Asian Journal of Water, Environment and Pollution, Vol. 13, No. 3 (2016), pp. 85–93.
DOI 10.3233/AJW-160030

Assessment of Water Quality of Tung Dhab Drain—An International Water Channel—Using Multivariate Statistical Techniques

Rajbir Kaur and Anish Dua[1]*
PG Department of Zoology, Khalsa College, Amritsar – 143001, Punjab, India
[1]Aquatic Biology Laboratory, Department of Zoology, Guru Nanak Dev University, Amritsar – 143005, Punjab, India
✉ anishdua@gmail.com

Received May 27, 2015; revised and accepted June 21, 2016

Abstract: Different multivariate statistical techniques were applied to interpret the temporal variations in water quality of Tung Dhab drain, Amritsar, India and further to identify water pollution sources. Data was collected seasonally for a period of two years (2012-2013) using 34 water quality parameters. The recorded values for variables like turbidity, total suspended solids, biochemical oxygen demand, chemical oxygen demand, oil & grease, nitrate as N, lead, chromium, nickel and zinc were much higher than the recommended permissible discharge limits into inland waters. Significant correlations were found in between different physicochemical parameters ($p \leq 0.05$; $p \leq 0.01$). Cluster Analysis (CA) grouped four sampling seasons into two clusters. CA confirmed that the water quality of rainy season was different from other three seasons in terms of similarity and distance indices. Principal Component Analysis/Factor Analysis (PCA/FA) explained minerals, organic, agricultural and industrial pollutants responsible for deterioration of drain water quality. The present study will help environmental agencies to make and enforce decisions regarding improvement of water quality of Tung Dhab drain.

Key words: Tung Dhab drain, water quality parameters, municipal & industrial pollutants, agricultural runoff, multivariate statistical analysis.

Introduction

Nowadays, the water quality is the major issue of concern due to the ever increasing pollutant loads in both developing and developed countries. Worldwide, a huge quantity of municipal and industrial origin pollutants along with agricultural run-off enters into the rivers along their vast drainage basins (Singh et al., 2005). According to Carpenter et al. (1998), the municipal and industrial wastewater discharge constitutes the constant polluting source, whereas the surface runoff is a seasonal phenomenon. Nutrients from agricultural and urban runoff cause diverse problems such as toxic algal blooms, loss of oxygen and loss of biodiversity. Various pollutants that include solids, nutrients (e.g. phosphorus and nitrogen), toxic substances (e.g. heavy metals and pesticides) and other substances (e.g. chloride and salts) that come from variety of sources, seriously degrade the aquatic ecosystems (Ouyang et al., 2006).

Therefore, regular monitoring programmes are required for reliable estimates of water quality, effective pollution control and water resource management (Singh et al., 2005). The application of different multivariate approaches offers a better understanding of water quality and ecological status of the studied systems (Razmkhah et al., 2010; Yang et al., 2010; Wang et

*Corresponding Author

al., 2013). PCA/FA is a very powerful technique used to reduce the dimensionality of various inter-related variables of large data sets without losing the original information. To achieve this reduction, data sets are transformed into principal components (PCs) (Shreshta and Kazama, 2007; Qadir et al., 2008). Varifactors (VFs), a new group of variables, are obtained by rotating the axis defined by PCA. This procedure reduces the contribution of less significant variables to further simplify the data obtained from PCA (Koklu et al., 2010). Cluster analysis helps in grouping objects into clusters on the basis of homogeneity and heterogeneity. Hierarchical agglomerative clustering (HACA) is the most common approach to classify variables or objects into clusters, by starting with the most similar pair of objects and forming higher clusters step by step (Shrestha and Kazama, 2007).

The present study was aimed to investigate the main physical and chemical characteristic changes in water quality of Tung Dhab drain during the years 2012-2013, usage of various multivariate data reduction techniques such as PCA/FA and CA that identify various water quality parameters responsible for temporal variations, to assess the degree of contamination and to provide information about the similarities or dissimilarities between sampling.

Materials and Methods

Study Area

Tung Dhab Drain near village Mahal (31°67′612″N and 74°74′280″E) was chosen as the sampling site during the present study (Figure 1). Tung Dhab drain is a 20 km long storm water drain designed to remove excess rainwater and surface runoff but is being used as a dumping ground for untreated waste (municipal and industrial) and agricultural runoff leading to contamination of underground water. It has a catchment area of 208.83 km^2, capacity of 53 m^3/min, bed width of 13.72 m (at outfall) and 1.22 m (at starting point). The drain receives effluents from the other two drains that is the Gumtala drain and the Verka drain and also receives sewage water of the Amritsar city. The level of pollution in the drain is extremely high, as no treatment plant is yet installed along the drain. The drain covers many areas/villages along its course, after that, it joins with Hudiara drain near Khiala Khurd and further enters the river Ravi near the international border (Figure 1).

