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Water quality index of fresh water streams feeding Wular Lake, in Kashmir Himalaya, India

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The quality of drinking water is of vital concern for human health and life. The present investigation was aimed at assessing the water quality index (WQI) of five fresh water streams feeding Wular lake. Analysis of the data revealed that the WQI values ranged from a minimum of 45.4 to a maximum of 48.9. Among the study sites, Makdhoomyari stream showed higher values of WQI while as lowest was shown by Madhumati. Pearson matrix revealed that conductivity showed significant positive correlation with total dissolved solids ($P < 0.01$, $r = 0.807$) and total alkalinity ($P < 0.01$, $r = 0.635$). Total hardness was found to bear strong positive correlation with calcium ($P < 0.01$, $r = 0.819$), while temperature maintained inverse relationship with dissolved oxygen ($P < 0.01$, $r = 0.78$). The results support that the water parameters are desirable and the water quality of these streams falls under Category I based on water quality index values. Bray Curtis similarity dendrogram depicted that Erin and Gurura streams had maximum (99%) similarity; while as lowest similarity was observed between Makdhoomyari and Ashtungu streams (85.98%). The present finding revealed that these streams need immediate attention to prevent them from further deterioration.

Key words: Water quality index, Wular lake, Pearson correlation, Kashmir, Himalaya.

INTRODUCTION

The fresh water streams in Kashmir Himalaya are the potable sources of water for the region but unfortunately due to their exploitation for various purposes like drinking, domestic, agriculture, hydropower, etc. These vital resources are getting not only degraded but also polluted as the human population grows. Comparatively, little work has been done on the stream ecosystems of the Kashmir valley and it is only very recently some work have been conducted on the physicochemical and biological aspects of streams (Rashid et al., 2006; Bhat et al., 2011; Hussain and Pandit, 2011). Further, very recently, WQI was applied to evaluate the water quality of Vishav stream in Kashmir (Hamid et al., 2013). However, no substantial work on WQI has been carried out on the incoming streams of Wular lake, the largest fresh water lake in Indian subcontinent.

MATERIALS AND METHODS

Description of the study area and sites

Wular Lake is the largest fresh water body in the Indian Sub-continent is located 34 km northwest of Srinagar city. Geographically, the lake is situated at an altitude of 1,580 m (a.m.s.l), between 34°16´-34°20´N latitudes and 74°33´-74°44´E longitudes and covers an area of 189 km^2 (Shah et al., 2014). For

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Table 1. Location of five sampling sites around Wular lake.

Site	Sampling sites	Latitude E	Longitude N	Elevation
I	Makhdoomyari	34°17´39.8´´	74°37´-29.6´´	1586
II	Gurura	34°22´37.6´´	74°40´-21.7´´	1598
III	Erin	34°24´26.5´´	74°39´10.2 ´´	1599
IV	Madhumati	34°25´30.7´´	74°37´45.1´´	1594
V	Ashtang	34°24´30.3´´	74°32´23.6´´	1585

