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Investigation of the Water Quality of Alpsarı Pond (Korgun- Çankırı)

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Abstract

The objectives of this study carried out in Alpsarı Pond located in Çankırı city are to evaluate (i) the seasonal, monthly and annual changes of water samples, (ii) the water quality properties, (iii) the water pollution sources, (iv) the suitability level in terms of aquatic life, and (v) the quality of water in accordance with the Surface Water Quality Management Regulation (SWQMR) criteria. The study was started in June 2014 and water samples were taken from three stations for 12 months. In total, 21 physicochemical parameters and 7 heavy metals were investigated to determine the water quality. Such a detailed study has been done firstly in this pond used for irrigation purpose. As a result of performing analyses, it was found that the water quality was suitable for both the Alpsarı Pond hosting aquatic animals and aquatic life. According to the SWQMR, the actual water quality was detected as a level Class (I-III-IV). The result is that the pond is under pollution pressure due to domestic and animal wastes.

Key words: Fresh water, pond, water pollution, heavy metal, hierarchical cluster analysis (HCA)

Introduction

The effects of global climate change are increasingly experienced in any domain of life. Water sources and thus the hydrologic cycle and their local, regional and global distribution and management have been affected the highest potential. Since the water is a vital component of all the ecosystems and human life, the researches on characteristics, availability, and quality of aquatic ecosystems have continued. Due to the increasing water use and pollution depending on the increasing population in recent years, the quality of water sources is under threat and the amount of water decrease. Only 3% of the world's water stock consists of fresh water. The release of domestic and industrial wastes into aquatic receiver media such as rivers, dams, lakes and seas without sufficient treatment discharged significant risk for ecological systems and water sources (Ramazan, Sait, & Kemal, 2008). The pollutants reached to aquatic ecosystems have toxic effects on aquatic ecosystem organisms as well as they threaten human health through the food chain (Balcı, Karagüler, Yelboğa, & Vardar, 2009; Bakan, Böke Özkoç, Tülek, & Cüce, 2010; Polat & Akkan, 2016). Therefore, for a life of healthy human and aquatic, it is very important for food chain and hydrological cycle to protect the existing water sources and regularly controlling their quality. Nowadays, the signs of water pollution are seen in lakes and ponds used for drinking water and irrigation water aims. The levels of underground water decrease, the lakes become smaller, and wetlands disappear.

In general, the ponds are constructed with embankments or sets next to the riverbeds. Some ponds, however, are created by transferring the river waters into natural pots or artificially excavated locations through the pipelines. The flow rate of rivers feeding the ponds slows down near the pond zone and starts accumulating the sediments. Due to the structural features and locations of ponds, their aquatic ecosystem is a special and it is very important

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to maintain the cleanness of water feeding in the pond. If it is a natural pond, the components constituting the pond's environment and its ecosystem, which are soil, flora, fauna and the ecological environment, where the aquatic organisms will live together, should be planned.

The present study was aimed to observe the monthly and seasonal changes, to determine the water quality properties, to reveal the pollution sources, to evaluate the suitability level in terms of aquatic life, and to classify the quality of water in accordance with Surface Water Quality Management Regulation's (SWQMR) Inland Surface Water Classes criteria. In addition, statistical methods have been used to make the interpretation of relations and interrelationships easier. In accordance with this purpose, the use of different multivariate statistical techniques such as Pearson's correlation, Hierarchical Cluster Analysis (HCA), and One-way ANOVA provide more information related to ecological status and the water quality of this study area.

Material and Methods

Sample location and sampling

Alpsarı Pond is located within the borders of the Alpsarı village in Çankırı city; it is 21 km away to Çankırı and 155 km to Ankara, has 22.7 ha surface area, the deepest point of the pond is 25 m. With these features of it, this pond is the largest pond of its region. The altitude of Alpsarı Pond is 890 m. Precipitation, snow waters, and Galat Stream feed the pond. Because of the visual quality of flora around the pond, the location is widely used as a recreational area by the community for Çankırı. Its neighbors, as well as irrigate the agricultural lands around the pond. In pond, there are *Cyprinus carpio* (carp) and *Silurus glanis* (catfish) fishes.

In this study, the sampling stations (3 stations) were determined considering the factors such as facilities, hydrological status of the pond, distance to the streams, and sampling points. (Table 1, Figure 1)

Warm climate conditions dominate the region of Alpsarı Pond, and significant level of raining is observed. Even in most draught months, there is a high level of raining. The study was performed on June 2014 - May 2015, and samples were collected monthly during 12 months. Samples were collected in 2.5 L plastic bottles. For the analysis of heavy metals, water samples were collected in 1-liter pre-cleaned (with 50% HNO_3 and then thrice with deionized water) polyethylene bottles and acidified with 10 ml concentrated HNO_3 per liter of wastewater. The collected samples were kept in ice bags while being transported to the laboratory and about 4°C until being analyzed.

Determination of physico-chemical parameters

Among the physical parameters of water quality, water temperature, dissolved oxygen, salinity, and electrical conductivity were measured on-site using YSI 556 MPS model multi-meter. Other water quality parameters such as chemical oxygen demand, biological oxygen demand, total hardness, Variations of nitrite-nitrogen, nitrate-nitrogen, ammonium-nitrogen, total alkalinity, phosphate-phosphorus, sulfite, sulfate, chloride, calcium, magnesium, sodium, potassium was analyzed in a laboratory using standard method (APHA, 2012; Clesceri, Greenberg, Trussell, APHA, AWWA, & WPCF, 1989). The analyses of ferrous, lead, cadmium, zinc, nickel, copper and water samples were conducted by ICP-MS device in the laboratory.

The creation of the calibration curve was made using the certified multi-element standard. An intermediate stock of 10 mg L^{-1} was prepared from the main stock solution and calibration curves were drawn from standard stocks

RESEARCH PAPER

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of 5, 10, 20, 50, 100 and 250 μg L^{-1}. The samples were prepared in triplicate and analyzed as 10 readings in each parallel ICP-MS device. Blind sample prepared with 1% HNO_3 solution was taken 20 times and taken 3 times of standard slope and LOD (detection limit) and 10 times LOQ (determination limit) were determined (Şengül, 2016).

Statistical Analysis

SPSS statistical package software was utilized for the statistical analysis of water analysis results. In order to determine if there are significant differences between mean values by the stations, months and seasonal, One-way ANOVA was employed and the level of significance was set to (0.01-0.05). The significance of differences between the mean values was tested using Tukey's multiple range tests. In order to determine the relationship between the physico-chemical parameters and Pearson's correlation was used. Additionally, multivariate analysis of the pond water quality data set was performed through Hierarchical Cluster Analysis (HCA) techniques (Liu, Lin, & Kuo, 2003). The pond water quality data were initially standardized by z-scale transformation (Özdemir, 2016; Kannel, Lee, Kanel, & Khan, 2007).

Result and Discussion

The water samples were taken monthly from three stations. The mean values, standard error and minimum-maximum values for each of the stations are presented in Tables 2 and 3.

