REPUBLIC OF TURKEY
BİNGÖL UNIVERSITY
INSTITUTE OF SCIENCE

SEASONAL WATER QUALITY ANALYSIS USING LIMNOLOGICAL STUDIES OF DUHOK LAKE AND USING GIS IN DUHOK (NORTH OF IRAQ)

MASTER THESIS

Ahmed Basser MOHAMMED

SOIL SCIENCE AND PLANT NUTRITION

SUPERVİSOR OF THESİS
Assoc. Prof. Dr. Ali Rıza DEMİRKIRAN

BİNGÖL-2017

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This dissertation was accepted by the following committee on 27.07.2017 with the vote unity

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Dedication

I give this work to the one who encouraged me by her love kind heartedness and carefully which I sense when I am with the mother, to who provided me his love heart and qualified me the meaning of life my Father, to the person took my hand and raised me up to a higher level of his knowledge, Assoc. Prof. Dr. Ali Riza DEMIRKIRAN, and to everyone who needs science.

Ahmed Basser MOHAMMED

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LIST OF SYMBOLS

%	: Percentage
°C	: Degree Celsius
µS	: Micro Siemens
ANOVA	: Analysis of Variance
Ca	: Calcium
CaCO3	: Calcium Carbonate
CCME	: Canadian Council of Ministries of the Environment
Cl	: Chloride
DO	: Dissolved Oxygen
E	: East
EC	: Electrical Conductivity
GIS	: Geographic Information Systems
GPS	: Global Positioning System
H2SO4	: Sulfuric Acid
HCl	: Hydrochloric acid
IDW	: Inverse Distance Weighted Interpolation
K^+	: Potassium
meq/L	: Milliequivalents of Per Liter
Mg	: Magnesium
mg/L	: Mille Gram per litter
MPN	: Most Probable Number
N	: North
Na	: Sodium
NaOH	: Sodium hydroxide
NO_3	: Nitrate
NTU	: Nephelometric Turbidity Unit
P	: Phosphorus
pH	: Potential of Hydrogen
ppm	: Part Per Million
SO_4	: Sulfate
TA	: Total Alkalinity
TDS	: Total Dissolved Solid
TH	: Total Hardness
TS	: Turkish Standards
UNEP	: United Nations Environment Program
WHO	: World Health Organization

DUHOK GÖLÜ (DUHOK, KUZEY IRAK) SU KALİTESİNİN LİMNOLOJİK ÇALIŞMALARLA CBS TEMELLİ ANALİZİ

ÖZET

Duhok Gölü, Irak'ın kuzeyinde Duhok ilinde bulunan, tarım arazileri, evsel su kaynağı gibi pek çok amaç için su sağlayan ve yerel su organizmaları ve bitki türleri için ev sahibi olan bir tatlısu gölüdür. Bu nedenlerle bölgenin ekosistemi ve insan sağlığının korunması için bu gölün su kalitesi önemlidir.

Bu çalışma, Duhok Gölü'nün mevsimsel su kalitesi analizini belirlemek için, Duhok Gölü suyunun fiziksel ve kimyasal özellikleriyle ilgili limnolojik çalışmaları yapmayı ve bu çalışmalar için istatistiki analizler ve GIS enterpolasyon haritasını kullanmayı amaçlamıştır. Suyun fiziko-kimyasal özellikleri Ekim-Aralık 2016 - Mart-Temmuz 2017 arasındaki farklı mevsimler olmak üzere dört farklı ayda incelenmiş ve analiz edilmiştir. Gölün değişik bölümlerinde (yedi farklı istasyonda olmak üzere) yüzey su örneklerinde mevsimsel değişim gözlenmiştir. Analizlerde; hava sıcaklığı ve su sıcaklığı, çözünmüş oksijen, bulanıklık, pH, elektrik iletkenliği, toplam çözünmüş katı madde, toplam alkalilik, toplam sertlik, kalsiyum, magnezyum, klorür, sülfat, nitrat, sodyum ve potasyum gibi çeşitli parametreler incelenmiştir.

Çalışma, bazı fiziko-kimyasal parametrelerde ve bütün olarak önemli mevsimsel değişiklikler olduğunu ortaya koymuştur Analiz edilen veriler yaz mevsiminde incelenen parametrelerin daha yüksek olduğunu, bahar mevsiminde ise daha düşük olduğunu göstermektedir. Göl su gövdesine bölgedeki kaplıca suyunun doğrudan katıldığı S3 numune istasyonunda, tüm mevsimde incelenen parametreler daha yüksek değerlerde çıkmıştır. Bu istasyondaki elde edilen değerler, WHO standartları tarafından içme suyunun izin verilen seviyesinden daha yüksek olarak kaydedilmiştir.

Ve sonuç olarak, Göl ekosistemi ile fiziksel, kimyasal ve biyolojik bütünlüğünü korumak için, gıda zincirini olumsuz etkileyen hidro-jeokimyasal ve hidro-biyolojik döngülerdeki ekolojik dengesizliğin önüne geçmek, mevcut dengeyi korumak ve olumsuzlukları önlemek için uygulanabilir, ciddi bir restorasyon ve yönetim taktiklerine ihtiyaç duyulmaktadır.

Anahtar Kelimeler: Sezona bağlı değişimler, su kalitesi, limnoloji, Duhok Gölü, GIS interpolasyon.

SEASONAL WATER QUALITY ANALYSIS USING LIMNOLOGICAL STUDIES OF DUHOK LAKE AND USING GIS IN DUHOK (NORTH OF IRAQ)

ABSTRACT

The Duhok Lake is a freshwater lake located in Duhok governorate-north of Iraq, which supplies water for crops land and many other purposes and is home for native aquatic organisms and plant species, therefore the water quality and health is vital for the conservation of ecosystem and human health.

The study aimed at seasonal water quality analysis of Duhok Lake using limnological studies that related to physical and chemicals characteristics of Duhok lake water. Also using the statistical analysis and using GIS interpolation map for this study. The physiochemical characteristics have been studied and analyzed at four differed months in the different season, during October-December 2016 to March-July 2017. Seasonal variation of seven different surface water-sampling stations in different part of the Duhok Lake has been observed. Several parameters have been studied and analyzed including ‘’air temperature, water temperature, dissolved oxygen, turbidity, pH, electrical conductivity, total dissolved solid, total alkalinity, total hardness, calcium, magnesium, chloride, sulfate, nitrate, sodium, and potassium’’.

The study has revealed that there are significant seasonal variations in some physicochemical parameters and as a whole analyzed data depicted the higher values of studied parameters during the summer season and lower contents during the spring season. Moreover, the higher data obtained from the sample station S3, which the hot spring water is directly discharged into the lake water body. In the station S3, the higher values of the studied parameter were recording in all season which is higher than the permissible level of drinking water according to (WHO) and standards. In the sampling station S3, and is need physical, chemical and biological reliability with possible and inflexible repair and management strategies in instruction to uphold, preserve, protect and to avoid ecological disparity and trouble in hydro-geochemical and hydro-biological cycles which eventually harmfully and impact the food chain of ecosystems and ecological imbalance of the lake ecosystem.

Keywords: Seasonal variations, water quality, limnology, Duhok Lake, GIS interpolation.

1. INTRODUCTION

The earth is called a blue planet because 71 percent of the earth's surface is cover with water. Water also exists under the land surface and in the air as water vapor. Water is a limited source. Water that is used today might possibly be the same water that once trickled down the back of a dinosaur (Nordstrom 2002).

The water that was here centuries ago is the same water that we used today because the earth is a closed system, which implies that very tiny matter, including water, over leaves or enters the air. Nevertheless, the earth cleans and replenishes the water supply through the water cycle (Enge and Whiteford 2013). The earth has an abundance of water, but sadly, only a few percentage about 0.3 %, is even can be used directly by humans is a fresh water but other 99.7 percent is in the soils, oceans, ice caps, and floating in the atmosphere. Still, much of the 0.3 percent that is useable is not at hand (Perlman 2013).

Nevertheless, fresh water is fundamental to life. All creatures (humans, animals, and plants etc.) need fresh water to survive. We utilize fresh water for drinking, industrial factories, as part of sanitation systems, and irrigate crops etc. (Rosenfeld and Todd 2006).

Water used up from lakes, streams, and underground water is replenished by rain and snowfall, lakes are large water bodies that are bounded by the land and are not part of a sea and comparably still bodies of water when compared to a stream where the water flows (Perlman 2013). The lake can be either fresh or salty water and the freshwater lake is considered as one of the most significant resources of fresh water that human can utilize it as resources of irrigation, drinking and industrial factories etc (Dudgeon 2003).

Duhok Lake is an artificial small freshwater lake fed by spring from the surrounding rocky hills and mountains. These mountains, Garmava, and Bajlor, have moderate plant cover covers of dry grasses, with a high number herbs and shrubs and trees such as *Ficus* sp., *Vitis* sp., *Pyrus communis*, *Prunus amygdalus*, *Quercus* sp., and *Orobanche* sp.

Actually, the Duhok lake is an artificial lake created by an earth-fill embankment dam on the Dohuk River which is located north of the city Duhok (Ararat 2009). The dam was completed in 1988 with the primary purpose of providing water for irrigation and for the city of Duhok (Issazadeh and Govay 2014). The dam is 50 m high, can hold 52 million m^3 of water and has a maximum discharge of 81 m^3. At the normal operation level, the reservoir is about 4 km long and 1.7 km wide. The area to be irrigated from this reservoir is about 46 km^2 (Ararat 2009).

Limnology is the study that deals with inland water bodies ecosystem and environmental factors that affecting on and this word (Limnology) come from the Greek which means “(limne) lake” and “(logos) study”. Limnology is considered as a part of the ecology and It covers the physical, chemicals, biological, geological and other features of all inland waters bodies both standing as in dam lentic ecosystems and running as in streams lotic ecosystems. Studies helpful for conserve and manage these aquatic ecosystems using a landscape perspective (Bertoni 2011).

One of the essential parts of environmental monitoring is water quality analysis, because if the quality of water is low, it affects not only aquatic ecosystems but also affects the surrounding environment. It covers the all parameters feature that impacts the quality of water in the nature. These characteristics can be physical-chemical, biological or radiological factors. Water quality nursing can assistance researchers to foretelling and study from natural processes in the environment and control human impacts on an ecosystem. The water quality analyses can also help in ensure that that aquatic ecosystem standards are being met (Öztürk et al. 2009).

The lakes, rivers or any freshwater resources is influenced by water contaminations. Water contamination happens when poisons elements, substances or chemicals that make water contaminated discharge indirectly or directly into water bodies without enough treatment to dispose of unsafe compounds. Contaminants get into water mainly by human causes or human factors. The source of pollution can be from a point, non-point source, or transboundary in nature (Alford 2014).

Some application and techniques can help to control and assist the studies to be more clearable and more understandable such as geographic information systems, by Steingier et al (2009). Geographic information system is a tool to collect, input, process, analyses, display, and output geographic and descriptive information for specific purposes. This definition includes the ability of systems to enter geographic information maps, aerial photographs, satellite imagery, descriptive, names, table, and processing of this information of errors, stored, retrieved, inquired, analyzed spatial and statistical analysis, displayed on a computer screen or printed on paper in ‘’reports, maps, tables, graphs, and charts’’. The advantage of geographic information systems compared to the rest of the other information systems is that it has the highest power of analysis the dealing large databases and with spatial data. Thus, geographic information systems system found to be an effective tool to assist in the study and analysis of lake water quality (Ballousha 2011).

The objective of this study is to evaluate the quality of water in Duhok Lake. In addition, evaluate the health of Duhok Lake by using geographic information systems mapping after using limnological studies to analyzing the physical and chemical properties of water and to increase the public awareness and possibly health, and to knowing the suitability of water for aquatic life, recreation etc., Finally to foretell the future contamination level and its impacts on Duhok Lake.

2. LITERATURE REVIEW

2.1. Water Quality

Water is fundamental material for human survival after air (Ahuja 2009).Water quality is recognized in terms of the ‘’biological, physical and chemical‘’ properties of water body. The quality of freshwater lakes, and streams is change with the seasons and geographic area, even when there is no pollution exist, there is no just a single measure that sets up excellent water quality, for example ‘’water suitable for drinking can be utilized for irrigation, but water utilized for irrigation may not meet drinking water guidelines‘’ Water quality guidance provides essential scientific information about water quality parameters and ecologically relevant toxicological verge values to protect special water uses (Vickers 1997).

2.2. Water Quality and Public Health

Water quality and public health are linked in many ways Forget and Lebel (2001). Safe water is fundamental for human life Michiels et al (2000). Several theories have recommended that water was responsible for transmission of various waterborne diseases through the microbial contamination of drinking water Ganjo (1997). And major risk danger factor in potential widespread of disease and continues to be a main cause of mortality and morbidity report by UNEP and WHO (1996). In spite of overall endeavors and the accessibility of present day advancements used for the generation of innocuous drinking water, it has been portrayed that the transmission of waterborne ailment involves significant concern Stevens et al (1995).The contamination of drinking water during storage, an absence of guidelines, restricted comprehension and mindfulness among the populace is recognized Wright et al (2004) and Mackenzie (1994). The adverse implications of mechanical failure, human mistake or deterioration in the quality of the source water, even with the good treatment system and disinfection process, can sometimes destroy the quality of water (Roefer 1996; Geldreich 1996 and Mackenzie 1994). Diseases resulting from water contamination with chemicals is negligible compared to the number of pollution caused by microbial contamination. But, in the case of bacterial pollution, a presence of only small numbers causes a health danger to the consumer life according to WHO (1997). Lee et al (1993) epidemiological studies have presented that low quality of drinking water, due to ecological infection or un-chlorinated water as the major transmission route was responsible for many of the water diseases examples of these transmission routes for the waterborne disease to humans are:

- Use contaminated water or contaminated water directly or indirectly by preparing food.
- Body contact with polluted waters, for example, swimming pool, freshwater and marine water.

2.3. Impacts of Climate Change on Water Quality of Lake

Surface water bodies possible impacts on, such as streams and lakes, in terms of their nutrient status, hydrological regimes, hydro-morphology, acidification possible and noxious elements activate. The second, long-term changes in the water quality for specific features of the freshwater environment such as estuaries and urban areas(Williams et al. 2000). presented that great diurnal variations in lakes dominated by macrophytes occur and thus contamination events in such streams could also cause low (DO) concentrations. Under reduced flows in summer, (BOD) and phosphorus concentrations levels would rise, whereas ammonia concentrations would decrease due to higher nitrification degrees (Jacob and Winner 2009). This gives rise to increased nitrate concentrations as ammonia decays to nitrate. There could be enhanced growth of algal blooms in lakes which affect (DO), concentrations and water may supply. Also, with increased storm events, specifically in the summer season, there might be more frequent occurrences of combined sewer overflows discharging highly contaminated waters into receiving water bodies, also it can be beneficial in that storms will also expel away algal blooms (Jacob and Winner 2009).

2.4. Water Pollution

There is no life without water. An adequate supply of fresh water is necessary for industrial processes as well as domestic. Water bodies have become sources of fresh water and containers for domestic and industrial waste that lead to water pollution according to Greenstone and Hanna (2014). The contamination of the aquatic ecosystem is happening by human directly or indirectly of energy or substances which result In such adverse effects as damage to living resources, threats to human health, obstacles to aquatic activities including fish and low water quality to using it in industrial factors, agronomic and often reduction of amenities etc.

Water contamination influences water quality. Water quality indicated the all nature of the aquatic ecosystems (Chapman 1996). The description of the quality of the aquatic environment can carry out through a variety of ways. It can achieve through quantitative measurements such as physical and chemical determinations particulate material, water, or biological tissues and biochemical/biological tests toxicity tests, (BOD) test or through semi-quantitative and qualitative descriptions such ‘’ Species stocks, visual features, and biotic indices etc. ‘’ these determinants are taken out in the field and in in the research centre and produce many types of data, which lend themselves to dissimilar methods Chapman (1996). The quality of freshwater at any point on a landscape reflects the combined special effects of numerous processes along water pathways and both quality and quantity of water is impacted by man activity on all spatial measures documented by Peters and Meybeck (2000).

2.4.1. Effects of Pollution on Water Quality

The primary effect of lake pollution is the reduction in the quality of water which carried by the river. In the less developed countries of South America, Africa, and Asia, 95 per cent of all sewage is discharging untreated into rivers, lakes or the ocean and in India, for example, it is estimated that 2/3 of the surface waters are polluted sufficiently to be considered not safe for human health. The Yamuna River in India had 7,510 coliform bacteria per 100 ml thirty-seven times the level considered safe for swimming in the United States before in going the city. The coliform count increased to 24 million cells per 100 ml as the river take twenty million liters of industrial activity effluents daily from New Delhi city in India death rates were therefore high and life expectancy was low in those location (Cunningham and Saigo 1999). In addition, revealed a worsening trend of contamination from the study of Holoka River in Ethiopia from the upstream to the downstream end of the stream, when water samples collected from downstream and analyzed revealed eight to ten times 23 higher values of COD and BOD and also, measured ions also presented an increasing trend. Thus, research evidence suggests that the effects of the degradation of a water resource are not limited to the area of discharge but could have widespread implications for the entire watershed. Users of polluted or degraded water resources could suffer negative effects downstream studied by Prabu et al (2008).

2.4.2. Effects of Pollution on Freshwater Quantity

Peters and Meybeck (2000) assert that water quality degradation is a principal cause of water scarcity and could reduce the amount of freshwater available for portable, agricultural and industrial use. The quantity of available freshwater is thus linked to quality which may limit its use (Chapman 1996). Human activity such as the indiscriminate dumping of refuse and the channeling of untreated industrial and domestic effluents into the lake and reduce water quality, reduce water quantity and reduce the uses that can put water.

2.5. Features of Water Quality

The principal features of water quality in rivers, streams, and lakes with which water engineers are most concerned are divided into three main groups Physical, Chemical, and Biological (Shaw 1994).

2.5.1. Physical Features

Solids form the most common matter to drive along by a flowing river. These solids could be from organic or inorganic sources. Examples include refuse, tree barks, tree trunks, silt, and boulders. When evaluating water quality, suspended solids are measured in water (mg/l) (Anyanwu 2015). Colour, taste, and odor are properties that are subjectively determined. They are caused by the discharge of noxious substances like excreta, oil, and bath water into the watercourse by from the dissolved impurities from natural sources or by a human (Shaw 1994).

Turbidity refers to the cloudiness of water due to fine suspended colloidal particles of silt or clay, waste effluents or microorganisms and is measured in turbidity units (NTU), (Shaw 1994). Electrical conductivity is a physical property of water, which is reliant on the value of dissolved salts, and measure in micro Siemens per centimeter (μS/cm), and it stretches a decent estimate of the dissolved salt content of a stream. Water and air temperature (°C), which is a decent measure for evaluating the effects of temperature changes on organisms (Shaw 1994).

2.5.2. Chemical Features

The chemical features worth studying in water quality analyses and is very extensive since water is a universal solvent and many chemical compounds can be found in solution in naturally occurring water bodies (Shaw 1994), only a selection of the most significant would be discussed.

(pH) measures the concentration of hydrogen ions and it is an indicator of the degree of ‟alkalinity or acidity” of water. On the scale from zero to 14, a (pH) of seven indicates a neutral solution. Where pH is less than seven, the water is acidic and if (pH) is greater than seven are, the water is alkaline (Perrin 2012). In addition, from the study of Ceyhan River in Turkey the result was recorded that the nutrients, Cl^- and Na^+ affected mostly to the stations of Erkenez-2, Sr-2, and Sır-3 in the ordination diagram correspondence analysis which this result shows that the chemical element affect the feature of the water quality Tanrıverdi et al. (2010).

Dissolved oxygen (mg/l) has an important role in the assessment of water quality. Fish and other forms of aquatic life require dissolved oxygen for their sustenance. Dissolved oxygen affects the taste of water and high concentrations of dissolved oxygen in domestic supplies are encouraged by aeration Nilsson and Renofalt (2008). Nitrogen is measured (mg/l) and can be present in the form of organic compounds usually from domestic wastes, Examples of these compounds are ammonium or ammonia salts. Nitrogen occurs in the environment in various forms and changes forms as it moves through the nitrogen cycle. Measures of nitrogen stretch a suggestion of the state of contamination by organic wastes (Venkatesharaju 2010).

Chlorides, which found in brackish water bodies contaminated by seawater or in ground water aquifers with high salt-water content. The presence of chlorides in a river is an indication of sewage pollution from other chloride compounds (Shaw 1994).

2.5.3. Biological Features

Waterborne organisms transmit some harmful diseases. An example is Bilharzia caused by Schistosoma. The common organism found in all human excreta is Escherichia coli and this gives an indication of sewage pollution or pollution from human sources. This, which measured in most probable number (MPN) per 100 ml, which is determined statistically from of water, samples (Medema 2003).

2.6. An Overview of Limnological Studies in North of Iraq

It is clear that many limnological studies were carried out on different water systems within the north of Iraq. But in general, it can be said that the first ecological studies in Iraq date back to many papers prepared by German group led by (Kolbee et al. 1942).

These investigations comprise of ninety-seven collections from eleven areas completed by Handel Mazzetti’s expedition to Iraq and Turkey around Euphrates and Tigris, it recorded 248 taxa of diatoms from fresh and brackish water habitats. From the study assessment of chemical and physical characteristics of Dokan, Derbendikhan and Duhok lakes, the physical and chemical characteristics of these lakes have been studied and analyzed for years, during January-April-July and October 2009. Different season the variations of two sampling sites of the lakes have been observed. Many parameters including water temperature, air temperature, dissolved oxygen, pH, TDS and total hardness etc. The study has revealed that there are important seasonal variations in some chemical and physical parameters and as whole, lots of the parameters are different in the three lakes was studied by (Toma 2013).

In spite of number of hot springs water in the north of Iraq, a limited study was observed to be found concerning it. There is a little information concerning their types of organisms. The present study is an attempt to expand springs water characteristics and algal occurrences. Monthly variations in physical-chemicals variables and algae were studied in Mermaid and a Jale springs from July-2007 to February-2008. It was found that water temperature ranged from 23 to 34 C°. The minimum value of pH was 6.8 and the maximum value of electrical conductivity is 1350 µs/cm. Oxygen concentration was zero. No significant variations are found in the total hardness and alkalinity during the period of study. Sulfate and calcium ions are the dominant cations and anions respectively. It was found 22 taxa of algae identified; dominant by *Cyanophyta* was studied by Yaadi et al (2009).