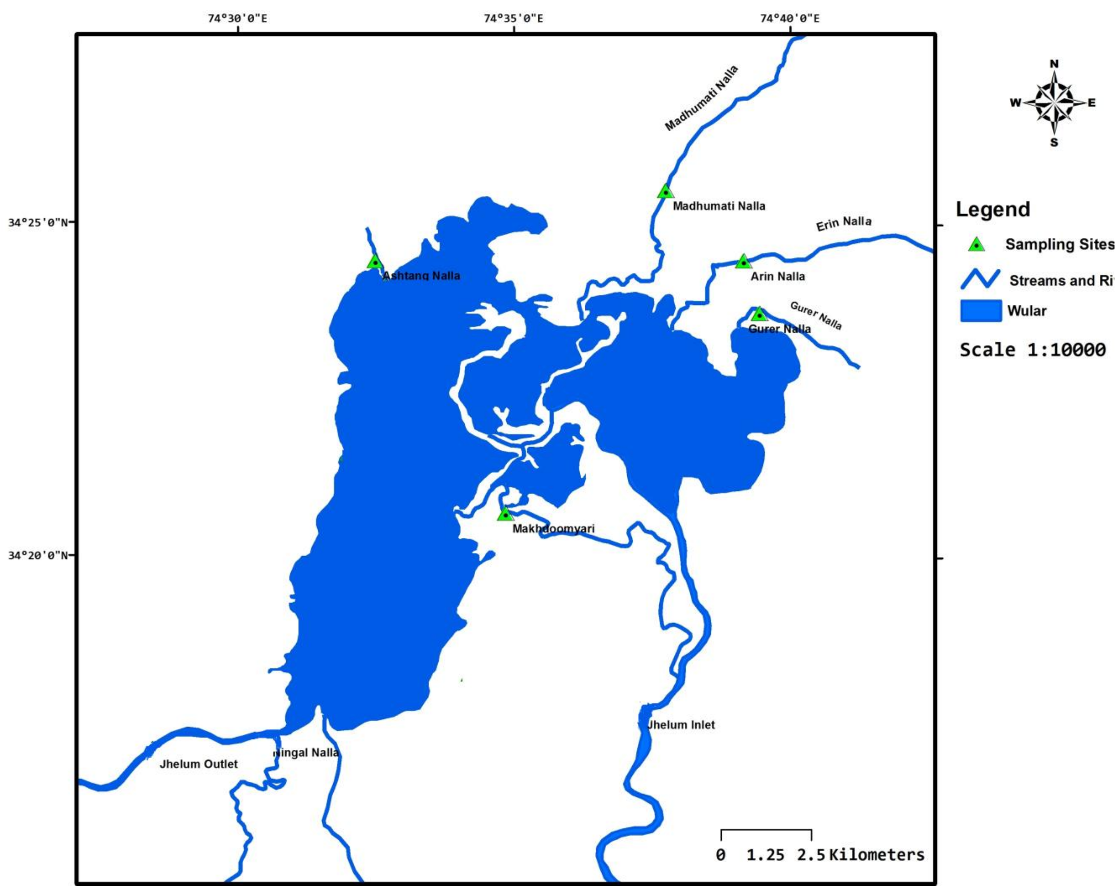

Figure 1. Location map of the study area with sampling stations.

the present investigation, five streams namely Makhdoomyari, Gurura, Erin, Madhumati and Ashtungu were selected which directly drain into the Wular lake for the assessment of water quality and calculation of Water Quality Index (Table 1 and Figure 1).

Sample collection and analysis

Surface water samples were collected in clean polyethylene bottles for the analysis of various physico-chemical parameters on monthly basis from December, 2011 to November, 2012. Parameters like water temperature and pH were measured on spot by means of a mercury thermometer and digital pH meter. The remaining parameters were analysed in the laboratory as per the standard methods of APHA (2005).

Statistical analysis

Statistical analysis were performed using SPSS (statistical version 16 for windows 7, SPSS and Chicago, IL,USA). The relation between various study sites were calculated by another software programme PAST (statistical version 1.93 for windows 7).

Calculation of Water Quality Index (WQI)

Eight water parameters were considered for calculation of water quality index (Tiwari and Manzor, 1988; Mohanta and Patra, 2000; Kesharwani et al., 2004; Padmanabha and Belagalli., 2005):

Water Quality I index (WQI) = $\Sigma qiwi$

Table 2. Physico chemical characteristics and water quality index at Site I.

Parameter	WHO Standard	Wi (unit weight)	Mean (±) S.D	WIQI
Temperature (ºC)	……		14.1±8.2	-
pH	8.5	0.319	7.8±0.3	17.01227
EC (µS/cm)	750	0.0036	232.3±80.8	0.111979
TDS (mg/l)	500	0.0054	155.6±54.1	0.112509
DO (mg/l)	5	0.5423	9.1±1.6	31.06837
Total alkalinity (mg/l)	200	0.0136	91±18.3	0.164498
Total hardness (mg/l)	300	0.009	133±41.3	0.16028
Calcium (mg/l)	75	0.0362	53.3±17.6	0.25693
Chloride (mg/l)	250	0.0108	10.4±4.2	0.01504
Nitrate (mg/l)	45	0.0603	0.76±0.33	0.00612
Water Quality Index ∑WiQi = 48.91				

Table 3. Physico chemical characteristics and water quality index at Site II.