According to the analysis results, regardless of difference of seasons and stations, the annual mean values of water quality parameters were found as dissolved oxygen (DO) (10.21±0.870 mg L^{-1}), salinity (0.088±0.032 ‰), pH (8.782±0.247), water temperature (WT) (12.080±6.981 °C), electrical conductivity (EC) (312.70±50.612 µS cm^{-1}), suspended solid content (SSC) (6.392±2.921 mg L^{-1}), chemical oxygen demand (COD) (6.175±8.552 mg L^{-1}), biological oxygen demand (BOD_5) (1.414±0.557 mg L^{-1}), chloride (Cl^-) (6.726±1.216 mg L^{-1}), phosphate (PO_4^{3-})(0.373±0.178 mg L^{-1}), sulfate (SO_4) (88.492±16.644 mg L^{-1}), sulfite (SO_3) (0827±0.361 mg L^{-1}), sodium (Na^+) (65.712±12.758 mg L^{-1}), potassium (K^+) (13.136±3.672 mg L^{-1}), total hardness (TH) (346.27±22.083 mg L^{-1}), total alkalinity (TA) (442.68±510.96 mg L^{-1}), magnesium (Mg^{2+}) (48.507±11.445 mg L^{-1}), calcium (Ca^{2+}) (57.010±15.394 mg L^{-1}), nitrite (NO_2^-)(0.0031±0.0019 mg L^{-1}), nitrate (NO_3^-) (5.7097±3.105 mg L^{-1}), ammonium (NH_4^+) (0.0005±0.0003 mg L^{-1}), ferrous (Fe^{2+}) (0.0014±0.0016 mg L^{-1}), lead (Pb^{2+}) (0.531±0.572 µg L^{-1}), copper (Cu^{2+}) (4.611±3.751 µg L^{-1}), cadmium (Cd^{2+}) (0.161±0.146 µg L^{-1}), mercury (Hg^{2+}) (0.0068±0.0038 µg L^{-1}), nickel (Ni^{2+}) (4.694±1.618 µg L^{-1}) and zinc (Zn^{2+})(15.361±6.825 µg L^{-1}).

In this study, no statistically significant difference was found between the mean values of the stations ($P > 0.05$) and seasonal and monthly mean values were determined (Tables 2 and 3).

The DO that is important for water quality and aquatic life is inversely proportional to the water temperature (Yılmaz Öztürk and Akköz, 2014). The DO level of Alpsarı Pond range from 8.65 to 11.59 mg L^{-1} (Table 2 and 3). The lowest DO level was observed at Station 1 in September, while the highest level was found at Station 2 in May. Considering all of the months, it was found that mean values of January and December are similar to those of November and August, while other months differ in terms of the mean level of DO (Tables 2 and 3). The seasonal mean values of summer and winter were found to be similar (Table 3). This value was found to be lower than the Yayladağ pond and higher than the Samandağ-Karamanlı pond (Mutlu and Tepe, 2014; Tepe, Mutlu, Ateş, & Başusta, 2004). When DO is analyzed by using the Pearson correlation method (Table 4); DO is in negative

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significant relationship at *P<0.05* with salinity (r = -0.715), WT (r = -0.544), EC (r = -0.861) and SSC (r = -0.767). Moreover, it is in a positive significant relationship with Na (r = 0.692), K (r = 0.523) and NO_3 (r = -0.543). For aquatic life, the DO level of inland waters must be not lower than 5 mg L^{-1} (Atay & Pulatsü, 2000; SWQMR, 2015). It was concluded that this pond is suitable for aquatic life. According to the inland water classification criteria of SWQMR, this pond is Class I (> 8 mg L^{-1}) in terms of the DO, which means it is clean water (SWQMR, 2015).

Since the fresh waters are also used for irrigation in addition to the drinking water needs, salinity is a very important factor. Salinity alters the chemical and physical properties of soil and water, increases the osmotic pressure, and has toxic and physiological effects on plants. The salinity level of Alpsarı Pond changes between 0.09 and 0.15. The lowest level of salinity was observed at Station 2 in February, while the highest level was found in October (Table 2, and 3). This value range is similar to the Kemeriz Dam Lake but it is higher than Karamanlı Pond (Mutlu & Demir, 2016; Tepe *et al.*, 2004). The Pearson Correlation table shows a positive very strong correlation salinity between the WT (r = 0.923), BOD_5 (r = 0.804), Cl (r = 0.838), pH (r = 0.714), TH (r = 0.715), TA (r = 0.762) and Mg (r = 0.733) (Table 4). Since the salinity of the pond is low as expected from the fresh waters and it is suitable for aquatic life.

pH (Taş, 2006), which is the indicator of the acidity of waters, is one of the factors influencing the aquatic life. The flora is significantly affected by the changes of pH (Tanyolaç, 2009). The pH level of Alpsarı Pond ranges from 7.68 to 9.10. The lowest pH was observed at Station 1 in February, while the highest level was found at Station 3 in October (Table 2 and 3). This value range is almost similar to the Eğirdir Lake and Borçka Dam Lake (Taş, 2015; Şener, Şener, Davraz, Karagüzel, & Bulut, 2010; Eryılmaz, İpek, & Yalçın Çelik, 2012). When pH indicating the acidity of water is analyzed using Pearson correlation test (Table 4); pH is in a positive significant relationship with WT (r = 0.773), salinity (r = 0.714), EC (r = 0.623), SSC (r = 0.682), BOD_5 (r = 0.676), Cl (r = 0.677), TH (r = 0.658), Mg (r = 0.581) and NO_2(r = 0.530). According to inland water quality criteria of SWQMR, the pond is Class IV (> 9) in terms of pH, which means it is highly polluted water (SWQMR, 2015).

Water temperature affects the biological, chemical, and physical activities in the water, and increases the metabolic and respiratory rates of aquatic organisms, affects the dissolubility of gases. When the temperature increases, then the metabolic rate increases and the level of oxygen decreases (Ünlü, Çoban, & Tunç, 2008). Water temperature has vital importance for the reproduction and nutrition of some organisms (Egemen, 2006). Alpsarı Pond's WT changes between 2.50 and 21.50 C°. The lowest temperature level was observed at Station 2 in February, while the highest level was observed at Station 1 in September (Table 2 and 3). The highest temperature value is higher than the Çiğdem pond, lower than the Hazar Lake and Işıktepe Dam Lake (Kurnaz *et al.*, 2016; Ünlü *et al.*, 2008; Küçükyılmaz *et al.*, 2014). There is a positive significant relationship with EC (r = 0.811), Cl (r = 0.927), TA (r = 0.922) and salinity. Moreover, at the same level of significance, it was found to have a negative relationship with DO (Table 4). In conclusion, it was found that this pond is suitable for aquatic life and there is no seasonal threat. According to the inland water quality criteria of SWQMR, the pond was found to be Class I in terms of water temperature.