One of the important limnological studies on different good waters in Sulaymaniyah province was conducted by (Anon 1957), he appears a detail data for different good waters, by examining the water samples for several chemicals, physicals, and bacteriological water tests. The mean value of water temperature was 19.5 °C, the potential of hydrogen ion value ranged between 6.8 to 7.72, electrical conductivity value ranged from 0.38 to 1.149 mho/cm. While the mean value of alkalinity as CaCO3 between 2 to 6.5 meq/l, the concentration of dissolved oxygen ranged from 2.37 to 8.8 mg/l. The mean value of biological oxygen demand for five days of incubation under 20 ºC did not exceed 0.81 mg/l. Nitrate concentrations revealed that all the wells water was found to be suitable for irrigation purpose.

Ecological studies in Iraq developed with developing universities and scientific centers, therefore from the beginning of the 1970s on word many papers have been published in north of Iraq-region (Antoine et al, 1977; Hamed et al 1978). They were almost restricted to aquatic and marine ecology. Limnological, oceanographical, and psychological parameters were considered in the areas of these water bodies. An overall ecological survey was conducted for Iraqi inland waters by Islam et al (1985). The primary water quality analysis using limnological in north of Iraq region started at Sulaymaniyah

(Maulood et al. 1978). Some dissertations have been produced in Sulaymaniyah University, which has a great role in a limnological study in Iraq. In Kurdistan, only a few postgraduate students deal with limnological studies in various aquatic ecosystems.

It is apparent that water systems cover a wide range of north of Iraq area; they include ground water, wells, surface water, lake, spring, and impoundment in one hand, channel, tributaries, and river on the other hand. Results of the various study illustration the presence of mineral water, sulfur spring, stenothermal and eurythermal water system. The variation in their chemical and physical properties in the various areas have been dealt by many authors and investigators. El-Yossif and Al-Najim (1977) studied the hydrology and quality of Sarchinar spring water. They provided that mean value of potential hydrogen ranged from 6.94-7.4, electrical conductivity values ranged from 502-682 μS/cm, chloride from 0.02-0.06 (meq/l), where is the mean value of calcium concentration ranged from 0.40-0.39 (meq/l), and magnesium values ranged from 0.40-4.72 (meq/l). (Maulood et al. 1979) estimated that trace elements content of Sarchinaar spring was higher than of water of Kiliassan stream but, never reached the toxic level.

2.7. Geographic Information Systems (GIS)

There are many different definitions of geographic information systems (Clark 2001). But the basic and common concept of all definitions is that geographic information systems are a block of programs that stores, manages, processes and represent a certain type of data for various components and spatial (Nandi and Shakoor 2010). Geographic information includes reference data, maps, and statistics. The first Geographic Information System was first designed in Canada in 1960 by Roger Tomlinson; in Canada's land resources conservation organization by focusing on the integration of spatial data from various sources and the development of image interpretation techniques the digital dimension of 1972 increased the connection of satellite data with algebraic variables (ERDAS 2003).

3. MATERIAL AND METHOD

3.1. Description of the Study Area

3.1.1. Location and Area

Physiographically Duhok dam Lake belongs to the Zargross mountain region. It is located at the headwater of the mainstream passing through the city of Duhok. It is bounded by parallels N36o 87.110′ and N37o 01.015′ and meridians E42o 84.055′ and E 43o 06.010′ and covering an area of 134.37 km2. It is bordered on the North by Kamaka Mountain, from the south by the White Mountain, or Duhok city, from the east and northeast by Zawita and from the west by Baikhair Mountain. It is an artificial lake and its water mainly comes from rain, snowmelt and the main tributaries of Sunder and Garmava which on their joining make up Duhok River (Figure 3.1).

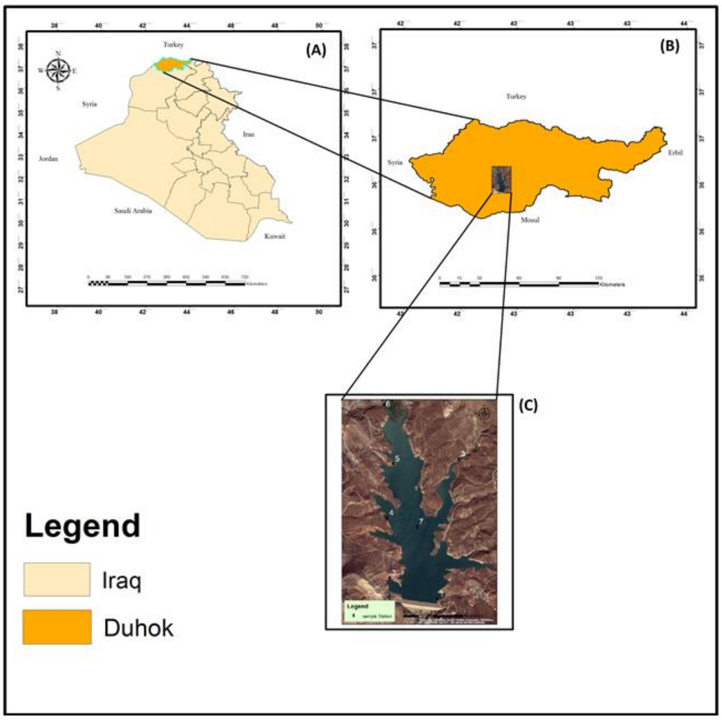


Figure 3.1. A: Map region of Iraq. B: The site of Duhok governorate. C: The site of the study area

3.1.2. Climate

The climate of the study area as a mountain region is of Mediterranean type. The annual evaporation exceeds the annual rainfall. As a whole, wide diurnal and annual ranges of temperature characterize its climate. Annual average temperature is 19.4 °C with an average summer high of 32.8 °C in July and an average winter low of 5 °C in January. The ratio of actual sunshine duration to maximum possible sunshine duration ranges from about 0.35 in January to about 1.0 in July (Aziz 2002). A unimodal rainfall regime lasting 5 – 6 months, which is characterized by low, erratic rainfall and a dry period of 6 – 7 months. Mean annual rainfall is about 560 mm, of which more than 90% occurs between December and April. High concentrations in spring months are caused by thunderstorms with relatively high rainfall intensities. The analysis of climatological data revealed that according to the Koppen climate classification, the lake fell in class warm temperate rainy climate (Critchfield 1974)). Apart from this, it can be classified under semi-wet and semi-arid according to the classification schemes proposed by Emberger and Lang respectively (Aziz 2002).

3.1.3. Hydrology and Hydrography

With exception of Khaziava stream, the remaining streams in the catchment are intermittent, i.e., water flow can be observed only in the rainy season. Apart from this, the discharge of the Khaziava stream ranges from a minimum of 0.08 m^3/s during July to more than 9.34 m^3/s during April. Its water is originated from rainwater and ground water. And the trunk of the mainstream is about 2.8 km from the source to its mouth. Along its course joins by further tributaries and several springs with the catchment. According to Meinzer’s classification, these springs are of sixth order. There are also eight deep wells, which drilled to supply water for domestic purposes.

3.1.4. General Geology and Lithology

Tectonically, the study area is located within the high folded zone (Buday and Jasim 1987). Structurally, this zone is characterized by wavy anticlines and synclines obvious as mountains and valleys. The area is covered by rock formations, which belong mainly to Cretaceous and partly to Jurassic ages. These, are represented by Shiranish, Tanjarero, Komitan, Aqra, Sarmord, Gulneri, Qamchuqa, Avana and Philaspi formations. They are generally composed of different types of limestone, gray shales, and dolomites, blue marls and clastics of silty marls, siltstone, clayton and conglomerates (Aziz 2002).

One of the most important features is the karstification, a phenomenon, which is the product of erosion in some types of rocks such as limestone. They range in size from small surface irregularities and declines to large sinkholes and caves, which are diagnostic features in limestones of Shiranish, Qamchuqa and Bekhma formations the other surface features covers landslide, rockfalls, and soil fall. The anticlines of the high folded zones are separated by relatively well expressed synclinal depressions. The valleys are a dip in the form of rugged topography gullies. The drainage pattern can be described as dendritic (Yahya 2012).

3.1.5. Description of the Reservoir

The dam was commissioned at the outlet of the mainstream draining the catchment in 1987 as a source of drinking water and for irrigation. The average surface area is 1298 hectare. Maximum dam height is 60.5 m, whilst reservoir storage capacity is 52.1 Mm^3 with an annual flow rate of 0.439 m^3/s. The reservoir length for maximum water level is 4 km. There is a diversion structure for irrigation of Sumail plain. Besides, the height of the spillway and that of capacity zero are 55.47 and 4.48 m respectively.

3.2. Material

Seven sampling stations were select from Duhok Lake in Figure 3.2. The exact location for water sampling nodes was determined by GPS reading of sampling station as it is showing in Table 3.1. Water samples were collected for physical and chemical analysis. Water samples were taken from the surface of the lake and collect all the samples from the seven sampling stations in different part of the lake intervals four months October-December 2016 to March-July 2017 during four seasons autumn, winter, spring, and summer. And Various parameters have been analyzed including, air temperature, water temperature, total dissolved solid; electrical conductivity and pH were estimated on the spot at the time of sampling by using digital portable water. While other parameters were estimated in the Directorate of water Duhok, Water Quality Control laboratory and other in Duhok environmental directorate laboratory. Standard methods as prescribed by (APHA 2012).

Table 3.1.Sampling station nodes at Duhok Lake location

Sampling Stations Code	Coordinate point X	Coordinate point Y
S1	43.006985	36.87681
S2	42.999545	36.879491
S3	43.010173	36.893898
S4	42.999153	3690071
S5	43.000104	36.893562
S6	42.999153	36.886631
S7	43.003735	36.885601

3.3. Method

The samples were collected and analyzed from seven representative surface-waters from different locations of Duhok Lake area during four months from October-December 2016 to March-July 2017 for the studied period. The samples were analyzed for the parameters: water temperature, air temperature, turbidity, electrical conductivity (EC), total dissolved solids (TDS), pH, dissolved oxygen (DO), total alkalinity, sulfate (SO_4), Chloride (Cl^-), Nitrate (NO_3), total hardness (TH), Calcium (Ca), Potassium (K^+), Magnesium (Mg), and Sodium (Na). The analysis was carried out by using standard procedures (APHA 2012) in Table 3.2. Which illustrates the mean value of 16 water quality parameters and compared with four standards as WHO (2008), Turkish Standards-TS-266 (2005), CCME (2012), and Iraqi standard of Ministry of Environment **(**1998)

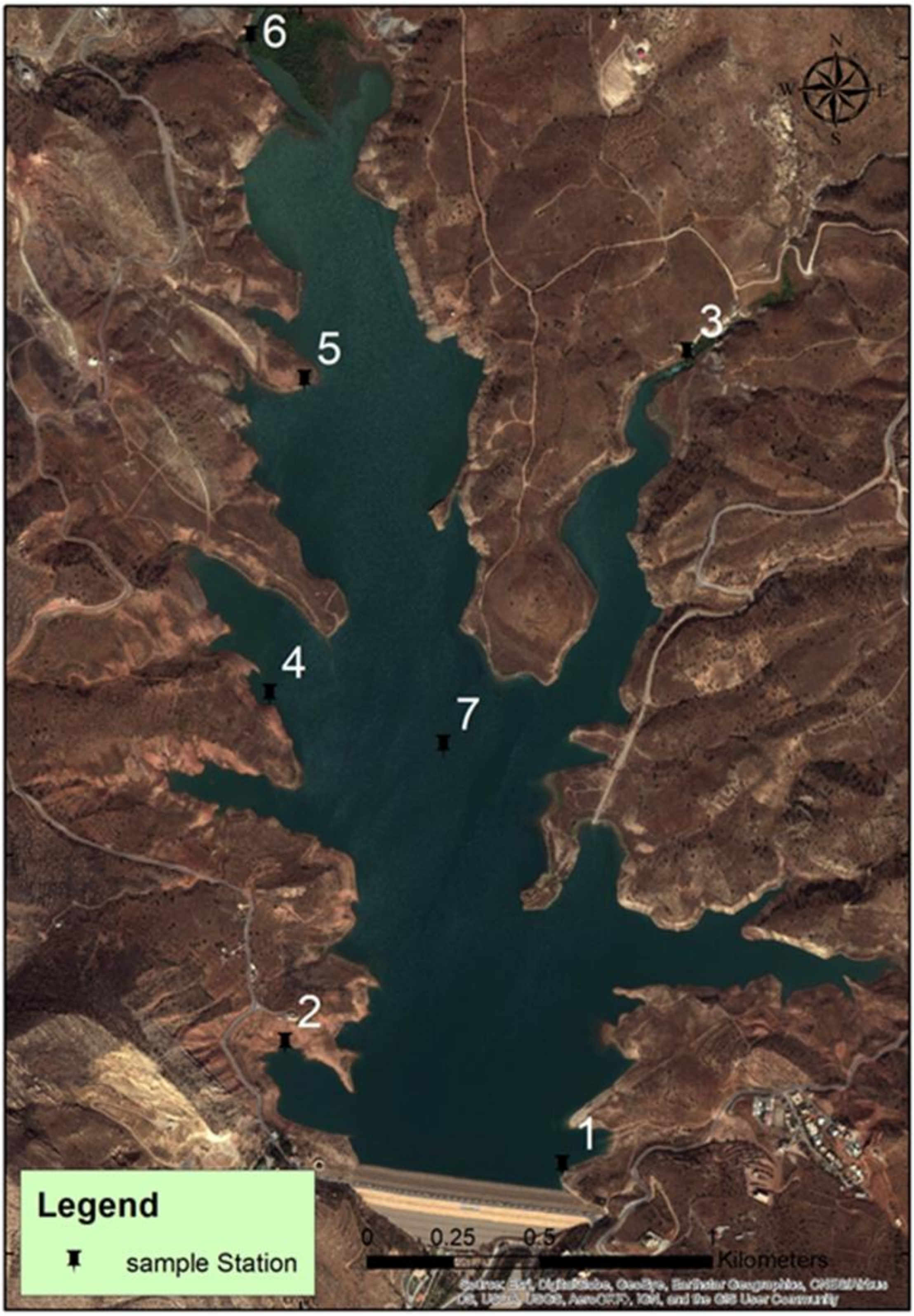


Figure 3.2. Water sampling station (GIS image)

Table 3.2. Analytical methods and equipment used for the study

No.	Parameter	Method	Instruments/Equipment
1	Air Temperature	Electrometric	Temperature Meter
2	Water Temperature	Electrometric	pH Meter
3	Turbidity	Electrometric	Turbidity Meter
4	EC	Electrometric	Conductivity Meter
5	TDS	Electrometric	Conductivity/TDS Meter
6	pH	Electrometric	pH Meter
7	Total Alkalinity	Titration by H2SO4	
8	Total Hardness	Titration by EDTA	
9	Chloride	Titration by AgNO3	
10	Sulphate	Turbid metric	Turbidity Meter
11	Nitrate	Ultraviolet screening	UV-VIS Spectrophotometer
12	Ca	Titration by EDTA	
13	Mg	Titration by EDTA	
14	K	Flame emission	Flame Photometer
15	Na	Flame emission	Flame Photometer
16	DO	Electrometric	DO Meter

3.4. Water Quality Mapping Using GIS

To represent water quality map of the lake, (GIS) tool was utilized. Geographical Information system (GIS) is a computer based technology for handling geographical data in digital form. It is designed to store, capture, analyse, manipulate, and display diverse sets of spatial or georeferenced data (Kadhem 2013, Saeedrashed and Guven 2013) Coordinates of sampling points were recorded by mobile (GPS). The results of the physical and chemicals analysis value per sampling point. Then we used as input data in ArcGIS 10.4.1. The sampling stations were integrated with the water data for the generation of spatial distribution maps. The present study used the Inverse Distance Weighted (IDW) method for spatial interpolation of water parameters. (IDW) determines cell values using a liner-weighted combination set of sample points. The weight assigned is a job of the distance of an input point from the output cell stations. The greater the distance, the littler influence the cell has on the output value (Childs 2004).

3.5. Statistical Analysis

To study the differences between the stations in terms of changes in various parameters, repeated measures and analyses of variance (ANOVA) (one-way or two-way) was used. Comparing the average of parameters with significant (F) between the sampling stations was performed using Duncana test. Statistical analysis was performed using SPSS v.22 and Excel 2010 software. The analysis of variance (ANOVA) followed by Duncan test ($\alpha = 0.05$) was applied to determine the differences among the groups. And also the correlation matrix analysis has been carried out to find out correlation between any two tested parameters. The significance of the correlation matrix was also tested.

4. RESULTS AND DISCUSSION

4.1 Generally

After conducting, the detailed survey identified the main resource that affecting on water quality of Duhok Lake stations, longitude and latitude of the station also marked Table 4.1. Those water samples were taken from different stations at different months from the seven sampling stations in different part of the lake during four seasons start from autumn October 2016 to summer July 2017 for analyzing of water quality. Illustrates the mean value of 16 water quality parameters which compared with four standards as WHO (2008), Turkish Standards-TS-266 (2005), CCME (2012), and Iraqi standard of Ministry of Environment (1998) in Table 4.6.

Table 4.1. List of sampling stations and marked

Sampling Stations	Coordinate point X	Coordinate point Y	Remarks
S1	43.006985	36.87681	The front side of the dam
S2	42.999545	36.879491	The destruction of the hillocks, intense soil erosion, and deposition of mud in the lake
S3	43.010173	36.893898	Lake fed by hot water springs from garmava springs
S4	42.999153	3690071	Agricultural activities
S5	43.000104	36.893562	Soil erosion and agricultural activities
S6	42.999153	36.886631	The Duhok River flows into the lake
S7	43.003735	36.885601	Centre of the lake

4.2. Water Quality Analysis

The GIS interpolation map and limnological studies with statistical analysis for seasonal water quality analysis were done by using the four different months range data of parameters from all sampling stations during four seasons autumn, winter, spring and summer Table 4.2, 4.3, 4.4 and 4.5.

Table 4.2. Duhok Lake water quality analysis October 2016 autumn season

Sample number and station code	**Parameters and Units**															
	AT °C	WT °C	Do mg/l	TUR NTU	pH	EC µS	TDS mg/l	TA mg/l	TH mg/l	Ca^{+} mg/l	Mg^{+} mg/l	CL^{-} mg/l	SO$_4$ mg/l	NO$_3$ mg/l	Na mg/l	K mg/l
S1	20	18	9.2	0.8	7.9	612	320	204	396	96	38.1	77	300	24	53.1	4.97
S2	21	17	8.5	2.7	8.5	620	322	204	368	91	34.2	76	315	22	52	5.05
S3	21	25	3	5.2	6.5	945	434	332	664	211	33.2	134	324	37	61.6	8.15
S4	19.5	16.3	8	0.5	7.8	632	327	224	400	98	38.1	112	310	23	53.1	5.46
S5	20	17.2	8.7	0.6	7.8	643	319	188	400	101	36.1	93	294	20	53.1	4.14
S6	21.4	18.5	8.3	2.4	8.3	710	325	228	452	112	42	106	363	21	56.3	5.07
S7	19	17.5	9.5	0.5	7.6	632	318	224	412	106	36.1	102	297	18	54.1	5.63
Min	**19**	**17**	**3**	**0.5**	**6.5**	**612**	**318**	**188**	**368**	**91**	**33.2**	**76**	**294**	**18**	**53.1**	**4.14**
Max	**21.4**	**25**	**9.5**	**5.2**	**8.5**	**945**	**434**	**332**	**664**	**211**	**42**	**134**	**363**	**37**	**61.6**	**8.15**
Average	**20**	**18**	**7.8**	**1.79**	**7.8**	**684**	**338**	**229**	**442**	**116**	**36.8**	**100**	**314.7**	**23.6**	**54.7**	**5.49**

AT=Air temperature, WT= Water temperature, DO= Dissolved oxygen, TUR= Turbidity, pH=potential of hydrogen, TDS=Total dissolved solid, EC= Electrical conductivity, TH= Total hardness, TA= Total Alkalinity, Ca=calcium, Mg=magnesium, Cl= Chloride, SO$_4$= Sulfate, NO$_3$= Nitrate, Na=Sodium, K=Potassium.

Note: The above data is compared with the standards in Table .4.6.

Table 4.3. Duhok Lake water quality analysis December 2016 winter season

Sample number and station code	**Parameters and Units**															
	AT °C	WT °C	Do mg/l	TUR NTU	PH	EC µS	TDS mg/l	TA mg/l	TH mg/l	Ca$^+$ mg/l	Mg$^+$ mg/l	CL$^-$ mg/l	SO$_4$ mg/l	NO$_3$ mg/l	Na mg/l	K mg/l
S1	7	9.3	9.2	0.9	7.8	623	297	210	400	100	40	75	282	26	55	5.06
S2	7.6	9	8.9	3.0	8.3	627	299	205	370	96	35.2	77	304	27	54.6	5.2
S3	8	24	3.0	7.0	6.3	820	422	340	672	220	34.8	132	326	40	64.3	9.3
S4	8.4	9.1	7.9	0.5	7.5	630	315	225	410	98	40.3	106	293	24	54.8	5.39
S5	8.9	9.8	8.7	0.6	7.8	614	316	190	416	110	37	90.6	282	22	55.1	4.92
S6	8.4	10	8	3.4	8.5	760	372	230	460	122	43.4	97.2	359	24	57.8	4.79
S7	9	10.6	9.6	0.5	7.6	605	300	227	417	107	39	109	297	19	56	5.94
Min	**7**	**9**	**3**	**0.5**	**6.3**	**605**	**297**	**190**	**370**	**96**	**34.8**	**75**	**282**	**19**	**54.6**	**4.79**
Max	**9**	**24**	**9.6**	**7.0**	**8.5**	**820**	**422**	**340**	**672**	**220**	**43.4**	**132**	**359**	**40**	**64.3**	**9.3**
Average	**8.1**	**11.7**	**7.9**	**2.27**	**7.6**	**668**	**331**	**232**	**449**	**122**	**38.5**	**98.1**	**306**	**26**	**56.8**	**5.8**

AT=Air temperature, WT= Water temperature, DO= Dissolved oxygen, TUR= Turbidity, pH=potential of hydrogen, TDS=Total dissolved solid, EC= Electrical conductivity, TH= Total hardness, TA= Total Alkalinity, Ca=calcium, Mg=magnesium, Cl= Chloride, SO$_4$= Sulfate, NO$_3$= Nitrate, Na=Sodium, K=Potassium.

Note: The above data is compared with the standards in Table .4.6.