Sampling and Physico-chemical Analysis of Wastewater

Water samples were collected from the site during the dry (winter – January; spring – March) and wet seasons (summer – May; rainy – August) in 2012-2013 once in a month. Samples were collected in pre-treated, properly labelled plastic and glass bottles, immediately preserved and analyzed as recommended in manual of APHA/AWWA/WEF (2005).

The four water quality parameters i.e. pH, temperature (temp), dissolved oxygen (DO) and electrical conductivity (EC) were measured at the sampling sites using portable water analyzer kit (WTW Multy 340i/SET). Electrodes in the kit were calibrated prior to every sampling event by following the instructions supplied with the equipment. Turbiquant 1100 IR was used for measuring turbidity (TD). Biochemical oxygen demand (BOD) was calculated using Oxitop measuring system at 20ºC in a thermostat (TS 606-G/2-i). Acidity (AD), alkalinity (AK), total hardness (TH), calcium (Ca), magnesium (Mg), total solids (TS), total dissolved solids (TDS), total suspended solids (TSS) and oil & grease (OG) were calculated using standard methods recommended in manual of APHA/AWWA/WEF (2005). Chemical oxygen demand (COD), ammonium as N (NH_4-N), nitrate as N (NO_3-N), nitrogen (N), phosphates (P), potassium (K), chlorides (Cl^-) and heavy metals like lead (Pb), manganese (Mn), nickel (Ni), chromium (Cr), cadmium (Cd), iron (Fe), copper (Cu) analysis was done by using Merck cell test kits & heavy metal testing kits and their concentrations were measured using the UV/VIS spectrophotometer (Spectroquant® Pharo 300). Mean±S.E. values were calculated for water quality data of Tung Dhab drain using Minitab statistical software (MINITAB, version 14).

Data Treatment and Multivariate Statistical Methods

The variables chosen for present study were normally distributed as confirmed by KolmogoroveSmirnov (KeS) statistics. Karl Pearson's Correlation matrix was constructed using the mean values (seasons) of studied parameters using SPSS Software. Significant correlated values between different parameters were further tested for significance by applying *t*-test (MINITAB). The mean values of data set (34 variables), standardized through *z* scale transformation were subjected to three multivariate techniques: cluster analysis (CA), principal component analysis and factor analysis (PCA/FA) as per