Parameter	WHO Standard	Wi (unit weight)	Mean (±) S.D	WiQi
Temperature (ºC)	……		13.4±7.9	-------
Ph	8.5	0.319	7.8±0.3	17.01227
EC (µS/cm)	750	0.0036	214.3±64.8	0.103302
TDS (mg/l)	500	0.0054	143.5±43.4	0.10376
DO (mg/l)	5	0.5423	9.3±1.6	29.94038
Total alkalinity (mg/l)	200	0.0136	91.6±21.1	0.165582
Total hardness (mg/l)	300	0.009	124.2±37.3	0.149675
Calcium (mg/l)	75	0.0362	45.2±12.8	0.217884
Chloride (mg/l)	250	0.0108	10.1±3.6	0.014606
Nitrate (mg/l)	45	0.0603	0.80±0.4	0.006427
Water Quality Index ∑WiQi = 47.7				

Where qi (water quality rating) = 100 x (Va- Vi) / (Vs-Vi), when Va = actual value present in the water sample, Vi = ideal value (0 for all parameters except pH and dissolved oxygen which are 7.0 and 14.6 mg/L respectively). Vs = standard value. If quality rating qi = 0 means complete absence of pollutants, While 0< qi < 100 implies that, the pollutants are within the prescribed standard; When qi > 100 implies that, the pollutants are above the standards:

Wi (unit weight) = K / Sn

Where $\mathrm{K(constant)} = 1 + \frac{1}{\frac{1}{Vs1} + \frac{1}{Vs2} + \frac{1}{Vs3} + \frac{1}{Vs4} + \cdots \frac{1}{Vsn}}$, Sn = 'n' number of standard values.

RESULTS AND DISCUSSION

The annual average values of various physico-chemical properties and water quality index of five streams are presented in Tables 2 to 6 and in Figure 2. During the present study, the annual mean water temperature ranged from 12.8 to 14.8°C, with highest temperature being recorded at Site I and lowest at Site III. The higher temperature during the summer season can be attributed probably to high atmospheric temperature, low relative humidity (Sinha et al., 2004; Ayoade et al., 2006; Atobatele and Ugwumba, 2008). pH is an important parameter in water quality assessment as it influences many biological and chemical processes within a water body (Gray, 1999; Shah and Pandit, 2013). In this present study, pH value ranged between 7.7 at Site V to 7.9 at Site III. In the majority of studies conducted on freshwater ecosystems, the pH values are generally reported between 6 and 9 (Kamran et al., 2003).

Specific conductivity in aquatic ecosystems depends on ionic concentration or dissolved in organic substances. It can also be used to give a rough estimate of the total amount of dissolved solids in water. In the present study, the highest conductivity of 232 µScm^{-1} was registered at Site I as against the lowest of 123.7 µScm^{-1} being recorded at Site V. The high conductivity values recorded at Site I can be due to excessive use of agricultural fertilizers (Clenaghan et al., 1998).

A total dissolved solid is very useful parameter

Table 4. Physico chemical characteristics and water quality index at Site III.

Parameter	WHO Standard	Wi (unit weight)	Mean (±) S.D	WiQi
Temperature (ºC)	……		12.8±7.2	
pH	8.5	0.319	7.9±0.3	19.14
EC (µs/cm)	750	0.003615	215.6±70.2	0.103929
TDS (mg/l)	500	0.005423	144.4±47.0	0.104411
DO (mg/l)	5	0.5423	9.8±1.3	27.115
Total alkalinity (mg/l)	200	0.013558	90.4±22.6	0.163413
Total hardness (mg/l)	300	0.009038	118.2±35.5	0.142444
Calcium (mg/l)	75	0.036153	44.1±15.9	0.212582
Chloride (mg/l)	250	0.010846	9.1±2.9	0.01316
Nitrate (mg/l)	45	0.060256	0.80±0.4	0.006427
Water Quality Index ∑Wi Qi = 47.00				

Table 5. Physico chemical characteristics and water quality index at Site IV.