Table 4.4. Duhok Lake water quality analysis March 2017 spring season

Sample number and station code	**Parameters and Units**															
	AT °C	WT °C	Do mg/l	TUR NTU	PH	EC µS	TDS mg/l	TA mg/l	TH mg/l	Ca^{+} mg/l	Mg^{+} mg/l	CL^{-} mg/l	SO$_4$ mg/l	NO$_3$ mg/l	Na mg/l	K mg/l
S1	13	12.2	8.9	2.50	7.9	514	257	172	312	104	12.7	68	274	21	44.5	4.5
S2	13.4	12	7.9	3.00	7.9	574	286	155	340	85	31.2	80	255	20	45.5	4.55
S3	14	22	2.5	6.60	6.8	940	470	365	592	198	23.4	70	325	37	58.4	7.41
S4	13.7	12.5	9	3.50	7.6	628	314	192	376	91	36.1	82	255	20	46.6	4.58
S5	13.4	12.4	9.4	3.60	7.7	616	313	236	284	83	18.5	76	156	21	46.6	4.61
S6	14.3	13	8	3.50	7.7	648	324	233	288	90	15.6	92	183	19	48.8	4.71
S7	12.6	11.5	7.8	1.70	7.8	618	309	198	280	82	18.5	86	268	18	48.8	4.62
Min	**12.6**	**11.5**	**7.8**	**1.70**	**7.9**	**514**	**257**	**155**	**280**	**82**	**12.7**	**68**	**156**	**18**	**44.5**	**4.5**
Max	**14.3**	**22**	**9.4**	**6.6**	**6.8**	**940**	**470**	**365**	**592**	**198**	**36.1**	**92**	**325**	**37**	**58.4**	**7.41**
Average	**13.4**	**13.6**	**8.6**	**3.49**	**7.6**	**648**	**325**	**197**	**353**	**105**	**22.2**	**79**	**245**	**22**	**48.4**	**4.99**

AT=Air temperature, WT= Water temperature, DO= Dissolved oxygen, TUR= Turbidity, pH=potential of hydrogen, TDS=Total dissolved solid, EC= Electrical conductivity, TH= Total hardness, TA= Total Alkalinity, Ca=calcium, Mg=magnesium, Cl= Chloride, SO$_4$= Sulfate, NO$_3$= Nitrate, Na=Sodium, K=Potassium.
Note: The above data is compared with the standards in Table .4.6.

Table 4.5. Duhok Lake water quality analysis July 2017 summer season

Sample number and station code	**Parameters and Units**															
	AT °C	WT °C	Do mg/l	TUR NTU	PH	EC µS	TDS mg/l	TA mg/l	TH mg/l	Ca^+ mg/l	Mg^+ mg/l	CL^- mg/l	SO_4 mg/l	NO_3 mg/l	Na mg/l	K mg/l
S1	28	22	8.6	2.1	8	789	334	223	391	94	31	75	300	18	56	6.00
S2	27	21	8.3	3	8.1	810	353	230	310	93	28	76.5	312	18	59	7
S3	26	27	1.8	5.7	6.5	998	532	395	490	158	26.3	198	463	34	67	9.18
S4	27.6	23	7.9	2	7.6	814	419	234	300	93	25	123	310	19	55	6.19
S5	28	22.4	8.2	2.0	8.1	785	356	221	314	89	31	112	326	18	59	5.36
S6	29	23	7.7	2.3	7.8	735	343	285	322	82	36	98	270	19	54	5.25
S7	26.7	21.6	8.2	1.3	7.9	589	339	223	334	96	38	72	319	17	52	5.37
Min	**26**	**21**	**1.8**	**1.3**	**6.5**	**589**	**334**	**221**	**300**	**82**	**25**	**72**	**270**	**17**	**52**	**5.25**
Max	**29**	**27**	**8.5**	**5.7**	**8.1**	**998**	**532**	**395**	**490**	**158**	**38**	**198**	**463**	**34**	**67**	**9.18**
Average	**27.4**	**22.8**	**7.3**	**2.6**	**7.7**	**790**	**396**	**239**	**351**	**100**	**30.75**	**107**	**328**	**20.6**	**57.4**	**6.33**

AT=Air temperature, WT= Water temperature, DO= Dissolved oxygen, TUR= Turbidity, pH=potential of hydrogen, TDS=Total dissolved solid, EC= Electrical conductivity, TH= Total hardness, TA= Total Alkalinity, Ca=calcium, Mg=magnesium, Cl= Chloride, SO_4= Sulfate, NO_3= Nitrate, Na=Sodium, K=Potassium.
Note: The above data is compared with the standards in Table .4.6.

Table 4.6. The Iraqi and international standards

Parameters	Unit	Permissible level of drinking water (WHO 2008)	Turkish standard for drinking water TS-266	Guidelines for irrigation (Ministry of Environment 1998)	Guidelines for aquatic ecosystem According to (CCME 2012)
		Level	Level	Level	Level
Air Temperature	°C	-	-	-	-
Water temperature	°C	-	-	-	5.0-30.0
Dissolved Oxygen	mg/L	5	-	-	-
Turbidity	NTU	5	5	-	5
Electrical Conductivity	µS	1250	2500	1500	
Total Dissolved Solid	mg/L	1000	-	1000	500
pH		6.5-8.5	6.5-9.5	6.5-8.5	6.5-9.0
Sulphate	mg/L	250	250	200	-
Chloride	mg/L	250	250	250	0.0-200
Nitrate	mg/L	50	50	0.0-15	13
Total Hardness	mg/L	100-500	-	-	-
Total Alkalinity	mg/L	150-200	-	-	-
Calcium	mg/L	75-200	200	-	-
Magnesium	mg/L	30-150	150	-	-
Potassium	mg/L	2-3	12	-	-
Sodium	mg/L	200	200	-	-

4.2.1. Air Temperature

One of the primary environmental factors is temperature, which affects and governs biological activities and solubility of gases at the water. Gases in the air, humidity, dust and other colloidal particles. Air temperature is often higher than water temperature. The variations in the air temperature at the different season from the seven sampling station were, presented in Table 4.2, 4.3, 4.4 and 4.5. In addition, the GIS interpolation map represented respectively in Figure 4.1, 4.2, 4.3 and 4.4. And also the seasonal average showed in Figure 4.65, 4.66, 4.67 and 4.68.

The variations of air temperature of Duhok Lake at the autumn season ranged from a minimum 19 °C recorded around sample station S7 and maximum 21.4 °C recorded around sample station S6 and total average was 20 °C from all sampling station, but at the winter season the range is recorded as a minimum 7 °C around sampling station S1 and maximum 9 °C around sampling station S7 and the average was 8.1 °C, and at the spring season the range is recorded as a minimum 12.6 °C around sampling station S7 and maximum 14.3 °C around sampling station S6 when an average 13.4 °C, however at summer season the range is recorded as a minimum 26 °C around sampling station S3 and maximum 29 °C around sampling station S6 when the average was 27 °C.

The variations in the surface water temperature and air temperature are due to changing seasons. The high temperature is a record at spring and the lower temperature was a record in the winter. Which is normal features in the freshwater bodies, but in special cases, sometimes water temperature is higher than the air temperature when spring hot water is discharged directly into the lake at that area. The temperatures have a direct effect on some chemicals reaction in the aquatic ecosystem and it is very important physicals parameter (Jakhar and Rawat 2003). When water temperature increases it leads to decrease in the dissolved oxygen concentration (Huet and Timmermans 1986).

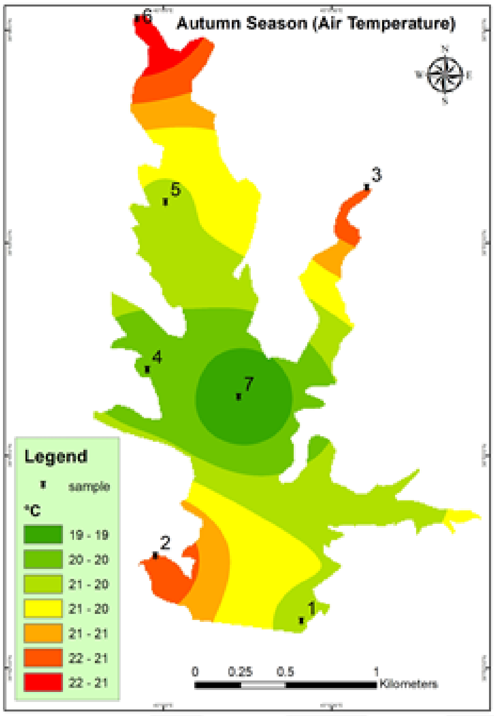


Figure 4.1. GIS interpolation of air temperature in autumn season

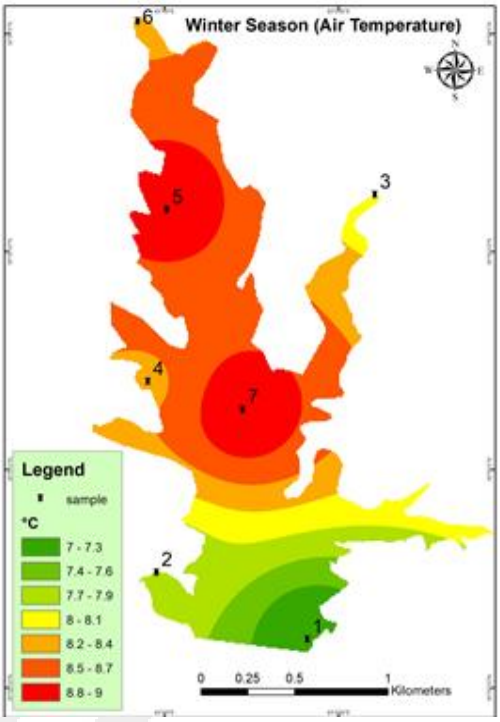


Figure 4.2. GIS interpolation of air temperature in winter season

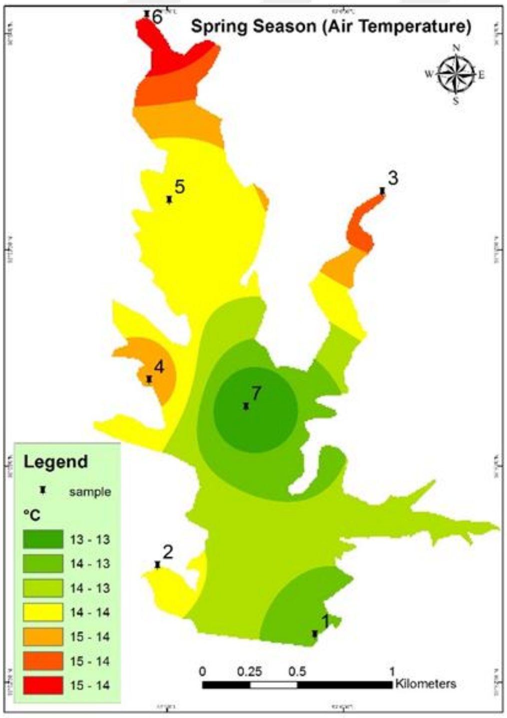


Figure 4.3. GIS interpolation of air temperature in spring season

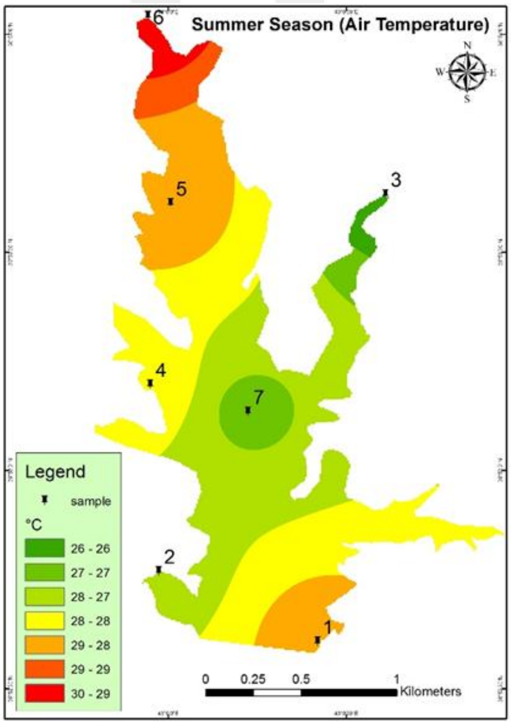


Figure 4.4. GIS interpolation of air temperature in summer season

4.2.2. Water Temperatures

Temperature considered as important parameters and have a biochemical effect on the organism in the water (Trivedi and goel 1986). Surface water temperature measured and the seasonal analysis during the period of study as shown in Table 4.2, 4.3, 4.4 and 4.5. In addition, the GIS interpolation map represented respectively in Figure 4.5, 4.6, 4.7 and 4.8. And also the seasonal average showed in Figure 4.65, 4.66, 4.67 and 4.68.

The temperature of the surface water of Duhok Lake in all seasons is high at sample station S3. Water temperatures in often lower than air temperature, water temperature is high due to low water level, low velocity, clear atmosphere and greater solar radiation but lower values can be attributed to frequent clouds, high percentage of humidity, high current velocity and high water levels, but in special cases, sometimes water temperature is higher than the air temperature when spring hot water is discharged into the lake directly. High seasonal variations observed at the different site of Duhok Lake.

The water temperature was high due to the low water level and higher air temperatures. (Toma 2013) observed that water temperature fluctuates between 7 °C to 26 °C during limnological studies of Duhok lake. Water temperatures influence the chemicals and biological characteristic of the water body. Noticed that air temperature is always higher than water temperatures due to various reasons such as gases in the air, humidity, runoff, dust and other reasons.

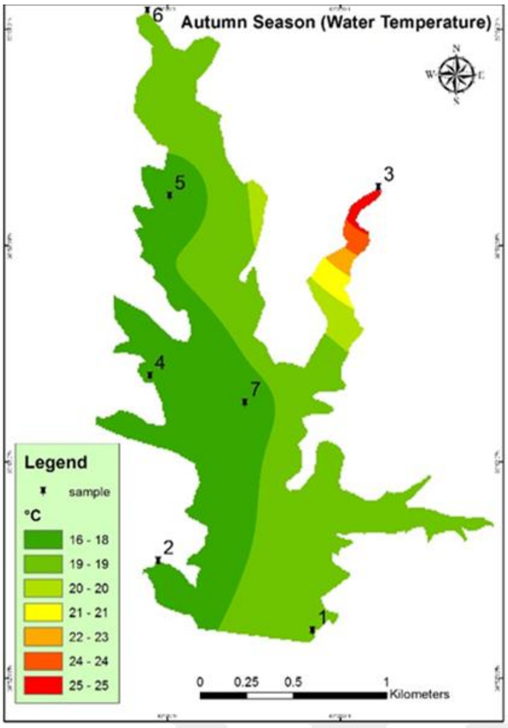


Figure 4.5. GIS interpolation of water temperature in autumn season

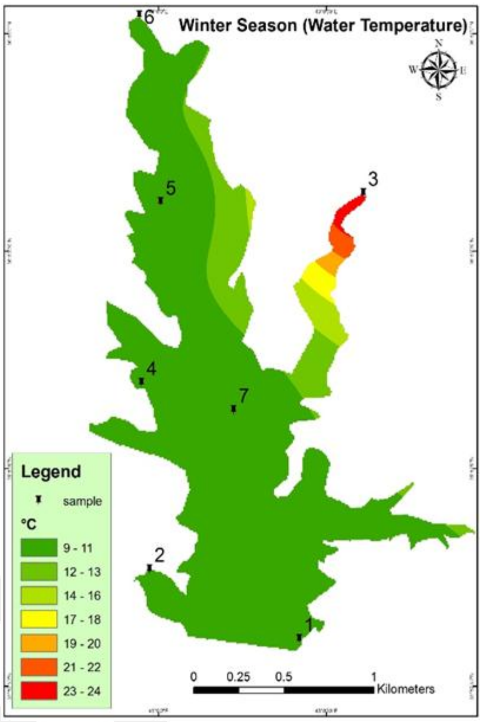


Figure 4.6. GIS interpolation of water temperature in winter season

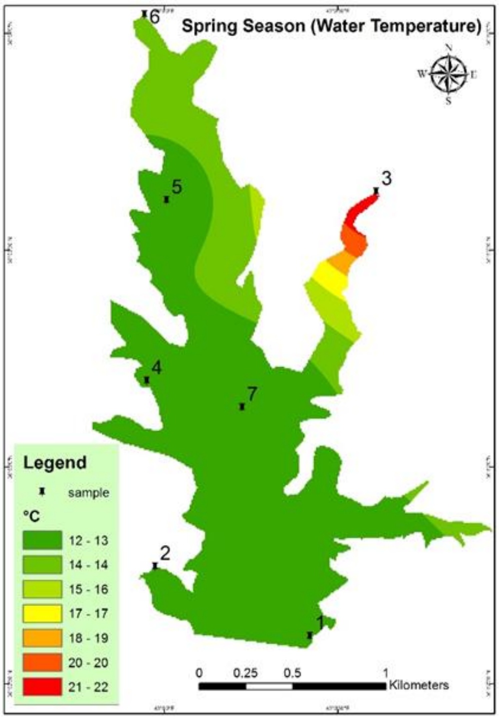


Figure 4.7. GIS interpolation of water temperature in spring season

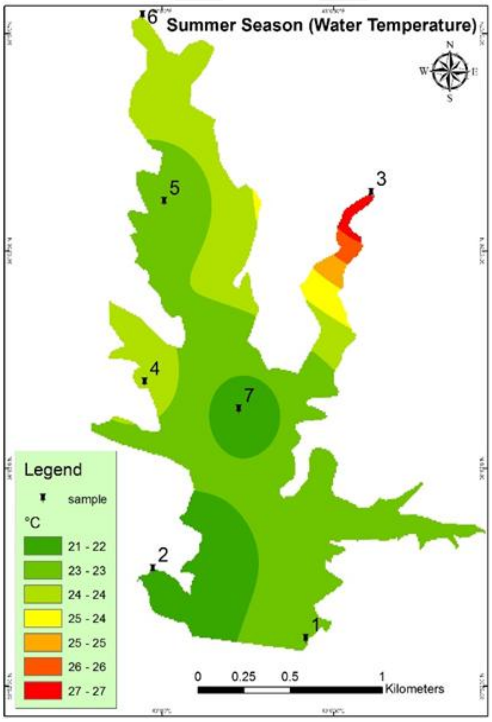


Figure 4.8. GIS interpolation of water temperature in summer season

4.2.3. Dissolved Oxygen

In limnology, the study of the lake, dissolved oxygen is a most important aquatic parameter. It is vital aquatic fauna. It has an important role in the respiration process. Adequate dissolved oxygen is very necessary for good water quality.

The variations in the concentration of dissolved oxygen in different season period of the study were, presented in Table 4.2, 4.3, 4.4 and 4.5.and represented respectively in GIS interpolation map as shown in Figure 4.9, 4.10, 4.11 and 4.12. And also the seasonal average showed in Figure 4.65, 4.66, 4.67 and 4.68.

In the present study, the dissolved oxygen concentration in all seasons is low at sample station S3, which is lower than the permissible range of drinking water and it should be 5 mg/L according to (WHO 2008). Moreover, highest dissolved oxygen concentration at both seasons an autumn and winter was recorded 9.5 mg/l and 9.6 mg/l in sample station S7. When highest dissolved oxygen concentration at both seasons an spring and summer was recorded 9.4 mg/l and 8.6 mg/l in sample station S5 and S1, which is higher than permissible level of drinking water WHO.

The low concentration of dissolved oxygen is my due to the hot spring water that is directly discharged into the water body, because of the solubility of oxygen decreases as water temperature increases. The previous study reported by (Hassan and Al-barware 2016) stated that dissolved oxygen concentration ranged from 7.5 to 8.4 mg/L during the study of Duhok Lake water, which is productive for fish culture. As dissolved oxygen levels in water drop below 5.0 mg/l, many life forms will put under pressure (Bouuman et al. 2008).

