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College of Agricultural Engineering Sciences

IMPACTS OF NATURAL PROCESSES AND ANTHROPOGENIC ACTIVITIES ON THE WATER QUALITY OF DUKAN LAKE CATCHMENT AREA/IKR

A Dissertation
Submitted to the Council of the College of Agricultural Engineering Sciences at the University of Sulaimani in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Agricultural Sciences
(Water Quality)

By
Ali Bawasheakh Ahmad Baba
B.Sc. Agricultural Sciences/ Soil Science/ University of Sulaimani (2004)
M.Sc. Agricultural Sciences/ Water Chemistry/ Salahaddin University (2010)

Supervised by
Dr. Khalid Taiyb Muhammad Barzinji
Assistant professor in Hydrology

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

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صدق الله العظيم

الفرقان (٢)

Supervisor Certification

I certify that this dissertation was prepared under my supervision at the University of Sulaimani, College of Agricultural Engineering Sciences, as partial fulfillment of the requirements for the degree of **Doctor of Philosophy** in **Agricultural-Water quality**.

Dr. Khalid Taiyb Muhammad Barzinji
Supervisor
Assistant professor
Date: / / 2020

In view of the available recommendation, I forward this Dissertation for debate by the examining committee.

Dr. Khalid Taiyb Muhammad Barzinji
Assistant professor
Head of Natural Resources Department
College of Agricultural Engineering Sciences
Date: / / 2020

Examining Committee Certification

We Chairman and Members of the Examining Committee have read this dissertation and discussed the candidate (**Ali Bawasheakh Ahmad Baba**) in its contents on (**6/2/2020**). Accordantly, we found this dissertation is accepted as a partial of the fulfillment of the requirements for the degree of Doctor of Philosophy in **Agricultural-Water quality**.

Dr. Akram Othman Esmail
Professor
Salahaddin University
(/ /2020)
(Chairman)

Dr. Khasraw Abdulla Rashid
Professor
University of Sulaimani
(/ /2020)
(Member)

Dr. Kamal Haji Karim
Professor
University of Sulaimani
(/ /2020)
(Member)

Dr. Mohammed Abdulrazzaq Fattah
Assistant professor
University of Sulaimani
(/ /2020)
(Member)

Dr. Ahmed Ibrahim Khwakaram
Assistant professor
University of Sulaimani
(/ /2020)
(Member)

Dr. Khalid Taiyb Muhammad Barzinji
Assistant professor
University of Sulaimani
(/ /2020)
(**Supervisor-Member**)

Approved by the Council of the College of Agricultural Engineering Sciences

Dr. Karzan Tofiq Mahmood
Assistant professor
(/ /2020)
(**The Dean**)

DEDICATION

I dedicate this work to my parents, "Thanks for guiding me through the dark paths towards knowledge", and to my lovely wife Chya with Dima my sweet son and to my entire family for the given support.

The author

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The author

SUMMARY

The study was carried out in the Dukan catchment area to evaluate the impacts of natural processes and anthropogenic activities on physicochemical and hydrological qualities of rivers were fed Dukan Lake. Twenty one sampling sites were selected for collecting water on the main Qalachwalan-Lesser Zab River, Hizop River, Inlet of Dukan Lake, Dukan outlet and other tributaries from Ranya plains that fed Dukan Lake and 34 soil samples were also collected around the study area.

Water samples were collected and analyzed in (August, November, February, March, April and May) depending on discharge fluctuations from these sites during the period of August, 2016 to May, 2017. The water samples were analyzed for temperature, turbidity, pH, conductivity, dissolved oxygen, biochemical oxygen demand, total solid, total dissolved solids, total suspended solid, nutrients (nitrate, nitrite, ammonium and phosphorus), color, major cations and anions, and heavy metals. In addition to assess rivers water quality by using some indices and models like (metal pollution indices and sag curve model). The results were compared with World Health Organization (WHO) and Iraqi Quality Standards (IQS) for drinking water and some international standards for irrigation water. The results were showed that the water temperature ranged from (7.7 to 31.4) ^{o}C, the lowest value during February and highest value during August were recorded. Turbidity values were ranged from (<0.01 to 659) NTU. The lower turbidity was found at sample site (W21-Qashqoli) and sample site (W2-Mawakan) during August and November respectively, while the highest value was found at sample site (W12-Doli-Shahidan) during November.

The pH was ranged from (7.45 to 8.70). The least water pH value was noted from the sampling site (W21-Qashqoli) during November, beside the highest value was found at sampling site (W10-Zharawa) during February. Electrical conductivity values were ranged from (218 to 976) μS cm^{-1} at field temperature. The lowest EC value was observed at sampling site (W15-Dukan-Lake) during May and the highest value was at sampling site (W18-Hizop) during August, while the electrical conductivity at lab temperature ranged (220.12 to 1120.26) μS cm^{-1}. The lowest lab EC value was observed at sampling site (W13-Darbany-Ranya) during August and the higher value was recorded during November at sampling site (W14-Bosken). The lowest and highest values of water salinity at sampling site (W13-Darbany-Ranya) and (W14-Bosken) during August and November and ranged from (140.88 to 716.97) mg L^{-1}.

