Since, there is no proper management system for waste disposal, most of it finds its way in the natural water bodies, fresh water resources and ground water reservoirs (Qadir *et al.,* 2008).

Groundwater is one of the prime sources, used for domestic, industrial and agricultural practices in most of the countries. It is anticipated that almost one-third population of the world uses groundwater for drinking purposes (UNEP, 1999). The consumption of contaminated water causes severe health impacts, such as, Hepatitis, dysfunctional circulatory system, skin problems, kidney damages, stomach disorders,

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elevated risk of cancer and nervous system disorders, etc. It has also been reported that, in Pakistan, 20 to 40% patients in hospitals are suffering from water borne diseases (WHO/UNICEF, 2004). Eighty percent diseases, such as, cholera, typhoid and dysentery, hepatitis, giardiasis, cryptosporidiosis and worm infections, cause 33% of deaths annually (Tahir, 1994).

The concern over the presence of arsenic (As) and fluoride (F) in water of Pakistan is widely prevailing due to its toxicity and carcinogenic nature (Khan *et al.,* 2004). As has been categorized as Class A carcinogen. Naturally occurring water contamination of As and F has been reported as a severe health toxic agent throughout the world (Saha and Sahu, 2016). Furthermore, WHO has also declared As, as one of the major health issues. Exposure to As from drinking water via oral and dermal track can lead to various health impacts, i.e., skin lesions, black foot disease and several cardiovascular and neurological disorders. Pakistan has been suffering from the ill effects of As and F^{-} contamination. Various studies report a high concentration of As and F^{-} in water throughout country (Brahman *et al.,* 2013; Shakoor *et al.,* 2015).

The present situation of drinking water quality in Pakistan indicated that there is an urgent need of initiation of safe drinking water projects. Such projects are indispensible to improve the quality of life of the people regarding health care, particularly, those living in the rural areas. Therefore, the aim of the present study was to assess the drinking water quality of Dera Ismail Khan, Pakistan, through physicochemical analysis of water by applying multivariate statistical approach.

MATERIALS AND METHODS

Study area: Dera Ismail Khan district is the main district of Khyber Pakhtunkhwa (KPK) province of Pakistan (Fig. 1). Total area covered by the district is 7,326 square kilometers (km²) and, according to the 1998 census, it has a population of 852,995. The district of D.I. Khan is situated at 31° 49' 58" North, 70° 54' 9" East (Khan, 2003). The majority of the region-range is bone-dry alluvial plain. The slopes, inside the region, are those of Khisor Range, which lies in the north-eastern part of Pakistan. The Khisor Range is otherwise called the Ratta Koh or Koh-e-Surkh, which means "red-mountain". It lies near the Indus River in north-east to south-west direction. D.I. Khan faces extremely harsh weather conditions. The summer season is hot, the highest temperature is observed during May-August. June is the hottest month, in which the temperature exceeds 42°C. In winter, the day time temperature is not very low but, at night, it falls harshly (Anonymous, 1998).