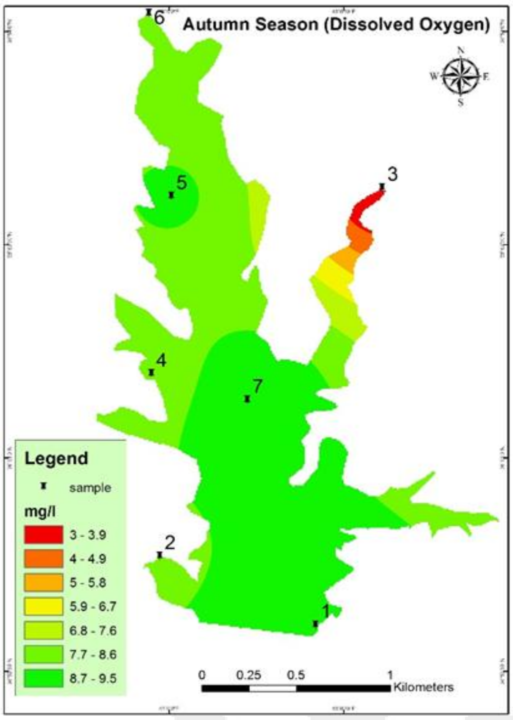


Figure 4.9. GIS interpolation of dissolved oxygen in autumn season

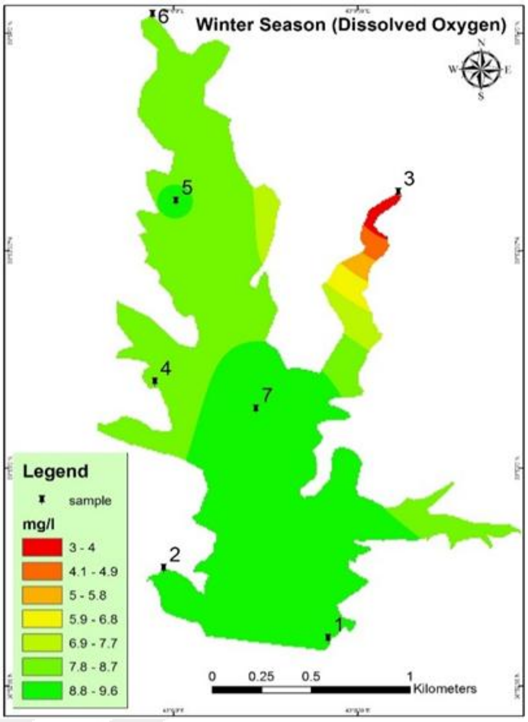


Figure 4.10. GIS interpolation of dissolved oxygen in winter season

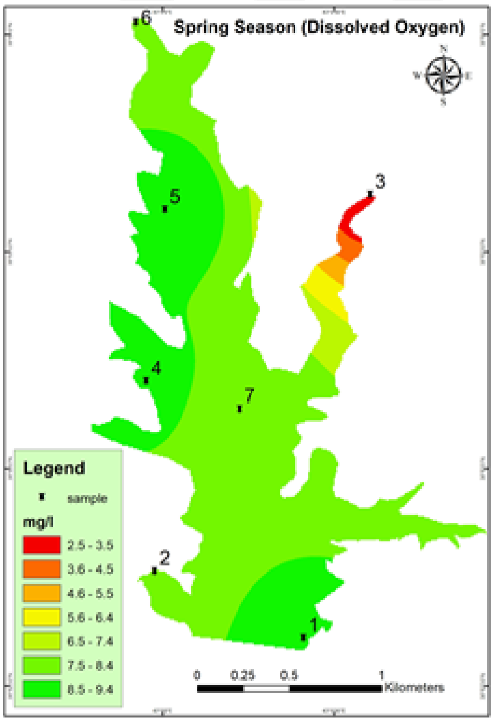


Figure 4.11. GIS interpolation of dissolved oxygen in spring season

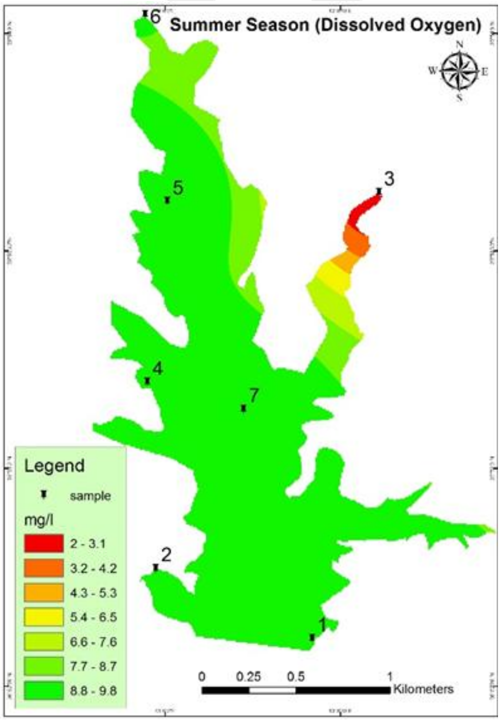


Figure 4.12. GIS interpolation of dissolved oxygen in summer season

4.2.4. Turbidity

The variations of turbidity in deferent season during the period of the study is showing respectively in Table 4.2, 4.3, 4.4 and 4.5.And in Figure 4.13, 4.14, 4.15, 4.16, 4.65, 4.66, 4.67 and 4.68. Water turbidity is mainly risen due to the suspended inorganic substance like clay, silt, plankton and sand grains reservoirs with clay bottom are likely to have high turbidity. During the present study in all seasons, the turbidity values are high at sample station S3, which is over than the standard of drinking water that is should be between 0.1 - 5 NUT according to (WHO 2008) and (TS-266 2005). And the high average of turbidity was recorded at spring season and low average at summer season. The high value of turbidity may be due to the geological of that, area soil erosion, suspended solid etc. and hot spring water that is directly fed into the water body in that area.

4.2.5. pH

During the present study of water, the variations of pH values in four seasons of the lake water are showing in Table 4.2, 4.3, 4.4 and 4.5. In addition, the GIS interpolation map represent showed respectively in Figure 4.17, 4.18, 4.19 and 4.20. And also the seasonal average showed in Figure 4.65, 4.66, 4.67 and 4.68. The pH values in all seasons is low at sampling station S3, but at the spring season the pH values are recorded 6.3 at sample station S3, which is lower than permissible range of drinking water and guidelines of aquatic ecosystem also guidelines of irrigation, it should be between 6.5-8.5 for drinking and irrigation and 6.5-9.0 for aquatic life according to (WHO 2008), (TS-266 2005), (CCEM 2012) and (Ministry of Environment 1998) Table 4.6. In addition, the high average of pH was recorded at the autumn season and low average at winter and spring seasons. It is indicating that the high pH values throughout the study period it is maybe due to the agriculture around the lake, soil erosion and discharging of spring hot water. In addition, pH values are very important for phytoplankton growth and zooplankton growth (chistw 2002). The earlier study recorded by (Toma 2013) recorded that pH is ranged from 7.5 to 8.1 which is best for plankton growth. The pH of water affects much chemical and biological process in the water. The largest variety aquatic animals preferred a range of (6.5 – 9.0) according to (Collins et al. 2007).

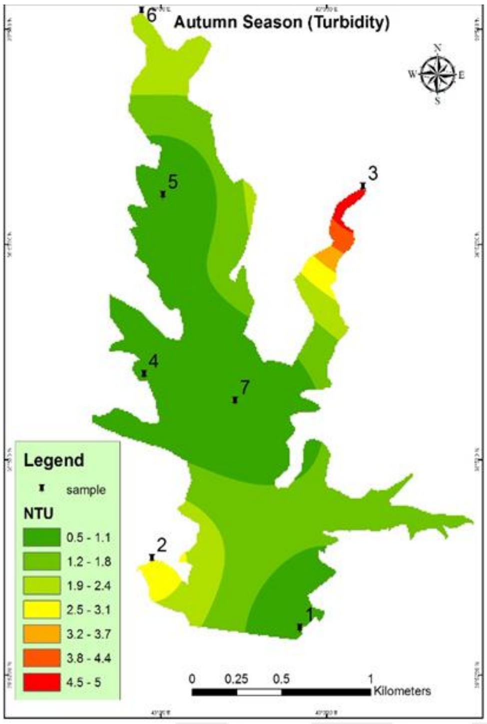


Figure 4.13. GIS interpolation of turbidity in autumn season

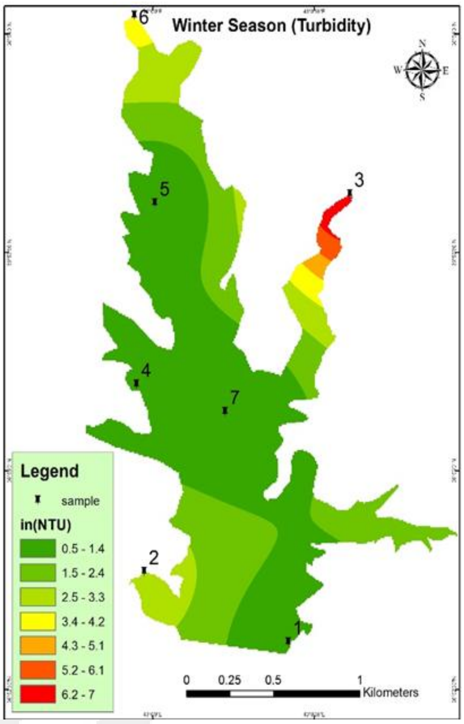


Figure 4.14. GIS interpolation of air turbidity in winter season

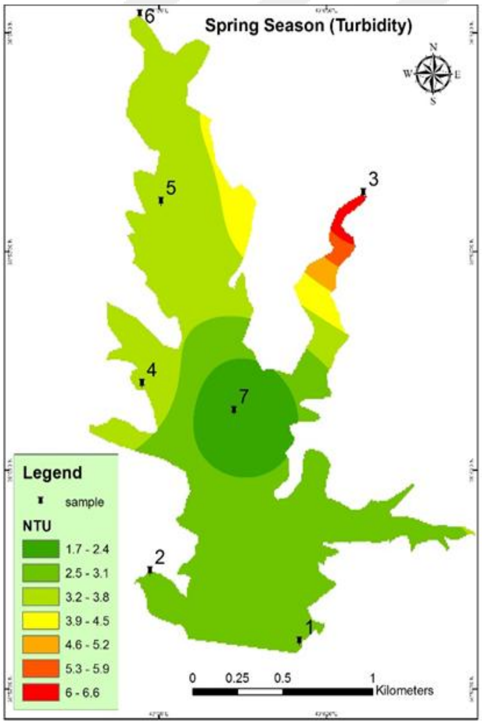


Figure 4.15. GIS interpolation of turbidity in spring season

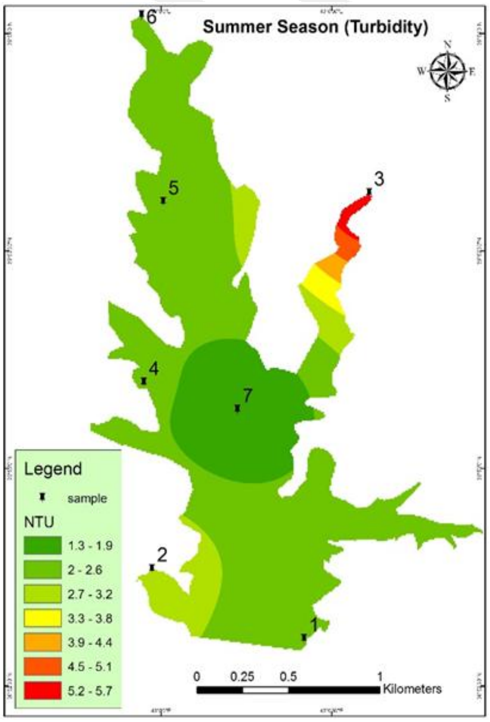


Figure 4.16. GIS interpolation of turbidity in summer season

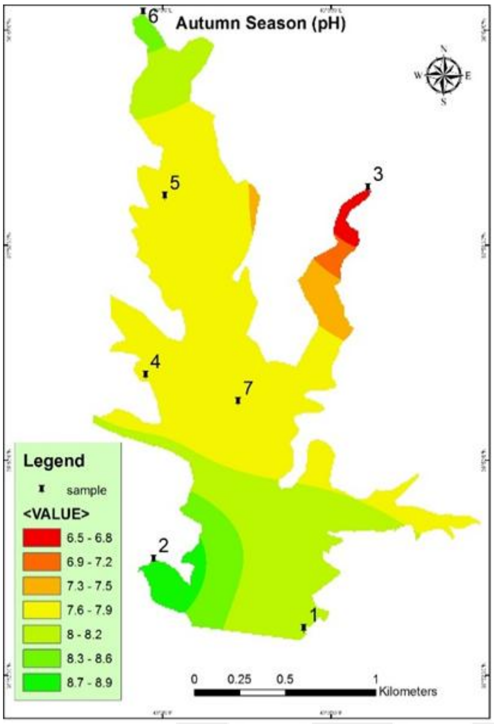


Figure 4.17. GIS interpolation of pH in autumn season

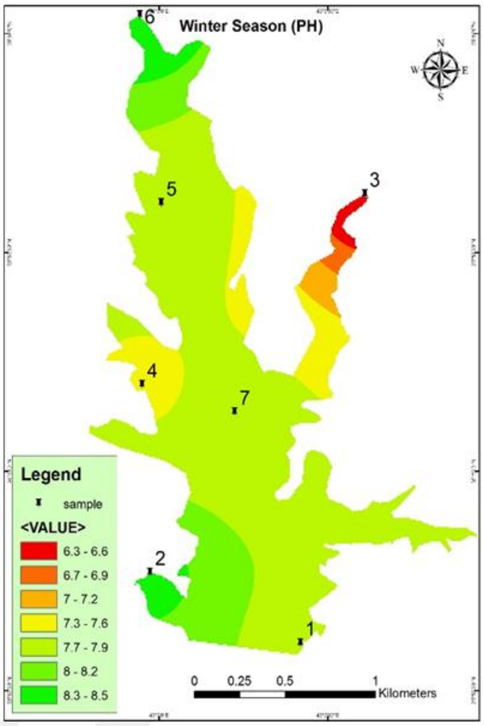


Figure 4.18. GIS interpolation of pH in winter season

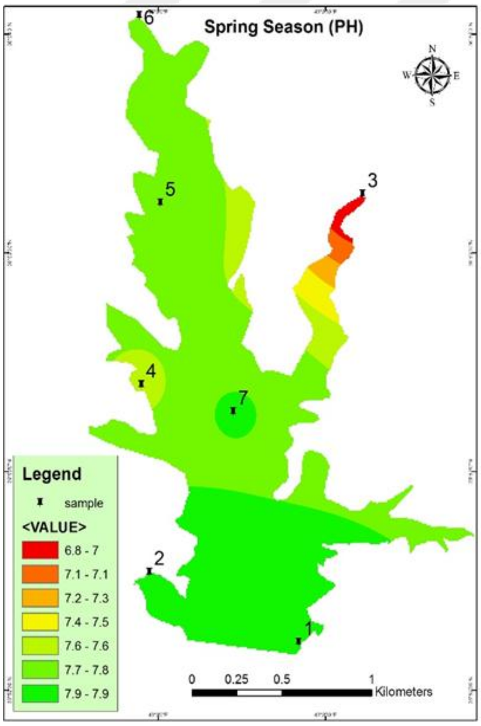


Figure 4.19. GIS interpolation of pH in spring season

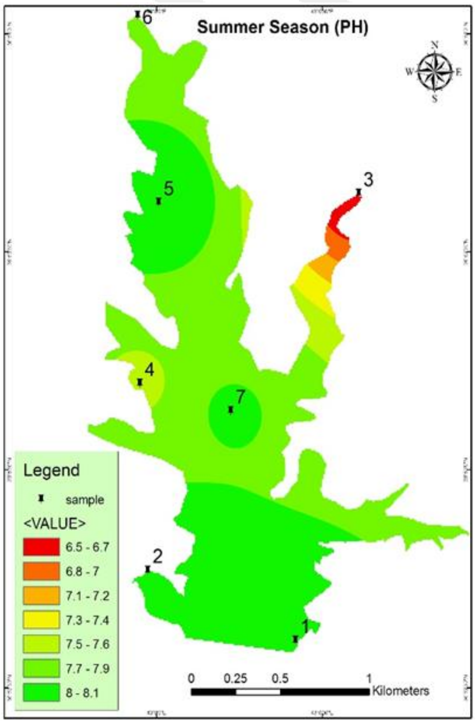


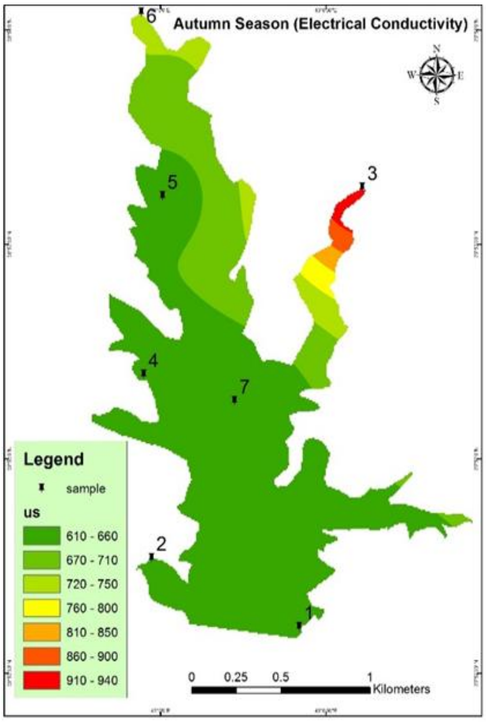
Figure 4.20. GIS interpolation of pH in summer season

4.2.6. Electrical Conductivity

Seasonal variations of electrical conductivity of the lake are showing in Table 4.2, 4.3, 4.4 and 4.5. In addition, GIS interpolation map represented respectively as shown in Figure 4.21, 4.22, 4.23 and 4.24. And also the seasonal average showed in Figure 4.65, 4.66, 4.67 and 4.68.

The electrical conductivity of water depends upon ions present in the water. It reflects the nutrient status of water and distribution of macrophytes. During the present study at the autumn season ranged as minimum 612 μS/cm recorded at sample station S1 and maximum 945 μS/cm recorded at sample station S3, but at the winter season the range is recorded as a minimum 605 μS/cm at sampling station S7 and maximum 820 μS/cm at sampling station S3, and at the spring season the range is recorded as a minimum 514 μS/cm at sampling station S1 and maximum 940 μS/cm at sampling station S3, however at summer season the range is recorded as a minimum 589 μS/cm at sampling station S7 and maximum 998 μS/cm at sampling station S3. And the high average of electrical conductivity was recorded at summer season 790 μS/cm and low average at spring season 648 μS/cm.

The seasonal variation of the conductivity in the present study may be due to the insufficient inflows of Garmava spring hot water, discharge of silt and salt from the surrounding Garmava springs. According to Toma (2013) through the limnological study of Duhok Lake the electrical conductivity is range between 1055 – 1420 μs/cm.



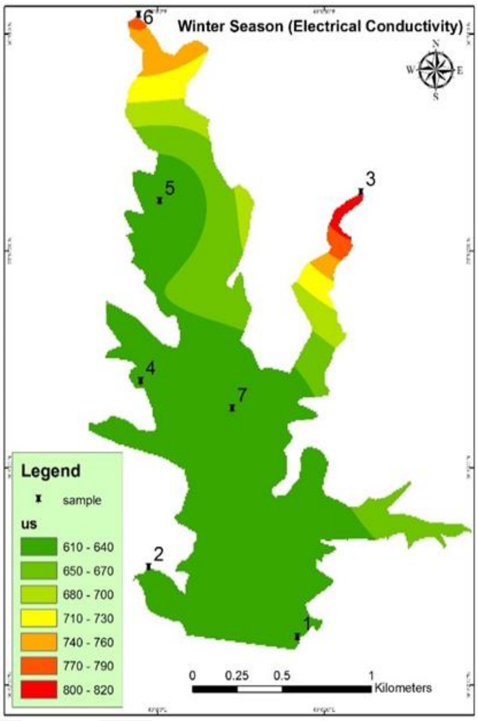
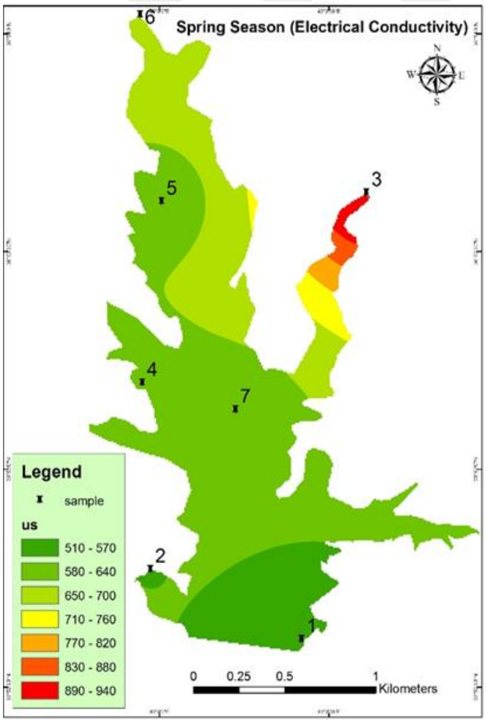


Figure 4.21. GIS interpolation of electrical conductivity in autumn season

Figure 4.22. GIS interpolation of electrical conductivity in winter season



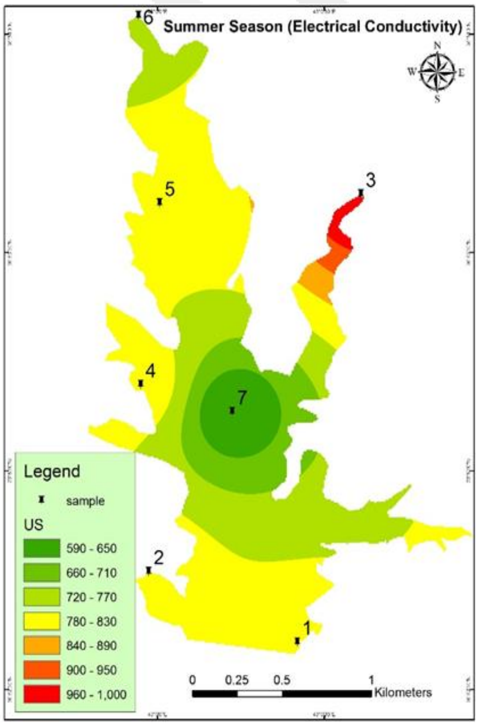


Figure 4.23. GIS interpolation of electrical conductivity in spring season

Figure 4.24. GIS interpolation of electrical conductivity in summer season

4.2.7. Total Dissolved Solid

In the present study, the variations of total dissolved solid different seasons were illustrated in Table 4.2, 4.3, 4.4 and 4.5. In addition, GIS interpolation map represented respectively in Figure 4.25, 4.26, 4.27 and 4.28. And also the seasonal average showed in Figure 4.65, 4.66, 4.67 and 4.68.

Dissolved solid are important in drinking water and other water quality standard. Water probability depends on the total dissolved solids. Total dissolved solid value in all seasons is high at sampling station S3, but at the summer season, the TDS value is recorded 592 mg/l in sampling station S3, which is higher than the guideline of CCME for aquatic ecosystem Table 4.6.and is low at sampling station S7. In addition, the high average of TDS was recorded at summer season 396 mg/l and low average at spring season 331 mg/l.

The high and low variations of TDS in the present study may be due to the seasonal change or discharge of silt and salt from the surrounding sampling stations. The desirable level of TDS is 500 mg/l where are the permissible limited is 1000 mg/l. Where TDS values reported by Ali and Abdul-Qader (2017), range between 629 – 488 mg/l through the study of duhok lake water quality. The total dissolved solid analyses play important roles in the control of biological and chemical wastewater treatment process. During present essential for plant and animal.