For good aquaculture in fresh water, EC was determined as 100-150 µS cm^{-1} (Nisbet and Verneaux, 1970). The EC value of Alpsarı Pond varied between 246.90 and 391.507 µS cm^{-1}. The lowest EC level was observed in March at Station 2, while the highest level was found at Station 1 in October (Table 2, and 3). The mean value of EC is

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higher than the Derbent Lake, and it is similar to the Borçka Lake (Taş, 2006; Eryılmaz *et al.*, 2012). The EC has a positive significant relationship with SSC (r = 0.940), TH (r = 0.611), Mg (r = 0.750), pH and salinity. Also, it was found that EC has a negative relationship with the DO (Table 4). Vast amounts of dissolved mineral indicate the level of conductivity. Especially the presence of Cl^- and Na^+ ions determines the conductivity. Since the cations and anions are limiter for growth and development of algae, they are also limiter for the food chain. According to the classification criteria of SWQMR, the pond is suitable in terms of EC and is a Class I (suitable for the use for recreational purposes, including those involving personal contact such as swimming and for animal husbandry and agricultural purposes) (< 400 µS cm^{-1}) in terms of EC, which means it is clean water (SWQMR, 2015).

The level of suspended solid content (SSC) in waters is significantly affected by the phytoplankton concentration. It is transmitted in aquatic media through domestic and industrial waste waters. Then, the turbidity of water increases, light transmission decreases, and the photosynthesis is naturally affected negatively. High levels of SSC damage the sensitive tissues of fishes such as gills, and cause deaths of larvae and eggs of aquatic organisms. The SSC level of Alpsarı Pond ranges from 3.08 to 11.50 mg L^{-1}. The lowest SSC level was observed at Station 3 in February, while the highest level was found at Station 1 in September (Table 2 and 3). The average value of SSC is considerably higher than the Kemeriz Dam Lake (Mutlu, & Demir, 2016). The Pearson correlation analysis revealed not only a high positive correlation between SSC to BOD_5 (r=0.757), chloride (r=0.799), TA (r=0.833), TH (r=0.771) but also a negative relationship with DO (Table 4).

Chemical oxygen demand (COD), which is one of the most important parameters used for determining the pollution level of domestic and industrial waste waters, varied between 3.00 to 7.64 mg L^{-1}. The lowest COD level was observed at Station 3 in February, while the highest level was found at Station 1 in July (Table 2 and 3). The average value of COD is considerably higher than the Oyun Reservoir and Kemeriz Dam Lake (Mustapha, 2008; Mutlu, & Demir, 2016). A significant positive correlation was observed between COD values to are BOD_5 (r=0.953), Cl (r=0.772), K (r=0.755), TH (r=0.854), TA (r=0.792), Mg (r=0.710), NO_2 (r=0.745), NO_3(r=0.777), salinity, WT, pH and it has a negative relationship with DO (Table 4).

Biological oxygen demand (BOD_5), which is accepted to be the indicator of pollution level of waters (Boztuğ *et al.*, 2012), changes between 0.60 and 2.183 mg L^{-1}. The lowest BOD_5 level was observed at Station 3 in February, while the highest level was found at Station 1 in June (Table 2 and 3). A significant positive correlation was observed between BOD_5 values to chloride (r=0.953), potassium (r=0.564), TH (r=0.902), TA (r=0.887), Mg (r=0.827), NO_2(r=0.769), pH, EC, WT, COD, SSC and salinity. There was a significant negative correlation with DO (Table 4). Moreover, according to the inland water quality criteria of SWQMR, the pond was found to be Class I (<4 mgL^{-1}) in terms of BOD_5 which means it is clean water (SWQMR, 2015). This value is higher than the Çiğdem pond, lower than the Borçka Lake (Kurnaz, Mutlu, & Aydin Uncumusaoğlu, 2016; Eryılmaz *et al.*, 2012).

In natural waters, the concentration of chloride ion is generally low, but this concentration is very important for both of drinking, industrial and irrigation water quality (Ünlü *et al.*, 2008). Alpsarı Pond's chloride value ranged from 4.96 to 7.960 mg L^{-1}. The lowest chloride concentration was observed at Station 2 in January, while the highest one was found at Station 1 in November (Table 2 and 3). The parameters, with which chloride has a positive significant relationship with TH (r=0.827), TA (r=0.887), Mg (r=0.799), NO_2 (r=0.718), pH, WT, EC, SSC, COD, BOD_5, and salinity (Table 4). Additionally, at the same level of significance, it was found to have a

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negative relationship with DO. According to the classification criteria of SWQMR, is a Class I (≤ 10) in terms of chloride, which means it, is clean water (SWQMR, 2015).

Phosphate, which is one of the nutrient minerals, affecting the fertility of natural waters, exists in the form of inorganic phosphate, dissolved phosphate, and organic particles in lakes and rivers (Egemen, & Sunlu, 1999). Dissolved phosphate is taken by photoautotroph bacteria, and then added to the food chain. Increasing levels of phosphate in domestic and organic wastes, the undesired algae increase and consequently eutrophication may be seen (Boyd, & Tucker, 1998). The acceptable limit of phosphate for aquatic organisms in ponds is 0.03-2.0 mg L^{-1}, higher values indicate stress in living organisms (Bhatnagar, & Devi, 2013). Alpsarı Pond's phosphate level varied between 0 and 0.724 mg L^{-1}. The lowest phosphate concentration was observed at Station 1 in August, while the highest level was found in the same station in November (Table 2 and 3). A significant positive correlation was observed between phosphate values to NH_4 (r=0.635) and Mg (r=0.490). In addition, it was found to have a negative relationship with DO, SO_4 (r=-0.559) and K (r=-0.283) (Table 5). The highest phosphate value in this pond is higher than the Derbent pond and Borçka Dam Lake, lower than the Işiktepe Dam Lake (Taş, 2006; Bilgin, 2015; Küçükyılmaz *et al.,* 2014). According to the inland water quality criteria of SWQMR, the pond was found to be Class IV (>0.65) in terms of phosphate, which means it is highly polluted water (SWQMR, 2015).

Sufficient level of sulfate ion ($SO_4^{=}$) is necessary for the development of phytoplankton, which is important for the increase in biological fertility of natural waters. Natural lakes' $SO_4^{=}$ levels vary between 3 and 30 mg L^{-1} (Atıcı, & Obalı, 1999). The increase of sulfate in aquatic media due to industrial wastes, agricultural activities, and domestic wastes is a sign of pollution. The mean sulfate level of Ulugöl was found to be 2.5 mg L^{-1}. The sulfate level varies between 5- 100 mg L^{-1} in natural waters (Taş, Candan, Can, & Topkara, 2010). Alpsarı Pond's sulfate concentration ranged between 70.82 and 170.88 mg L^{-1}. The lowest sulfate concentration was observed at Station 3 in December, while the highest level was found at Station 3 during the same month (Table 2 and 3). The acceptable limit for aquatic organisms is 90 mg L^{-1} (Kurnaz *et al.*, 2016). There is a positive significant correlation between sulfate values to Mg (r=0.301), K (r=0.255), TH (r=0.232) and negative significant relationship with TA (r=- 0.026) (Table 4). The highest SO_4 value of this pond is much lower than the Derbent Lake and higher than Oyun reservoir and Kemeriz Dam Lake (Taş, 2006; Mustapha, 2008; Mutlu & Demir, 2016).