Parameter	WHO Standard	Wi (unit weight)	Mean (±) S.D	WiQi
Temperature (ºC)	……		13.6±7.7	-------
pH	8.5	0.319	7.7±0.2	14.88773
EC (µs /cm)	750	0.003615	123.7±39.6	0.059629
TDS (mg/l)	500	0.005423	142.1±56.4	0.102748
DO (mg/l)	5	0.5423	9.1±1	31.06837
Total alkalinity (mg/l)	200	0.013558	94.3±18.8	0.170463
Total hardness (mg/l)	300	0.009038	123.7±39.6	0.149072
Calcium (mg/l)	75	0.036153	47.7±13.1	0.229935
Chloride (mg/l)	250	0.010846	11.7± 5	0.01692
Nitrate (mg/l)	45	0.060256	0.6±0.2	0.00482
Water Quality Index ∑WiQi = 46.68				

Table 6. Physico chemical characteristics and water quality index at Site V.

Parameter	WHO Standard	Wi (unit weight)	Mean (±) S.D	WiQi
Temperature (ºC)	-	-	13.2 ±7.7	-
pH	8.5	0.319	7.9±0.4	19.14
EC (µs /cm)	750	0.003615	211.3 ± 68.5	0.101856
TDS (mg/l)	500	0.005423	141.6 ± 45.9	0.102386
DO (mg/l)	5	0.5423	10 ± 1.6	25.54233
Total alkalinity (mg/l)	200	0.013558	95.5 ± 22.4	0.172632
Total hardness (mg/l)	300	0.009038	117.3 ± 22.3	0.14136
Calcium (mg/l)	75	0.036153	42.9 ± 13.6	0.206797
Chloride (mg/l)	250	0.010846	8.9 ± 3.8	0.012871
Nitrate (mg/l)	45	0.060256	0.7 ± 0.3	0.005624
Water Quality Index ∑WiQi = 45.43				

describing chemical constituents of the water and can be in general related to the edaphic factor that contributes to the productivity within the water body (Goher, 2002). In the present study, total dissolved solids fluctuated between a high of 155.6 mg/L at Site I and a low of 82.9 mg/L at Site V. The concentration of total dissolved solids tends to be higher at Site I due to increased siltation caused by surface run-off (Shinde, 2011). Dissolved

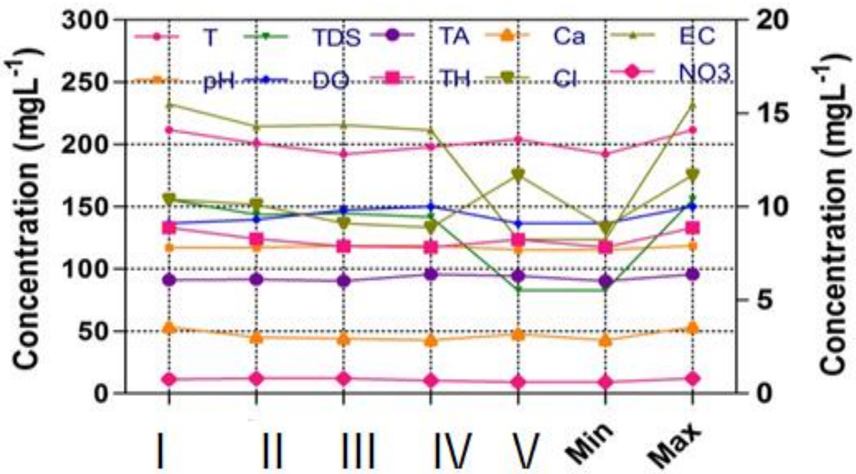

Figure 2. Spatial variation of annual average physico chemical characteristics of water.

oxygen is of paramount importance in all aquatic ecosystems as it regulates most of metabolic processes of organism and also the community architecture as a whole (Hussain and Pandit, 2011). The highest amount of dissolved oxygen (10 mg/L) was noted at Site IV while the lowest dissolved oxygen of 9.1 mg/L was evinced at Site V.