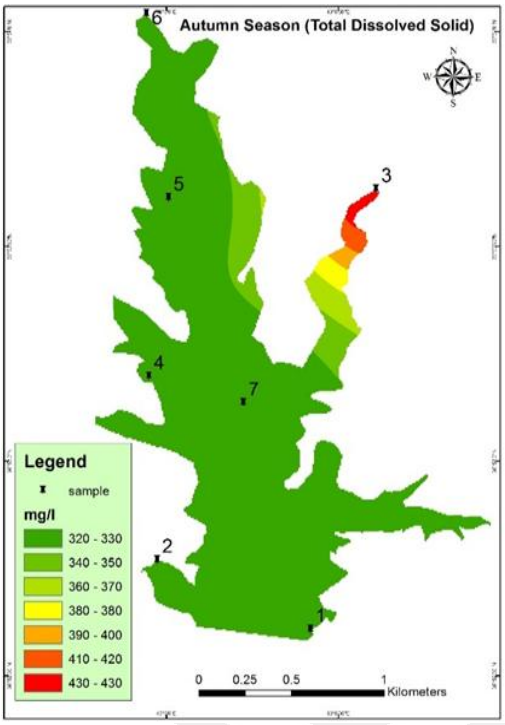


Figure 4.25. GIS interpolation of total dissolved solid in autumn season

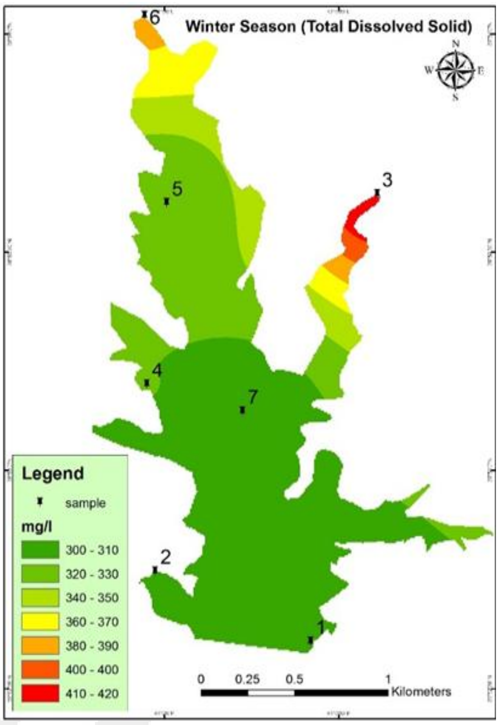


Figure 4.26. GIS interpolation of total dissolved solid in winter season

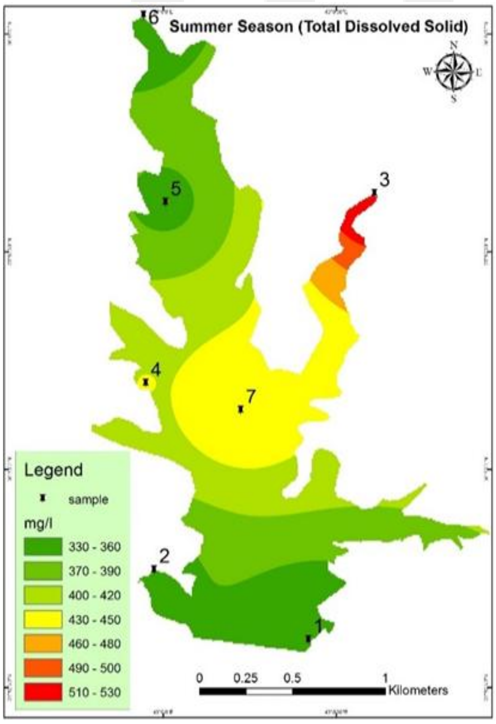


Figure 4.27. GIS interpolation of total dissolved solid in spring season

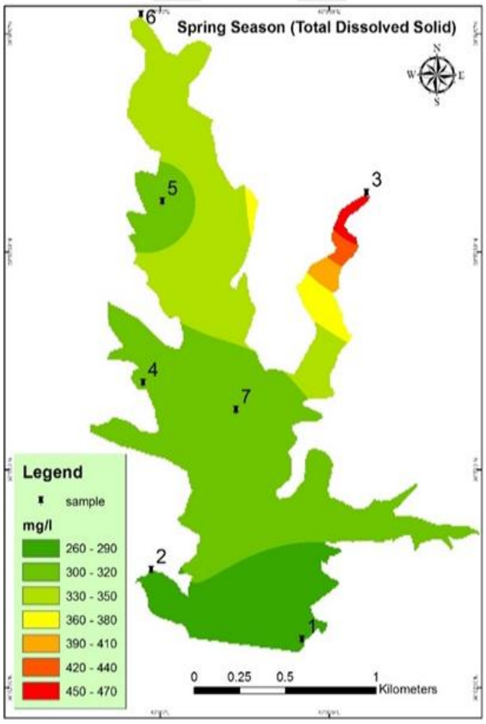


Figure 4.28. GIS interpolation of total dissolved solid in summer season

4.2.8. Total Alkalinity

Seasonal variations of total alkalinity of the lake are showing in Table 4.2, 4.3, 4.4 and 4.5 and GIS interpolation map represented respectively as shown in Figure 4.29, 4.30, 4.31 and 4.32. And also the seasonal average showed in Figure 4.65, 4.66, 4.67 and 4.68.

In the present study alkalinity values were ranged at autumn season from minimum 188 mg/l recorded in sample station S5, which are slightly higher than the permissible level recommended by the WHO for drinking water (WHO 2008), to maximum 332 mg/l in sample station S3, which is greatly higher than the permissible level recommended by the WHO for drinking water it should be between (150-200) according to (WHO 2008). Moreover, at the winter season is ranged from a minimum 190 mg/l in sample station S5 to maximum 340 mg/l in sample station S3, which is greatly higher than the permissible level recommended by the WHO for drinking water. Also at spring season is ranged as a minimum 155 mg/l at sampling station S2 and maximum 365 mg/l at sampling station S3, which are greatly higher than the permissible level, and at summer season is ranged as a minimum 221 as sampling station S5 and maximum 395 mg/l at sample station S3, which are greatly higher than the permissible level.

The variations of alkalinity value may be due to the geology of that area, soil erosion and the hot spring water in that area dissolved limestone – dolomite and picks up minerals on the way to the water body. (gold man and Wetzel man 1963) has reported the direct relation on alkalinity to productivity, an increase in the free co_2 may result in the increase in alkalinity (Singhal et al. 1986).

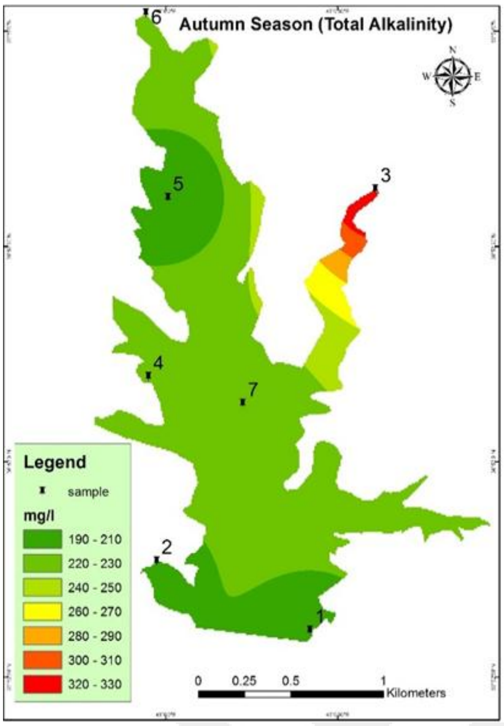


Figure 4.29. GIS interpolation of total alkalinity in autumn season

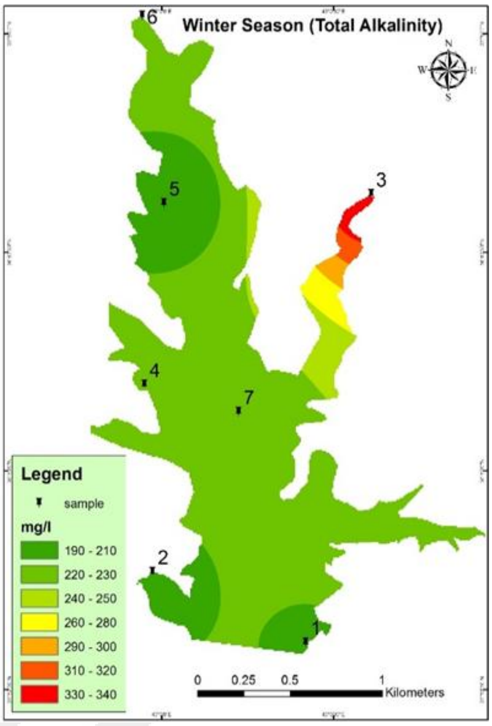


Figure 4.30. GIS interpolation of total alkalinity in winter season

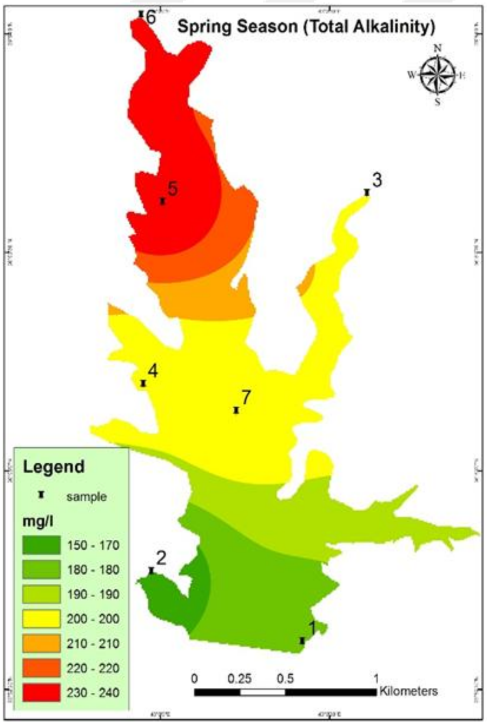


Figure 4.31. GIS interpolation of total alkalinity in spring season

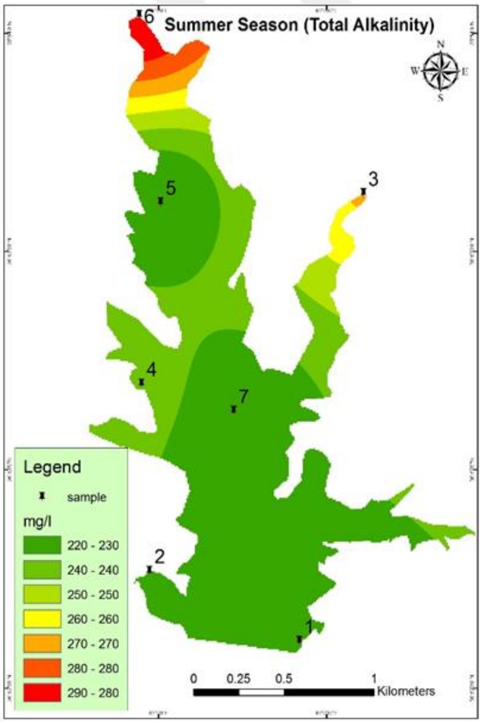


Figure 4.32. GIS interpolation of total alkalinity in summer season

4.2.9. Total Hardness

In the present study, the variations of total hardness in four season were illustrated Table 4.2, 4.3, 4.4 and 4.5 and GIS interpolation map represented respectively in Figure 4.33, 4.34, 4.35 and 4.36. And also the seasonal average showed in Figure 4.65, 4.66, 4.67 and 4.68.

The total hardness at autumn season is ranged from a minimum 368 mg/L in sampling station S2, to maximum is 664 mg/l in sampling station S3, which is slightly higher than the permissible level recommended by the WHO for drinking water it should be between 100-500 according to (WHO 2008), but in the winter season is ranged as a minimum is 370 mg/l recorded in sample station S2 and maximum is 672 mg/l recorded in sampling station S3 which is slightly higher than the permissible level recommended by the WHO for drinking water (WHO 2008), but at the spring season is ranged as a minimum is 280 mg/l recorded in sample station S7 and maximum is 592 mg/l recorded in sampling station S3 which is slightly higher than the permissible level. And at the summer season is ranged as a minimum is 300 mg/l recorded in sample station S4 and maximum are 490 mg/l recorded in sampling station S3.

The hardness often employed as an indicator of water quality depends on the concentration of carbonate and be carbonate salts of calcium and magnesium or sulfate and chloride or other ions on mineral acids (Lerga et al. 2008). The above higher values may be due to increased concentration of these ions. Hardness is inversely proportional to water volume and directly proportional to the rate of evaporation. When the concentration of magnesium and calcium ions is less than 40 ppm, it is conceded as a soft water if the concentration is greater than 40 ppm it is hard water. Toma (2012) reported total hardness ranged from 383 mg/l to 416 mg/l during the water quality study of Duhok Lake.

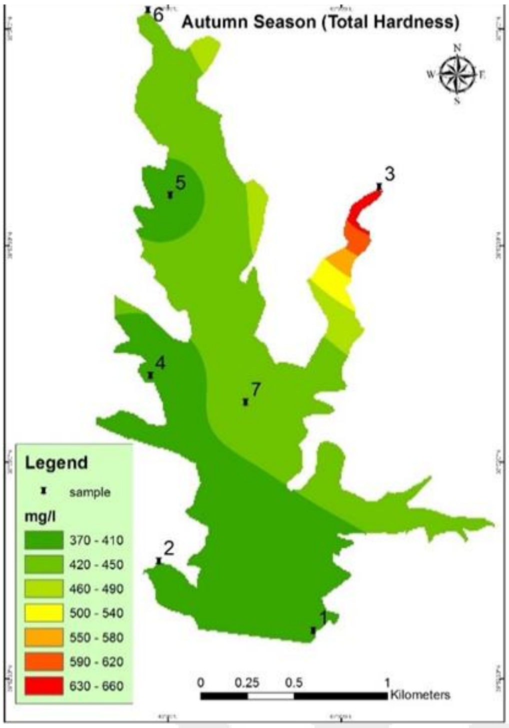


Figure 4.33. GIS interpolation of total hardness in autumn season

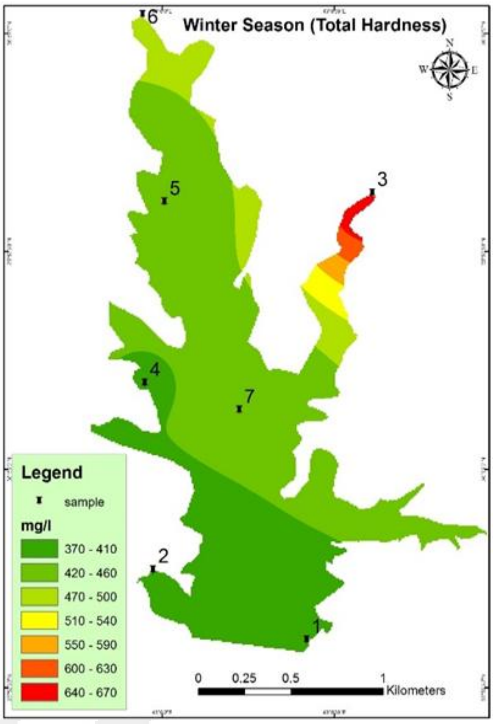


Figure 4.34. GIS interpolation of total hardness in winter season

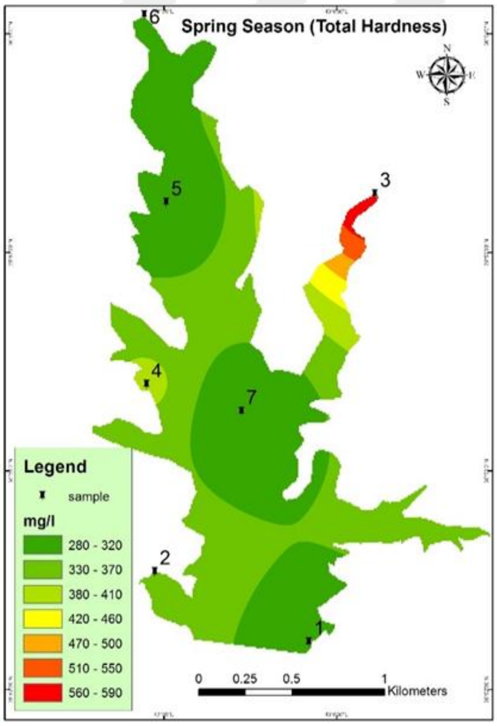


Figure 4.35. GIS interpolation of total hardness in spring season

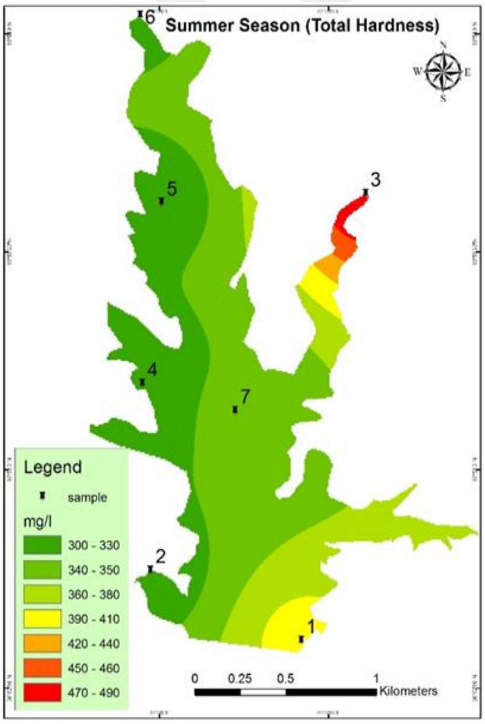


Figure 4.36. GIS interpolation of total hardness in summer season

4.2.10. Calcium

The variations of calcium in different season during the period of the study are showing respectively in Table 4.2, 4.3, 4.4, 4.5 and in Figure 4.37, 4.38, 4.39, 4.40, 4.65, 4.66, 4.67 and 4.68. Calcium is found in all natural water bodies and it is the main source is weathering of rocks from which it leaches out. In the present study, calcium variations in all seasons are high at sample station S3. Nevertheless, in autumn and winter season the value of calcium is higher than the permissible level. According to WHO drinking water standard calcium must be between these ranges 75 -200 mg /l (WHO 2008). Moreover, the highest average of calcium was recorded at winter season 122 mg/l and lowest at summer season 100 mg/l. The variation in calcium concentrations may be related to the human activities, geology of the area, seasonal change and climate, different biogeochemical activities in the water ecosystem, and water use and due to the addition of surface runoff from agricultural and another catchment area (Kumar et al. 2006).

4.2.11. Magnesium

During the present study of water, the variations of magnesium at different seasons of the lake water are showing Table 4.2, 4.3, 4.4 and 4.5. In addition, the GIS interpolation map represent showed respectively in Figure 4.41, 4.42, 4.43 and 4.44. And also the seasonal average showed in Figure 4.65, 4.66, 4.67 and 4.68. Magnesium concentration in water always remains lower than that of calcium content. During the present study at the autumn season magnesium values is ranged from minimum 33.2 mg/l in sample station S3 to maximum 42 mg/l in sample station S6. Nevertheless, at the winter season, is ranged from minimum 34.8 mg/l in sample station S3 to maximum 43.4 mg/l in sample station S6. But in the spring season is ranged as a minimum 12.7 mg/l in sample station S1 and maximum 36.1 in sample station S4, and in the summer season minimum was recorded 25 mg/l in sample station S4 and in sample station, S7 was recorded maximum range 38 mg/l. The variation of magnesium concentration may be related to the human activities, geology of the area, seasonal changes and climate, different biogeochemical activities in water ecosystem in addition of surface runoff from agriculture and another catchment area (Toma 2013).