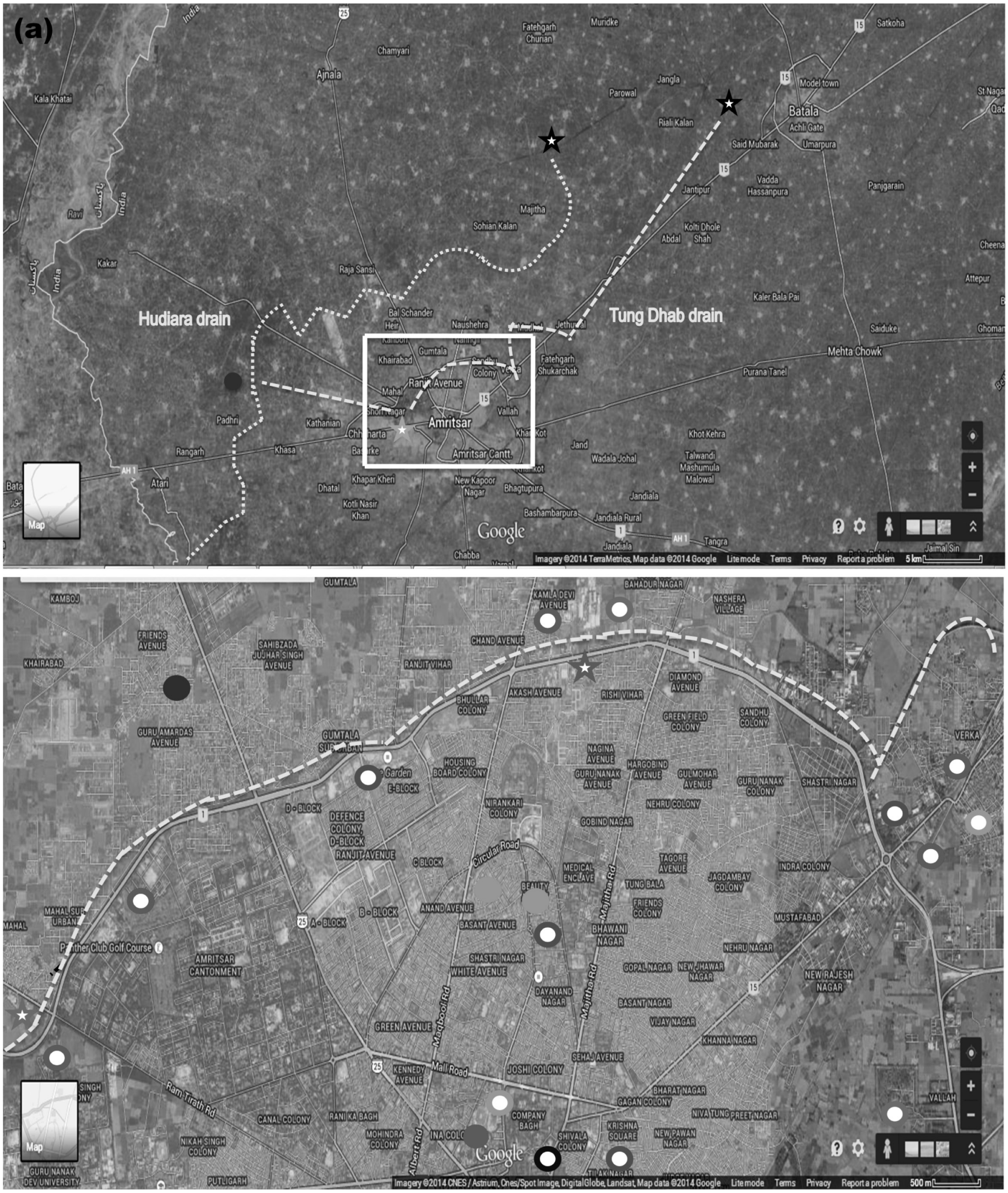

Figure 1: Map showing Tung Dhab drain and Hudiara drain. (a) The sampling site is marked by a star (★); origin of drains is shown by (★); confluence of Tung Dhab drain and Hudiara drain is marked by (●). (b) Map showing main industries and sewer outfalls along Tung Dhab drain. (O) is indicating sewer outfalls; (O) metal foundries; (O) paper mill; (O) food; (●) leather; (●) chemical industries.

Source: **Adapted from Google earth maps(R), accessed August, 2014.**

standard methodologies (Shreshta and Kazama, 2007; Wang et al., 2013). All statistical tests and computations were performed using the SPSS statistical software (Version 16.00) and PAST statistical software (Version 3.0).

Results and Discussion

Analytical Results

Table 1 represents summary of mean ± S.E. values of 34 physicochemical parameters of municipal wastewater of Tung Dhab drain studied for four seasons over a period of two years. The average concentration of variables such as TD, TSS, BOD, COD, OG, NO_3-N and heavy metals like Cr, Mn, Ni, Pb, Zn and As were much higher than the recommended discharge limits into inland waters stated under Environment Protection Amendment Rules (EPAR, 2012). The elevated values for different water quality parameters pointed towards the deteriorated state of Tung Dhab drain. The present study recorded higher values of COD and BOD in summer season and lower concentrations during rainy season (although the values still exceeded the discharge limits) due to dilution of organic matter caused by huge volume of rain water. The increased values of COD and BOD indicated contamination with organic wastes and, therefore, pointed towards the anthropogenic stress on the water quality of drain.

The increased values of NO_3-N due to sewer outfalls and runoff from the adjoining agricultural lands in the drain water leads to depletion of dissolved oxygen. The decreased DO values also indicated the dissolved oxygen being used by the microorganisms during the biodegradation of huge amounts of organic waste. EC values exceeded the standard limit value during three sampling seasons except for rainy season. The higher EC values are attributed to the elevated degree of anthropogenic activities along the course of the drain. The elevated values of heavy metals such as Cr, Mn, Ni, Pb, Zn and As were due to the discharge of metal, leather & chemical industries and metal foundries along the course of the drain. Similar results were reported in studies that assessed seasonal impacts of sewage pollution on water quality (Najar and Khan, 2012; Bhat et al., 2013; Wang et al., 2013).

Karl Pearson's Correlation Coefficients

Highly significant correlations (0.90-1.0) among the studied physicochemical parameters along with the calculated *t* values are given in Table 2. LP bears significant negative correlation with TSS and TS, DO and Mn. The inverse relationship between LP and TSS is a normal process as less amount of light enters into the water body due to the presence of large amount of suspended particles. DO has strong significant negative correlation with TSS i.e., DO decreases as amount of TSS in water increases. It is concluded from these negative correlations that less light enters into the drain water due to high concentrations of TS and TSS, which reduced the photosynthetic activity and in turn lowers the amount of dissolved oxygen.