Dissolve oxygen, biochemical oxygen demand, total solids, total dissolved solids and total solids values were ranged from (4.30 to 10.35, 0.13 to 78.3, 145 to 1449, 126 to 611 and 1 to 1228) respectively. The lowest value of DO during May was recorded at water sampling site (W14-Bosken), while the highest amount was recorded during February at sampling site (W9-Sndollan). The lowest value of BOD was recorded during February at sampling site (W13-Darbany-Ranya) and highest value recorded in all over the periods at sampling site (W14-Bosken). The lowest value of TS during May at sampling site (W15-Dukan-Lake) was recorded and highest TS were at sampling site (W12-Doli-Shahidan) during November. The lowest values of TDS were found at sampling sites (W8-Hallsho) during April, (W13-Darbany-Ranya) and (W15-Dukane-Lake) during May, but the highest TDS was at sampling site (W18-Hizop) during the August and it can be seen that sampling site (W20-Jali) and (W21-Qashqoli) during November and August have the lowest observed TSS, while the highest observed TSS value during November at sampling site (W12-Doli-Shahidan).

Water nutrient levels from high to low value were (1.1 to 7.9, 0.03 to 5.10, 0.01 to 1.16 and 0.01 to 0.22) mg L^{-1} for NO_3-N, NH_4-N, PO_4-P and NO_2-N respectively. Minimum concentration of nitrate was noted at some sites during November and maximum concentration was found at sampling site (W6-Qashan) during February. The lowest and highest NH_4-N concentration were noted at the sampling site (W6-Qashan) and (W14-Bosken) during November respectively. Among the sites, the lowest PO_4-P concentration was noted from the sampling site (W2-Mawakan) during May, whereas the highest concentration was found at sampling site (W14-Bosken) during February and the concentration of nitrite was found in small amount in all sampling sites and the highest value was founded during May at sampling site (W14-Bosken). The discharge and color values for water samples were ranged from (0.01 to 321) $m^3\ sec^{-1}$ and from (0.2 to 93.2) Hazen unit respectively. The lowest discharge value was at sampling site (W18-Hizop) recorded during August, while the highest value was at sampling site (15-Dukan-Lake) during March. The minimum and maximum color values were recorded at sampling site (W5-Kuna-Masi) and (W14-Bosken) during August respectively.

The pattern of ionic dominance in the rivers/streams during the present study was $HCO_3^- > SO_4^{2-} > Ca^{2+} > Cl^- > Na^+ > Mg^{2+} > K^+$ and the total hardness ranged from (121.41 to 377.14) mg L^{-1}. The lowest amount of TH was recorded during May at sampling site (W15-Dukan-Lake), while the highest amount of TH was during August at sampling site (W18-Hizop). The concentration of heavy metals in water samples from high to low value were, Cr (0.211 to 0.790) mg L^{-1}, Fe (0.088 to 0.389) mg L^{-1}, Zn (0.112 to 0.223) mg L^{-1}, Cd (0.074 to 0.153) mg L^{-1}, Pb (0.006 to 0.091) mg L^{-1}, Mn (0.001 to 0.067) mg L^{-1} and Cu (0.002 to 0.016) mg L^{-1}. It was found that the heavy metal concentrations at river water sampling site (W14-Bosken) were higher than the measured concentrations at other sites.

Clearly appeared that the highest pollution loads of physicochemical and heavy metal concentrations comes from water sampling site (W2-Mawakan, W9-Sndollan, W12-Doli-Shahidan, W14-Bosken, W17-Khdran, W18-Hizop, W19-Smaquli and W20-Jali) by the impact of anthropogenic activates like (agricultural activities which are practiced at different sites along the river, refuse dump very close to or into the rivers, disposal of domestic wastes and open dump area leachate). In addition to natural processes, like weathering of the rock and natural runoff of the soil. The average self-purification capacity in the studied water sites more than unity for August (1.173), November (2.037), February (1.011), March (1.171) and May was (3.032), which were higher than the April (0.297). The reason for these values except April could be as a result of less DO reduction. The month of April seems to be the most polluted month due to (high DO reduction) exactly at (W14-Bosken and W12-Doli-Shahidan) by the force of anthropogenic activates. At all the sites, the irrigation water quality criteria from high to low value were ranged (220.12 to 1120.26) μS cm^{-1} for salinity, (3.04 to 35.48) % for soluble sodium percent, (0.08 to 2.09) meq L^{-1} for sodium adsorption ratio and (-2.015 to 0.182) meq L^{-1} for residual sodium carbonate. Depending on calculated criteria for irrigation water quality of studied the river waters were compared with international water quality standards set for irrigation. EC of collected water samples fall in the class ‘low to high’, SAR in ‘excellent’, SSP in ‘good to excellent’ and RSC in ‘suitable’ for irrigation water quality.

The result of soil analysis revealed that the soil pH values ranged (7.29 to 8.09). The lowest pH value was found in the croplands at soil sample (S22-Twasuran), while the highest value was recorded at soil sample (S31-Smaquli near bridge). The EC_e, TDS, bulk density, organic matter and saturated hydraulic conductivity values of soil samples were ranged from (309.56 to 1305.97) μS cm^{-1}, (198.56 to 835.82) mg L^{-1}, (1.33 to 1.52) g cm^{-3}, (0.60 to 2.98) % and (2.52E-06 to 6.12E-04) cm sec^{-1} respectively. EC_e and TDS took the same trend at all sites were the lowest values at soil sample (S11-Qashan near bridge) and highest at soil sample (S7-Wazha), the lowest value of bulk density was under the crop land at soil sample (S28-Khdran up) and the highest value was recorded on the grazing land at soil sample (S34-Jali up), the lowest value of SOM was found in the croplands at soil sample (S21-Dolishahidan near bridge), while the highest value was recorded in the natural grassland at soil sample (S31-Smaquli near bridge). The lowest SHC was recorded at soil sample (S21-Dolishahidan near bridge), while the highest was recorded at soil sample (S34-Jali up). The particle size distrbution of the soil samples are showed that the texture classes: clay, clay loam, silty clay, silty clay loam, loam, silt, silty loam and sandy loam around the study area. The pattern of ionic dominance in the soil samples for the study area was $HCO_3^- > Ca^{2+} > SO_4^{2-} > Cl^- > Na^+ > Mg^{2+} > K^+$, while the nutrient levels from high to low value were (0.28 to 21, 0.4 to 5.4, 0.15 to 3.59 and 0.03 to 0.28) for NO_3-N, PO_4-P, NH_4-N and NO_2-N respectively. The highest values of NO_3-N and NO_2-N were recorded in soil sample (S24-Bosken). The NH_4-N and PO_4-P concentrations were the highest in soil sample (S29-Khdran near bridge).