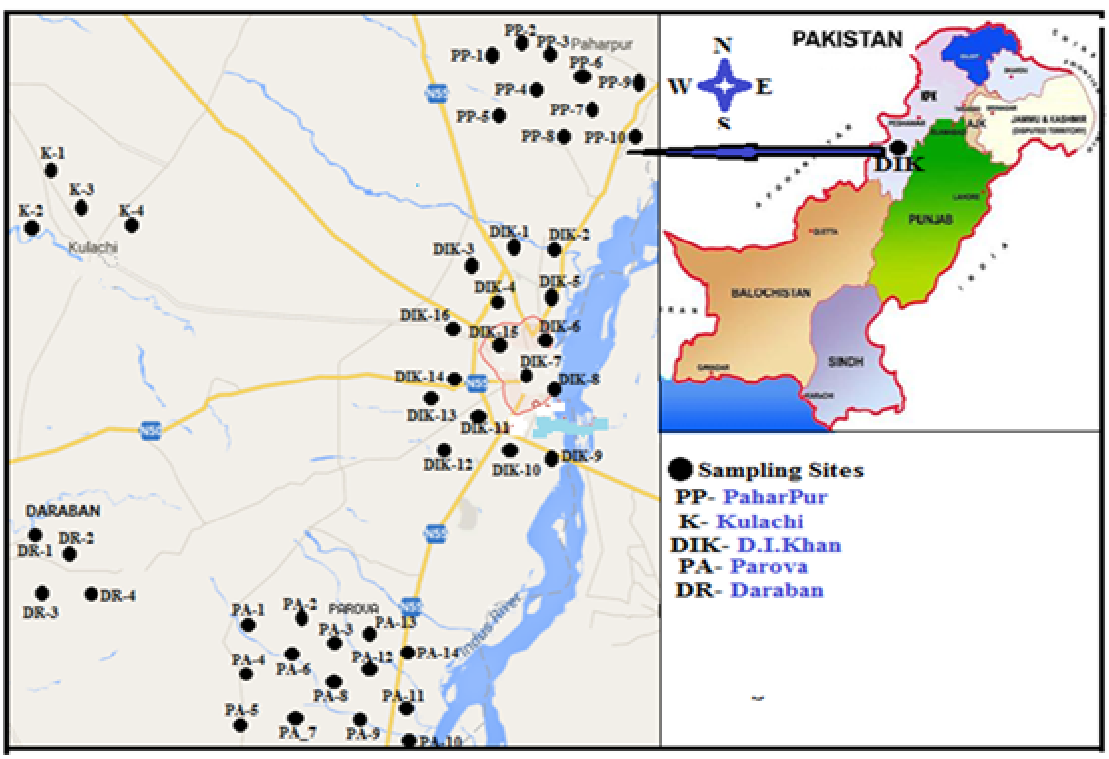

Fig. 1: Map of the study area.

Water sampling: In D.I. Khan, water is supplied to communities through different schemes, constructed by the Public Health Engineering Department of KPK. The list of schemes provided by Public health engineering department was used as a standard for water samples collection.

Water samples were collected from different sources, i.e., taps/hand pumps and tube-wells, from three tehsils of D.I. Khan Districts. These taps/hand pumps were cleaned and allowed to run for a few minutes before collecting the sample. When taking water sample from taps/hand pumps and un-rusted taps were preferred. The water samples from tube-wells were taken after allowing them to run for at least 10 minutes. Water samples for chemical analysis were collected in polythene bottles. Sterilized containers (200 mL) were used for collecting samples for microbiological testing. Water samples were preserved through different ways, i.e., water samples for trace element were preserved through 2 ml. L^{-1} HNO_3, whereas samples for nitrate analysis were preserved by adding 1 mL/100 mL, 1 M boric acid (Subramanian *et al.*, 1978).

Water analysis: The water samples were analyzed for various physico-chemical parameters, using standard methods (APHA, 1992). pH, Electrical conductivity (EC) and Turbidity were determined by pH meter (Model HANNA 210). EC meter (Hach-44600-00, USA) and Turbidity Meter (Model HANNA HI 93703) were used for identifying EC and Turbidity, respectively. Calcium ions (Ca^{2+}), magnesium ions (Mg^{2+}), bicarbonate ions (HCO_3^-), chloride ions (Cl^-) and hardness were determined through standard titration method (Srimurali *et al.*, 1998). Sodium ions (Na^+) and potassium ions (K^+) were analyzed by Flame Photometer (DV710W), while sulfate ions (SO_4^{2-}) and nitrate ion (NO_3^-) were determined by a Spectrophotometer (Turbidimetric Method). F^- determination was carried by SPANDS (trisodium 2-parasulfophenylazo-1, 8-dihydroxy-3, 6-napthalenedisulfonate or 4, 5-dihydroxy-3 paraphenylazo-2, 7-napthalenedisulfonic acid tri-sodium salt) method using colorimeter (DR/890 HACH). Iron was analyzed by Colorimeter (TPTZ Method HACH Cat. No. DOC022.5300720) using Iron Pillows. As concentration was analyzed on hydride generation mode of atomic absorption spectrophotometer (Analytic Jena, Vario 6, Germany) at National Water Quality Laboratory (NWQL) of Pakistan Council of Research in Water Resources (PCRWR), Islamabad.

Quality control: All chemicals, used in research study, were of analytical grade. De-ionized water was used throughout experiments. Standard solutions of the studied metals were prepared by diluting stock solutions of 1000 part per million (ppm). All the containers/glassware, used in fields or laboratory, were washed with detergent, followed by several times rinsing with de-ionized water. Before washing, the glassware was soaked overnight in 10% HNO_3 and then washed with de-ionized water.

Statistical analysis: Multivariate statistical analysis was employed through CA and PCA, using XLSTAT, 2017. Multivariate statistical approach is an important modeling tool to explore the degree of variance among various variables. The technique is widely used to reduce the dimensionality of huge datasets. In the current study, CA and PCA were used to understand the level of variance. CA is used to group similar objects in one group based on the degree of similarity or dissimilarity by forming dendrogram, a visual demonstration of correlation data (Malik and Hashmi, 2017).

PCA is a technique, used to highlight the variation and illustrate strong pattern in the given dataset. It transformed data into different variables, called principal component or factors in the form of factor loading (Abdi and Williams, 2010). It makes the data easy to explore and visualize. Eigen value of each factor greater than 1 was considered as significant value (Simeonov *et al.,* 2003; Firdous *et al.*, 2016).

