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SOIL AND WATER ANALYSIS FOR MICRO-NUTRIENTS IN WETLAND'S ASSOCIATED GRASSLAND ECOSYSTEMS

S. T. Raza, Z. Ali, I. Zainab, S. Sidra, A. Nimra, Z. Zona and K. Aziz

Environmental Health & Wildlife, Department of Zoology, University of the Punjab, Lahore, 54590, Pakistan
Corresponding Author: Email: zali.zool@pu.edu.pk

ABSTRACT

Soil and water degradation put crucial impact on the global ecosystems and human health. The paper focuses on the principal chemical and physical attributes serving as indicator of soil and water quality of the grassland and wetland of Makra Meadows (Elevation 3089 m) and Kallar Kahar, (Elevation 554 m) Pakistan. Soil samples were collected from the topsoil, at a depth of 30 cm and 60 cm from both locations while water samples were collected from the natural lakes present in both ecosystems. Practiced indicators considered in soil analysis at three different depths and gradients of soil embrace EC, pH, organic matter, phosphorus, potassium, and texture and percentage saturation while the water quality assessment comprised of electrical conductivity, Ca^{++} and Mg^{++}, Na^{+}, Cl^{-}, carbonates, and bicarbonates. Soil and water data is presented to provide necessary information about natural ecosystems.

Key words: Soil & water quality, Ecosystem, Makra meadows, Kallar Kahar, Pakistan.

INTRODUCTION

An ecosystem comprises of both biotic (living beings) and abiotic factors (physical and chemical factors). Despite a wide variety of ecosystems around the globe, all ecosystems have in common their dependency upon the solar energy and the availability of a limited pool of nutrients in soil. The understanding and apprehension of a particular ecosystem is largely dependent upon the soil characteristics. The soil and water characteristics of an area are determinants of the flora of an area which in terms is useful in describing the faunal characteristics of an area. It is therefore essential to have an extensive knowledge regarding the soil structure of a particular area to assess its bio-diversity.

In order to assess the ecological condition of an ecosystem, repeated evaluation is necessary. Nutrients cycle within the same ecosystem and among other ecosystems as well through bio-geochemical cycles. Soil acts as a sensitive indicator for assessment of ecological condition of a particular environment. The soil testing enables us to determine the deficiency or overabundance of the particular available nutrients. It helps us in determining nutrient supplying capacity of the soil and maintaining a specialized environment thus supporting the ecosystem (Mader, 1998; Cohen *et al.,* 2006).

Soil is a heterogeneous mixture of air, water, minerals and organic content which may vary in different soil types e.g. an average loam soil profile is comprised of 25 % air, 25 % water, 45 % mineral matter while the remaining 5 % consists of organic matter (NRCS, 2006). The soil quality can be considered as the three legged stool requiring integral balance of the environmental quality, animal -plant health and sustainable biological productivity (Karlen *et al*., 1997). A basic soil test determines two factors, pH and basic nutrients availability (i-e Ca, P, Mg, K, and renders assistance for soil improvements (lime or dolomite and phosphate) while the specialized soil analysis includes determination of soil salinity, Nitrogen, Aluminum, Organic carbon and micronutrients (B, Cu, Mg and Zn) (Hue *et al.*, 1997).

Soils act as a supplier of nutrients to higher vascular plants as roots keep extracting nutrients from the soil for long time periods. The soil's nutrient supplying capacity is assessed by mixing soil with the extracting solution (mostly an acid or combination of acids) for some minutes. Most soil test values do not vary greatly from year to year. However, some soil and environmental conditions cause fluctuations in measurements such as pH and nitrate-nitrogen may vacillate due to environmental conditions (Horneck *et al.,* 2011). The nutrient cycling between soils and trees nature of soil profiles and pH are facilitating factors to determine the site quality. Vegetation improves water retaining capacity, soil structure, infiltration rate, hydraulic conductivity and aeration thereby affecting physio-chemical properties of soil (Siddiqui *et al.,* 2014).