Alkalinity of water is the capacity to neutralize strong acids and is primarily a function of carbonate, bicarbonate and hydroxide content, being formed due to the dissolution of carbondioxide in water (Dallas and Day, 2004). During the present investigation, the maximum alkalinity of 95 mg/L was registered again at Site IV as against the minimum of 90.4 mg/L, being registered at Site III. The lower alkalinity values in the present investigation may be attributed to the high flow discharge (Harlow, 2003).

Hardness usually includes only Ca^{2+} and Mg^{2+} ions expressed in the terms of equivalent $CaCO_3$ (Das and Singh, 1996). During the entire study period, the highest value of total hardness (133 mg/L) were maintained at Site I as against the lowest of 117.3 mg/L at Site IV. The slightly higher hardness values may be attributed to the increased mobilization of elements (calcium and magnesium) from subsurface ground (Badrakh et al., 2008). Calcium is present in all waters as Ca^{2+} and is readily dissolved from rocks rich in calcium minerals, particularly as carbonates and sulphates, especially limestone and calcite (Chapman, 1996). In the present study the values of calcium hardness ranged between a high of 53.3 mg/L at Site I and a low of 42.9 mg/L at Site IV. The higher concentration of Ca^{2+} at Site I is the direct attribute of the lithology of catchment area as suggested by the findings of (Jaiswala et al., 2009). Chloride is chemically and biologically unreactive and it occurs naturally in all types of water. It enters surface waters, with the weathering of some sedimentary rocks (mostly rock salt deposits) and from industrial and sewage effluents, and agricultural and road run-off (Link and Inman, 2003). In the present study, the levels of chloride fluctuated between 11.7 mg/L at Site V and 8.4 mg/L at Site IV. The highest chloride concentrations at Site V may be explained on the account of the increasing anthropogenic activities (Mooers and Alexander, 1994).

Nitrate-nitrogen is known to be a vital nutrient for growth, reproduction, and the survival of organisms. In the present investigation, the concentration of nitrate could not show marked fluctuations and ranged from (0.6 mg/l) to (0.8 mg/l). Higher levels of nitrate were obtained at Sites II and III, while as lower levels were registered at Site V. High nitrate levels (>1 mg L^{-1}) are not good for aquatic life (Kilham, 1990). Further, the fluctuations noticed in the concentration of nitrate may be attributed to increased agricultural runoff and sewage contamination (Ali et al., 1999).

Water quality index (WQI)

The concept of water quality index (WQI) is based on the comparison of water quality parameters with respect to regulatory standard (Khan et al., 2003). WQI is defined as a rating that reflects the composite influence of different water quality parameters. WQI is calculated from the point of the suitability of surface waters for variety of uses including human consumption (Cude, 2001; Atulegwu and Njoku, 2004).

Analysis of the data revealed that the WQI values for the streams fluctuated from a high of 48.9 at Site I and to a low of 45.4 at Site IV with an average value of 47.1 ± 1.3 (Figure 3). Higher values of WQI obtained at Site I may be attributed to the fact that it drains out through the large catchment surrounded by huge tracts of agriculture fields and also has severe anthropogenic stresses as