Alpsarı Pond's sulfide concentration changed between 2.42 and 3.84 mg L^{-1}. The lowest sulfite concentration was observed at Station 3 in December, while the highest level was found at Station 1 in April (Table 2 and 3). The parameters, with which sulfide has a positive significant relationship with Na (r=0.681), K (r=0.631), NO_2 (r=0.608), NO_3 (r=0.516) and negative significant relationship with NH_4 (r=- 0.026), Mg (r=- 0.026) and TA (r=-0.011) (Table 4). In conclusion, it was found that this pond is suitable for aquatic life and there is no seasonal threat. According to the inland water quality criteria of SWQMR, the pond was found to be Class III (<10 mg L^{-1}) in terms of sulfite, which means it is polluted water (SWQMR, 2015).

Presence of dissolved Na^+ and Cl^- ions in waters determine the conductivity level. The presence of cations and anions is also seen as a limiter factor for growth and development of algae. Alpsarı Pond's sodium concentration varied between 53.08 and 90.56 mg L^{-1}. The lowest sodium concentration was observed at Station 3 in October, while the highest level was found at Station 1 in June (Table 2 and 3). The highest sodium value of this pond is much lower than the Derbent Lake, higher than Işıktepe Dam Lake and Çiğdem pond (Taş, 2006; Küçükyılmaz *et al.*, 2014; Kurnaz *et al.,* 2016). The Pearson's correlation analysis revealed not only a high positive correlation

www.trjfas.org
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between sodium to K (r=0.899), NO_2 (r=0.639), NO_3 (r=0.917), DO, SO_3, $S0_4$, COD but also a negative relationship with salinity, SSC and PO_4 (Table 4).

One of the inorganic salts providing the taste of water, potassium exists in aquatic media in the form of K_2SO_4 mineral. It plays role in the development of herbal organisms. Moreover, it also accelerates the development of plankton. It has indirect contribution to the nourishment of fishes (Özdemir, 1994). In this study, potassium concentration ranged between 9.72 and 21.55 mg L^{-1}. The lowest potassium concentration was observed at Station 2 in October, while the highest level was found at Station 1 in June (Table 2 and 3). The high potassium value of this pond is much lower than the Çiğdem Pond and Kemeriz Dam Lake, higher than Apa Dam Lake (Kurnaz *et al.*, 2016; Mutlu, & Demir, 2016; Yılmaz Öztürk, & Akköz, 2014).

A significant positive correlation was observed between potassium to sodium (r=899), TH (r=0.631), NO_2 (r=0.630), NO_3 (r=0.825), COD, SO_3 and DO. Also, there was a significant negative correlation with NH_4 (r=-0.026), Mg (r=- 0.026) and TA (r=- 0.011) (Table 4).

Total hardness, which is one of the most important characteristics of waters, varies depending on the geological characters of their location. The hardness of water originates from the calcium and magnesium bicarbonate ions, calcium and magnesium chloride, calcium and magnesium nitrate, and limited amount of ferrous, aluminum and strontium elements (Güler, & Çobanoğlu, 1997). Alpsarı Pond's TH ranged between 315.26 and 377.59 mg L^{-1}. The lowest TH was observed at Station 2 in January, while the highest level was found at Station 1 in June (Table 2 and 3). The highest TH value of this pond was found to be lower than Çavuşçu Lake, Sarısu-Mamuca and Çiğdem ponds (Aşıkkutlu, Akköz, & Yilmaz Öztürk, 2014 ; Demir *et al.*, 2007; Kurnaz *et al.*, 2016). A significant positive correlation was observed between TH values to Mg (r=0.822), NO_2 (r=0.755), salinity, WT, SSC, COD, BOD_5, Cl, Na, SO_3, EC, K and a negative significant relationship with DO and PO_4 (Table 4).

Alpsarı Pond's total alkalinity (TA) ranged between 326.54 and 387.12 mg L^{-1}. The lowest potassium concentration was observed at Station 2 in January, while the highest level was found at Station 1 in September. A significant positive correlation was observed between TA values to NO_2 (r=0.743), Mg (r=0.805), salinity, WT, SSC, COD, BOD_5, Cl, TH and a negative significant relationship with DO (Table 4).

Magnesium exists in all natural waters. It is a component of chlorophyll and there are no ecosystems free of magnesium, and it makes this element very important in life (Balcı *et al.*, 2009). Alpsarı Pond's magnesium concentration changed between 30.8 and 63 mg L^{-1}. The lowest Mg concentration was observed at Station 2 in January, while the highest level was found at Station 1 in June (Table 2 and 3). The highest Mg value of this pond is significantly higher than the Apa Dam Lake, lower than the Işıktepe and Derbent Dam Lakes (Yılmaz Öztürk, & Akköz, 2014; Küçükyılmaz *et al.*, 2014; Taş, 2006). There was a significant negative correlation with DO, SO_3 and a positive significant correlation with NO_2 (r=0.581), NH_4 (r=0.596), salinity, WT, EC, SSC, COD, BOD_5, Cl and pH (Table 4).

Calcium and magnesium cations in irrigation waters make water more permeable and more cultivable. It is an important characteristic for the ponds used for irrigation purposes. Alpsarı Pond's calcium concentration ranged from 0 and 76.26 mg L^{-1}. The lowest calcium concentration was observed at Station 2 in August, while the highest level was found at Station 1 in May (Table 2 and 3). The highest calcium value in Alpsarı Pond was found to be lower than the Çiğdem Pond and Apa Dam Lake, higher than aquaculture ponds in Orissa (Kurnaz *et al.*, 2016;

Yılmaz Öztürk, & Akköz, 2014; Mishra, Rath, & Thatoi, 2008). A significant positive correlation was observed between calcium values to NO_3 (r=0.625), NO_2 (r=0.462), NH_4 (r=0.342) COD, BOD_5, Na and Cl (Table 4).