Makra meadows and Kallar Kahar are two famous tourist locations of Pakistan renowned for their natural beauty and stunning landscapes. Both sites contain natural lakes recharged by rain water and mountain brooks. The current study was undertaken to assess the soil and water characteristics of these two different ecosystems present at high and low altitudes and was an attempt to infer the functionality of two ecosystems frequented by tourists from all over the country.

MATERIALS AND METHODS

Site A: Makra meadow, Shogran is a beautiful tourist spot of the Kaghan valley in northern Pakistan (Figure 1). The alpine grassland (34°37’42’’N, 73°29’22’’E) lies at an elevation of 3089 m above sea level and is accessible through trekking or on jeep and mules only during the summer months i.e. from May to September. The meadow lies in the temperate zone (Anwar, 1971) and is surrounded by Makra peak and other mountains. Snow from these ice-covered peaks melts during summers and collects in the Payee Lake in the Makra catchment area. The average temperatures during the day and night vary greatly with 20ºC during the day and as low as 3ºC at night. The vegetation of the Shogran valley includes trees such as *Cedrus deodara, Pinus wallichiana, Abies pindrow, Picea smithiana* (Ahmed *et al.*, 2011). A wide variety of agarics has also been reported in the area by Sultana *et al.* (2011) such as *Boletus subvelutipes. Tylopilus prophyrosporus, and Chalciporus piperatus* to name a few.

Site B: Kallar Kahar is situated at an elevation of 554m above sea level in the province of Punjab, district of Chakwal lying between 32º 46’ 30.31” North latitude and 72º 42’ 23.80” East longitude. Kallar Kahar is a famous tourist spot notable for its saltwater lake, surrounding gardens and abundance of peacocks and is situated 25km away towards north of Chakwal. Kallar Kahar is a wet land recognized as the breeding site of many migratory birds. The land of Kallar Kahar is a central consistently brackish water lake reservoir where the base of the hill is served by numerous fresh water springs. Though the water springs are fresh in nature but interchange to brackish water when coalesce with salt range hills base. However the lake has been polluted by the sewage water and a remediation program is in progress (Raza *et al.*, 2007). Soil of the region is affected by the aridity that prevails throughout the year that has perceived limited moisture and reduced vegetative cover. Soil of the region is rich in minerals and rock salt but has depleted quantities of the nitrogen content. Lime, coal, salts and various kinds of gypsum and clay are characteristic feature of the soil of the region. The vegetation recorded includes grasses such as *Cynodon dactylon, Brachiaria ramosa* and the broad-leaved weed *Conyza bonariensis*. Herbaceous species such as *Cannabis sativa, Parthenium hysterophorus, Malvastrum coromandelianum, Datura innoxia, Oxalis corniculata, Amaranthus viridis* and *Aerva javanica* also present while the tree species are dominated by *Ziziphus mauritiana, Morus nigra* and *Eucalyptus citriodora* as documented by Arshad (2011).

Figure 1. Location map of the observation sites (Site A = Makra meadows; Site B = Kallar Kahar).

Sample collection: Soil samples were collected at a distance of 20 meters away from the lakes and from three different depths i.e. from the top, at a depth of 30 cm and 60 cm. The soil was collected in polythene bags and labeled accordingly for later analysis. The samples were air dried for 48 hours and passed through a muslin cloth acting as a sieve before sending to laboratory for testing. The texture of the soil was determined along with other variables including the pH of soil, organic matter, elemental carbon, available potassium, available phosphorus, Zn, Cu, Mn, Fe, B, and sulphates.

Similarly two water samples were collected from each lake. Sample 1 was collected from the edge of the lake while sample 2 was collected at a distance of approximately 10 feet from the edge. The samples were collected in clear bottles and labeled thus. The pH and electrical conductivity of the water samples were determined. The samples were also analysed for total dissolved solids (TDS), presence of ions of Calcium, Magnesium, Sodium, Carbonate, Bi-carbonate and Chloride. Both the soil and water samples were submitted to the Soil and Water Testing Laboratory for Research (Lahore) for analysis.