Cluster Analysis

A dendrogram was constructed to identify temporal similarity (Bray Curtis) and distance (Ward's method) between different sampling seasons using cluster analysis (Figure 2). Cluster analysis grouped four seasons into two clusters: cluster I corresponds to rainy season, cluster II grouped the spring, summer and winter seasons. Spring and summer seasons showed maximum similarity of 93.3%. The similarity between spring and winter was more (92.4%) followed by summer and winter with the value of 88.6% (Figure 2A). The results obtained through Ward's method were further supported by Bray Curtis method of clustering. The least Euclidean distance (229) was seen for spring and summer seasons and highest distance (656) between rainy and the other three seasons (Figure 2B). The calculated distance between winter and spring seasons (320) was less than winter and summer season (443). These two dendrograms confirmed our finding that water quality of rainy season was different from other three seasons in terms of similarity and distance indices.

Principal Component Analysis

The scree plot was used to identify the number of PCs during seasonal sampling of physicochemical parameters (Figure 3). The 34 physicochemical parameters were reduced to three main factors (factor 1, 2 and 3). Factor 1 with the largest eigenvalue of 17.85 corresponds to 52.5% of the total variance. The second factor corresponds to the second eigenvalue (9.92) and accounts for 29.2% of total variance. The third factor corresponding to the lowest eigenvalue (6.23) accounts for approximately 18.3% of the total variance. A pronounced change of slope was seen after the 3rd eigenvalue as the remaining 31 factors have eigenvalues of less than one and therefore not considered significant and ignored. Loadings of three retained PCs are shown in Table 3.

There were 16 major factors contributing to the water quality of Tung Dhab drain as analyzed from

Table 1: Physicochemical characteristics of water samples collected from Tung Dhab drain in different seasons

Parameters	*Sampling Seasons*				*EPAR MPL*
	Winter	*Spring*	*Summer*	*Rainy*	
	Mean±S.E	*Mean±S.E*	*Mean±S.E*	*Mean±S.E*	
Temp	22.46±0.26	25.36±0.60	31.63±0.30	28.33±0.29	20-35
pH	7.72±0.01	6.92±0.01	7.68±0.01	7.08±0.005	5.5-9
DO	0.31±0.01	0.56±0.01	0.19±0.02	0.83±0.02	-
EC	1082.7±1.45	1065.0±1.15	1038.70±1.20	958.67±1.20	-
TD	306.22±1.83	283.13±1.17	172.43±1.07	126.17±1.59	300
LP	8.53±0.20	9.38±0.02	9.23±0.09	10.26±0.01	-
AD	145.97±1.49	181.93±0.81	108.30±1.33	71.00±1.42	-
AK	539.20±0.64	664.67±0.78	752.77±1.07	375.20±1.89	-
CO_2	75.58±0.74	92.53±0.59	83.56±0.41	35.43±0.69	-
TH	285.67±0.92	215.17±1.34	300.50±1.57	241.77±1.07	-
Ca	96.25±0.64	77.49±0.79	65.64±0.50	76.33±0.64	100
Mg	45.63±0.64	33.43±0.38	32.39±0.64	39.63±0.48	100
TS	1292.3±1.22	1071.6±1.59	1020.9±1.25	820.93±1.32	-
TDS	870.10±0.72	788.23±0.97	750.93±1.85	703.70±2.59	-
TSS	422.17±0.49	283.70±0.75	270.00±0.63	117.23±1.27	100
COD	213.67±1.20	207.67±0.88	283.00±1.53	181.33±1.45	250
BOD	153.07±1.75	138.67±1.20	224.00±1.15	135.00±1.15	30
OG	262.33±1.20	325.33±0.88	343.67±2.73	289.67±0.88	10
N	51.67±1.20	49.33±1.45	39.67±1.20	37.33±0.90	-
P	3.92±0.02	3.49±0.03	3.09±0.02	3.84±0.01	10
K	19.40±0.40	21.7±0.69	17.63±0.55	18.80±0.57	-
NH_4-N	19.78±1.01	14.56±0.70	6.70±0.30	4.93±0.44	50
NO_3-N	15.67±0.46	11.50±0.64	4.50±0.64	3.50±0.56	10
Cl^-	83.78±0.83	91.21±0.90	68.51±0.66	48.98±0.73	1000
SO_4^{2-}	81.00±1.15	68.66±0.88	62.66±0.88	55.00±1.73	1000
Cr	0.77±0.02	0.74±0.01	0.42±0.03	0.46±0.02	0.1
Cd	0.197±0.001	0.236±0.001	0.336±0.001	0.106±0.01	2.0
Cu	1.086±0.01	1.28±0.01	1.11±0.02	0.14±0.01	3.0
Fe	0.260±0.02	0.85±0.02	0.59±0.01	0.19±0.02	3.0
Mn	2.65±0.01	2.17±0.01	2.37±0.01	2.08±0.01	2.0
Ni	3.43±0.01	2.34±0.005	1.83±0.01	1.67±0.008	3.0
Pb	3.73±0.08	2.18±0.01	2.28±0.008	1.66±0.01	0.1
Zn	3.30±0.49	9.63±0.60	5.63±0.13	1.70±0.62	5.0
As	0.14±0.04	0.18±0.08	0.20±0.11	0.020±0.005	0.2