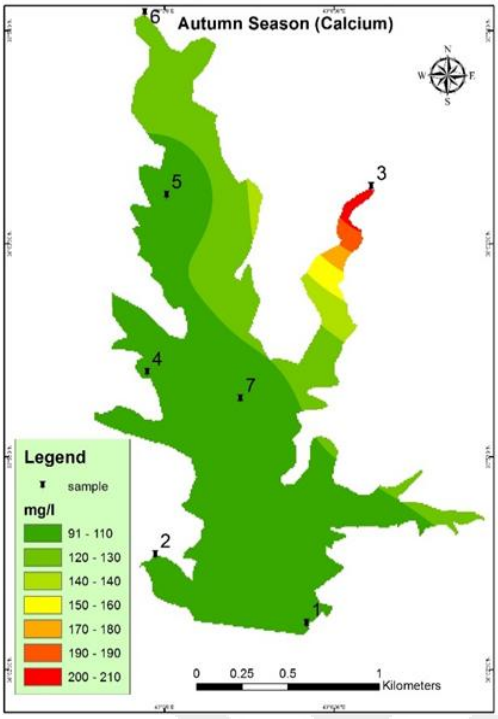


Figure 4.37. GIS interpolation of calcium in autumn season

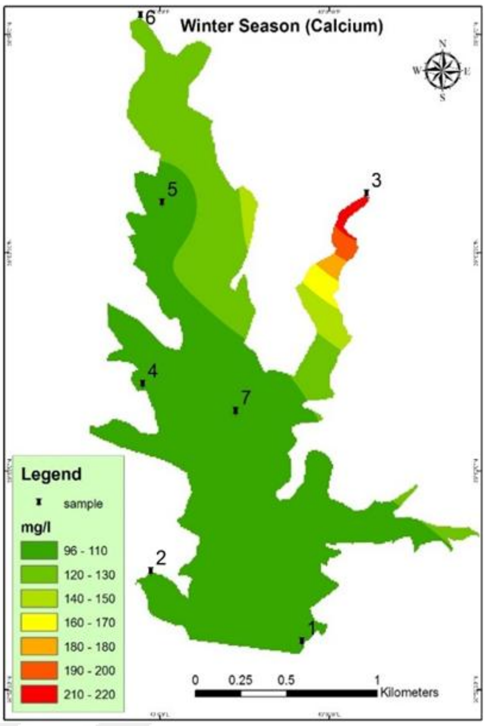


Figure 4.38. GIS interpolation of calcium in winter season

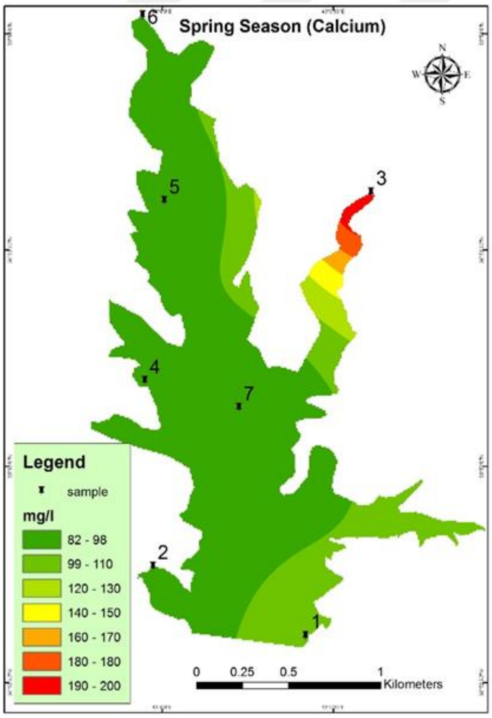


Figure 4.39. GIS interpolation of calcium in spring season

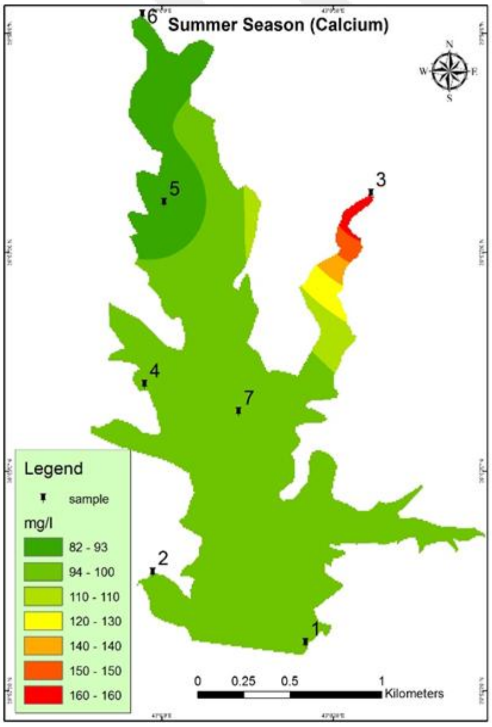


Figure 4.40. GIS interpolation of calcium in summer season

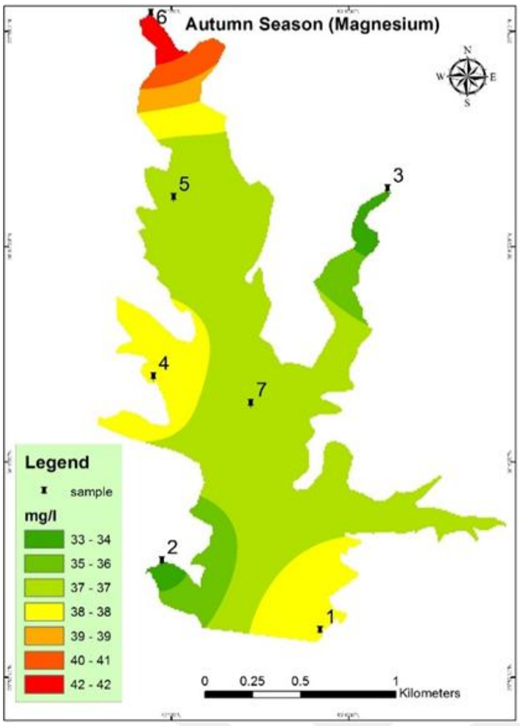


Figure 4.41. GIS interpolation of magnesium in autumn season

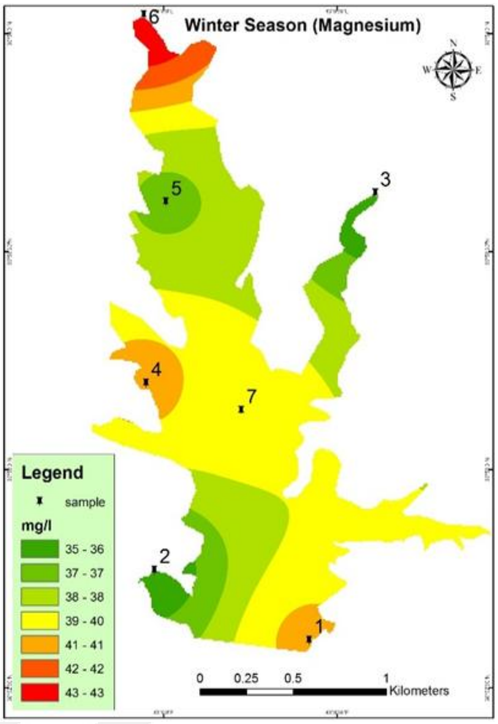


Figure 4.42. GIS interpolation of magnesium in winter season

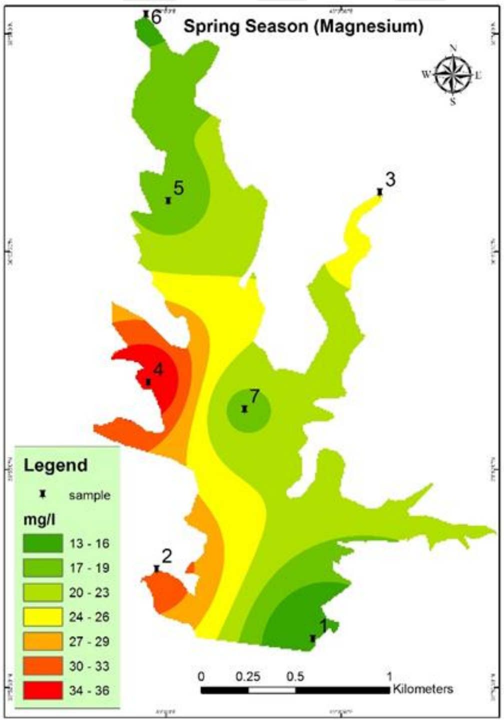


Figure 4.43. GIS interpolation of magnesium in spring season

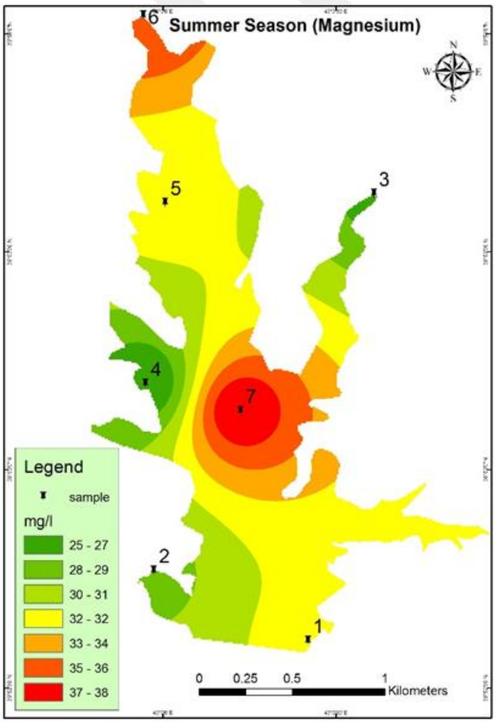


Figure 4.44. GIS interpolation of magnesium in summer season

4.2.12. Chloride

In the present study, the variations of chloride at winter and spring season were illustrated Table 4.2, 4.3, 4.4 and 4.5. In addition, GIS interpolation map represented respectively in Figure 4.45, 4.46, 4.47 and 4.48. And also the seasonal average showed in Figure 4.65, 4.66, 4.67 and 4.68. During the present study in autumn, winter, spring, and summer the chloride concentration is recorded minimum range in sample station S2, S1, S1 and S7, 76 mg/l, 75 mg/l, 68 mg/l and 72 mg/l, and all maximum range was recorded in sample station S3 except the spring season which is recorded 92 mg/l in sample station S6. The average variation of chloride is recorded as the highest concentration 107 mg/l at summer season and lowest 79 mg/l at spring season. The chloride concentration of lake depends upon the degree of contamination resulting from waste materials poured into the water body. The presence of chloride where it does not occur naturally indicates possible water pollution (Al-Ansari et al. 2014).

4.2.13. Sulfate

The variations of sulfate in different seasons during the period of the study is showing respectively in Table 4.2, 4.3, 4.4 and 4.5. In addition, in Figure 4.49, 4.50, 4.51, 4.52, 4.65, 4.66, 4.67 and 4.68. The sulfate occurs naturally in numerous minerals, including barite BASO4, epsomite MGSO4.7H2O and gypsum SASO4.2H2O (Sissakian et al. 2014). These dissolved minerals contribute to the mineral content of many drinking glasses of water. During the present study at the autumn season sulfate values is ranged from minimum 294 mg/l in sample station S5 to maximum 363 mg/l recorded in sample station S6. However, at the winter season is ranged as a minimum 282 mg/l in sample station S1 and S5. Moreover, the maximum is 359 mg/l recorded in sample station S6. In addition, at the spring season, the minimum range is recorded in sample station S5, 156 mg/l and maximum in sample station S3, 325 mg/l. However, at summer season minimum range of sulfate was recorded in sample station S6, 270 mg/l and maximum 463 mg/l in sample station S3. This increase occurred as result to Agriculture and runoff transport sulfate from fertilizer to water bodies (Hassan and Al-barware 2016).

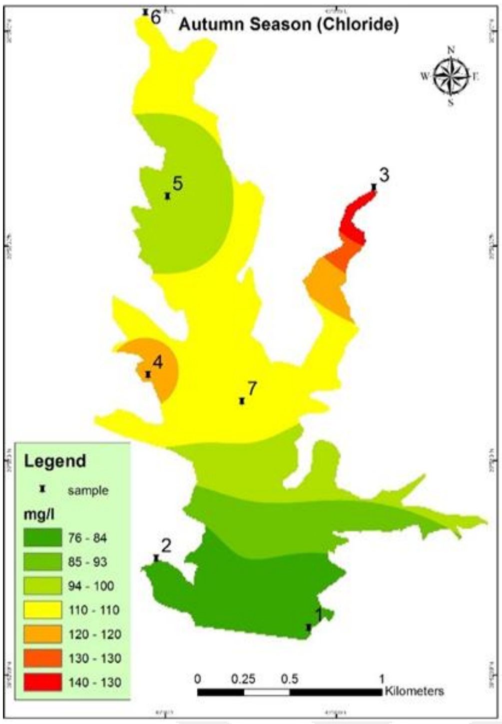


Figure 4.45. GIS interpolation of chloride in autumn season

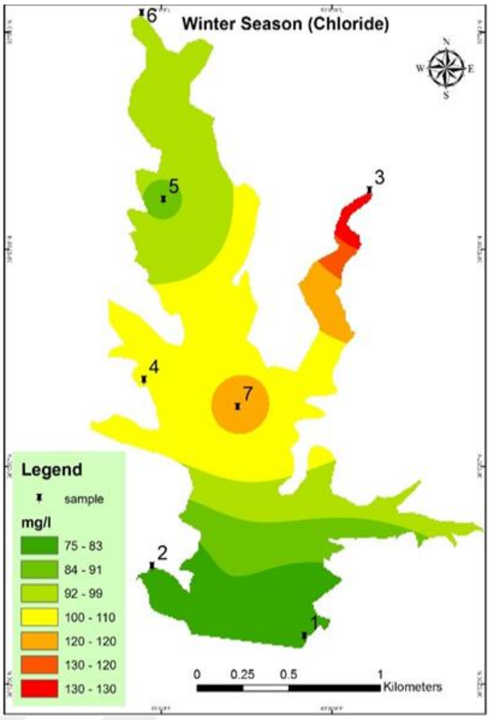


Figure 4.46. GIS interpolation of chloride in winter season

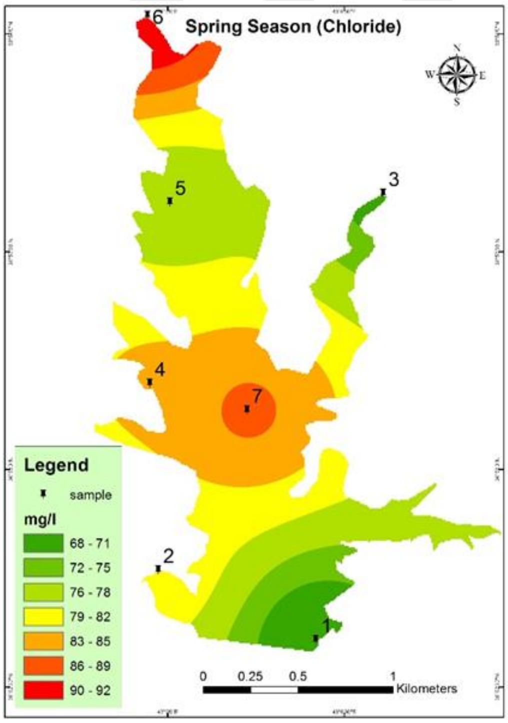


Figure 4.47. GIS interpolation of chloride in spring

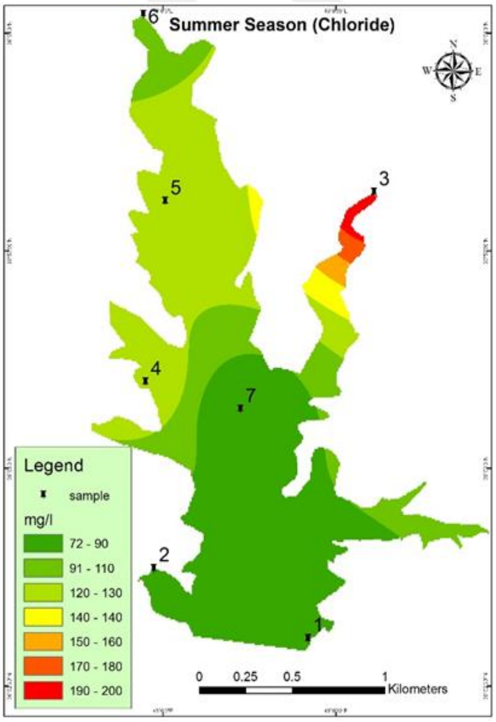


Figure 4.48. GIS interpolation of chloride in summer season

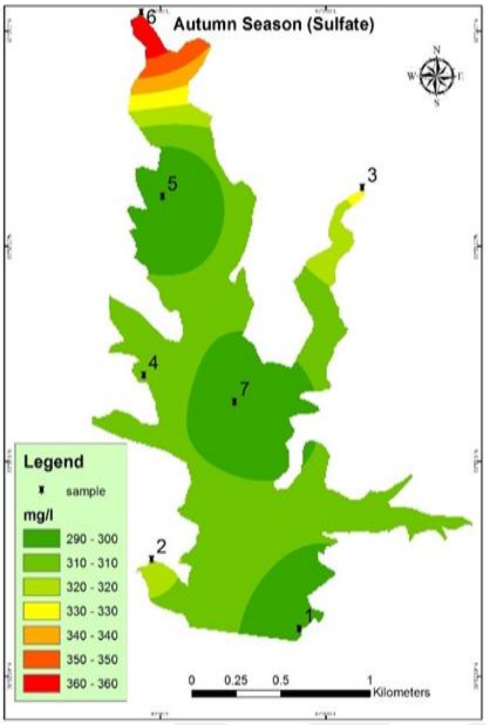


Figure 4.49. GIS interpolation of sulfate in autumn season

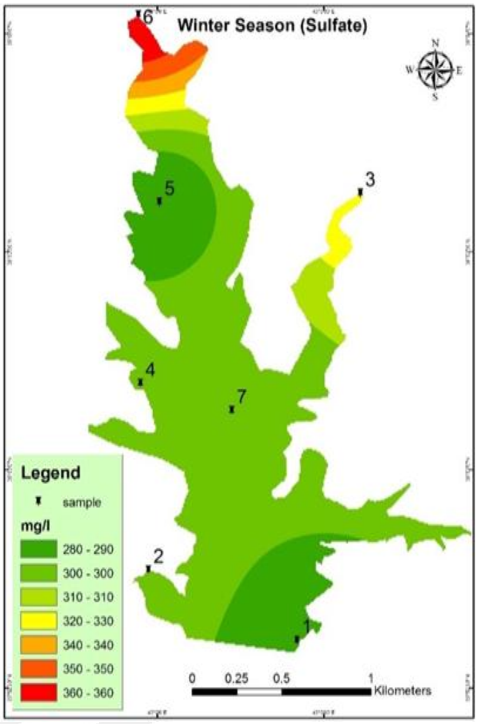


Figure 4.50. GIS interpolation of sulfate in winter season

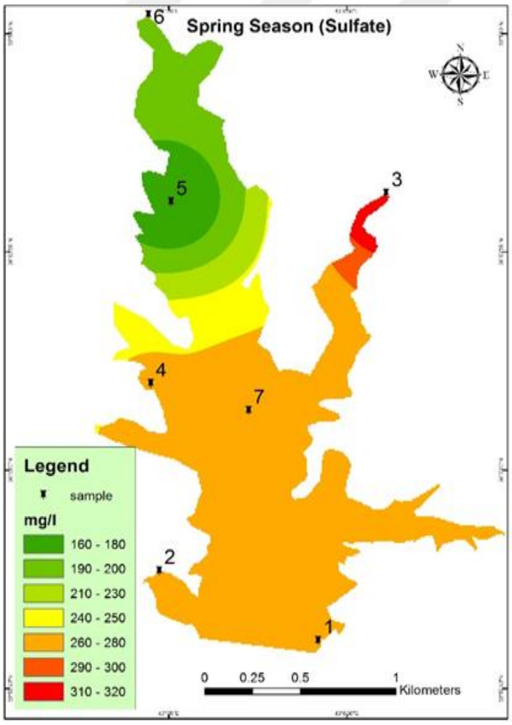


Figure 4.51. GIS interpolation of sulfate in spring season

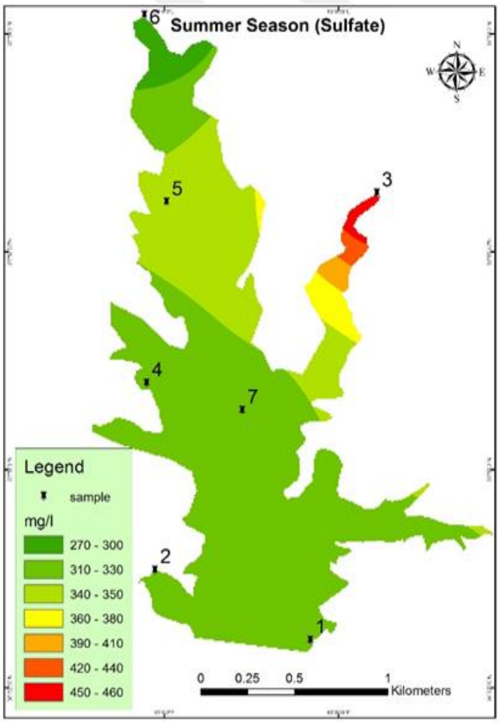


Figure 4.52. GIS interpolation of sulfate in summer season

4.2.14. Nitrate

The seasonal variations of nitrate of the lake water are showing in Table 4.2, 4.3, 4.4 and 4.5. In addition, the GIS interpolation map represented respectively in Figure 4.53, 4.54, 4.55 and 4.56. And also the seasonal average showed in Figure 4.65, 4.66, 4.67 and 4.68. Nitrate is essential for plant growth .during the study nitrate in all season minimum range was recorded in sample station S7 and maximum was recorded in sample station S3, which is higher than the both guidelines of CCME and ministry of environment, it should be between 0.0-0.13 mg/l for irrigation and it should be between 0.0 to 0.15 mg/l for aquatic ecosystem. And the seasonal variations of nitrate were recorded highest average 26 mg/l at winter season and lowest 20.6 mg/l at summer season. These values are much higher than (Toma 2013) high concentration in the drinking water is toxic (Marathi et al. 2007). The highest recorded values may be due to the increased phytoplankton excretion, oxidation of ammonia and the reduction of nitrate and by the recycling of nitrogen and bacterial decomposition of planktonic detritus, which are present in the environment. Further, the DE nitrification and air- sea interaction exchange of chemicals are also responsible for these increased values (Mathew and Pillai 1989). On the other hand, the low value recorded during summer season may be due to less freshwater inflow and high salinity (Murugan and Ayyakkannu 1991).

4.2.15. Sodium

Seasonal variations of Sodium of the lake are showing in the in Table 4.2, 4.3, 4.4 and 4.5. In addition, represented respectively in Figure 4.57, 4.58, 4.59, 4.60, 4.65, 4.66, 4.67 and 4.68. Sodium is command element in the natural environment and often found in food and drinks water. Sodium can occur naturally in water due to organization and salts in nature, sodium is not conceded to be toxic (Jensen et al. 2015). The Canadian guidelines for sodium are 200 mg/l. Sodium concentration above 200 mg/l will make water taste salt (WHO 2008). During the present study, the concentration of sodium in all season is high in sample station S3, but all concentration was within the permissible level of drinking water WHO. The seasonal average variations of sodium concentration were recorded as a highest 57.4 mg/l at summer season and lowest 48.4 mg/l at spring season. These variations of Sodium may be due to the seasonal change or geological of that area which sodium stems from rocks and soils.