RESULTS AND DISCUSSION

Water quality is an important factor that determines the suitability of water for drinking purposes. The results of the statistical summary of the physicochemical analysis are presented in Tables 1-3). Tehsil-wise results of the study showed that all physico-chemical water quality parameters of D.I. Khan were in accordance with the WHO prescribed permissible limits except for SO_4^{2-} and As (WHO, 2011). In the same way, results for water quality of Tehsil Parova illustrated that all the studied parameters were within the safe range of WHO except SO_4^{2-}, Ca^{2+}, Cl^-, hardness and As. Similarly, the results of water quality of tehsil Daraban depicted that all the studied parameters were in the safe range of WHO, except the concentration of SO_4^{2-}, F^- and As. SO_4^{2-} were found in low abundance in water. The main natural sources of high level of SO_4^{2-} in the drinking water were due to SO_4^{2-} mineral dissolution and oxidation, whereas the anthropogenic sources were industrial effluents and phosphates (PO_4^{3-}) fertilizers being used in the agricultural practices. SO_4^{2-} make their way into ground water reservoirs, such as, tubewell by percolation or infiltration of rain water that carries high level of SO_4^{2-} (Krouse and Mayer, 1999). F^- occurs abundantly in the earth crust in the form of different rocks and minerals. There are several agents that control the level of F^- in water, i.e., the climate of the study area and the composition of aquifer (Farooqi *et al.*, 2007). The F^- availability in water also depends upon pH, it increases with increase in pH (Nash and McCall, 1995; Paul and Salifu, 2015). It is considered as one of the lethal elements for public. Those areas where oxygen penetrates into soil because of increased pumping of ground water, the natural weathering of As containing mineral is common and it indicates the presence of high concentration of As in the area. This process may facilitate oxidative breakdown of arsenic containing sulphide (S^{2-}) minerals and would generate acid which permeates As from other minerals. Oxidation states of natural As is 0, 3^+ and 5^+, as sulfides or metal arsenide or arsenates. Water usually contains arsenate

5+ but if the condition is anaerobic then it is possible that arsenite 3+ is present (Le, 2002). Various anthropogenic activities, such as, waste from fuel refining, glass melting and smelting of metal S^{2-} ores are other sources of ground and surface water contamination with As. As-containing pesticides and fertilizers are also other possible sources of As contamination. It has harmful effects on human health, therefore, more research should be carried out on its removal from water. The results of this study are in line with various other studies, indicating high level of As and SO_4^{2-} in ground water samples (Waqas *et al.*, 2017; Farooqi *et al.*, 2007).

Table 1: Descriptive statistics of water quality parameters of D.I. Khan tehsil.

Variable	Observations	Minimum	Maximum	Mean	Std. deviation	WHO standard
EC (µS/cm)	16	324	1033	548.563	198.400	
pH	16	7	8	7.463	0.263	6.5-8.5
SO4 (ppm)	16	20	330	79.313	69.251	250
NO3 (ppm)	16	0.15	1.8	0.745	0.530	10
Na^+(ppm)	16	12	82	61.875	17.045	200
K (ppm)	16	1	5	2.688	1.401	12
Ca^{2+} (ppm)	16	20	72	37.750	15.438	75
Hardness	16	110	450	197.500	92.664	500
Mg^{2+} ppm	16	10	97	24.313	20.369	150
Cl (ppm)	16	52	155	94.688	33.641	250
HCO3(ppm)	16	70	200	133.875	42.319	NGVS
F (ppm)	16	0.030	1.23	0.602	0.387	1.5
TDs (ppm)	16	162	516	274.500	98.401	1000
Turbidity NTU	16	0.300	2.70	0.919	0.598	5
As (ppb)	16	2.080	56.18	22.594	14.668	10

Table 2: Descriptive statistics of water quality parameters of Parova tehsil.

Variable	Observations	Minimum	Maximum	Mean	Std. deviation	WHO standard
pH	14	1356	2366	1794.786	393.237	NGVS
SO4 (ppm)	14	7.30	7.8	7.500	0.166	6.5-8.5
NO3 (ppm)	14	310	800	574.286	168.282	250
Na^+ (ppm)	14	0.01	1.560	0.443	0.343	10
K (ppm)	14	125	237	177.000	41.556	200
Ca^{2+} (ppm)	14	3	8	6.143	1.562	12
Hardness	14	16	116	41.214	27.462	75
Mg^{2+} ppm	14	61	194	116.786	42.216	150
Cl (ppm)	14	56	190	128.214	40.840	250
HCO3 (ppm)	14	110	230	177.357	37.004	NGVS
F (ppm)	14	0.210	0.950	0.594	0.208	1.5
TDs (ppm)	14	682	1190	899.500	198.262	1000
Turbidity NTU	14	420	860	585.714	156.535	500
As (ppb)	14	2	4.30	3.250	0.857	5
As	14	3.90	92.35	29.280	24.310	10

Table 3: Descriptive statistics of water quality parameters of Daraban tehsil.