The nitrogenous compounds widely existing in natural waters are nitrite, nitrate, ammonium and organic nitrogen (Taş, 2011). The sources of these nitrogenous materials may be the atmospheric nitrogen conveyed by precipitation water and the nitrate salts within the structure of soil, as well as they may originate from the compounds used in agricultural activities and those originating from domestic and industrial wastes. By increasing the primary production, the nitrogenous compounds mixing in aquatic media may cause eutrophication (Henry, Tundisi, & Curi, 1984). The nitrite concentration in natural waters varies between 0.0002 and 0.006 mg L^{-1}. The lowest concentration of nitrite was found at Station 3 in February, while the highest level was determined at Station 1 in August (Table 2 and 3). The highest nitrite level in the pond is higher than the Karamanlı Pond, which is much lower than the Çavuşçu Lake and Apa Dam Lake (Tepe *et al.*, 2004; Aşıkkutlu *et al.*, 2014; Yılmaz Öztürk, & Akköz, 2014). According to the Pearson's correlation; the nitrite is a positive significant relationship with NO_3 (r=0.602), NH_4 (r=0.484), COD, BOD_5, TA, TH, WT, SO_3, Na and K (Table 4). In conclusion, it was found that this pond is suitable for aquatic life. Additionally, according to the inland water quality criteria of SWQMR, the pond was found to be Class I (≤ 0.01 mg L^{-1}) in terms of NO_2 ,which means it is clean water (SWQMR, 2015).

Nitrate widely exists in oxygen-rich waters, and it is an important mineral that can limit or increase the algal growth. Nitrate level is generally low in surface waters. In oligotrophic waters, the level of nitrogen is low, while it is very high in eutrophic waters (Taş, 2011). The nitrate concentration in natural water changes between 2.28 and 13.74 mg L^{-1}. The lowest concentration of nitrate was found at Station 2 in February, while the highest level was determined at Station 1 in June (Table 2 and 3). The highest nitrate level in the pond is higher than the Sarısu-Mamuca and Yayladağı Ponds (Demir *et al.*, 2007; Mutlu, & Tepe, 2014). There is a weak correlation between nitrate to NH_4 (r=0.238), COD, Na, K, DO, BOD_5, Ca and NO_2 (Table 4). In conclusion, the pond was found to be Class III (<20) in terms of nitrate by the inland water quality criteria of SWQMR, which means it is polluted water (SWQMR, 2015).

Ammonium ion is not significantly toxic to organisms living in aquatic ecosystems. Nevertheless, it transforms into ammonium depending on high pH and temperature, and becomes toxic to fish and other creatures (Ünlü *et al.*, 2008). This pond's ammonium concentration varies between 0 and 0.001 mg L^{-1}. The lowest concentration of ammonium was found in all Stations 2 in January and February, while the highest level was determined at Station 1 in December (Table 2 and 3). The highest NH_4 level in the pond is much lower than the Yayladağı Pond and Apa Dam Lake (Mutlu, & Tepe, 2014; Yılmaz Öztürk, & Akköz, 2014). A significant positive correlation was observed between NH_4 to PO_4 (r=0.635) and Mg (r=0.596). There was a significant negative correlation with DO (r=-0.639) and SO_3 (r=-0.235) (Table 4). According to the inland water quality criteria of SWQMR, the pond was found to be Class I (<0.2 mg L^{-1}) in terms of NH_4, which means it is clean water (SWQMR, 2015).

Since the ferrous is used for secretion of many enzymes that are necessary for autotroph bacteria in aquatic media, this element is very important. Besides that, since it is an active element for redox, it provides significant information regarding the geochemistry of the environment. The acceptable limit is 0.1 mg L^{-1} for fresh waters (EPA, 2005). The ferrous level of Alpsarı Pond ranges between zero and 0.006 µg L^{-1}. The lowest concentration of ferrous was found in all Stations in winter and spring, while the highest level was determined at Station 1 in October (Table 2 and 3). The ferrous level in the surface water of Maslak pond is considerably higher than this

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pond (Balcı *et al.,* 2009). The Çiğdem Pond's ferrous level was found to be significantly higher than this pond (Kurnaz *et al.,* 2016). According to Pearson correlation results of ferrous (Table 5); there is a positive significant relationship with Cd (r=0.601), Hg (r=0.514) and Ni (r=0.674). According to the inland water quality criteria of SWQMR, the pond was found to be Class I (≤300 µg L^{-1}) in terms of ferrous, which means it is clean water (SWQMR, 2015).

Copper, Cr, Cd, Zn, and Pb are among the heavy metals, and their source in fresh waters is generally anthropogenic (Weisz, 2000). Heavy metals originate from non-point sources in the waters. They may accumulate within the livers, kidneys, and muscular structures of aquatic organisms. The mean lead level of Alpsarı Pond ranged between 0-1.80 µg L^{-1}.The lowest concentration of lead was found in all stations in December, January and February while the highest level was determined at Station 1 in June (Table 2 and 3). This pond's lead level was found to be higher than Çiğdem and Maslak ponds (Kurnaz *et al.*, 2016; Balcı *et al.*, 2009). There is a positive significant correlation between lead values to Cu (r=0.880), Hg (r=0.733) and Zn (r=0.800) (Table 5). According to the inland water quality criteria of SWQMR, the pond was found to be Class I (≤10 µg L^{-1}) in terms of lead (SWQMR, 2015).

The copper level of Alpsarı Pond ranges from 0 - 14.0 µg L^{-1}. The lowest level of copper was observed at all stations in winter and spring (Table 2 and 3). The highest level was found Station 1 in January. In addition, Yağlıdere Stream's water in the amount of copper is the high season is spring (Aydın Uncumusaoglu *et al.*, 2016). This pond's copper level was found to be significantly higher than Çiğdem, Maslak ponds and Kemeriz Dam Lake (Kurnaz *et al.,* 2016; Balcı *et al.,* 2009; Mutlu, & Demir, 2016). A significant positive correlation was observed between copper to Hg (r=0.912), Zn (r=0.959) (Table 5). According to the inland water quality criteria of SWQMR, the pond was found to be Class I (≤20 µg L^{-1}) in terms of copper (SWQMR, 2015).

The cadmium level of Alpsarı Pond changes between zero and 0.50 µg L^{-1}. The lowest level of Cd was observed at all stations in winter and spring. The highest level was found Station 1 in September (Table 2 and 3). The highest cadmium value is higher than the Çiğdem Pond, lower than the Kemeriz Dam Lake (Kurnaz *et al.*, 2016; Mutlu, & Demir, 2016). The Pearson correlation results of Cd (Table 5); there is a positive significant relationship with Hg (r=0.325), Ni (r=0.347), Cu, Pb and Fe. According to the inland water quality criteria of SWQMR, the pond was found to be Class I (≤2 µg/L) in terms of Cd (SWQMR, 2015).

The mercury of Alpsarı Pond varies between 0.001 and 0.015 µg L^{-1}. The lowest Hg level was observed at Station 3 in October, while the highest level was observed at Station 1 in June (Table 2 and 3). The highest mercury value in this pond is higher than the Çiğdem Pond (Kurnaz *et al.*, 2016). There is a strong positive significant correlation between mercury to Zn (r=0.956), Ni (r=0.584), Pb, Cu and Fe (Table 5). According to the inland water quality criteria of SWQMR, the pond was found to be Class I (≤0.1 µg L^{-1}) in terms of mercury (SWQMR, 2015).