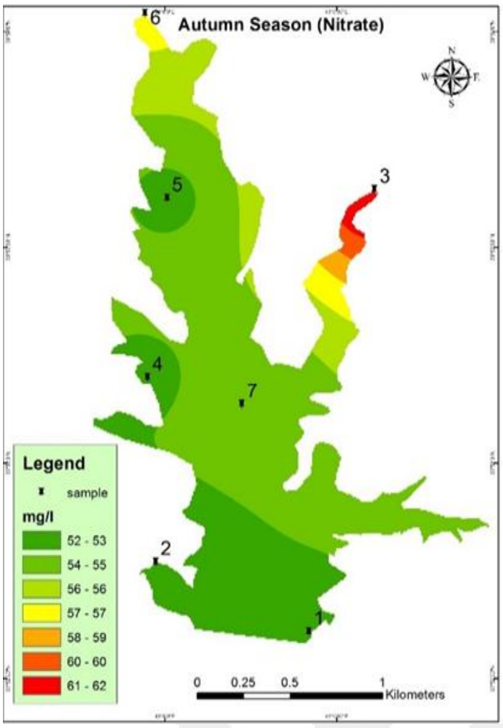


Figure 4.53. GIS interpolation of nitrate in autumn season

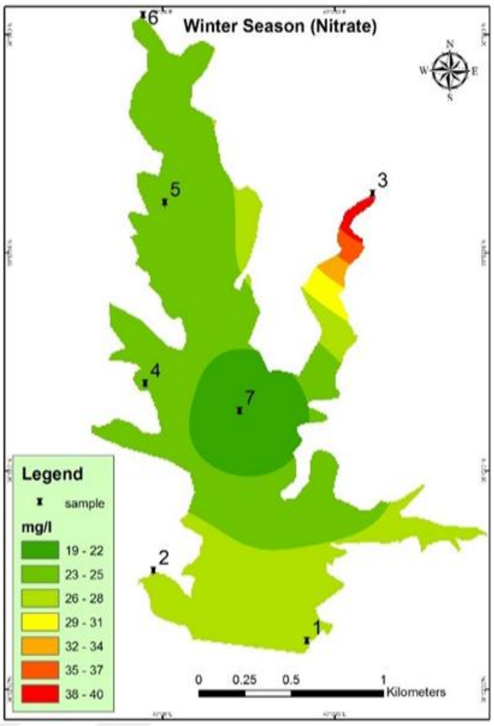


Figure 4.54. GIS interpolation of nitrate in winter season

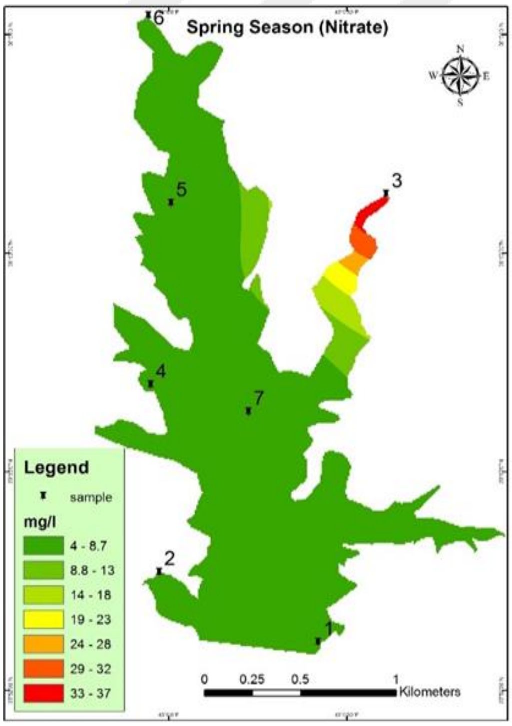


Figure 4.55. GIS interpolation of nitrate in spring season

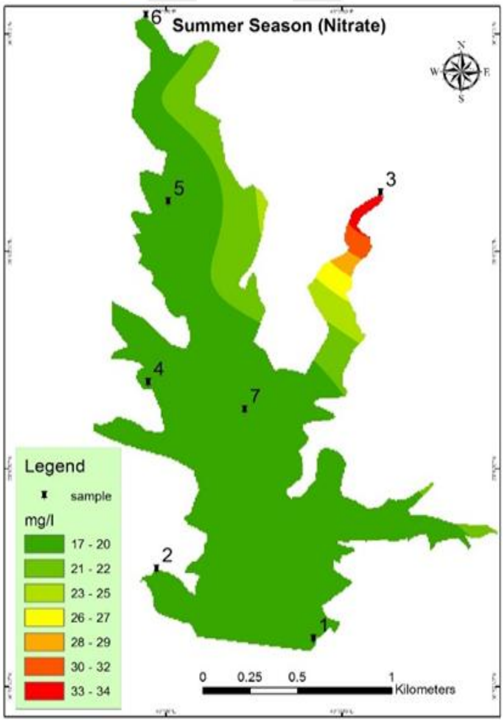


Figure 4.56. GIS interpolation of nitrate in summer season

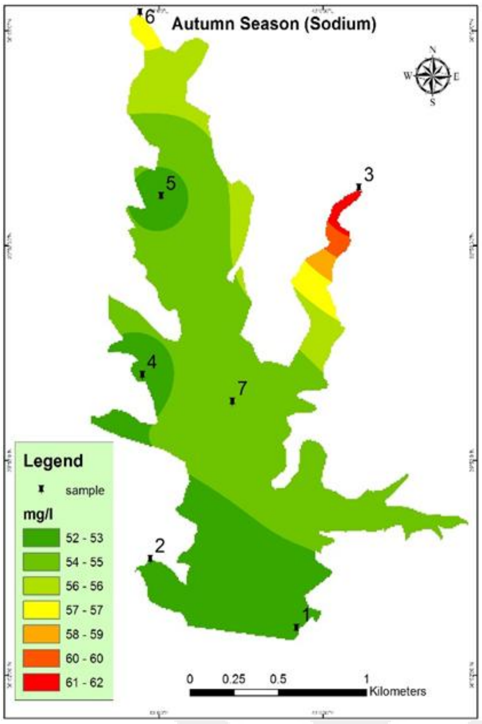


Figure 4.57. GIS interpolation of sodium in autumn season

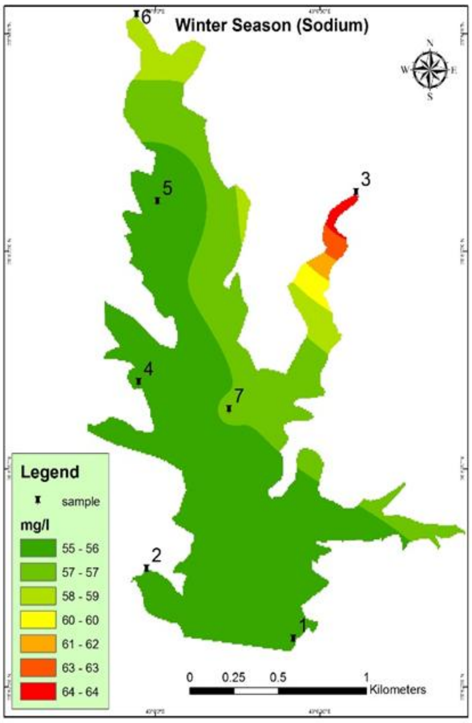


Figure 4.58. GIS interpolation of sodium in winter season

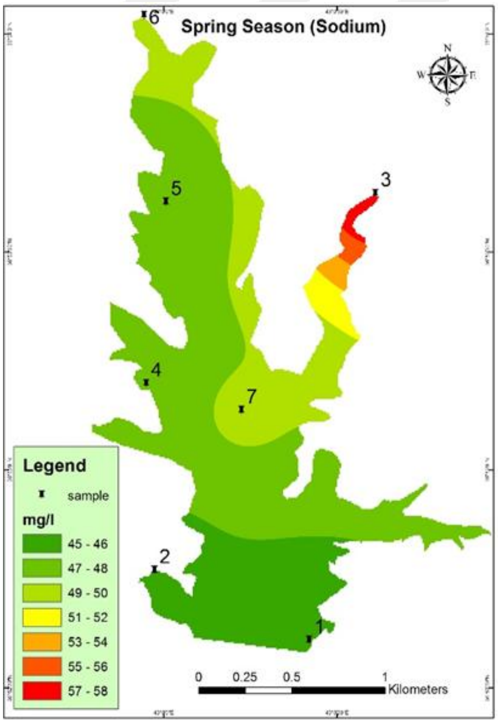


Figure 4.59. GIS interpolation of sodium in spring season

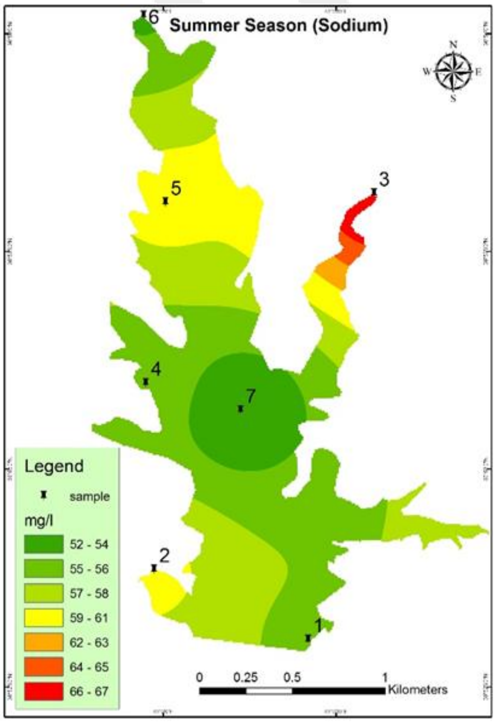


Figure 4.60. GIS interpolation of sodium in summer season

4.2.16. Potassium

The variations of potassium in deferent season during the period of the study are showing respectively in Table 4.2, 4.3, 4.4. In addition, represent showing in Figure 4.61, 4.62, 4.63, 4.64, 4.65, 4.66, 4.67 and 4.68. Potassium is an essential element in human's body and seldom, ever, found in drink water at levels that could be a worry for healthy humans. It occurs widely in the nature, including all natural waters. It can also occur in drinking water such as a consequence of the use of potassium permanganate as an oxidant in water treatment. According to (WHO) standards of drinking water potassium should be between those ranges 2-3 mg/l (WHO 2008).

During the present study in the autumn season, the potassium consternation is recorded as a minimum 4.14 mg/l in sample station S5 and maximum 8.15 mg/l in sample station S3. Although, at winter season, is ranged from minimum 4.79 mg/l in sample station S6 to maximum 9.3 mg/l in sample station S3. Although, at spring season is ranged between 4.5 mg/L to 7.41 mg/l, in sampling station S1 and S3, and in the summer season is ranged between 5.25 mg/l to 9.18 mg/l, in sampling station S6 and S3, which the concentration of potassium in all seasons is higher than the permissible level recommended by the WHO for drinking water (WHO 2008).

These variations of potassium may be due to the seasonal changes, climate, hot spring water discharge into the water body, biological activity, geology of the area in addition to the anthropogenic inputs to the water body. The obtained results agree with the results of (Toma 2000, Rasheed 2008 and Raoof 2002), all the studied water samples reveal the lower concentration of potassium than sodium. Both sodium and potassium show likeness in the timing of increase and decrease, this comes in accordance with the opinions of (Toma 2000; Rasheed 2008 and Raoof 2002).

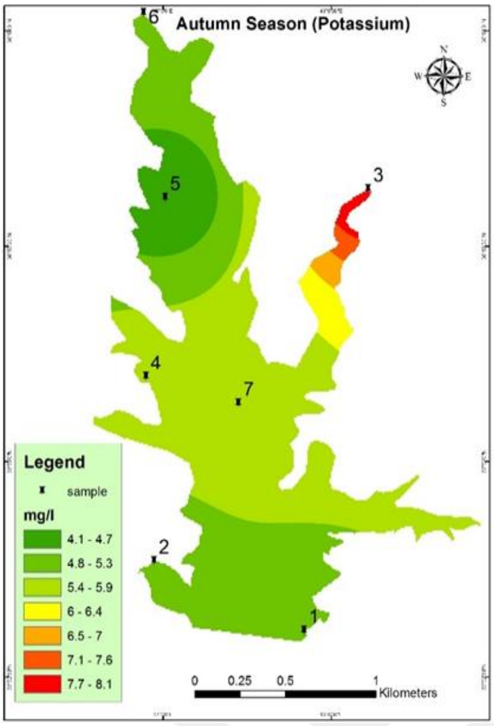


Figure 4.61. GIS interpolation of potassium in autumn season

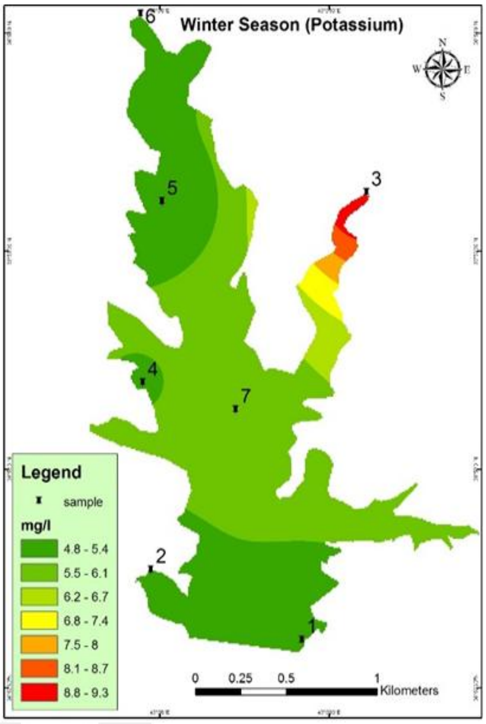


Figure 4.62. GIS interpolation of potassium in winter season

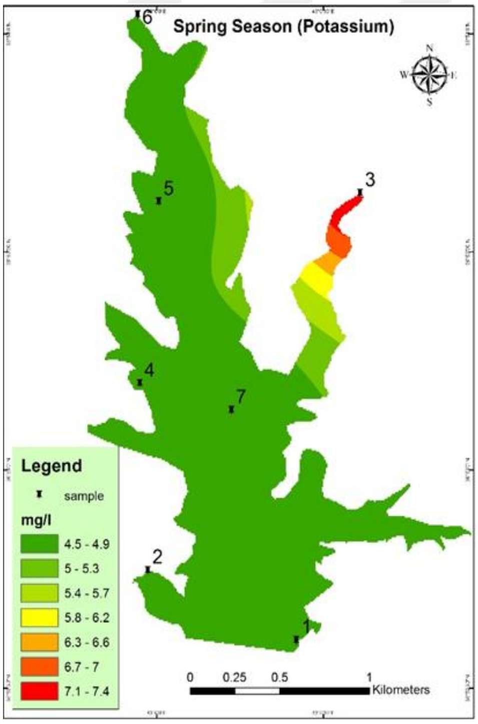


Figure 4.63. GIS interpolation of potassium in spring season

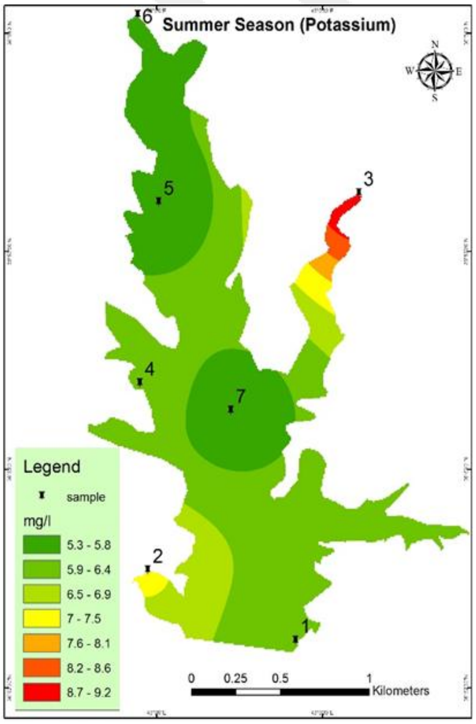


Figure 4.64. GIS interpolation of potassium in summer season

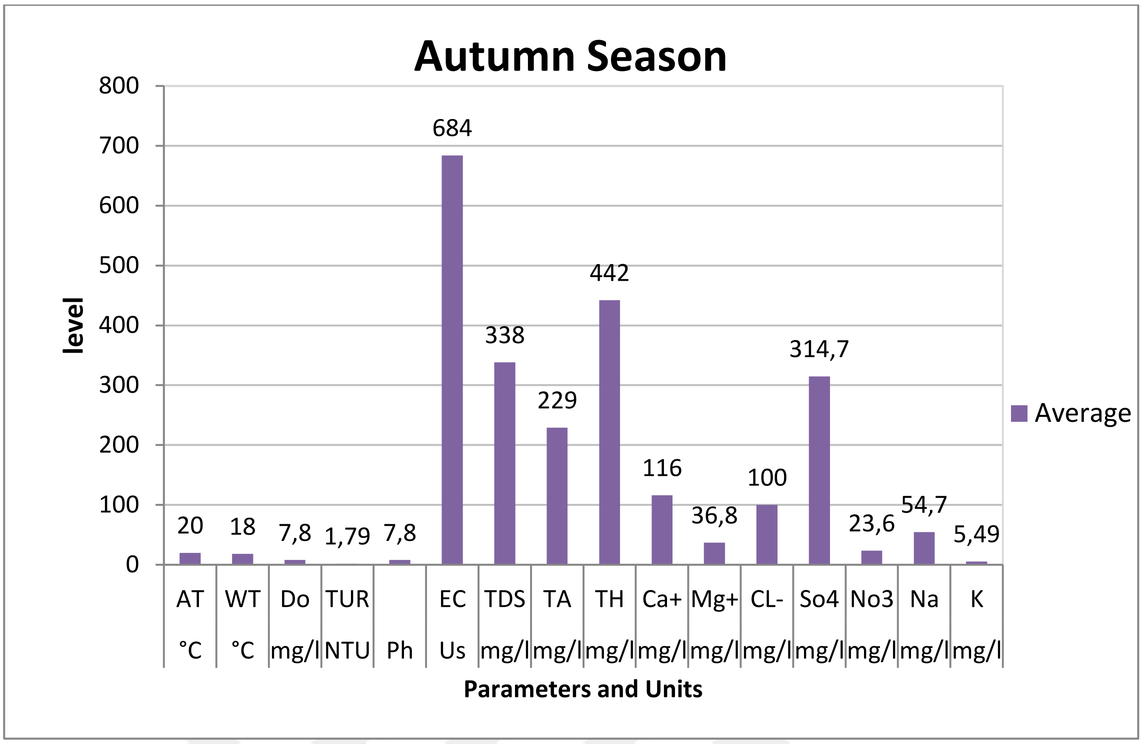


Figure 4.65. The average of parameters October 2016 autumn season

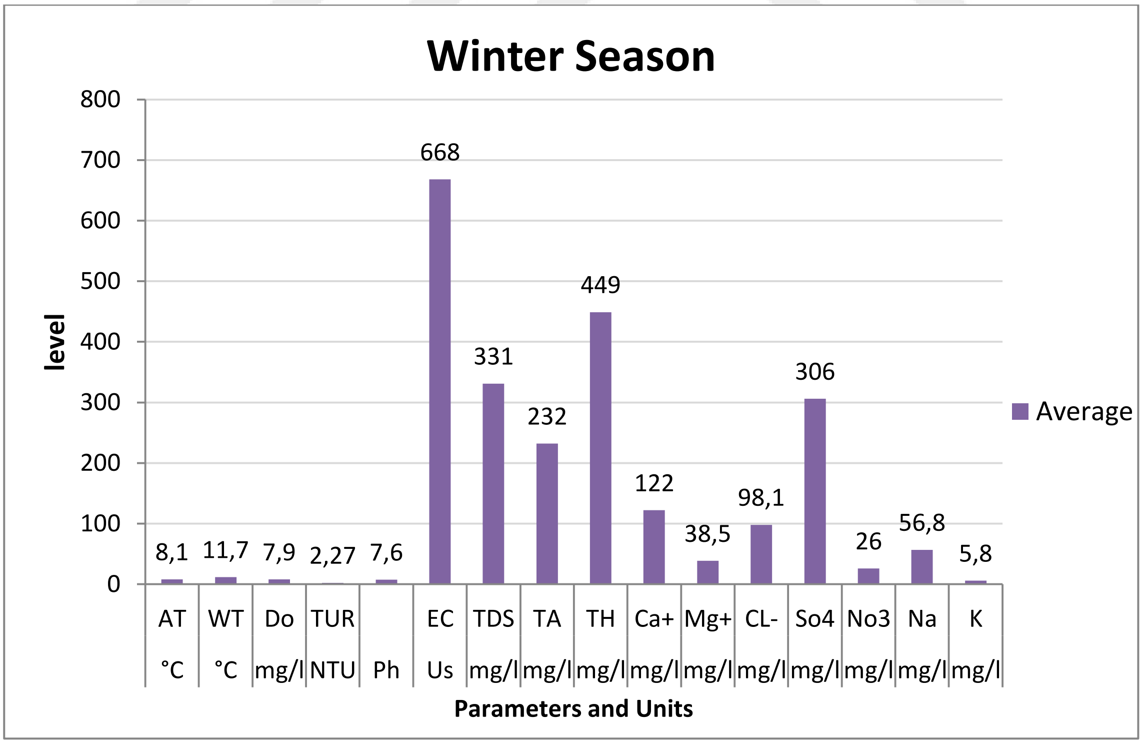


Figure 4.66. The average of parameters December 2016 winter season

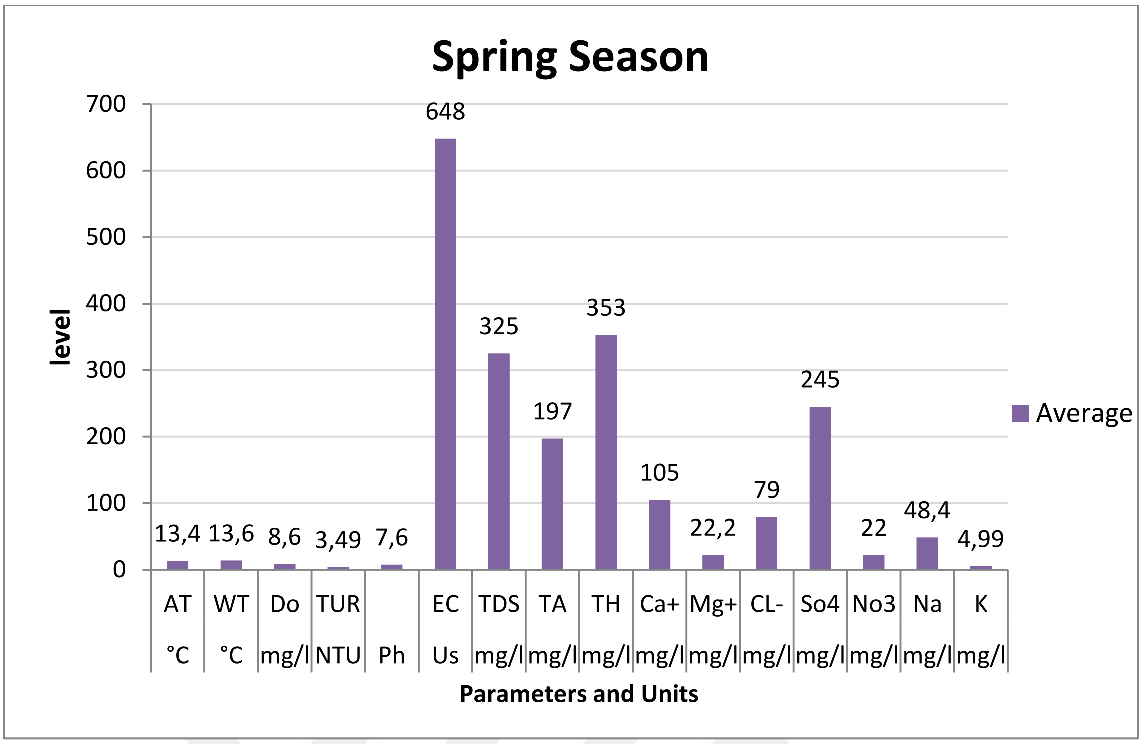


Figure 4.67. The average of parameters March 2017 spring season

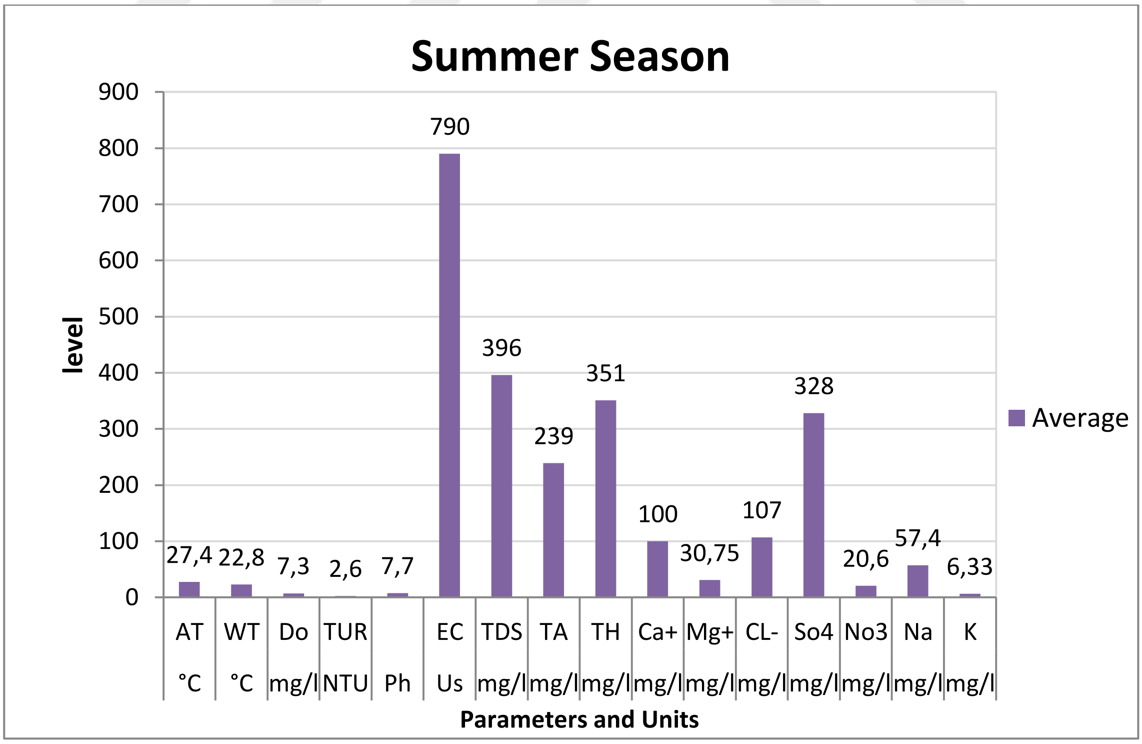


Figure 4.68. The average of parameters July 2017 summer season

4.3. Statistical Analysis

4.3.1. Descriptive Statistics

The descriptive statistics of physiochemical parameters under Duhok Lake studied are given in Tables 4.7. They provide a summary of the mean, standard deviation, variance values of sixteen measured parameters for four season's data.