RESULTS

Soil quality: The texture of soil at site A was clay at 0 cm, clay loam at a depth of 30 cm and again clay at a depth of 60 cm while at site B, samples from all three depths were of loam. The pH of the soil is a major indicator of the nutrient availability in the soil. The soil was acidic in nature at Site A (Makra meadows) and alkaline at Site B (Kallar Kahar). Various other parameters were observed in soil to characterize its properties at varying depths (Table 1).

Table 1. Soil composition of two different environments at high and low altitudes.

Parameters	Makra meadows			Kallar Kahar		
	0 cm	30 cm	60 cm	0 cm	30 cm	60 cm
Texture	Clay	Clay loam	Clay	Loam	Loam	Loam
EC mScm-1	0.9	0.3	0.3	23.6	6.6	4.2
pH	6.3	5.8	6.6	8.3	8.3	8.4
Organic Matter %	0.81	0.9	0.77	0.85	0.81	0.79
Available Phosphorus (mg/Kg)	4.4	3.6	2.6	2.2	2	2.4
Available Potassium (mg/Kg)	102	98	102	157	79	71
Saturation %	70	60	66	34	36	40
Zn (mg/kg)	14.73	1.46	0.62	1.29	0.46	0.26
Cu (mg/kg)	2.84	0.63	0.42	1.48	0.82	0.69
Mn (mg/kg)	34.87	0.75	0.5	4.81	7.94	7.36
Fe (mg/kg)	110	39.33	67	19.15	4.01	4.01
B (mg/kg)	-	-	-	1.28	0.13	0.15
SO_4 (mg/kg)	-	-	-	635.4	112.7	65.4

Electrical Conductivity (EC): Electrical conductivity determines the level of available soluble salts present in the soil sample. The soil salinity is effectively measured using electrical conductivity test. The soil at site A was acidic in nature while a high level of soluble salts was observed in soil at Site B giving it a highly saline characteristic. The electrical conductivity was also observed to decrease with increasing depth (Figure 2).

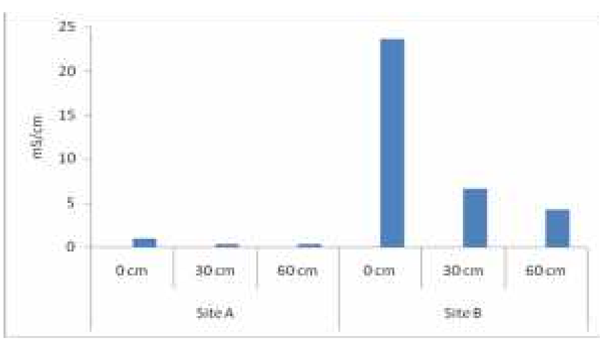

Figure 2. Electrical conductivity of soil samples at varying depths

Organic matter (OM): Organic matter is the decomposed or un-decomposed animal or plant remains in the soil acting to provide essential nutrients to the soil. It not only provides the plants with appreciable amounts of nitrogen, phosphorus and sulphur, but also aids in increasing the aeration and water retention capacity of the soil. The levels of the nutrients in OM can be measured but the rate of mineralization that keeps on fluctuating due to weather and climate cause unreliable prediction (NRCS, 2006). Organic matter was observed to be higher at a depth of 30 cm at Site A while at site B, the organic matter decreased with increase in depth of soil (Figure 3).

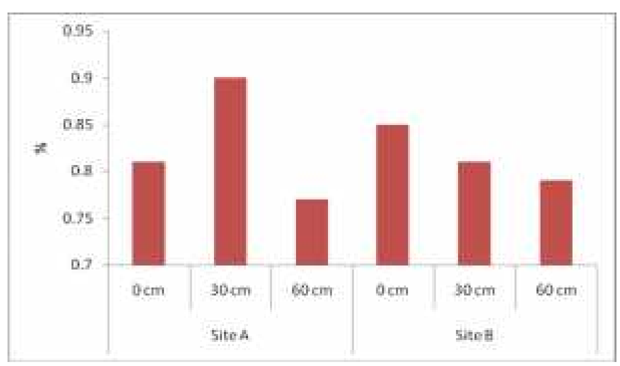

Figure 3. Percentage of organic matter observed in the soil samples at varying depths