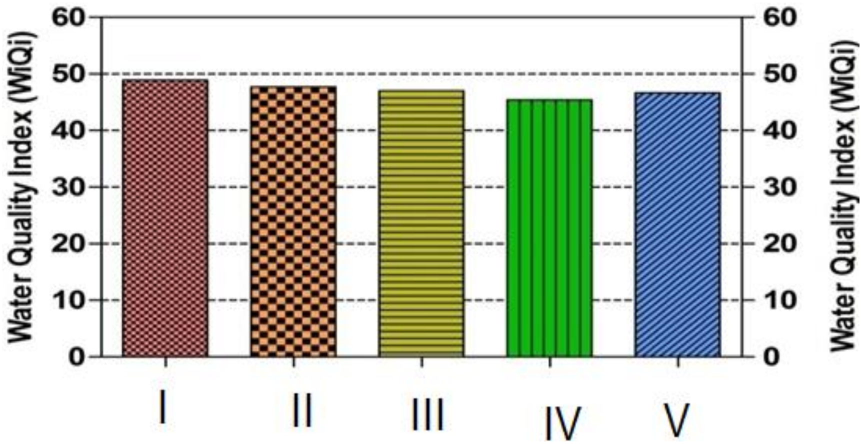

Figure 3. Variation of WQI of five study sites.

compared to other sites. On the other hand, lower WQI values obtained at Site IV may be on the account of its glacier fed nature, being surrounded by catchments of dense forests and meadows (Kanth and Hassan, 2012). The findings of the present study revealed that the water quality parameters are desirable and the water quality of these stream falls under Category I (that is, slightly polluted based on water quality index values) as per (Sinha et al., 2004). Yet, they need immediate attention as they are main sources of water to Wular lake.

Relationship among hydrological parameters

In the present study, water temperature showed negative correlation with almost all the parameters. The parameters depicting highly significant negative correlation with water temperature were dissolved oxygen ($P < 0.01$, $r = -0.784$), (Gurumahum et al., 2002; Idowu et al., 2013), nitrate ($P < 0.01$, $r = -0.820$) (Shah and Pandit, 2012), total dissolved solids ($P < 0.01$, $r = -0648$) and total hardness ($P < 0.01$, $r = -0.676$). Conductivity revealed highly significant positive correlation with total alkalinity ($P < 0.01$, $r = 0.635$). However, the highly significant positive correlation between conductivity and total dissolved solids was evident from the results which was proved statistically ($P < 0.01$, $r = 0.807$) (Heydari and Abbasi, 2013). The most significant positive correlation of total dissolved solids was recorded with total alkalinity ($P < 0.01$, $r = 0.765$) and chloride ($P < 0.01$, $r = 0.655$). Total hardness was found to bear strong positive correlation with calcium ($P < 0.01$, $r = 0.819$) (Kumar and Sinha, 2010) pH was the only exception which could not depict strong positive correlation with any of the parameters. The relationship among hydrological attributes has been also diagrammatically shown in Figure 4.

Bray Curtis similarity analysis shows that Sites II and III have maximum (99%) similarity, while as lowest similarity was observed between Sites I and V (Figure 5). This may be attributed to the fact that the former two sites are very close to each other and both the streams have almost same origin but drain through different watersheds of almost similar catchment, Sites I and V are totally dissimilar due to the fact that Site I is an inlet of river Jhelum, perennial in nature and drains out through large catchment while as site V is a stream having very low flow and thus has large quantity of pollutants due to the absence of strong dilution effect also carries out with itself the whole domestic sewage of villages present in its banks immediately into the Wular lake, hence has great anthropogenic stress.

Conclusions

From the observations, it may be concluded that among five streams, the water quality of all the streams is slightly polluted based on water quality index. The study revealed that these streams are experiencing initial stage of anthropogenic stress pollution and needs immediate attention of aquatic ecologists. Further, the results of the study could be helpful in the management of the lake for its water quality, fisheries and recreation. The data obtained could also form baseline and reference point while assessing further changes that might be caused by nature or man in the lake.

Conflict of Interest

The authors have not declared any conflict of interest.