The heavy metals concentration in soils from high to low value were Fe (24.50 to 1225.50) mg kg^{-1}, Mn (16.25 to 672.50) mg kg^{-1}, Zn (2 to 22) mg kg^{-1}, Cu (0.50 to 10.25) mg kg^{-1}, Cr (0.25 to 6.50) mg kg^{-1}, Pb (0.11 to 1.66) mg kg^{-1} and Cd (0.02 to 0.75) mg kg^{-1}. The lowest value of iron was noted at (S34-Jali up), while highest value was recorded at soil sample (S32-Smaquli up). Soil sample (S9-Kuna-Masi up) was recorded the lowest value of Mn and (S32-Smaquli up) had the highest value. Soil sample (S25-Chwarqurna) had the lowest Zn value, but (S11-Qashan near bridge) had the highest. The lowest value of Cu was recorded at soil sample (S9-Kuna-Masi up); whereas the highest value was noted at (S7-Wazha). Soil sample (S2-Mawakan) had the lowest value of Cr, while (S32-Smaquli up) had the highest value. Soil sample (S26-Sarwchawa) had the lowest value of Pb, as to (S4-Jogasur near bridge) had the highest value and soil sample (S33-Jali low) had the lowest value of Cd, as for (S6-Kanarwe) had the highest value.

The soil erosion values (ton/hectare/year) for all studied watersheds from high to less value were Zharawa > Kuna-Masi > Shawr > Kawe > Hallsho > Doli-Shahidan > Siwayl > Qarani-Aqha > Twasuran > Mawakan > Khdran > Jali > Joga-Sur > Bosken > Smaquli > Dolabafra. The highest value of erosion observed at Zharawa watershed (46.843) ton/hectare/year and the lowest value of erosion during this study was recorded at Dolabafra watershed (19.976) ton/hectare/year. It obviously appeared that Zharawa, Kuna-Masi and Shawr watersheds had highest load of erosion compare with other. The highest value of sediment yield using Bali method was observed at Doli-Shahidan watershed (17.196) ton/hectare/year, and the less value was appeared at Dolabafra watershed (6.449) ton/hectare/year, but the highest value of the sediment yield by using the FSM method was (7.037) ton/hectare/year at Bosken watershed, while the less value (0.803) ton/hectare/year recorded at Siwayl watershed. It seemed that the highest value of sediment delivery ratio (0.411) was at Bosken watershed, and the less value of SDR (0.116) observed at Siwayl watershed.

List of Contents

List of Tables

List of Figures

List of Appendices

List of Abbreviations

APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
BOD_5	Biological Oxygen Demand after five days
CWT	Clean Water Team
CSU	Colorado State University
Cd	Degree of Contamination
C	Plant Cover
DO	Dissolved Oxygen
$dS\ m^{-1}$	Deci-Siemens per meter
DWAF	Department of Water Affairs and Forestry
Do	Initial Dissolved Oxygen
D	Deficit Dissolved Oxygen
EC	Electrical Conductivity
FSM	Factorial Scoring Model
F	Fair Ratio
F	Fournier’s Index
GSDA, CGWB	Groundwater Surveys and Development Agency, Central Ground Water Board
GPS	Geographic Position System
HPI	Heavy Metal Pollution Index
HEI	Heavy Metal Evaluation Index
HC	Hydraulic Conductivity
I	Total Scoring Index
ICP	OES-Inductively Coupled Plasma Optical Emission Spectrometer
IQS	Iraqi Quality Standards
K	Soil Erodibility
K1	De-oxygenation Constant
K2	Re-oxygenation Constant
Lo	Ultimate Biochemical Oxygen Demand
La	initial Biochemical Oxygen Demand
m.a.s.l.	Meter above sea level
$\mu S\ cm^{-1}$	Micro-Siemens per centimeter
NTU	Nephelometric Turbidity Unit

ND	Non Detected
O.M	Organic Matter
ODNR	Ohio Department of Natural Resources
pH	Hydrogen Ion Concentration
P	Conservation Practice
RAMP	Regional Aquatics Monitoring Programme
RUSLE	Revised Universal Soil Loss Equation
RSC	Residual Sodium Carbonate
R	Rainfall Erosivity
SL	Topographical
S	Soil Sample
SAR	Sodium Adsorption Ratio
SSP	Soluble Sodium Percent
SDR	Sediment Delivery Ratio
Y	Sediment Yield
SSY	Specific Sediment Yield
TCU	True Color Unit
TCEQ	Texas Commission on Environmental Quality
TS	Total Solid
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TH	Total Hardness
USEPA	United States Environmental Protection agency
USDA	United State Department of Agriculture
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USLE	Universal Soil Loss Equation
USSL	United State Salinity Laboratory
USGS	United States Geological Survey
W	Water sample
WQI	Water Quality Index
WHO	World Health Organization
WPN	Watershed Professionals Network

CHAPER ONE

1. INTRODUCTION

There is a fact about the water bodies as they are the mirror of their environment as well as they reflect the society exists around surface water bodies and collect all wrongdoing of humanity (Roopshah, 2016). Water is very essential for human beings and the health of its ecosystem. Thus quality of water is extremely important. The surface water quality is a very sensitive issue and is also a great environmental fear worldwide. The water quality from the rivers has a considerable importance since these water resources are generally used for multiple matters such as: drinking domestic and residential water supplies, agriculture, hydroelectric power plants, transportation and infrastructure, tourism, recreation, and other human or economic ways to use water (Venkatramanan *et al.*, 2014).