Phosphorus (P): Phosphorus availability in soil is highly dependent on the nature of P complexes the soil contains. Phosphorus is compactly bound to the particles of soil or composed of comparatively insoluble complexes. P comprising complexes acts very differently with alkaline than in acidic or neural solution. The P extractant used in the soil test should be compatible to soil properties as the P detached during soil extraction is dependent upon the type of extractant used and the nature of P complexes.

The available Phosphorous in soil was determined and it was observed that at Site A, the concentration decreased with depth while there was not much difference observed at Site B (Figure 4).

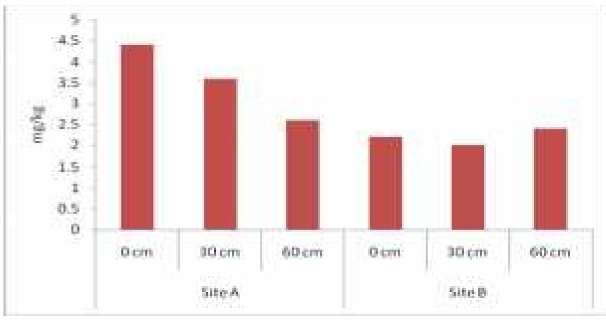

Figure 4. Available Phosphorous (mg/kg) in the tested soil samples at different depths

Potassium (K): Potassium along with Calcium, Magnesium and Sodium is a major exchangeable cation present in soil. All are essential plant nutrients except Na. The levels of available Potassium in the soil were higher in the topsoil of Site B with not much difference observed in all three samples at Site A (Figure 5).

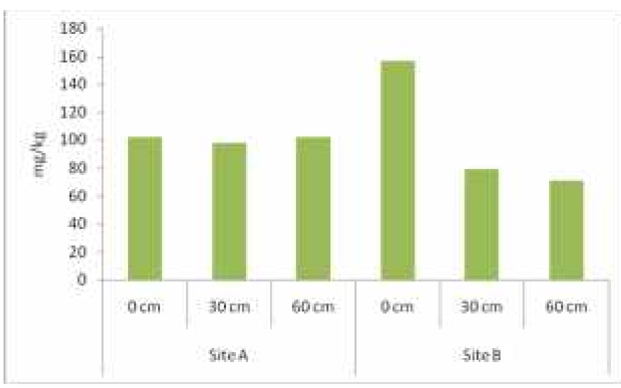

Figure 5. Available Potassium (mg/kg) in the tested soil samples at different depths.

The levels of micro-nutrients i.e. Zinc, Copper, Manganese and Iron were also measured. Fe was in higher quantities in top soil than the deeper layers. Moreover, levels of iron were higher in soils of Site A than Site B (Figure 6).

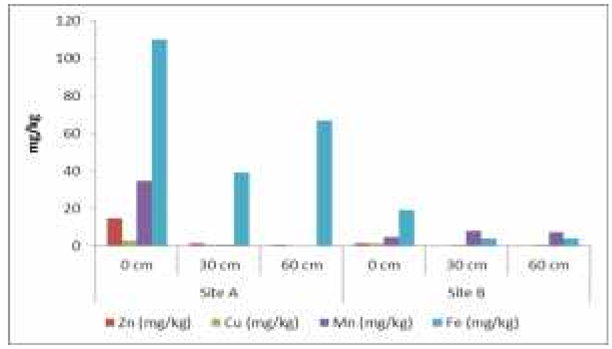

Figure 6. Micro-nutrient levels in varying depths of soils

Saturation percentage (SP): Saturation percentage is indicative of the soil texture and water holding capacity of soil and can also be used to determine soil characteristics at different depths. Saturation percentage however did not show much variation in the three depths sampled for this study. SP was higher for the clay soils of Site A than the loam soils of Site B (Figure 7).