Note: Values represent mean ± S.E; n = 8; all the values except pH, temp (ºC), TD (NTU) and EC (µS/cm) are reported in mg L^{-1}; EPAR – Environmental Protection Amendment Rules; MPL – Maximum Permissible Limits

factor loadings obtained from PCA. These were EC, TD, LP, AD, TS, TDS, TSS, N, NH_4-N, NO_3-N, Cl^-, SO_4^{2-}, Cr, Cu, Ni and Pb. PC1 was highly contributed by variables such as EC, TD, LP, TS, TDS, TSS, N, NH_4-N, NO_3-N, SO_4^{2-} and Ni with highest factor loadings (>0.90). High positive loadings indicated strong linear correlation between the factors and water quality parameters. PC2 explained 29.2% of the variance and

Table 2: Significant correlations (Karl Pearson's) between different water quality parameters along with *t*-values

Parameter	*Paired with*	*r*	*T*
Temp	Ca, NO_3-N, Cr	-0.939′, -0.913′, -0.937′	6.33**, 3.81*, 12.83**
pH	TH	0.974′	13.02**
DO	LP, TSS, Mn	0.958′, -0.909′, -0.933′	39.73**, 4.37*, 7.00 **
EC	LP,TD, TS, TSS, Cl^-, Cu	-0.925′, 0.913′, 0.929′, 0.942′, 0.938′, 0.932′	38.00**, 37.03**, 0.21^{NS}, 20.26**, 50.89**, 38.12**
TD	AD, TDS, N, NH_4-N, NO_3-N, Cl^- SO_4^{2-}, Cr	0.906′, 0.922′, 0.996″, 0.974′, 0.972′, 0.938′, 0.928′, 0.949′	3.99*, 32.02**, 4.46*, 5.27**, 5.27**, 4.29*, 4.06*, 5.13**
LP	TS, TDS, TSS, SO_4^{2-}, Mn, Pb	-0.976′, -0.931′, -0.991″, -0.933′, -0.928′, -0.929′	10.73**, 21.66**, 4.21*, 9.88**, 14.81**, 8.78**
AD	Cl^-	0.984″	3.62*
AK	Cd, As	0.972′	7.11**, 7.12**
CO_2^-	Cu, As	0.990″, 0.959′	5.74**, 5.70**
Ca	OG, Ni	-0.900′, 0.900′	9.41**, 12.79**
Mg	OG	-0.986″	12.61**
TS	TDS,TSS, NH_4-N, NO_3-N, SO_4^{2-}, Ni, Pb	0.987″, 0.996″, 0.923′, 0.908′, 0.989″, 0.936′, 0.951′	4.38*, 22.13**, 11.11**, 11.07**, 10.77**, 10.88**, 10.88**
TDS	TSS, N, NH_4-N, NO_3-N, SO_4^{2-}, Ni, Pb	0.969′, 0.922′, 0.965′, 0.956′, 1.0″, 0.977′, 0.953′	17.09**, 22.97**, 24.09**, 23.75**, 23.97**, 22.31**, 22.33**
TSS	SO_4^{2-}, Ni, Pb	0.971′, 0.902′, 0.939′	3.62*, 4.37*, 4.37*
COD	BOD, Cd	0.959′, 0.941′	9.53**, 10.22**
OG	P	-0.952′	16.44**
N	NH_4-N, NO_3-N, Cl^-, SO_4^{2-}, Cr	0.984″, 0.985″, 0.909′, 0.927′, 0.971′	52.79**, 42.67**, 4.54**, 8.64**, 12.76**
NH_4-N	NO_3-N, SO_4^{2-}, Cr, Ni	0.999″, 0.967′, 0.950′, 0.960′	4.69**, 23.91**, 3.22*, 2.97*
NO_3-N	SO_4^{2-}, Cr, Ni	0.957′, 0.960′, 0.956′	20.45 **, 2.91*, 2.56*
Cl^-	Cu	0.908′	7.94**
SO_4^{2-}	Ni, Pb	0.973′, 0.947′	12.65**, 12.70**
Cd	As	0.932′	4.64**
Cu	As	0.944′	3.49*
Fe	Zn	0.985″	2.92 *
Ni	Pb	0.950′	1.04 ^{NS}
Mn	Pb	0.958′	0.45^{NS}