Water is needed by all living organisms. It plays an important role in many natural processes and is essential in numerous physical and chemical reactions. So, surface water resources are not adequate to fulfill the demand of water (Biswas *et al.*, 2012). This little water source is also under pressure of anthropogenic activities that polluting throughout the world. Kazi *et al.* (2009) mentioned that water quality is largely depends on the natural processes and anthropogenic activities like industrial activities, municipal waste management, homesteads and agricultural activities; which make up a continuous polluting source. Rapid industrialization along with speedy population growth made great pressure on the demand of fresh water for the last few decades. Avnish and Saksena (2010) added that pollution of surface water is largely a problem due to rapid urbanization and industrialization. The large scale urban growth due to increase in population or migration of people from rural areas to urban areas has increased domestic effluents.

An anthropogenic activity like larger agricultural runoff has become a threat problem of surface water quality around the world (Yadav *et al.*, 2014). Generally, all of land use and anthropogenic activities create a serious threat not only to aquatic ecosystem in the river but also the provinces in which river water is used as domestic supply. Wastes usually contain a wide variety of organic and inorganic pollutants including plastics, heavy metals, pesticides and suspended solids (Rose, 2011). Pollutants entering a river system normally result from many transport pathways including storm water runoff, discharge from ditches and creeks, groundwater seepage and atmospheric deposition. Because of the anthropogenic activities, fresh water resources are deteriorating day-by day at a very fast rate (Ramadhan, 2007).

1.1 Previous Studies

A number of studies on water quality with respect to drinking and irrigation purposes have been carried out in the different locations of the world and various works or studies have also been done on water quality in Kurdistan Region but there are little or no studies about the impacts of anthropogenic and natural processes on water quality. Most of the previous studies were focused on hydrogeology, hydrology and limnological characteristics.

1.2 Objectives of the Study

The specific objectives of the study are:

(a) To identify the impact of each anthropogenic activity and natural process on the water quality in the studied rivers;

(b) To evaluate the degree of anthropogenic contamination using metal pollution indices and oxygen Sag model;

(c) To assess the river water quality for drinking and irrigation using some indices.

(d) To check the entry of pollutants directly in to the river and determine the spatial location of pollutants, and

(e) To estimate the river erosion and sediment delivery ratio.

CHAPTER TWO

2. LITRATURE REVIEW

2.1 Water Quality

Water quality plays essential roles in habitat protection, agriculture, industry, and public health as proved by (Xiao *et al.*, 2016). Water is a most plentiful physical substance and transparent liquid on earth. All processes of life are direct or indirectly connected to water; therefore human beings cannot survive much longer without water, as water plays a central and significant role for every cell and organ system in the human body to function property. Water plays an important role in the continuation of life and numerous economic sectors such as agriculture, aquaculture, electricity generation, industries and other important activities (Tyagi *et al.*, 2013). According to (USGS, 2010) water quality is a term used to express the suitability of water to sustain various uses or processes based on selected physical, chemical, and biological characteristics. The quality of water that human beings consume is critical in determining the quality of their lives and the usefulness of water for a particular purpose (Fetter, 1994).

Du Plessis *et al.* (2014) investigated water quality is becoming a global fear as a result of the important role it plays economically and socially. However in the last decades, we noticed the deterioration of water quality due to industrialization and human activities. It has become a very big issue today, partly because of the rapid growth of the nation's population and urban expansion and development. Rural areas can also contribute to water quality problems. Medium to large-scale agricultural operations can generate in animal feed, geted fertilizer, and manure, more nitrogen and phosphorus than can be used by crops or animals. These excess nutrients have the possible to degrade water quality if included into runoff from farms into streams and lakes. According to (Patil *et al.*, 2012) water quality is used to assess the health of water body and the purpose for which it has been used.

2.2 Factors Affecting Water Quality

Carpenter *et al.* (1998) stated that the hydro-chemical composition including quality of river water is affected by both the anthropogenic activities and natural processes. Natural processes influencing water quality include weathering of soil and rock, rainfall rate, surface runoff, sediment transport, changes in stream hydrology, erosion and forest fires, whereas anthropogenic activities include a range of activities that can degrade the water quality, depending upon the intensity and duration of contribution from point and non-point sources as studied by (Tarvainen *et al.*, 1997), include urban development and expansion, disposal of dead bodies, solid waste disposal, industrial effluents, mining, agricultural drainage and domestic discharges in the rivers (Zhao *et al.*, 2015). Today, freshwater resource is becoming scarcer and more polluted as the stresses on water quality and quantity due to development and increasing climate change every year and is as strongly felt in our country in the rivers. There are many factors that have an impact on water quality. Some of the main ones are natural process and anthropogenic factors.