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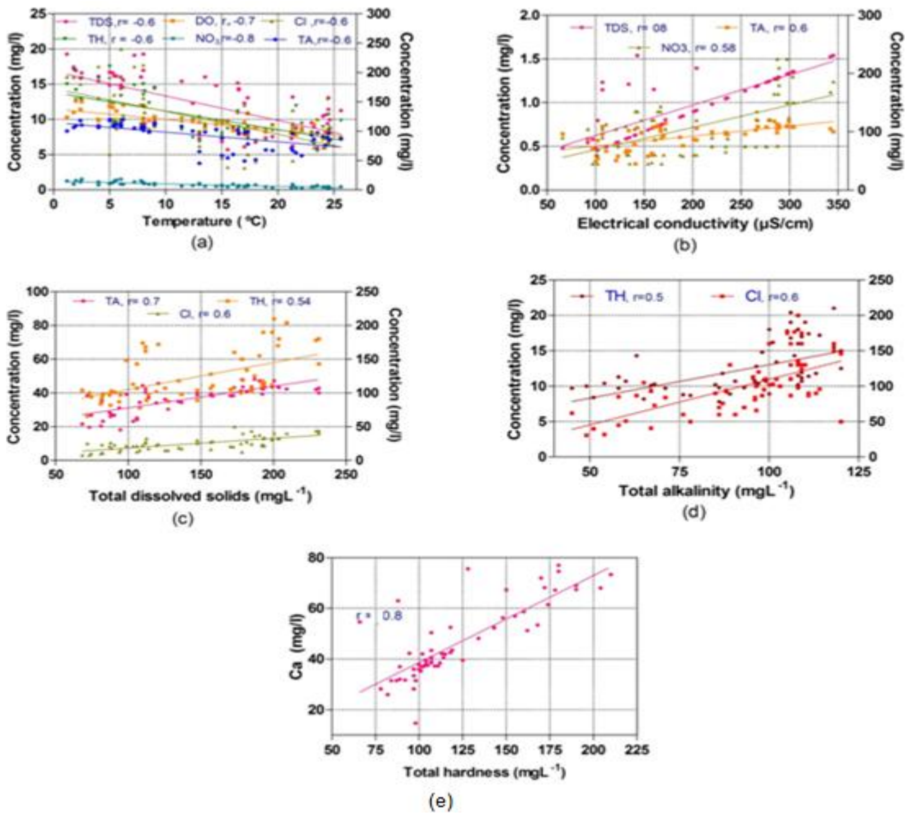

Figure 4. Nature of relationship between physico-chemical parameters of water.

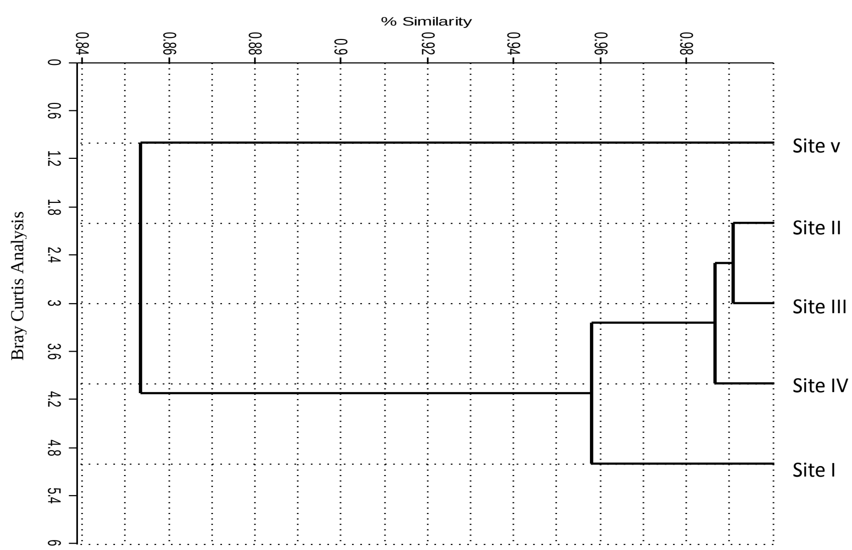

Figure 5. Bray Curtis similarity analysis of study sites.

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