Note: *r* represents Karl Pearson's correlation coefficient values: ′ correlation is significant at the 0.05 level (1-tailed) ″ correlation is significant at the 0.01 level (1-tailed). * indicates a significant difference at 5% level, ** depicts significant difference at 1% level and NS indicates Non Significant by *t* Test.

included Mg, AK, COD, OG, P and Cd. PC3 explained 18.3% of variance contributed to it by pH, TH and K. PC1 was highly contributed by minerals & nutrients, organic, agricultural and industrial pollution. PC2 was contributed by organic and mineral pollution while PC3 was contributed by mineral pollution.

For the more significant representation of the water quality parameters, the varimax rotation of three PCs was done which yielded the three new variables called varifactors (VFs). The loadings of VFs are presented in Table 3. The extracted VFs explained 100% of the variance in the data sets. The first two varifactors (VF1 – 51.4%; VF2 – 29.04%) explained less variance than that shown before rotation. Similar conclusions were drawn by Razmkhah et al. (2010) who worked on spatial and temporal variation in water quality of Jajrood River.

VF1 explained 51.4% of the total variance with high and positive scores on EC, TD, Ca, TS, TDS, TSS, N,

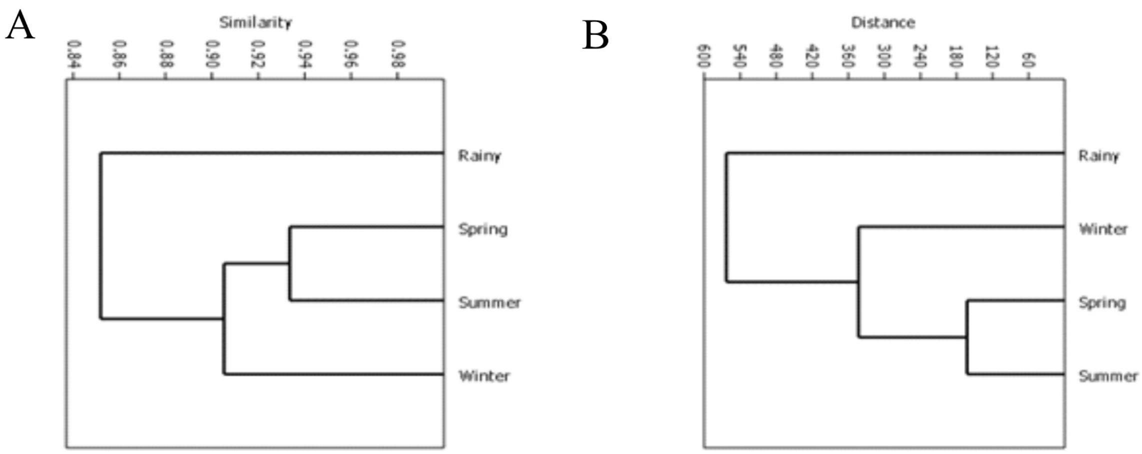

Figure 2: Dendrogram showing similarity (A) and distance (B) clusters obtained from water quality parameters of Tung Dhab drain.