Natural process factors are naturally caused, such as wind erosion and weathering. Anthropogenic factors are human produced causes such as fossil fuels, fertilizer, and waste disposal. Additionally, anthropogenic and animal activities affect water quality as stated by (GSDA and CGWB, 2014). Furthermore, (Marale *et al.*, 2012) found that the geology of the area, the soil condition, and contamination through seepage also contribute to alterations in the quality and availability of water. Wind erosion causes damage to water quality by increasing sedimentation, which causes one of the largest impacts to the quality of streams and other bodies of water. Weathering has a negative effect on water quality as well. It damages water quality by fragmenting the structure of aquatic ecosystems.

Esterby (1996) detected that river discharge has been used extensively as a covariate in water quality assessment and in the development of water quality criteria for rivers being evaluated for disposal of wastewater, based on low discharge conditions. However there is variation in component concentration and stream discharge among parameters with varying interactions in different rivers. This can be attributed to the fact that water in streams and rivers is influenced by avariety of factors such as drought or dry season which result in fluctuations in water quality as shown by (Atasoy *et al.*, 2006). Stream water quality variations are shaped by natural as well as human activities in the catchment area. Qadir *et al.* (2008) made a study on the effects of pollutants are mostly high near the source, however; it becomes diluted as water traverses the distance. Many authors have highlighted the harmful effects of natural and anthropogenic factors on water quality worldwide variations (Zeng and Rasmussen, 2005 and Qadir *et al.*, 2008).

2.2.1 Natural factors affecting water quality

According to (UNEP, 2004), without human influences, water quality would be determined by the weathering of bedrock minerals, atmospheric processes of evapotranspiration and the deposition of dust and salt by wind, natural leaching of organic matter and nutrients from soil, hydrological factors that lead to runoff, and biological processes within the aquatic environment that can alter the physicochemical composition of water. For this reason, the surface water quality not only depends on natural phenomenon (precipitation and erosion) but also on anthropogenic actions (urban, industrial and agricultural activities) as suggested by (Papatheodorou *et al.*, 2006).

Natural events such as heavy rainfall and storms lead to excessive erosion and landslides, which in turn increase the content of suspended materials in affected rivers and lakes. The quality of surface water at any point in a watershed reflect the combined effect of many physical, chemical, and biological processes that affect water as it moves along hydrologic pathways over, under, and through the land. The physical characteristics and mineralogical composition of soil and bedrock, topography, and biology largely affect water quality.

Meybeck (1996) estimated that natural water quality variations occur over a wide range of time scales. Long-term changes in water quality can occur over geologic time due to factors such as soil development and mountain building. Intermediate changes can occur due to successional changes in vegetation, forest fires, floods, and droughts. Seasonal and shorter-term variations in stream and river water quality. Twesigye *et al.* (2011) have pointed out that seasonal variation in precipitation and surface runoff have a strong effect on river discharge and subsequently on concentration of pollutants in the river water. Interlandi and Crockett (2003) underlined that river water quality depends on various geologic, climatic, catchment and land use characteristics. Among these, climate and land use are the key drivers of water quality in a river system.

Astarair-Imani *et al.* (2012) have pointed out that climate change is a key factor affecting the future of water quality and quantity in urbanized catchments, and is associated with significant uncertainty. Eutrophication can be influenced by climate, including precipitation, temperature and solar radiation. Precipitation and temperature firstly act on water discharge, which is widely acknowledged to be a dominant factor influencing eutrophication in river systems as reported by (Lack, 1971). Solar radiation is also a key factor for algal blooms as proved by (Whitehead and Hornberger, 1984) which is likely to vary in the future due to climate change factor (Stanhill and Cohen, 2001). Marale *et al.* (2012) demonstrated that the impact of seasonal change on water quality has been extensively documented and has attracted widespread attention in recent years. Seasonal changes like rising temperatures reduce dissolved oxygen levels in surface water. Lack (1971) has stated that limited rainfall leads to less dilution of pollutants whereas frequent heavy rainfall produces more pollution and sediment in river due to surface runoff.

2.2.2 Anthropogenic factors affecting water quality

Over the past 30-40 years much research on freshwater ecosystems has focused on the effects of various anthropogenic stressors and how the resulting degraded systems can be restored (Giller, 2005). The rivers are a safe haven to many plant and animal species besides protecting valuable resources of freshwater. Unfortunately, rivers have long been used and abused for the disposal of wastes. Although the rivers have the capacity of self-purification, this capacity is altered because of anthropogenic activities in the river catchment, leading to the destruction of this important ecosystem. Surface waters are most exposable to pollution due to their accessibility for disposal of wastewaters (Samarghandi *et al.*, 2007). The anthropogenic activities influences such as urban, industrial, and agricultural activities increasing abuse of water resources, degrade surface waters, and damage their use for drinking, recreational and other purposes (Nouri *et al.*, 2008) monitored the river water quality and concluded that industrialization, urbanization, and modern agriculture practices have direct impact on deteriorating water quality.

Salvato *et al.* (2003) noted that water sources both surface and groundwater are often contaminated by anthropogenic activities. These include discharges of agricultural, industrial and municipal wastewaters into water courses which ultimately reach the aquifers. Among the pollutants are nitrates from domestic sewage and fertilizers and pesticides in agriculture. Others are livestock farming that transmits pathogens from animal manure and fish farming that worsen eutrophication by adding biochemical oxygen demand and nutrients to the local environment as reported by (Kirby *et al.*, 2003). Letchinger (2000) showed that in rural areas population is less so it mostly contains fertilizers, pesticides and eroded soil and these pollutants reach to water bodies through runoff after rain and flood. Agricultural runoff cause freshwater body’s eutrophication. The human population has been increasing day by day which exerts an extensive pressure on the ecosystem and the resources due to increased discharge of wastewater into river corridors, degrading their water quality (Kannel *et al.*, 2007).