Variable	Observations	Minimum	Maximum	Mean	Std. deviation	WHO standard
pH	10	366	1261	663.20	274.946	NGVS
SO4 (ppm)	10	7.38	8.34	7.915	0.273	6.5-8.5
NO3 (ppm)	10	12	477	114.10	142.286	250
Na^{+} (ppm)	10	0.05	1.81	0.39	0.506	10
K (ppm)	10	23	156	76.10	50.580	200
Ca^{2+} (ppm)	10	1	6	2.90	1.524	12
Hardness	10	16	48	29.20	9.807	75
Mg^{2+} ppm	10	12	73	29.80	18.606	150
Cl (ppm)	10	25	110	66.10	26.036	250
HCO3 (ppm)	10	98	195	131.50	33.267	NGVS
F (ppm)	10	0.26	30	3.299	9.382	1.5
TDs (ppm)	10	183	630	331.70	137.847	1000
Turbidity NTU	10	100	420	195	97.325	500
As (ppb)	10	0.50	1.20	0.83	0.250	5
As	10	0.190	52.25	7.62	15.973	10

Cluster analysis: Cluster analysis (CA) is a technique, used to group objects in one cluster. Wards method (Shrestha and Kazama., 2007) was used, using analysis of variance for clustering of objects, whereas, Euclidean method (Zhou *et al*., 2007) was used as a distance of matrix. The objects within one cluster are similar to one another and dissimilar to the objects of the other groups. CA does not determine the properties of the objects within the class rather it gives a pattern of variation. The result of the CA (Fig. 2) of D.I. Khan tehsil showed that the whole dataset is divided into three main clusters consisting of cluster 1 (sample No. 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 15), cluster 2 (Sample No. 8 and 14) and cluster 3 (sample No. 16). The result of CA for water samples of tehsil Daraban (Fig. 3) showed that the whole dataset was divided into four main clusters, i.e., cluster 1 (Sample No. 1), cluster 2 (sample No. 2, 3, 4, 5, 9), cluster 3 (sample No. 6 and 7) and cluster 4 (sample No. 8 and 10). Correspondingly, the results for tehsil Parova (Fig. 4) were similarly divided into three main clusters, consisting of cluster 1 (sample No. 1, 2, 3, 5, 6, 8, 11, 12), cluster 2 (Sample No. 4, 7, 9, 13, 14) and cluster 3 (Sample 10). The water samples in one cluster possess same physico-chemical properties. There are several reports where similar techniques have been widely used in water quality determination (Singh *et al.*, 2017; Kumar *et al.*, 2017: Shahid *et al*., 2017).

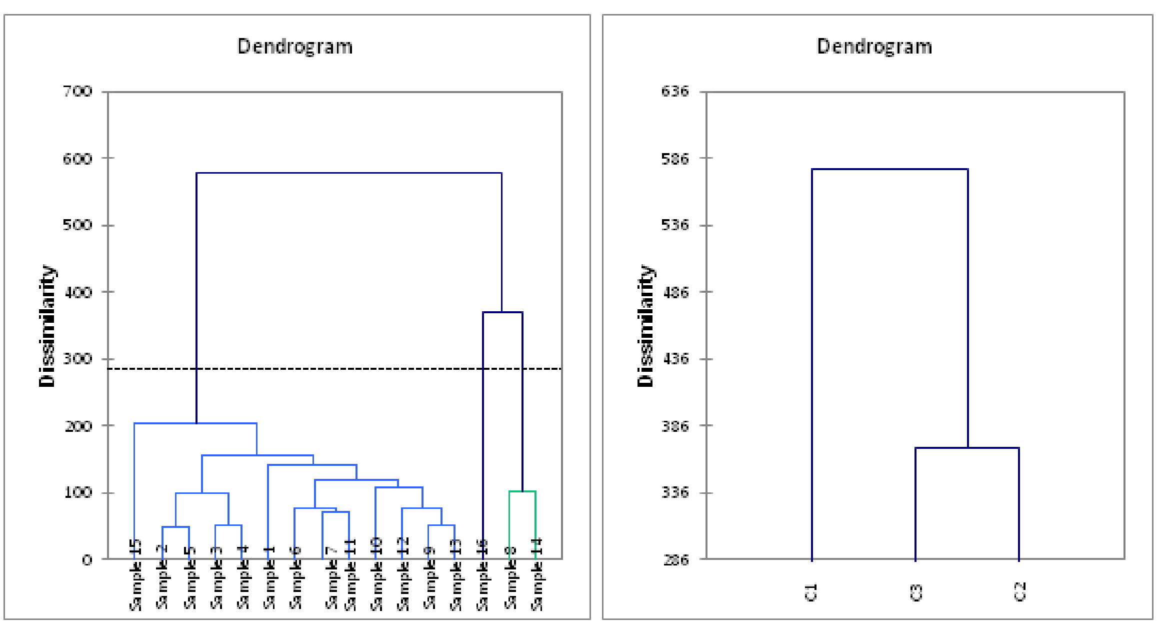

Fig. 2: Dendrogram showing clustering of water samples of D.I. Khan tehsil based on studied water quality parameters.