The nickel level of Alpsarı Pond ranges between 2.00 and 8.00 µg L^{-1}. The lowest level of nickel was observed at Station 3 in October, while the highest level was observed at Station 1 in June (Table 2 and 3). The nickel value in this pond is higher than the Çiğdem Pond and Kemeriz Dam Lake (Kurnaz *et al.*, 2016; Mutlu, & Demir, 2016). A significant positive correlation was observed between nickel to Zn (r=0.486), Fe and Hg (Table 5). The inland water quality criteria of SWQMR, the pond was found to be Class I (≤20 µg/L) in terms of Ni (SWQMR, 2015).

The zinc level of Alpsarı Pond ranges between 6.0-30.0 µg L^{-1}. The lowest level of zinc was observed at all stations in February and March, while the highest level was observed at Station 1and 2 in November (Table 2 and 3). The zinc level in this pond is higher than the Çiğdem, Maslak ponds (Kurnaz *et al*., 2016; Balcı *et al.*, 2009). A

www.trjfas.org
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significant positive correlation was observed between Zn values to Pb, Cu and Hg (Table 5). According to the inland water quality criteria of SWQMR, the pond was found to be Class I (≤200 µg/L) in terms of zinc (SWQMR, 2015).

Based on the seasonal mean values and stations' mean values determined over 28 parameters by using water samples taken from three stations on Alpsarı Pond, the HCA analysis was performed. According to the HCA analysis based on stations' mean values, it was determined that Stations 1 and 3 have similar characteristics in terms of pollution load, so their pollutant sources are similar. The reason for the similarity of these stations is the businesses (facilities, recreational areas) around Station 1 and the stream water entry into the pond for Station 3. According to the results of HCA analysis based on seasonal mean values, the seasonal differences clustered as seen in Figure 3. Between two main clusters, the cluster dominated by winter season draws attention. This result coincides with the results of ANOVA applied to seasonal mean values (Table 3). A second cluster consists of summer and autumn seasons. It was also determined that the inter-seasonal transition occurs in the spring months (Shrestha, & Kazama, 2007).

Conclusion

As a result of performing analyses, it was found that, in Alpsarı Pond hosting aquatic animals and being suitable for aquatic life. It is very important to maintain the water quality and sustain the ecological balance for irrigating the near agricultural lands. Major causes of concern are the fertilizers and chemicals. Considering this importance, the unconscious use of agricultural pesticides in near orchards should be prevented. HCA analysis's result coincides with the results of ANOVA applied to seasonal mean values. The leakage of domestic and animal wastes into the ponds through precipitation and/or snow waters should be eliminated, and the required measures should be taken in order to protect and improve the actual water quality level (Class I-III-IV) according to SWQMR. There are already four classes as water quality class and all classifications except class II are available. The water of the main pond is very high quality, polluted water and much polluted water respectively. We think that this study, which has reached the first information about the water quality of the Alpsarı Pond, will also be a source for further studies. In the future, research should provide for the development of non-source pollution, non-integrated pollution, modeling and monitoring, which is caused by non-agricultural production.

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Table 1. Coordinates of sampling stations

Station	Coordinate	
1	40°40'36.91"N	33°30'10.44" E
2	40°40'25.93"N	33°30'20.75"E
3	40°40'46.21" N	33°30'28.05" E

Table 2. Mean, Standard deviation (SD) and range (Minimum- maximum) of water quality parameters by the stations

	St.1	St.2	St.3
DO (mg/L)	10.198±0.8981 8.65-11.55	10.231±0.8940 8.69-11.59	10.21±0.8941 8.67-11.56
Salinity(‰)	0.093±0.033 0.05-0.15	0.082±0.032 0.04-0.14	0.09±0.0321 0.05-0.15
pH	8.738±0.368 7.68-9.1	8.794±0.165 8.58-9.07	8.813±0.169 8.59-9.09
WT (C°)	12.2±7.1981 2.6-21.5	11.991±7.1587 2.6-21.4	12.05±7.2096 2.5-21.4
EC (µS/cm)	314.5±52.264 248.36-391.5	310.62±52.109 246.9-388.56	313.00±51.914 247.54-390.88
SSC (mg/L)	6.42±3.017 3.12-11.5	6.378±3.003 3.1-11.48	6.378±3.004 3.08-11.44
COD (mg/L)	4.822±1.397 3.06-7.64	4.795±1.393 3.02-7.58	4.742±1.388 3-7.52
BOD_5 (mg/L)	1.446±0.578 0.64-2.18	1.42±0.576 0.62-2.14	1.377±0.566 0.6-2.06
Cl^- (mg/L)	6.763±1.2523 5.02-7.96	6.727±1.2601 4.96-7.94	6.693±1.2420 4.98-7.9
PO_4 (mg/L)	0.355±0.2048 0-0.724	0.388±0.1727 0.197-0.72	0.378±0.1676 0.196-0.712

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SO_4^{2-} (mg/L)	86.275±9.756 70.92-104.3	93.855±25.649 74.9-170.88	85.348±8.994 70.82-100.92
SO_3^{2-}(mg/L)	3.1216±0.3817 2.5-3.84	3.0766±0.3641 2.46-3.7	3.05±0.3655 2.42-3.72
Na (mg/L)	65.99±13.221 53.16-90.56	65.615±13.117 53.12-90.5	65.533±13.073 53.08-90.48
K (mg/L)	13.265±3.895 9.78-21.5	13.068±3.810 9.72-21.44	13.076±3.632 9.76-20.18
T.Hard. (mg/L)	347.21±22.773 316.88-377.5	345.39±22.739 315.26-375.22	346.20±22.675 316.6-376.48
T.Alka. (mg/L)	358,35±21,77 328,32-387,12	356,08±21,66 326,50-385,66	357,07±22,03 327,28-386,82
Mg (mg/L)	48.56±11.785 30.9-63.88	48.5±11.785 30.8-63.76	48.461±11.789 30.84-63.82
Ca (mg/L)	59.006±12.275 36.88-76.26	53.393±20.741 0-76.14	58.631±12.314 36.64-76.06
NO_2 (mg/L)	0.0036±0.0019 0.0004-0.006	0.0030±0.0020 0.0003-0.0058	0.0028±0.0019 0.0002-0.0056
NO_3 (mg/L)	5.7433±3.2043 2.32-13.74	5.7366±3.2417 2.28-13.7	5.6491±3.1441 2.31-13.56
NH_4 (mg/L)	0.0006±0.0003 0-0.0013	0.0005±0.0003 0-0.0011	0.0004±0.0002 0-0.0009
Fe^{2+} (mg/L)	0.0019±0.0019 0-0.006	0.0013±0.0016 0-0.005	0.0011±0.0014 0-0.004
Pb (µg/L)	0.608±0.6258 0-1.8	0.533±0.6020 0-1.7	0.45±0.5231 0-1.5
Cu (µg/L)	5.166±4.086 0-14	4.75±3.910 0-13	3.916±3.449 0-11
Cd (µg/L)	0.191±0.1443 0-0.5	0.175±0.1544 0-0.5	0.117±0.1403 0-0.4
Hg (µg/L)	0.0073±0.0040 0.002-0.015	0.007±0.0039 0.002-0.015	0.0060±0.0036 0.001-0.013
Ni (µg/L)	5.25±1.658 2-8	4.583±1.621 2-8	4.25±1.544 2-7
Zn (µg/L)	16±7.0064 7-30	15.583±7.0769 7-29	14.5±6.9084 6-27