According to (Nsiah-Gyabaah, 2010), many cities depend on the surrounding regions or peri-urban areas to act as sinks and disposal sites for domestic and industrial waste. A study performed by (Lundqvist, 1998) found that human activity is now one of the most important factors affecting hydrology and water quality. Human influences have had a direct effect on the hydrologic cycle by altering the land in ways that change its physical, chemical, and biological characteristics.

However, all human process produces waste products that can negatively affect water quality.

In history, human beings do not have a good record regarding pollution as observed by (Novotny, 2003). Mason (2002) indicated that two hundred years ago, deterioration of water courses due to organic pollution was not a serious problem for; a relatively small human population lived in scattered communities. When human population was small, and technologies were simple, pollutants were small to human and animals wastes as proved by (Davies and Day, 1998).

Generally, various pollutant sources related to industries, urbanization, agriculture and mining can have a strong impact on a river system (Kendall *et al.*, 2007). Tabari *et al.* (2011) found that in recent years, an increasing awareness has been noticed in different countries about the impacts of anthropogenic activities on river water quantity and quality. Anthropogenic activities are human activities that negatively affect the water resources making it polluted and hence unsuitable for normal uses. The anthropogenic activities that mainly affect the river water bodies can be placed into three groups as follows:

2.2.2.1 Deforestation

Deforestation is the clearing of vegetation and cutting down of tress and making the ground bare. Agricultural activities are the major source of deforestation. Deforestation practices causes water quality problems which includes decrease in dissolved oxygen concentration (Baillie *et al.*, 2005), enhancement of soil erosion (Fahey and Marden, 2006), increase in nutrient concentration (Reid *et al.*, 2010). Brooks *et al.* (2012) have worked on deforestation fuels nitrate concentration in nearby surface water bodies due to reduced uptake of nutrients by vegetation and decomposition of decayed plants material. Nitrate concentration in deforested catchment is 50 times as compared to forested catchment. Forests improve water quality owing to lower human intrusion and higher biological nutrients retention capacity (plant and microbial assimilation) as estimated by (Ding *et al.*, 2015).

2.2.2.2 Human settlements

Chindah *et al.* (2004) pointed out that an increase in human settlement means an increased need for sanitation services for waste disposal for the population. Sanitation services such as pit toilet steep ways, poorly constructed rubbish pits and broken sewer lines, are a source of pollutants into the rivers when wastes are washed away by rain water runoff according to the study conducted by (UNICEF, 2000). Li *et al.* (2015) also noted that human interference at urban frequent level badly effects surface water quality. Change in physical landscape and paved surface area alters watershed hydrology which badly impacts surface water quality as noted by (Kennen *et al.*, 2010).

2.2.2.3 Industrial activities

Industrialization is considered the keystone of development strategies due to its significant contribution to the economic growth and human welfare, but it carries certain costs and problems in terms of pollution of the water resources as underlined by (Kannj and Achi, 2011). Specially, water bodies near to industrial area have been extremely affected from disposal of waste which can alter the physical, chemical and biological nature of the receiving water body. So, industrial waste is the most common source of water pollution nowadays and it increases yearly due to the fact that industries are increasing because most countries are getting industrialized (Osibanjio *et al.*, 2011).

Taylor (1996) found that some industries produce toxic and hazardous wastes which when left exposed to the environment do kill plant and animal life. Reza and Singh (2010) indicated that wastewater from industries is the most common source of water pollution and it is increasing day by day. However the untreated/partially treated wastewater may contain toxic compounds, discharge from industries, and commercial areas enter the surface water body they get dissolved or lie suspended in water or get deposited on the bed (Panda *et al.*, 2006).

2.2.3 Other factors affecting water quality

2.2.3.1 Nutrients concentration

Nutrients such as phosphorus and nitrogen can have harmful effects on aquatic communities. Many elements and compounds are necessary for biosynthesis, but phosphorus and nitrogen have been considered the principal limiting nutrients for primary bio-production (Brezonik, 1972). Phosphorus is a limiting nutrient for many types of algae like blue-green algae (Ohio EPA, 2010). The concentration of nitrate has increased in rivers, lakes, and aquifers due to the increase in agricultural production over the last 50 years. This source of pollution has huge impacts on the eutrophication of surface waters, as well as the quality of drinking water (Nabais *et al.*, 2007). Nitrogen, often present as nitrate, the most inorganic form, is one of the most problematic nutrients when relating water quality to ecologically healthy systems. However, excess phosphorus levels are attracting the most attention in relation to nitrate as to causing water body disorder.

2.2.3.2 Runoff

Residential, urban, and other anthropogenic built-up areas are considered significant sources of this non-point source pollution from discharges due to storm waters. The imperviousness of urban land covers increase storm discharges so much that even small rainfalls can flush contaminates into nearby streams. Basnyat *et al.* (2000) indicated that pollutants, such as sediments, animal wastes, plant nutrients, crop residues, inorganic salts, minerals, and pesticides due to agricultural activities are known to impact water quality. This in turn results in how runoff waters will affect the physicochemical and biological processes in the receiving water bodies.