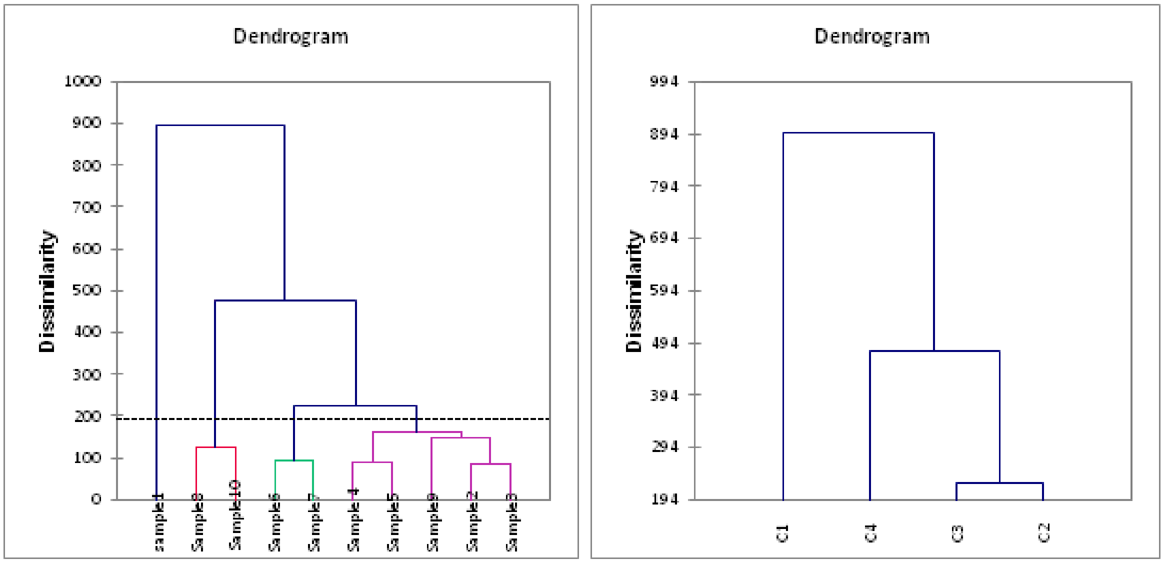

Fig. 3: Dendrogram showing clustering of water samples of Tehsil Daraban based on studied water quality parameters.

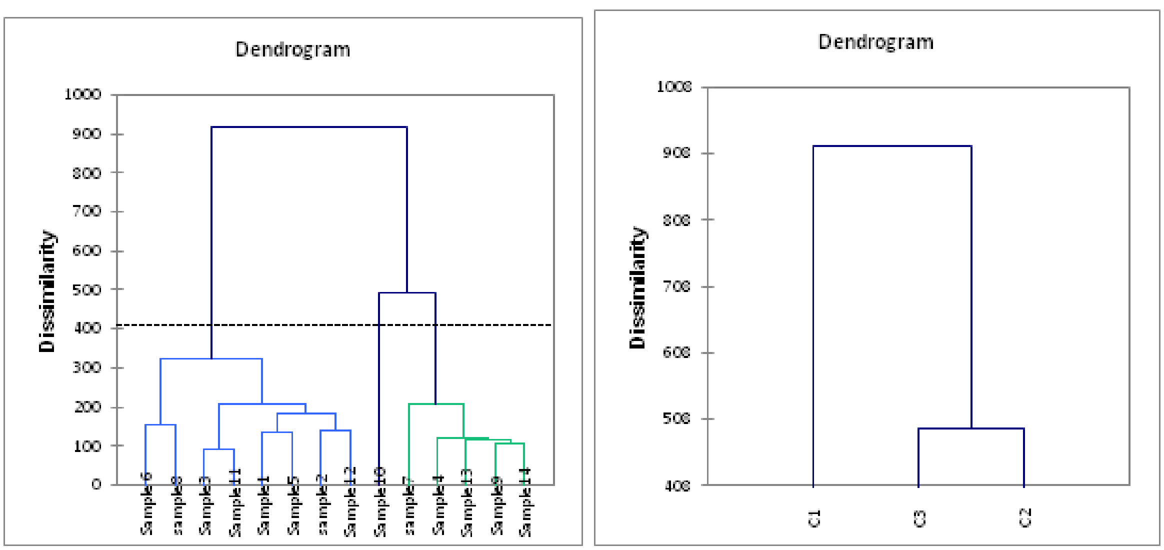

Fig. 4: Dendrogram showing clustering of water samples of Tehsil parova based on studied water quality parameters.