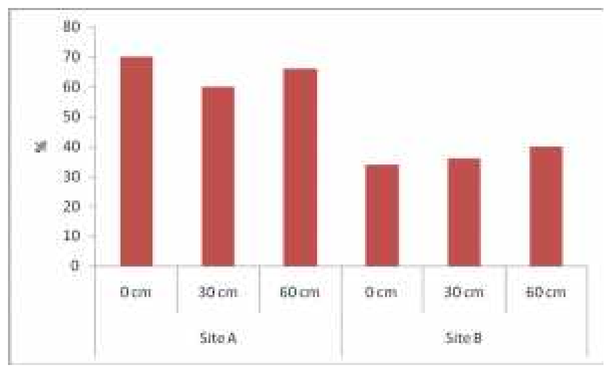

Figure 7. Water holding capacity of soil at both sites

Water quality: The water of Payee Lake at Site A was acidic with low quantities of TDS while the alkaline waters of Kallar Kahar Lake, Site B, contained high quantities of TDS.

Electrical conductivity of water: The electrical conductivity of water can be termed as the total count of the dissolved salt or as the forecaster of the individual ion. EC can effectively predict the hydrologic behavior of the particular catchments which is also reflected in terms of variations in TDS levels in Table 2.

Ionic compounds: Presence of varying amounts of ionic components defines the quality of water in general. Levels of calcium and Magnesium ions determine the hardness of water. In contrast to the acidic water of Payee Lake, the alkaline, hard water of Kallar Kahar Lake contained high amounts of these both ions as well as all other measured variables which also resulted in high levels of salinity in its waters.

Table 2. Water qualities of natural lakes at Site A and Site B.

	Payee lake (Site A)		Kallar Kahar lake (Site B)	
Parameters	**P1**	**P2**	**K1**	**K2**
pH	5.9	5.9	9	9
TDS (ppm)	48.3	50.2	2702	2716
Electrical Conductivity (µScm^{-1})	69	86	3860	3880
Calcium + Magnesium (Ca^{++}, Mg^{++})	0.6	0.8	13.7	15.3
Sodium (Na^{+})	Traces	Traces	24.9	23.5
Carbonate (CO_3^{--})	Nil	Nil	2.4	Nil
Bi-carbonate (HCO_3^{-})	0.6	0.6	7.8	10
Chloride (Cl^{-})	Traces	Traces	20	21.2

DISCUSSION

The soil samples collected at the two sampling sites exhibited high differences among the factors monitored. Payee meadows have more clay content and minimal loam while the clay of the Kallar Kahar comprised entirely of loam.

Soil around the lakes can be acidic or basic in nature owing to the source of water as well as the amount of nutrients present in soil. Rain water affects the pH of soil as it is acidic in nature. Environmental pollution and CO_2 also contribute towards the acidity of water and soil (Huo *et al.*, 2012). Other than these factors, the levels of soil nutrients such as Zinc, Iron, Aluminum, Nitrogen, Potassium, Calcium and Magnesium being acidic in nature also alter the pH of soil (Boul, 1995). The source of water at Payee Lake is the rain water and melting of snow from the surrounding snow-covered peaks. Moreover the nutrient concentration in all the three soil samples was much higher at Payee meadows than at Kallar Kahar. As a result, the pH of soil and water at Payee meadows was acidic in nature. Siddique *et al.* (2014) also reported the soil pH of the Makra meadows (Payee) to be acidic (5.23) as in correspondence with the current incurred results. On the other hand, the pH of soil at Kallar Kahar was 8.3 (basic in nature) as Kallar Kahar Lake is a brackish lake with high amounts of Total Dissolved Solids (TDS) and Chloride ions as well.