2.2.3.3 Land use

A multitude of studies have been made with reference to land use and water quality connections worldwide and the study drive is to continue. Ayers and Westcot (2000) have detected land use activities (urbanization and agriculture) severely affect water quality and aquatic ecosystem of rivers, streams, lakes, and creeks. Previous studies have shown that agricultural lands result in the highest concentrations of nutrients in the nearby water bodies (Tong and Chen, 2002) found that significant negative changes in water quality were related to urban development. Other studies found that urban areas did produce significant soluble pollutants (Wang and Yin, 1997).

Mallin *et al.* (2009) have investigated land use has a direct effect on the relationship between precipitation, run-off and water quality. Burns *et al.* (2005) showed that impermeable surfaces of urbanized areas increase run-off and the transport of pollutants into streams, rivers and the ocean. Changes in land use can result in greater erosion, more run-off and increased turbidity in rivers (Cebecauer and Hofierka, 2008). Dwight *et al.* (2011) pointed out that changes of land use within a watershed have a direct impact on the quality and quantity of receiving waters, and can even greatly delay stormwater collection capabilities by changing the hydrology. In fact, land use alterations are the most common form of geographic change (Tong *et al.*, 2009).

2.3 Water Pollution

Water pollution occurs when waste enter into water and contaminate the quality of water. This form of environmental degradation occurs when pollutants are directly or indirectly discharged into water bodies without adequate treatment to remove harmful compounds. Water pollution has become a global problem now a day’s continuing evaluation of water resource policy is needed to counter this problem. Deaths and diseases are caused worldwide due to water pollution and approximately 14000 people die every day due to water pollution as a study was done by (Pink, 2006). Noori *et al.* (2010) stated that surface water pollution remains a major problem worldwide, caused by both natural processes and anthropogenic activities.

The surface water quality in a region can be affected by both point and non-point sources of pollution (Nnane *et al.*, 2011). Lawson (2011) reported that water pollution directly or indirectly affects both terrestrial and aquatic life. This depends largely on the concentration of the pollutants, which is in turn determined by their degradation level and the volume of the receiving water body (Sterrit and Lester, 1998). Due to increased urbanization, industrialization, agriculture and other anthropogenic activities, water is becoming highly polluted with different harmful contaminants. High levels of organic and industrial pollutants in river water cause changes in many physicochemical parameters. The presence of pollutants in the rivers has impacted the water quality in a level that in such cases it cannot be used for drinking, irrigation or recreation.

2.3.1 Sources of water pollution

Baig *et al.* (2010) indicated that there are natural and anthropogenic sources of water pollution; nevertheless, anthropogenic activities are known to contribute more to the deterioration of water quality. Pollutants (chemical and mineral constituents) that affect surface water quality are separated into two categories: point and non-point sources as mentioned by (Jamwal *et al.*, 2011) and shown in (Fig. 2.1).

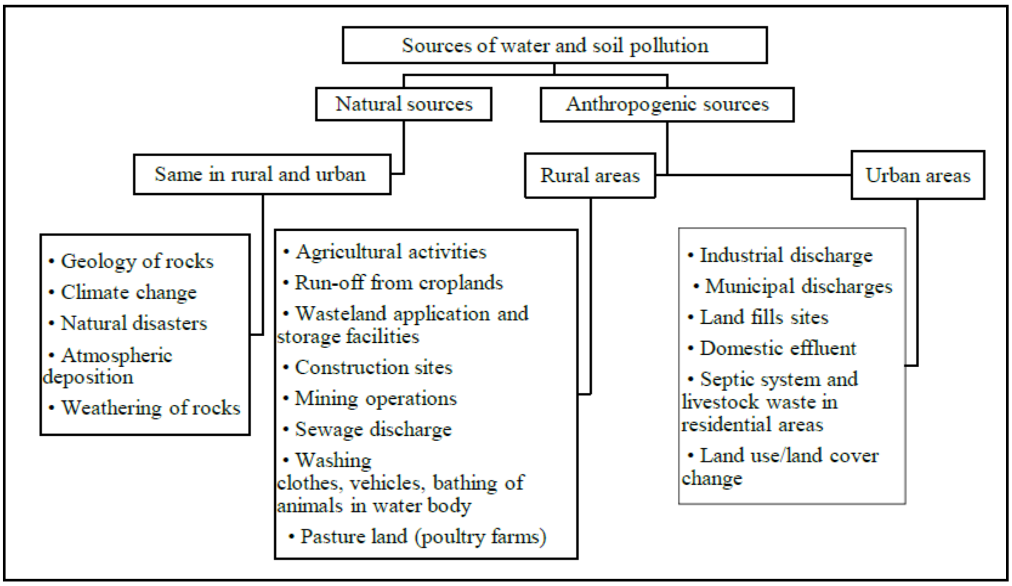

Figure 2.1 Graph of natural and anthropogenic sources of water and soil pollution.

2.3.1.1 Non-point sources of pollution

Brian (2008) explained that when source of water pollution is not known or pollution does not come from single discrete source pollution is known as non-point source pollution. It is very difficult to control and may come from different sources like pesticides, fertilizers industrial wastes etc. as studied by (TCEQ, 2013). The problems associated with water quality contamination and pollution from a non-point source is that its origin cannot be certain from a singular source, but rather a combination of sources of different natures. Generally, they originate from urban and rural runoffs, as a result of urban storm water runoffs from agricultural and anthropogenic activities, which are often described as non-point source discharges. Pollutants include nutrients, sediments, inorganic and organic matters, heavy metals, and bacteria, which will all eventually enter into waterways and water bodies if not treated, thus polluting surface water (Eemens, 2007). Nevertheless, Gyawali *et al.* (2013) showed that the management of non-point sources of pollution became the challenge, since its origin can be diffused from different unknown sources of agricultural practices, which is considered to be an important factor and the major cause of water pollution.