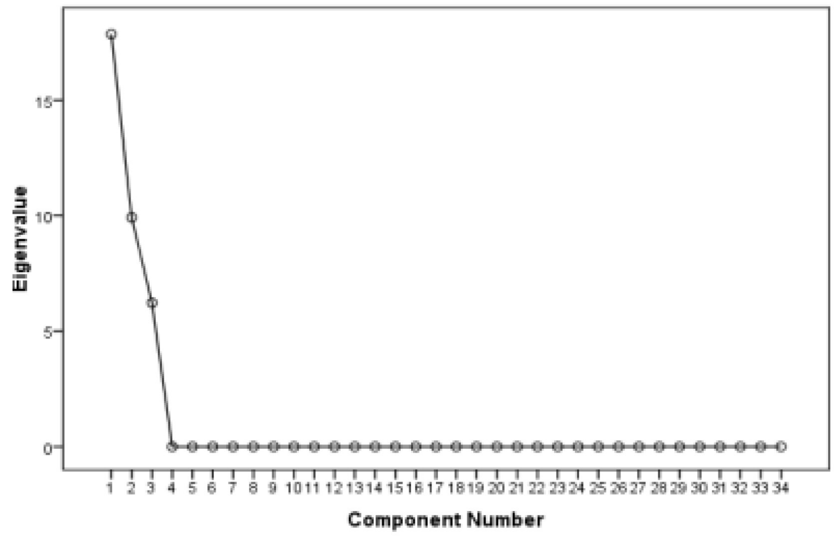

Figure 3: Scree plot of eigen values obtained from physicochemical data for all the seasons.

NH_4-N, NO_3-N, Cl^-, SO_4^{2-}, Cr, Ni, Pb & Temp and LP have negative load. These scores again confirmed that most of the variation in drain water quality was explained by nutrients, agricultural runoff, domestic wastewater and industrial effluents. Similar results were reported by Wang et al. (2013) when worked on water quality of Songhua river region. VF2 contained 29.04% of the total variance, which includes factors with positive scores like CO_2, AK, OG, Cd, Fe and Zn whereas Mg and P have a negative contribution to this varifactor. Mg being a basic metal increases the alkalinity of the environment. VF2 indicated high organic and industrial pollution. VF3 (19.6% of variance) indicated mineral and organic pollution, having high and positive loads of pH, TH and BOD whereas K contributed negatively to this varifactor. The increased BOD loads are interpreted as organic pollutants entering into the drain water from sewer outfalls. The increased nutrients demonstrated agricultural runoff flowing into the drain. Similar conclusions were drawn by Shrestha and Kazama (2007) and Yang et al. (2010) when different pollution patterns were studied in water quality studies. In the present study, PCA/FA concluded that the 100% of the total variance was due to minerals (soil leaching and runoff), organic (domestic sewage), nutrient group (agricultural runoff) and heavy metal pollution (industrial pollutants) responsible for deterioration of drain water quality.

Conclusion

The present study demonstrated the deterioration of water quality of Tung Dhab drain as evident from the

Table 3: Loadings of 34 variables on three significant principal components and varifactors for seasonal drain water samples

Variables	*PC1*	*PC2*	*PC3*	*Variables*	*VF1*	*VF2*	*VF3*
Temp	-.729	.646	-.225	Temp	**-.857**	.383	.344
pH	.401	.202	**-.894**	pH	.328	-.013	**.945**
DO	-.799	-.326	.506	DO	-.697	-.304	-.649
EC	**.962**	.267	.051	EC	**.882**	.457	.118
TD	**.961**	-.096	.258	TD	**.964**	.185	-.189
LP	**-.937**	-.148	.317	LP	**-.875**	-.226	-.428
AC	**.813**	.186	.552	AC	.764	.509	-.396
AK	.393	**.919**	.046	AK	.184	**.946**	.268
CO_2	.714	.656	.245	CO_2	.558	**.829**	.029
TH	.195	.294	**-.936**	TH	.106	.019	**.994**
Ca	.664	-.741	-.103	Ca	**.807**	-.587	-.067
Mg	.342	**-.847**	-.408	Mg	.509	**-.845**	.162
TS	**.982**	-.024	-.188	TS	**.959**	.116	.259
TDS	**.977**	-.171	-.128	TDS	**.988**	-.002	.157
TSS	**.974**	.060	-.219	TSS	**.932**	.182	.312
COD	.145	**.879**	-.454	COD	-.060	.703	.709
BOD	-.067	.781	-.621	BOD	-.249	.517	**.819**
OG	-.289	**.919**	.269	OG	-.476	**.879**	-.004
N	**.947**	-.183	.265	N	**.969**	.104	-.223
P	.138	**-.990**	-.006	P	.350	**-.894**	-.281
K	.410	-.204	**.889**	K	.464	.172	**-.869**
NH_4-N	**.955**	-.274	.113	NH_4-N	**.994**	-.027	-.105
NO_3-N	**.944**	-.299	.138	NO_3-N	**.989**	-.045	-.137
Cl^-	**.892**	.221	.393	Cl^-	**.831**	.508	-.228
SO_4^{2-}	**.981**	-.155	-.115	SO_4^{2-}	**.989**	.017	.149
Cr	**.848**	-.352	.395	Cr	**.913**	-.032	-.406
Cd	.310	**.937**	-.158	Cd	.094	**.883**	.460
Cu	**.800**	.576	.169	Cu	.658	.748	.084
Fe	.244	.722	.647	Fe	.095	**.922**	-.375
Mn	.785	-.027	-.619	Mn	.758	-.062	.649
Ni	**.917**	-.371	-.149	Ni	**.972**	-.207	.111
Pb	**.883**	-.214	-.418	Pb	**.899**	-.153	.411
Zn	.366	.609	.704	Zn	.240	**.859**	-.452
As	.609	.791	.057	As	.452	.860	.237
Eigen value	17.85	9.91	6.22	Eigen value	17.47	9.87	6.65
Var %	52.51	29.17	18.31	Var %	51.38	29.04	19.56
Cum %	52.51	81.68	100.0	Cum %	51.38	80.43	100.0