Table 3. Seasonal Mean, Standard deviation (SD) and range (Minimum- maximum) of water quality parameters

	Winter	Spring	Summer	Autumn
DO(mg/L)	10.44±0.14[bc] 10.34-10.63	11.03±0.41[c] 10.68-11.59	10.33±0.74[b] 9.64-11.31	9.05±0.46[a] 8.65-9.69
Salinity(‰)	0.05±0.01[a] 0.04-0.06	0.07±0.01[a] 0.05-0.09	0.10±0.01[b] 0.08-0.13	0.13±0.02[c] 0.10-0.15
pH	8.50±0.31[a] 7.68-8.67	8.77±0.04[b] 8.71-8.83	8.92±0.06[b] 8.82-8.98	8.93±0.018[b] 8.68-9.10
WT (C°)	2.70±0.146[a] 2.50-2.90	9.74±2.62[b] 6.70-13.00	17.54±2.06[c] 15.30-20.30	18.33±4.40[c] 12.30-21.50
EC (µS/cm)	280.35±21.04[a] 251.68-300.84	262.02±11.63[a] 246.90-275.84	337.14±36.80[b] 284.54-380.12	371.32±25.87[c] 335.42-335.42
SSC (mg/L)	3.58±0.36[a] 3.08-3.84	4.33±0.66[a] 3.42-4.80	8.35±2.37[b] 5.68-11.24	9.31±1.88[b] 37.12-11.50
COD_5 (mg/L)	3.29±0.21[a] 3.00-3.48	4.66±1.31[b] 3.08-6.16	6.11±1.10[c] 5.20-7.64	5.07±0.66[b] 4.17-5.56
BOD (mg/L)	0.70±0.06[a] 0.60-0.76	1.23±0.48[b] 0.64-1.80	1.94±0.14[c] 1.80-2.18	1.79±0.14[c] 1.58-1.94
Cl^- (mg/L)	5.01±0.04[a] 4.96-5.08	6.34±0.67[b] 5.44-7.02	7.72±0.08[c] 7.62-7.84	7.84±0.09[c] 7.70-7.96
PO_4 (mg/L)	0.35±0.21[a] 0.20-0.64	0.25±0.04[a] 0.20-0.28	0.35±0.14[a] 0-0.50	0.55±0.15[b] 0.38-0.72
SO_4^{2-} (mg/L)	89.53±30.90[a] 70.82-170.88	83.66±2.04[a] 81.04-86.76	98.54±4.55[a] 92.78-104.30	82.25±6.89[a] 74.86-90.84

RESEARCH PAPER

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SO_3^{2-} (mg/L)	2.80±0.26^{a} 2.42-3.02	3.37±0.32^{b} 2.98-3.84	3.34±0.15^{b} 3.12-3.54	2.82±0.21^{a} 2.60-3.12
Na (mg/L)	57.72±3.15^{a} 54.92-61.88	72.86±11.70^{b} 59.66-87.62	77.36±12.30^{b} 61.64-90.56	54.98±2.00^{a} 53.08-57.90
K (mg/L)	10.94±0.80^{ab} 10.0-11.96	13.60±3.60^{b} 11.06-18.45	17.57±2.91^{c} 13.76-21.50	10.43±0.92^{a} 9.72-11.72
T.Hard. (mg/L)	320.05±3.24^{a} 315.26-330.43	338.42±9.44^{b} 328.41-351.29	373.32±2.82^{c} 369.13-377.50	353.30±17.44^{d} 332.15-374.36
T.Alka. (mg/L)	331,78±3.62^{a} 326,54-336,30	350,00±12,92^{b} 339,98-364,58	381,14±4,71^{c} 374,64-387,00	365,74±17,86^{d} 344,30-387,12
Mg (mg/L)	38.48±9.35^{a} 30.8-50.86	38.59±3.73^{a} 35.52-43.62	60.88±2.26^{b} 58.8-63.88	56.08±2.51^{b} 53.08-58.98
Ca (mg/L)	44.40±9.57^{a} 36.64-57.18	60.35±12.62^{a} 47.36-76.26	61.49±23.23^{a} 0-71.84	61.80±2.55^{a} 58.58-64.90
NO_2 (mg/L)	0.0008±0.0006^{a} 0.0002-0.0018	0.0037±0.0019^{b} 0.0003-0.0050	0.0053±0.0004^{c} 0.0048-0.0060	0.0029±0.0004^{b} 0.0022-0.0036
NO_3 (mg/L)	3,3367±1,51^{a} 2.28-5.380	6,6911±2,23^{bc} 4,2400-9,700	8,3222±14,21^{c} 4,120-13,740	4,4889±0,63^{ab} 3,960-5,360
NH_4 (mg/L)	0,0004±0,0005^{a} 0-0,0013	0.0005±0.0002^{a} 0.0001-0.0008	0.0007±0.0002^{a} 0.0004-0.0009	0.0007±0.0002^{a} 0.0004-0.001
Fe_2^{+} (mg/L)	0.0001±0.003^{a} 0.000-0.001	0.0001±0.0004^{a} 0.000-0.001	0.0023±0.0010^{b} 0.00-0.004	0.0033±0.0015^{b} 0.002-0.006
Pb (µg/L)	0.0222±0.04^{a} 0.000-0.100	0.822±0.53^{b} 0.200-1.60	1.0889±0.515^{b} 0.400-1.800	0.1889±0.1054^{a} 0.100-0.400
Cu (µg/L)	1.222±1.30^{a} 0.00-3.00	5.00±3.84^{ab} 0.00-10.00	7.77±4.06^{b} 3.00-14.00	4.44±2.06^{ab} 2.00-7.00
Cd (µg/L)	0.044±0.0726^{a} 0.000-0.200	0.0778±0.0441^{a} 0.000-0.100	0.2556±0.088^{b} 0.200-0.400	0.267±0.180^{b} 0.000-0.500
Hg (µg/L)	0.0031±0.0001^{a} 0.001-0.006	0.0052±0.0029^{ab} 0.002-0.009	0.011±0.0030^{c} 0.007-0.015	0.0079±0.0020^{bc} 0.005-0.011
Ni (µg/L)	3.889±1.833^{a} 2.000-7.000	3.556±0.881^{a} 2.000-5.000	4.889±0.60^{a} 4.000-6.000	6.444±1.130^{b} 5.000-8.000
Zn (µg/L)	8.89±2.03^{a} 6.00-12.00	14.56±5.98^{b} 7.00-22.00	22.00±6.14^{c} 14.00-30.00	16.11±5.21^{bc} 10.00-23.00

$^{a.b.c}$ Means with different letters in the same column are statistically significant ($p<0.05$)