Principal component analysis: Principal component analysis was employed separately on the normalized datasets of (13 variables) three different regions of the study area. PCA identified the most meaningful parameters, responsible for major variations in the dataset and depicting data reduction with minimal loss of original information (Helena *et al.,* 2000). According to the results of PCA, the whole dataset of Tehsil D.I. Khan was classified into five significant factors (Table 4) with the Eigen values, i.e., F_1 (5.538), F_2 (3.421), F_3 (1.799), F_4 (1.318) and F_5 (1.144), respectively. Pertaining to the water quality in Tehsil D.I. Khan among the five major factors of PCA, F_1 has the largest factor, loading with accumulative variance of about 36.917%. F_1 has positive loading of EC, SO^{2-}_4, K, Hardness, Mg^{2+} and TDs, whereas, F_2 is responsible for 22.809% with positive loading of pH, NO^-_3, Ca^{2+} and As. F_3 factor represents about 11.992% of the total variance with positive loading of Cl^-, HCO^-_3, while, F_4 has the least factor loading and illustrated 8.789% accumulative variance. F_1 represents the most important water quality parameters that significantly influence the overall hydrochemistry of water. The main sources of these parameters might be the natural weathering of rocks and some anthropogenic activities (Ahada and Suthar, 2017).

Table 4: Factor loading of water quality variables of Tehsil D.I. Khan.

Variable	F1	F2	F3	F4	F5
EC	**0.852**	0.001	0.003	0.057	0.001
pH	0.127	**0.412**	0.084	0.012	0.134
$SO^{2-}{}_4$	**0.612**	0.304	0.009	0.048	0.002
NO_3^-	0.019	**0.588**	0.067	0.012	0.199
Na^+	0.243	0.000	0.085	**0.336**	0.123
K^+	**0.562**	0.234	0.018	0.001	0.072
Ca^{2+}	0.043	**0.689**	0.015	0.081	0.000
Hardness	**0.938**	0.020	0.003	0.001	0.000
Mg^{2+}	**0.749**	0.135	0.001	0.066	0.003
Cl^-	0.009	0.037	**0.809**	0.019	0.021
HCO_3^-	0.002	0.083	**0.520**	0.162	0.126
F^-	0.184	0.008	0.161	**0.334**	0.216
TDs	**0.854**	0.000	0.003	0.055	0.002
Turbidity	**0.343**	0.247	0.009	0.057	0.131
As	0.001	**0.664**	0.011	0.078	0.113
Eigen value	5.538	3.421	1.799	1.318	1.144
Variability (%)	36.917	22.809	11.992	8.789	7.628
Cumulative (%)	36.917	59.726	71.718	80.507	88.135

Similarly, pertaining to the application of PCA on water quality, dataset of tehsil Daraban was grouped into three major factors, contributing to 86.460% of total variance (Table 5). These three factors were selected on the basis of Eigen values higher than 1. The first factor was accounted for about 42.212% of the total variance. In the first factor $SO^{-2}{}_4$, EC, TDS, Turbidity, Ca^{2+}, K^+, Na^+ have the highest factor loading and depicted that these factors were the most important parameters, affecting the whole hydro-geochemistry of water of the study area. The second factor has accounted for approximately 30.764% of the variance, and has the positive loading of pH, $NO^-{}_3$, Mg^{2+}, F^-, As and hardness. The third factor is responsible for about 13.486% total variance with positive loading of $HCO^-{}_3$.

Table 5: Factor loading of water quality variables of Tehsil Daraban.

Variable	F1	F2	F3
EC	**0.916**	0.006	0.040
pH	0.027	**0.540**	0.121
$SO^{2-}{}_4$	**0.828**	0.005	0.074
NO_3^-	0.080	**0.646**	0.177
Na^+	**0.527**	0.276	0.145
K^+	**0.494**	0.302	0.120
Ca^{2+}	**0.501**	0.295	0.012
Mg^{2+}	0.386	**0.534**	0.034
Cl^-	**0.355**	0.009	0.271
HCO_3^-	0.092	0.000	**0.636**
F^-	0.136	**0.615**	0.194
TDs	**0.917**	0.007	0.038
Hardness	0.445	**0.511**	0.028
Turbidity	**0.527**	0.140	0.015
As	0.102	**0.728**	0.117
Eigen value	6.332	4.614	2.023
Variability (%)	42.212	30.762	13.486
Cumulative (%)	42.212	72.974	86.460

Moreover, PCA has divided the whole dataset of water quality parameters of tehsil Parova into three major factors with Eigen values higher than 1 (Table 6). Factor 1 accounted for about 42.212% of total variance with positive loading of EC, $SO^{2-}{}_4$, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, TDs, hardness and Turbidity. The F_2 was responsible approximately for 30.762% of total variance, with positive loading of PH, $NO^-{}_3$ and As, whereas, the F3 factor was responsible for about 13.486% total variance, with positive loading of $HCO^-{}_3$. The trend of loading was approximately similar in all the three studied sites. The first component of PCA in all the studied sites has the positive loading of major ions, i.e., K^+, Ca^{2+}, Cl^-, Na^+, Mg^{2+}. These ions accounted for achieving high values of EC, TDs, hardness and turbidity, respectively. These ions are major contributors in stabilizing the hydrochemistry variability of ground water. Consequently, these ions are geogenic or anthropogenic in nature. The first component of PCA includes hydro chemical variables, coming from mineralization or weathering of rocks, whereas, the other variables (NO_3^-, As, $SO^{2-}{}_4$) in other factors of PCA suggested intervention of anthropogenic actions (Reid and Spencer, 2009).