Electrical conductivity is a determinant of the level of available soluble salts present in the soil sample. The soil salinity is effectively measured using electrical conductivity test (Walworth, 2011). Salinity is a major threat to an ecosystem and two of the main problems caused by salinity include severe damage or demise of the plant or death of the plant and less permeability of soil. The more alkaline nature of the soil causes shift of ionic form of nutrient to a complex form that becomes unavailable to plants (Paridaa and Das, 2005).The soil of Makra meadows was reported to be low in soluble salts while salinity was a major distinguishing feature in the soil of Kallar Kahar.

Apart from the content of available salts in the soil, certain nutrients play a major role in defining the flora of an ecosystem. These nutrients are called the limiting nutrients. The phosphorous content in the soil play a major role in the vegetative cover of an ecosystem. Phosphorous and Potassium are two such major limiting nutrients in a terrestrial ecosystem that can affect plant growth and thus community structure. Phosphorus availability in soil is highly dependent on the nature of P complexes, the soil contains. Phosphorus is compactly bound to the particles of soil or composed of comparatively insoluble complexes. P comprising complexes acts very differently with alkaline than in acidic or neutral solution (Walworth, 2011). In the studied sites the high ratio of phosphorus was monitored at site B as compared to site A which may also explain the vegetation at site B to be more dense with more trees as compared to the grassland at site A.

In every range of pH there are reactions that result in limiting of the P content in the soil but it becomes well pronounced when dealing with the alkaline soil (pH>7.3). In case of acidic soil the articulated effect is seen when pH <5.5 as observed by Busman *et al.* (2009) that also accords with the collected results at the studied sites. Maintaining a pH between 7 to 6 increase the increased use of phosphate so does the pH at Makra meadows which was in the expected range thus supporting the ecosystem.

Another important factor relating to the distribution of limiting nutrients such as P and K stems from their shallow, vertical distribution in soil. Nutrients that are strongly cycled by the plants such as Phosphorous and Potassium tend to be more concentrated in the top 20 cm of soil (Jobbágy and Jackson, 2001). On analyzing the levels of these two nutrients at different depths, it was observed that the levels of Potassium were higher in the topsoil with their levels decreasing as we dig deeper. However the phosphorus level was observed to slightly increase at a depth of 60cm at site B.

Cu is a micronutrient which is an essential element for the plant growth although needed in low quantities. As the copper retention in the soil is strongly reckoned upon the pH, Cavallaro and McBride (1980) encountered that the retention capacity of the Cu in the soil increases within pH range >4. As Site A effectively fulfills the pH condition so contained more copper content in its soils. It was observed that the Cu, Zn, Mn content decreases as depth of soil sample increases. Highest concentrations of the above discussed elements were found in the surface layer at both studied sites. The elevated levels of Cu, Zn and Mn in the surface layer can be justified by the fact that these elements got adsorbed in the soil (McLean and Bledsoe, 1992). Significant levels of Zn, Cu, and Mn were sampled at site A as compared to the site B. These are the micro nutrient essential for the plant growth and their considerate levels facilitate the vegetative cover of the site B.

Chemically, water serves as transport agent for dissolved inorganic chemicals and suspended biological components, involved in the processes of soil development and degradation. Water retention capacity of soil is described by its Saturation percentage (SP) which is related to the mechanical constituents of soils and can, therefore, be regarded as a quantitative measure of soil texture, water-holding capacity, and cation exchange capacity. Soil profiles may be described in terms of SP, and soil maps may be developed to represent quantitative changes in soil texture within a region. Furthermore, measurement of soil water content is important in simulation of all aspects of hydrological cycle, for estimation of plant water use, and for characterizing most soil physical, chemical, and biological processes. The soil texture in a particular region can be defined by the percentage saturation of the soil. The percentage saturation basically defines cation-exchange and water holding capacity of the soil the percentage saturation is an important factor in the understanding the functionality of the biological, chemical and physical processes of soil (Aali *et al.*,2009). The water retention capacity in the upland soil (Site A) was increased as compared to that of the lowland soil (Site B).