Table 4.7. The descriptive statistics of physiochemical parameters

Parameters/Stations		**N (Seasons)**	**Mean**	**Std. Deviation**	**Std. Error**
Air Temperature	S1	4	170,000	905,539	452,769
	S2	4	172,500	850,627	425,314
	S3	4	172,500	788,987	394,493
	S4	4	173,000	822,800	411,400
	S5	4	175,750	831,159	415,579
	S6	4	182,750	890,894	445,447
	S7	4	168,250	777,448	388,724
	Total	28	173,536	741,597	140,149
Water temperature	S1	4	153,750	570,869	285,435
	S2	4	147,500	531,507	265,754
	S3	4	245,000	208,167	104,083
	S4	4	152,250	595,952	297,976
	S5	4	154,500	555,548	277,774
	S6	4	161,250	577,891	288,946
	S7	4	153,000	519,808	259,904
	Total	28	166,750	566,207	107,003
Dissolved Oxygen	S1	4	89,750	,28723	,14361
	S2	4	84,000	,41633	,20817
	S3	4	25,750	,56789	,28395
	S4	4	82,000	,53541	,26771
	S5	4	87,500	,49329	,24664
	S6	4	80,000	,24495	,12247
	S7	4	87,750	,91059	,45529
	Total	28	76,679	219,326	,41449
Turbidity	S1	4	15,750	,85391	,42696
	S2	4	29,250	,15000	,07500
	S3	4	61,250	,82209	,41105
	S4	4	16,250	143,614	,71807
	S5	4	17,000	142,829	,71414
	S6	4	29,000	,63770	,31885
	S7	4	10,000	,60000	,30000
	Total	28	25,500	183,374	,34654

Table 4.7. (Continue): The descriptive statistics of physiochemical parameters

Parameters/Stations		**N (Seasons)**	**Mean**	**Std. Deviation**	**Std. Error**
PH	S1	4	79,000	,08165	,04082
	S2	4	82,000	,25820	,12910
	S3	4	65,250	,20616	,10308
	S4	4	76,250	,12583	,06292
	S5	4	78,500	,17321	,08660
	S6	4	80,750	,38622	,19311
	S7	4	77,250	,15000	,07500
	Total	28	77,000	,55644	,10516
Electrical Conductivity	S1	4	6,345,000	11,405,993	5,702,996
	S2	4	6,577,500	10,418,693	5,209,347
	S3	4	9,257,500	7,522,577	3,761,289
	S4	4	6,760,000	9,201,449	4,600,725
	S5	4	6,645,000	8,141,458	4,070,729
	S6	4	7,132,500	4,805,119	2,402,559
	S7	4	6,110,000	1,834,848	917,424
	Total	28	6,975,357	12,315,407	2,327,393
Total Dissolved Solid	S1	4	3,020,000	3,365,511	1,682,756
	S2	4	3,150,000	2,938,253	1,469,127
	S3	4	4,645,000	4,940,648	2,470,324
	S4	4	3,437,500	5,051,320	2,525,660
	S5	4	3,260,000	2,014,944	1,007,472
	S6	4	3,410,000	2,243,509	1,121,755
	S7	4	3,165,000	1,670,329	835,165
	Total	28	3,441,071	6,005,821	1,134,993
Total Alkalinity	S1	4	2,022,500	2,166,987	1,083,494
	S2	4	1,985,000	3,139,533	1,569,766
	S3	4	3,580,000	2,839,014	1,419,507
	S4	4	2,187,500	1,839,157	919,579
	S5	4	2,087,500	2,362,731	1,181,366
	S6	4	2,440,000	2,741,046	1,370,523
	S7	4	2,180,000	1,344,123	672,062
	Total	28	2,354,643	5,698,959	1,077,002
Total Hardness	S1	4	3,747,500	4,199,504	2,099,752
	S2	4	3,470,000	2,821,347	1,410,674
	S3	4	6,045,000	8,438,602	4,219,301
	S4	4	3,715,000	4,975,607	2,487,804
	S5	4	3,535,000	6,444,377	3,222,189
	S6	4	3,805,000	8,833,836	4,416,918
	S7	4	3,607,500	6,589,575	3,294,788
	Total	28	3,989,286	10,291,706	1,944,950
Calcium	S1	4	985,000	443,471	221,736
	S2	4	912,500	464,579	232,289
	S3	4	1,967,500	2,736,634	1,368,317
	S4	4	950,000	355,903	177,951
	S5	4	957,500	1,209,339	604,669
	S6	4	1,015,000	1,864,582	932,291
	S7	4	977,500	1,161,536	580,768
	Total	28	1,109,286	3,796,190	717,412

Table 4.7. (Continue): The descriptive statistics of physiochemical parameters

Parameters/Stations		N (Seasons)	Mean	Std. Deviation	Std. Error
Magnesium	S1	4	304,500	1,245,110	622,555
	S2	4	321,500	324,705	162,352
	S3	4	294,250	545,306	272,653
	S4	4	348,750	680,312	340,156
	S5	4	306,500	851,998	425,999
	S6	4	342,500	1,284,095	642,048
	S7	4	329,000	967,505	483,753
	Total	28	321,000	820,528	155,065
Chloride	S1	4	737,500	394,757	197,379
	S2	4	773,750	179,699	,89849
	S3	4	1,335,000	5,226,535	2,613,267
	S4	4	1,057,500	1,732,772	866,386
	S5	4	929,000	1,478,423	739,211
	S6	4	983,000	578,158	289,079
	S7	4	922,500	1,658,061	829,031
	Total	28	962,607	2,736,580	517,165
Sulphate	S1	4	2,890,000	1,311,488	655,744
	S2	4	2,965,000	2,805,352	1,402,676
	S3	4	3,595,000	6,900,483	3,450,242
	S4	4	2,920,000	2,593,582	1,296,791
	S5	4	2,645,000	7,467,931	3,733,966
	S6	4	2,937,500	8,540,638	4,270,319
	S7	4	2,952,500	2,091,849	1,045,925
	Total	28	2,986,429	5,419,185	1,024,130
Nitrate	S1	4	222,500	350,000	175,000
	S2	4	217,500	386,221	193,111
	S3	4	370,000	244,949	122,474
	S4	4	215,000	238,048	119,024
	S5	4	202,500	170,783	,85391
	S6	4	207,500	236,291	118,145
	S7	4	180,000	,81650	,40825
	Total	28	230,714	637,082	120,397
Sodium	S1	4	521,500	523,991	261,996
	S2	4	527,750	564,528	282,264
	S3	4	628,250	368,273	184,136
	S4	4	523,750	394,324	197,162
	S5	4	534,500	518,234	259,117
	S6	4	542,250	393,986	196,993
	S7	4	527,250	308,477	154,239
	Total	28	543,607	533,002	100,728
Potassium	S1	4	51,325	,62830	,31415
	S2	4	54,500	107,005	,53502
	S3	4	85,100	,89677	,44839
	S4	4	54,050	,65831	,32915
	S5	4	47,575	,51396	,25698
	S6	4	49,550	,25000	,12500
	S7	4	53,900	,56374	,28187
	Total	28	56,571	135,868	,25677

4.3.2. ANOVA and Duncan Tests for Comparison of the Measurement Parameters at Different Stations

The results of the ANOVA and Duncan tests are provided in Table 4.8. The objectives of data (as bold color) were to test the significance of discriminant function and to determine the most significance variables that result in water quality variation in four seasons (as group). TDO, Turbidity, pH, EC, TDS, TA, TH, Ca, CL, NO_3, Na and K parameters was significantly affected according to the stations of lake. There was no significant difference between the air temperature, water temperature, Mg and SO_4 of various stations.

Table 4.8. The variance analyses of physiochemical parameters by ANOVA

		Sum of Squares	**df**	**Mean Square**	**F**	**Significancy** ***P<0.05** ****P<0.01**
Air Temperature	Between Groups	5,307	6	,885	,013	1,000
	Within Groups	1,479,603	21	70,457		
	Total	1,484,910	27			
Water temperature	Between Groups	289,690	6	48,282	1,761	,156
	Within Groups	575,902	21	27,424		
	Total	865,593	27			
Dissolved Oxygen	Between Groups	123,889	6	20,648	72,359	**,000****
	Within Groups	5,993	21	,285		
	Total	129,881	27			
Turbidity	Between Groups	71,900	6	11,983	13,322	**,000****
	Within Groups	18,890	21	,900		
	Total	90,790	27			
pH	Between Groups	7,360	6	1,227	25,760	**,000****
	Within Groups	1,000	21	,048		
	Total	8,360	27			
Electrical Conductivity	Between Groups	267,714,714	6	44,619,119	6,608	**,000****
	Within Groups	141,792,250	21	6,752,012		
	Total	409,506,964	27			

Table 4.8. (Continue): The variance analyses of physiochemical parameters by ANOVA

Total Dissolved Solid	Between Groups	72,857,929	6	12,142,988	10,395	**,000****
	Within Groups	24,530,750	21	1,168,131		
	Total	97,388,679	27			
Total Alkalinity	Between Groups	75,421,714	6	12,570,286	21,515	**,000****
	Within Groups	12,269,250	21	584,250		
	Total	87,690,964	27			
Total Hardness	Between Groups	200,616,357	6	33,436,060	8,225	**,000****
	Within Groups	85,365,500	21	4,065,024		
	Total	285,981,857	27			
Calcium	Between Groups	34,614,857	6	5,769,143	28,208	**,000****
	Within Groups	4,295,000	21	204,524		
	Total	38,909,857	27			
Magnesium	Between Groups	99,785	6	16,631	,203	,972
	Within Groups	1,718,035	21	81,811		
	Total	1,817,820	27			
Chloride	Between Groups	9,487,009	6	1,581,168	3,094	**,025***
	Within Groups	10,732,938	21	511,092		
	Total	20,219,947	27			
Sulphate	Between Groups	20,185,929	6	3,364,321	1,195	,347
	Within Groups	59,106,500	21	2,814,595		
	Total	79,292,429	27			
Nitrate	Between Groups	951,857	6	158,643	23,135	**,000****
	Within Groups	144,000	21	6,857		
	Total	1,095,857	27			
Sodium	Between Groups	346,049	6	57,675	2,877	**,033***
	Within Groups	420,997	21	20,047		
	Total	767,047	27			
Potassium	Between Groups	39,577	6	6,596	13,494	**,000****
	Within Groups	10,265	21	,489		
	Total	49,842	27			

4.3.3. The Descriptive Groups of Stations According to the Physic-Chemical Parameters of Water by Duncan Test

The descriptive groups of stations according to the physiochemical parameters of water by Duncan test are provided in Table 4.9, 4.10, 4.11, 4.12, 4.13, 4.14, 4.15, 4.16, 4.17, 4.18 and 4.19. These statistical analyses showed that there are different station group from most of the parameters and were given in Tables 4.9-19.

Table 4.9.The descriptive groups of stations according to dissolved oxygen

Duncan[a]

		Subset for alpha = 0.05		
Group	**N**	**1**	**2**	**3**
S3	4	2,5750 C		
S6	4		8,0000 AB	
S4	4		8,2000 AB	8,2000
S2	4		8,4000 AB	8,400
S5	4		8,7500 AB	8,7500
S7	4		8,7750 AB	8,7750
S1	4			8,9750 A
Sig.		1,000	,078	,078

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4,000.

Table 4.10. The descriptive groups of stations according to turbidity

Duncan[a]

		Subset for alpha = 0.05		
Group	**N**	**1**	**2**	**3**
S7	4	1,0000 C		
S1	4	1,5750 BC	1,5750 B	
S4	4	1,6250 BC	1,6250 B	
S5	4	1,7000 BC	1,7000 B	
S6	4		2,9000 B	
S2	4		2,9250 B	
S3	4			6,1250 A
Sig.		,351	,083	1,000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4,000.

Table 4.11. The descriptive groups of stations according to pH

Duncan[a]

Group	N	Subset for alpha = 0.05			
		1	2	3	4
S3	4	6,5250 D			
S4	4		7,6250 C		
S7	4		7,7250 C		
S5	4		7,8500 BC	7,8500 AB	
S1	4		7,9000 BC	7,9000 AB	7,9000
S6	4			8,0750 AB	8,0750
S2	4				8,2000 A
Sig.		1,000	,116	,182	,079

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4,000.

Table 4.12. The descriptive groups of stations according to electrical conductivity

Duncan[a]

Group	N	Subset for alpha = 0.05	
		1	2
S7	4	611,0000 B	
S1	4	634,5000 B	
S2	4	657,7500 B	
S5	4	664,5000 B	
S4	4	676,0000 B	
S6	4	713,2500 B	
S3	4		925,7500 A
Sig.		,133	1,000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4,000

Table 4.13. The descriptive groups of stations according to total dissolved solid

Duncan[a]

Group	N	Subset for alpha = 0.05	
		1	2
S1	4	302,0000 B	
S2	4	315,0000 B	
S7	4	316,5000 B	
S5	4	326,0000 B	
S6	4	341,0000 B	
S4	4	343,7500 B	
S3	4		464,5000 A
Sig.		,140	1,000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4,000.

Table 4.14. The descriptive groups of stations according to total alkalinity

Duncan[a]

Group	N	Subset for alpha = 0.05		
		1	2	3
S2	4	198,5000 C		
S1	4	202,2500 C		
S5	4	208,7500 BC	208,7500	
S7	4	218,0000 BC	218,0000	
S4	4	218,7500 BC	218,7500	
S6	4		244,0000 B	
S3	4			358,0000 A
Sig.		,300	,071	1,000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4,000.

Table 4.15. The descriptive groups of stations according to total hardness

Duncan[a]

Group	N	Subset for alpha = 0.05	
		1	2
S2	4	347,0000 B	
S5	4	353,5000 B	
S7	4	360,7500 B	
S4	4	371,5000 B	
S1	4	374,7500 B	
S6	4	380,5000 B	
S3	4		604,5000 A
Sig.		,518	1,000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4,000.

Table 4.16. The descriptive groups of stations according to calcium

Duncan[a]

Group	N	Subset for alpha = 0.05	
		1	2
S2	4	91,2500 B	
S4	4	95,0000 B	
S5	4	95,7500 B	
S7	4	97,7500 B	
S1	4	98,5000 B	
S6	4	101,5000 B	
S3	4		196,7500 A
Sig.		,380	1,000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4,000.

Table 4.17. The descriptive groups of stations according to nitrate

Duncan[a]

Group	N	Subset for alpha = 0.05	
		1	2
S7	4	18,0000 B	
S5	4	20,2500 B	
S6	4	20,7500 B	
S4	4	21,5000 B	
S2	4	21,7500 B	
S1	4	22,2500 B	
S3	4		37,0000 A
Sig.		,053	1,000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4,000.

Table 4.18. The descriptive groups of stations according to sodium

Duncan[a]

Group	N	Subset for alpha = 0.05	
		1	2
S1	4	52,1500 B	
S4	4	52,3750 B	
S7	4	52,7250 B	
S2	4	52,7750 B	
S5	4	53,4500 B	
S6	4	54,2250 B	
S3	4		62,8250 A
Sig.		,568	1,000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4,000.

Table 4.19. The descriptive groups of stations according to potassium

Duncan[a]

Group	N	Subset for alpha = 0.05	
		1	2
S5	4	4,7575 B	
S6	4	4,9550 B	
S1	4	5,1325 B	
S7	4	5,3900 B	
S4	4	5,4050 B	
S2	4	5,4500 B	
S3	4		8,5100 A
Sig.		,228	1,000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4,000.

4.3.4. Correlation Matrix for the Water Quality Parameters

The covariance matrix of the 16 analyzed variables was calculated from normalized data; therefore, it coincided with the correlation matrix. High and positive correlations with bold values were observed between chloride (Cl), sodium (Na), potassium (K), sulfate (SO4), nitrate (NO3), calcium (Ca), total hardness (TH), total alkalinity (TA), dissolved oxygen (DO), EC, and turbidity (TUR), which are related to soluble salts in water and responsible for water mineralization. Nitrate nitrogen is positively correlated with sodium and potassium representing agricultural runoff. As expected, DO was negatively correlated with water temperature because the solubility of oxygen in water decreases with increasing temperature. Nitrate nitrogen, sulfate, chloride, calcium sodium, and potassium were also anti-correlated with DO, as nutrients are responsible for the eutrophication of the lake water, thus causing a further increase in oxygen demand. In addition, DO is positively correlated with pH but negatively correlated with the other characteristics. We found pH values were positively associated with sodium and potassium but negatively correlated with the other characteristics in Table 4.20.

Table 4.20. Correlation matrix between physical and chemical parameters of Duhok Lake water analysis

Parameters	**AT**	**WT**	**Do**	**TUR**	**PH**	**EC**	**TDS**	**TA**	**TH**	**Ca**	**Mg**	**CL**	**SO4**	**NO3**	**Na**	**K**
AT	1															
WT	,780**	1														
Do	-,088	-,614**	1													
TUR	-,037	,444*	-,808**	1												
PH	,061	-,476*	,824**	- ,604**	1											
EC	,178	,562**	-,778**	,553**	-,550**	1										
TDS	,321	,728**	-,881**	,688**	-,694**	,752**	1									
TA	,186	,669**	-,897**	,730**	-,788**	,751**	,903**	1								
TH	-,209	,362	-,746**	,567**	-,692**	,738**	,600**	,685**	1							
Ca	-,148	,469*	-,872**	,734**	-,804**	,728**	,719**	,795**	,939**	1						
Mg	-,077	-,080	,164	-,345	,187	,153	-,090	-,092	,324	,025	1					
CL	,214	,484**	-,613**	,316	-,603**	,512**	,695**	,643**	,437*	,467*	,082	1				
SO4	,295	,497**	-,519**	,221	-,225	,542**	,625**	,491**	,499**	,450*	,376*	,609**	1			
NO3	-,278	,321	-,849**	,736**	-,755**	,752**	,675**	,767**	,874**	,914**	,036	,444*	,416*	1		
Na	,213	,594**	-,660**	,398*	-,496**	,622**	,770**	,750**	,676**	,666**	,320	,680**	,762**	,612**	1	
K	,184	,687**	-,851**	,673**	-,793**	,611**	,838**	,872**	,713**	,813**	-,036	,665**	,578**	,749**	,823**	1

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

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

AT=Air temperature, WT= Water temperature, DO= Dissolved oxygen, TUR= Turbidity, pH=potential of hydrogen, TDS=Total dissolved solid, EC= Electrical conductivity, TH= Total hardness, TA= Total Alkalinity, Ca=calcium, Mg=magnesium, Cl= Chloride, SO$_4$= Sulfate, NO$_3$= Nitrate, , Na=Sodium, K=Potassium.

5. CONCLUSION

1. The study has revealed that there are significant seasonal variations in most of the parameters, found to be increased during the summer season and have been diluted during the rainy season, which indicate that during the summer season, lake water is more affected than winter, and spring seasons. Therefore, this kind of changes would affect the aquatic environment and agriculture activity.

2. The results obtained that the sample station S3 is recording higher values of the studied parameter in all seasons, which is higher than the permissible level of drinking water and the guideline of irrigation and aquatic ecosystem. Owing to Garmava hot spring water is directly discharged into the lake water body in that area and is need physical, chemical and biological reliability with possible and inflexible repair and management strategies in instruction to uphold, preserve, protect and to avoid ecological disparity and trouble in hydro-geochemical and hydro-biological cycles which eventually harmfully distress the food chain and food web of the lake ecosystems.

3. The GIS ınterpolation map and physical-chemical study supported in cutting and identifying the factors or origins responsible for water quality differences in four seasons of the year. The normal parameters such as temperature, discharge, the inorganic parameter (totally solid), and other important parameters favorable water quality differences for entirely seasons. The effect of the study showed that a parameter that can be important in influence to water quality differences in Duhok Lake for one season may less or not be important for extra one. Therefore, it is essential that, when choosing water quality parameters for applying environmental nursing plans in the lake, the seasonal differences of parameters in the evaluation of water quality must be measured.

4. No site in Duhok Lake meets the (WHO) drinking water standard; therefore, it is not safe for human consumption without assessment and treatment process.

5. According to the classification of water for irrigation as a dependent of EC, TDS, and pH, the water of the study area is suitable for irrigation at all, site of the lake except sample station S3.

6. The general guidelines for classification of hardness water explain that most water in Duhok Lake is very hard.

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