Table 6: Factor loading of water quality variables of tehsil Parova.

Variable	F1	F2	F3
EC	**0.957**	0.075	0.200
pH	0.163	**0.735**	0.347
$SO^{2-}{}_4$	**0.910**	-0.074	0.272
NO_3^-	0.282	**0.804**	-0.421
Na^+	**0.726**	0.276	0.381
K^+	**0.703**	0.302	-0.346
Ca^{2+}	**0.708**	0.295	-0.111
Mg^{2+}	**0.621**	0.034	-0.184
Cl^-	**0.596**	0.095	0.521
$HCO3^-$	-0.303	0.001	**0.798**
F^-	0.369	**0.784**	-0.440
TDs	**0.957**	0.083	0.195
Hardness	**0.667**	-0.715	-0.168
Turbidity	**0.726**	0.375	-0.124
As	0.319	**0.853**	-0.343
Eigen value	6.332	4.614	2.023
Variability (%)	42.212	30.762	13.486
Cumulative (%)	42.212	72.974	86.460

Correlation matrix: Correlation matrix is further used to support the results obtained from PCA. It is often used to establish relationship between various parameters of water that can identify the probable source of the solutes and the processes, involved in regulating the hydrochemistry of water (Parizi and Samani, 2013; Varol and Davraz, 2015). A high correlation (r) 1 or near to 1 is considered as the strong positive relation and r value near to zero is regarded as no relationship (Manish *et al.*, 2006). More precisely, the parameters showing r values higher than 0.7 are strongly correlated and less than 0.7 to 0.5 are considered as moderately correlated. The correlation matrix was prepared for 13 physicochemical parameters of water quality (Tables 7, 8, 9). According to the results of correlation matrix EC is positively correlated to $SO^{2-}{}_4$, Na^+, K^+, Hardness, Mg^{2+}, TDS, turbidity. EC represents the total load of cations and anions in water. Various salt species such as Ca^{2+}, Mg^{2+}, Na^+, Cl^-, HCO_3^-, SO_4^{2-} and K^+ are responsible for achieving high TDS concentration (Ahada and Suthar, 2017). High TDS level is detrimental to health for human and soil quality. Hardness has positive correlation Ca^{2+} and Mg^{2+} in all studied water samples. Positive correlation illustrated that hardness in ground water of the study area is due to calcium and magnesium ions (Jalali, 2005). Correlation between Na^+, Ca^{2+}, Mg^{2+} and Cl^- confirmed their origin from similar sources, such as, from weathering of rocks rich in these minerals. The results of the study also suggested that water of the study area is rich in salts of Mg^{2+}, Ca^{2+}, Na^+ and Cl^- (Singh *et al.,* 2012). Similar positive relationship among water quality parameters of three different study areas denoted that the ground water of the study area has same hydrological characteristics.

Table 7: Pearson's correlation matrix of water quality parameters in tehsil D.I. Khan

Variable	EC	pH	SO^{2-}_4	NO^-_3	Na^+	K^+	Ca^{2+}	Hardness	Mg^+	Cl^-	HCO_3^-	F^-	TDs	Turbidity	As
EC	**1**														
pH	0.330	**1**													
SO^{2-}_4	**0.665**	-0.047	**1**												
NO_3^-	-0.123	-0.454	0.298	**1**											
Na^+	**0.531**	-0.065	0.264	-0.071	**1**										
K^+	**0.638**	**0.563**	0.323	-0.304	0.314	**1**									
Ca^{2+}	0.239	0.497	-0.413	**-0.590**	0.225	**0.588**	**1**								
Hardness	**0.902**	0.379	**0.687**	-0.243	0.475	**0.820**	0.323	**1**							
Mg^{2+}	**0.703**	0.045	**0.955**	0.102	0.308	0.483	-0.214	**0.809**	**1**						
Cl-	-0.039	-0.165	-0.056	0.134	0.002	0.168	0.048	-0.004	-0.107	**1**					
HCO_3-	-0.075	-0.013	-0.062	-0.194	0.136	0.113	-0.012	0.002	-0.010	**0.629**	**1**				
F^-	-0.247	-0.166	-0.319	0.428	0.065	-0.215	-0.144	-0.375	-0.465	0.328	-0.094	**1**			
TDs	**1.000**	0.320	**0.671**	-0.123	**0.530**	**0.630**	0.232	**0.902**	**0.709**	-0.046	-0.075	-0.258	**1**		
Turbidity	0.383	0.034	**0.752**	0.422	0.147	0.318	-0.259	0.420	**0.691**	-0.169	-0.243	-0.272	0.382	**1**	
As	-0.083	**0.589**	-0.365	**-0.503**	-0.179	0.456	**0.543**	0.065	-0.237	0.303	0.280	-0.009	-0.093	-0.210	**1**

Table 8: Pearson's correlation matrix of water quality parameters in Daraban Tehsil.