As mentioned before, both the highland and lowland ecosystems were characterized by the presence of natural lakes which are fed by the primarily by rainwater and by mountain streams or melting snow as the case may be. The hydro biological relationship and metabolism of an ecosystem is well defined by its water chemistry (Manjare *et al.,* 2010). The water quality is determined in terms of different parameters such as electrical conductivity, pH, turbidity and dissolve oxygen that are the presenters of the health of an ecosystem. Any substantial deviation in these parameters results in impairment of ecosystem (Goudey 2003).

The presumption that the source of water as well as the soil surrounding the water body determines the characteristics of the water quality holds true as observed in our study. The electrical conductivity of water can be termed as the total count of the dissolved salt or as the forecaster of the individual ion. EC can effectively predict the hydrologic behavior of the particular catchments (Moore *et al.,* 2008). Highest EC levels were monitored in Kallar Kahar Lake, Site B while significantly low levels were obtained at Payee Lake, Site A.

The water at site A has acidic pH while site B has high alkalinity in accordance with the surrounding soil. The highly alkaline pH can be related to the extreme ionic concentration present in the brackish water. The Ca ++ and Mg++ ion concentration were found to be most eminent in the water samples collected at site B. Usually carbonate rocks got dissolve on encountering to the carbonic acid present in water and serve as a richest source of calcium in the water. Gypsum is another reservoir of calcium. The low level of CO_2 in water causes the reverse reaction and lead to formation of $CaCO_3$ (Nikanorov and Brazhnikova, 2009). It should be remembered that Kallar Kahar is located in the Salt range and high amounts of salts in its waters should not be surprising.

As compared to Ca ++, Mg++ has fewer amounts in the crust of earth. Mg gets into the water body via weathering of rocks, marls and dolomite. The abundance of Mg in the water bodies as compared to calcium occurs due to the rich solubility of the hydro-carbonates and magnesium sulphates. High ratio of Na+ ions were monitored in the water at site B while traces have been found at site A. Weathering of lime stones ,rocks and displacement of Na+ from the soils by calcium and magnesium serves as a reservoir of Na+ in water.

TDS is the total measure of the organic matter, dissolve salts and inorganic salts in the water. Atmospheric precipitation and geology of drainage represents the composition and concentration of TDS in the natural waters. Uttermost TDS was sampled in the water of site B. This extreme TDS ratio represents the wretched water quality of the site. High ratio of TDS mostly results from the high rate of precipitation, effluents from industrial source, and increased waterutility.TDS appears to have drastic effect by changing ionic compositions of the water marking the toxicity of the individual ions and salinity of the water. The biological communities' shift, elimination of the less tolerant species, limitation of biodiversity and choric and acute impacts at certain life stages of biological entities are the adverse effects caused by high salinity in natural water (Scannell and Duffy, 2007). High TDS concentration in water samples of Kallar Kahar was also stated by Arshad (2011) in a report that was collaborative research by WWF and Ministry of Pakistan Wetlands Program.

Site B (Kallar Kahar) is recognized to be one of important low land areas which are a breeding site for a number of migratory birds. Water quality of the lake is undergoing degradation because of the restaurants and unsupervised tourism activities in the locality of lake. Water quality degradability was also reported by Rais *et al.*, 2010). The possible threats and spoiling water quality of Kallar Kahar lake was also reported by Iqbal *et al.*, 2006; Rais *et al.,* 2010; Rais *et al.,* 2011; Munir *et al.*, 2012. On the contrary the water quality at Payee Lake was much satisfactory owing to the remoteness of the location which allows minimal interference from the human activities.

Conclusion: The characteristics of an ecosystem are reflected in the structure of their soils and the water quality. The alpine grassland ecosystem (Site A) was characterized by its acidic soils, low electrical conductivity and thus lower nutrient content. On the other hand, Kallar Kahar (Site B) is located in the Salt range with a characteristic level of salinity in its alkaline soils and a high electrical conductivity. The water reservoirs of the both ecosystem replicated the surrounding soil characters within them with the water at Site A being acidic in nature with a low level of TDS. On the contrary, the lake at site B exhibited alkaline properties, a high electrical conductivity value and huge quantities of TDS.

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