Note: Upper loads for each component and varifactor are given in bold format; Var % - % Variance explained, Cum % - % Cumulative variance values of various physicochemical parameters that were above the maximum permissible discharge limits. The similarity and distance indices on seasonal data suggested that the sampling seasons can be reduced to two periods—rainy and other three seasons. The drain water is heavily loaded with nutrient, organic, municipal and industrial pollutants as well as agricultural runoff as documented from PCA/FA studies. The study supports the incorporation of multivariate statistical analysis in the water quality monitoring programmes. The present study suggests immediate efforts at different levels (Governmental and environmental agencies) to improve the water quality of Tung Dhab drain on priority basis. The agencies should further ensure regulated dumping of untreated effluents from various sources to save this storm water drain and human population inhabiting along the banks of drain.

Acknowledgements

The authors would like to thank the Department of Zoology, Guru Nanak Dev University for providing necessary infrastructural facilities and University Grants Commission for providing the financial support for the present study.

References

APHA, AWWA and WEF (2005). Standard methods for the examination of water and wastewater (21st ed.). American Public Health Association, Washington, DC.

Bhat, S.A., Meraj, G., Yaseen, S., Bhat, A.R. and A.K. Pandit (2013). Assessing the impact of anthropogenic activities on spatio-temporal variation of water quality in Anchar Lake, Kashmir Himalayas. *International Journal of Environmental Sciences*, **3:** 1625-1640.

Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N. and V.H. Smith (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications*, **8:** 559-568.

EPAR (2012). General standards for discharge of environmental pollutants. Part A: Effluents into inland surface waters. Environmental (Protection) Amendment Rules, G.S.R. 152 (E), Ministry of Environment and Forests, India.

Koklu, R., Sengorur, B. and B. Topal (2010). Water quality assessment using multivariate statistical methods – A case study: Melen river system (Turkey). *Water Resource Management*, **24:** 959-978.

Najar, I.A. and A.B. Khan (2012). Assessment of water quality and identification of pollution sources of three lakes in Kashmir, India, using multivariate analysis. *Environmental Earth Sciences*, **66:** 2367-2378.

Ouyang, Y., Nkedi-Kizza, P., Wu, Q.T., Shinde, D. and C.H. Huang (2006). Assessment of seasonal variations in surface water quality. *Water Research*, **40:** 3800-3810.

Qadir, A., Malik, R.N. and S.Z. Husain (2008). Spatio-temporal variations in water quality of Nullah Aik – Tributary of the river Chenab, Pakistan. *Environmental Monitoring and Assessment*, **140:** 43-59.

Razmkhah, H., Abrishamchi, A. and A. Torkian (2010). Evaluation of spatial and temporal variation in water quality by pattern recognition techniques: A case study on Jairood River (Tehran, Iran). *Journal of Environmental Management*, **91:** 852-860.

Shrestha, S. and F. Kazama (2007). Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji river basin, Japan. *Environmental Modelling & Software*, **22:** 464-475.

Singh, K.P., Malik, A. and S. Sinha (2005). Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques: A case study. *Analytica Chimica Acta*, **538:** 355-374.

Wang, Y., Wang, P., Bai, Y., Tian, Z., Li, J., Shao, X., Mustavich, L.F. and B.L. Li (2013). Assessment of surface water quality via multivariate statistical techniques: A case study of the Songhua river harbin region, China. *Journal of Hydro-environment Research*, **7:** 30-40.

Yang, Y.H., Zhou, F., Guo, H.C., Sheng, H., Liu, H., Dao, X. and C.J. He (2010). Analysis of spatial and temporal water pollution patterns in Lake Dianchi using multivariate statistical methods. *Environmental Monitoring and Assessment*, **170:** 407-416.