Variable	EC	pH	$So^2_4{}^-$	NO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	F^-	TDs	Hardness	Turbidity	As
EC	**1**														
pH	0.261	**1**													
SO^2-$_4$	**0.946**	0.214	**1**												
NO_3	0.235	0.404	0.050	**1**											
Na^+	**0.842**	**0.590**	**0.717**	0.465	**1**										
K^+	**0.548**	-0.396	**0.542**	-0.031	0.078	**1**									
Ca^{2+}	**0.550**	-0.415	**0.563**	-0.120	0.154	**0.871**	**1**								
Mg^{2+}	**0.514**	-0.421	**0.587**	-0.345	0.007	**0.916**	**0.793**	**1**							
Cl^-	**0.568**	0.376	**0.560**	0.079	**0.597**	0.250	**0.537**	0.157	**1**						
HCO3	-0.126	0.017	-0.111	-0.268	0.111	-0.400	-0.210	-0.364	0.260	**1**					
F^-	0.308	0.419	0.116	**0.987**	**0.515**	0.026	-0.041	-0.276	0.133	-0.358	**1**				
TDs	**1.000**	0.264	**0.944**	0.244	**0.845**	**0.547**	**0.547**	0.510	**0.567**	-0.128	0.317	**1**			
Hardness	**0.544**	-0.436	**0.605**	-0.306	0.045	**0.940**	**0.878**	**0.988**	0.262	-0.334	-0.232	**0.540**	**1**		
Turbidity	**0.730**	0.286	**0.667**	0.437	**0.679**	0.213	0.256	0.147	0.287	-0.454	**0.523**	**0.733**	0.176	**1**	
As	0.273	**0.542**	0.095	**0.974**	**0.538**	-0.078	-0.137	-0.360	0.187	-0.297	**0.981**	0.282	-0.322	0.495	**1**

Table 9: Pearson's correlation matrix of water quality parameters in tehsil Parova.

Variables	EC	pH	$So^2_4{}^-$	NO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	F^-	TDs	Hardness	Turbidity	As
	1														
EC	**-0.699**	**1**													
pH	**0.914**	**-0.799**	**1**												
SO^2-$_4$	-0.072	0.306	-0.313	**1**											
NO_3	**0.950**	**-0.779**	**0.917**	-0.188	**1**										
Na^+	-0.120	0.118	-0.114	-0.128	-0.107	**1**									
K^+	-0.185	0.057	-0.111	0.023	-0.229	-0.297	**1**								
Ca^{2+}	**0.870**	**-0.820**	**0.916**	-0.195	**0.861**	-0.275	-0.064	**1**							
Mg^{2+}	**0.502**	-0.347	0.446	-0.066	0.385	0.360	-0.350	0.358	**1**						
Cl-	**0.595**	-0.155	0.493	-0.009	**0.571**	-0.002	**-0.533**	0.476	0.338	**1**					
HCO3	0.277	-0.449	0.320	0.090	0.370	-0.201	**0.532**	0.366	-0.357	-0.255	**1**				
F-	**1.000**	**-0.697**	**0.917**	-0.074	**0.948**	-0.120	-0.180	**0.872**	**0.506**	**0.601**	0.271	**1**			
TDs	**0.959**	**-0.774**	**0.937**	-0.098	**0.902**	-0.158	-0.061	**0.911**	0.456	0.494	0.389	**0.961**	**1**		
Hardness	0.391	0.092	0.342	0.082	0.336	-0.241	-0.235	0.116	0.177	**0.594**	-0.253	0.397	0.308	**1**	
Turbidity	0.367	-0.148	0.300	-0.010	0.402	-0.015	-0.292	0.328	-0.179	0.241	0.146	0.365	0.330	0.028	**1**

CONCLUSION

The adequacy of ground water for its consumption is directly related to its physicochemical properties. Similarly, the portability of water is markedly influenced by regulating its hydrochemistry through regular monitoring of ground water. The current study aimed to determine the quality of ground water of D.I. Khan. It was found in the course of study that all the studied parameters were within the safe limits of WHO except $SO^2_4{}^-$, Ca^{2+}, Cl^-, hardness, As and F^-. Multivariate approach was recognized as an ideal tool in identifying spatial variability and source apportionment. Correlation matrix determined different relationship among the studied parameters. Water of the study area was rich in salts of Mg^{2+}, Ca^{2+} and Na^{+}. The main source of salt was found to be natural weathering of rocks and also identified human interventions as another deteriorating factor. In view of these results, a higher concentration of arsenic in the majority of water samples of the study area was found to be alarming threat to the health of local communities. Therefore, monitoring of water supply system by the management team and concerned authorities is strongly recommended to prevent the health hazards of contamination in near future. Consciousness about the risks of polluted drinking water and the significance of safe and clean drinking water for sound living ought to be made in the labor related with water supply schemes in the district through administration trainings. This awareness should also be spread within the community in conjunction with the provision of water purification and filtration facilities.

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