RESEARCH PAPER

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Table 4. Pearson correlation matrix among the variables

	DO	Salinity	pH	WT	EC	SSC	COD	BOD_5	Cl	PO_4	SO_4	SO_3	Na	K	T.H	TA	Mg	Ca	NO_2	NO_3	NH_4
DO	1																				
Salinity	-0.71**	1																			
pH	-0.413*	0.714**	1																		
WT	-0.544**	0.923**	0.773**	1																	
EC	-0.861**	0.899**	0.623**	0.811**	1																
SSC	-0.767**	0.898**	0.682**	0.912**	0.940**	1															
COD	0.045	0.601**	0.574**	0.750**	0.393**	0.506**	1														
BOD_5	-0.270	0.804**	0.676**	0.914**	0.659**	0.757**	0.915**	1													
Cl	-0.408*	0.838**	0.677**	0.927**	0.708**	0.799**	0.772**	0.953**	1												
PO_4	-0.422*	0.327	0.141	0.19	0.454**	0.253	0.028	0.230	0.342*	1											
SO_4	0.067	-0.002	0.075	0.061	0.063	0.066	0.191	0.117	0.025	0.045	1										
SO_3	0.447**	-0.021	0.211	0.243	-0.24	0.021	0.534**	0.371*	0.271	-0.55**	0.091	1									
Na	0.692**	-0.088	0.147	0.15	-0.286	-0.155	0.675**	0.452**	0.288	-0.156	0.241	0.681**	1								
K	0.523**	0.066	0.222	0.311	-0.086	0.06	0.755**	0.564**	0.371*	-0.283	0.255	0.631**	0.899**	1							
T.H	-0.255	0.715**	0.658**	0.893**	0.611**	0.771**	0.854**	0.902**	0.827**	-0.007	0.232	0.451**	0.436**	0.631**	1						
TA	-0.344*	0.762**	0.684**	0.922**	0.675**	0.833**	0.792**	0.887**	0.832**	0.014	0.196	0.400*	0.351*	0.550**	0.986**	1					
Mg	-0.422*	0.733**	0.581**	0.790**	0.750**	0.749**	0.710**	0.827**	0.799**	0.490**	0.301	-0.011	0.268	0.397*	0.822**	0.805**	1				
Ca	0.085	0.416*	0.371*	0.429**	0.179	0.206	0.601**	0.568**	0.511**	0.200	0.133	0.259	0.556**	0.478**	0.467**	0.454**	0.483**	1			
NO_2	0.085	0.441**	0.530**	0.659**	0.309	0.495**	0.745**	0.769**	0.718**	0.003	0.175	0.608**	0.639**	0.630**	0.755**	0.743**	0.581**	0.462**	1		
NO_3	0.543**	0.080	0.220	0.264	-0.145	-0.056	0.777**	0.567**	0.420*	0.053	0.252	0.516**	0.917**	0.825**	0.499**	0.388*	0.461**	0.625**	0.602**	1	
NH_4	-0.235	0.348*	0.304	0.324	0.443**	0.395*	0.240	0.390*	0.410*	0.635**	0.233	-0.168	0.142	0.012	0.276	0.308	0.596**	0.342*	0.484**	0.238	1

*. Correlation is significant at the 0.05 level (2-tailed)

RESEARCH PAPER
Turkish Journal of Fisheries and Aquatic Sciences
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Table 5. Pearson correlation matrix among the heavy metal variables

Correlations

	Fe	Pb	Cu	Cd	Hg	Ni	Zn
Fe	1						
Pb	0.002	1					
Cu	0.234	0.880**	1				
Cd	0.601**	0.093	0.102	1			
Hg	0.514**	0.733**	0.912**	0.325	1		
Ni	0.674**	0.017	0.408*	0.347*	0.584**	1	
Zn	0.328	0.800**	0.959**	0.129	0.956**	0.486**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

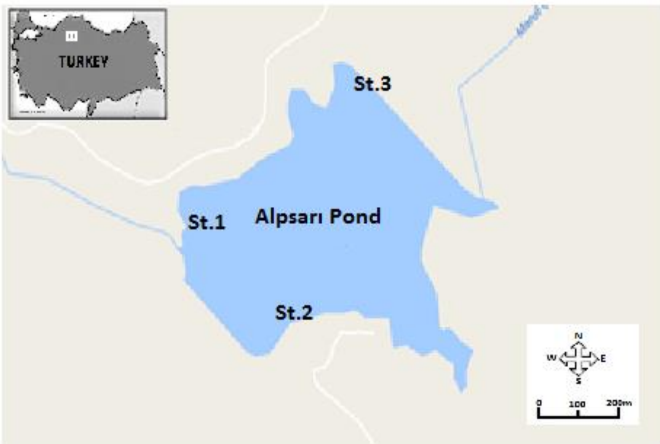

Figure 1. Map of study area with sampling point locations.

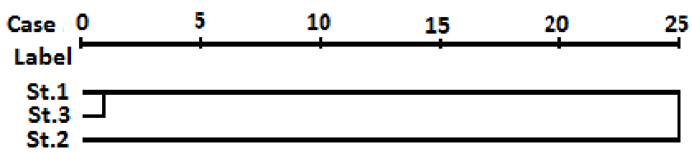

Figure 2. Dendogram (using Ward Method) shows clusters of variables (St.: Station)

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www.trjfas.org
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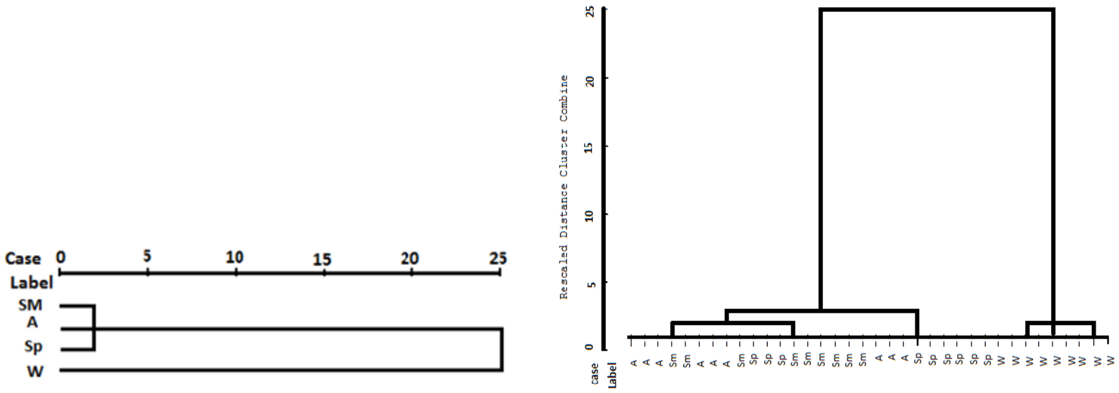

Figure 3. Dendogram (using Ward Method) shows clusters of variables (A: Autumn, Sm:Summer, Sp:Spring and W:Winter)