2.3.1.2 Point sources of pollution

Point source pollution is referred to as pollution from a known point of discharge or from a fixed outlet discharge and can be released into water bodies (Gyawali *et al.*, 2013). While possible contaminants from a point source can be easily monitored by measuring discharge and pollutant levels according to study was done by (Zhang and Wang, 2012) from an identified discharge point, its impact can be manageable, compared to non-point sources of discharges. Claudia (2016) reported that when source of water pollution is known or pollutants that are entering into water are from certain source pollution is known as point source pollution. It can be distinguished from other pollution sources (Hogan, 2010). Globally industrial activities are among the major point sources of pollution globally reported to affect the environmental condition of water, air and soil (Yusuff and Sonibare, 2005).

2.3.2 Types of pollutants

Brown *et al.* (1999) categorized storm-water pollutants into four subdivisions:

2.3.2.1 Suspended solids

Suspended solids are perhaps the greatest component, both in quantity and environmental impact, of urban storm-water runoff. Dust and dirt from impervious surfaces, along with eroded sediment caught in storm-water flow are considered suspended solids. Technically, suspended solids are particles whose size is greater than 45 microns. Suspended solids are disadvantageous to receiving waters for many reasons. A large amount of suspended solids may make water turbid and alter aquatic habitat (Schueler, 1987).

2.3.2.2 Nutrients

Nutrients are common in aquatic systems, and are a necessity for aquatic life. In excess amounts, however, nutrients reduce the water quality for organisms and human uses. There are three nutrients that are of interest to water quality: nitrate, nitrite and phosphate. Natural nutrient inputs into a watershed system include plant decay and natural soil erosion (Clark *et al.*, 1985). Excess quantities of nutrients are usually human caused, either from agriculture or soil fertilization.

2.3.2.3 Bacteria and pathogens

Water-borne bacteria, protozoa, and viruses cause many diseases that infect both humans and livestock (Chesters and Schierow, 1985). The primary sources of bacteria in the waterways are from livestock manure applications and urban sewer overflows. Many of the bacteria that are harmful to humans are not harmful to aquatic organisms. However, they become stored in fish and shellfish and can be passed to humans during consumption (USEPA, 1998).

2.3.2.4 Pesticides and heavy metals

Pesticides, compounds sprayed on grass or plants to kill insects, are commonly used in urban areas on lawns and gardens, and on golf courses and plant nurseries. Johnson *et al.* (1994) found that pesticide losses to the environment are less than 5% of those applied, and the concentration of pesticides in surface waters were extremely low. Environmental Databases (2006) observed that herbicides and pesticides are used to control weeds and pests. Both of them also contribute to water pollution. Similarly pesticides and herbicides also reach natural water bodies through runoff. These pesticides residues when reach to natural water bodies they disturb flora and fauna there. Pesticides which don’t degrade easily or take time to degrade are more harmful (Pope *et al.*, 2016).

Heavy metals are of much greater concern. Industrial process, mining, urban runoff and transportation all contribute to metal contamination of water. Metals are highly harmful to aquatic systems due to their inability to degrade and subsequent accumulation in sediment beds. Tsihrintzis and Hamid (1997) indicated that concentration of heavy metals in storm-water is nearly twice that of sanitary sewage.

2.4 Watershed and Surface Water Quality

A watershed is, exactly, the area which sheds water into a river. It includes all the land, extending from the watershed divide to the river, from which runoff water flows towards the river. Along with the water, sediments and dissolved materials drain to a common outlet or destination. Watershed surface water quality and quantity reflect and integrate the effects of watershed characteristics, inputs (precipitation and deposition), hydrologic and biogeochemical processes, climatic variability (droughts and floods), and human influences.

2.4.1 Watershed assessment

Watershed assessment is a process for evaluating the health of a watershed (WPN, 1999). It can help determine how natural processes, human activities, and land management practices influence the resources. There are many smaller components that must be considered when making a watershed assessment (WPN, 1999). The first component of an assessment is to identify issues that are in the watershed, such as high nutrient levels within streams. The next step is to develop a watershed description that includes historical conditions and channel habitat type classification. The third component is to characterize the watershed using a combination of hydrology and water use, riparian/wetlands, sediment sources, channel modification and water quality assessments. The final steps are to complete the watershed condition analysis and then create a monitoring plan based on the condition analysis.

2.4.2 Watershed functions

A watershed functions to carry out a number of valuable services, such as supporting biological diversity of aquatic and riparian ecosystems, supplying and purifying sources of fresh water for potable use, close off carbon dioxide to mitigate climate change, and supporting recreation and tourism (Postel and Thompson, 2005). Black (1997) has pointed out the three fundamental functions of a watershed are: (a) collecting water from rainfall, snowmelt, and runoff; (b) storing various amounts over time; and (c) discharging the water as runoff. In addition, watersheds support a diversity of aquatic life and allow important biological and chemical reactions to take place. The third watershed function, discharge, helps control and moves chemicals and materials out of the system. Postel and Thompson (2005) stated that well-functioning watersheds are a natural benefit supplying a plenty of goods and services to society, but when these functions are only slightly disturbed by external factors, they can be altered to the degree of being unable to function properly.

2.5 Self-purification

It is a well-known fact that the wastes discharged into natural water bodies such as rivers; lakes and the seas disappear slowly with time. Yustiani and Komariah (2017) have underlined that the removal of pollutants from a water body without any artificial controls is called self-purification. The mechanisms of self-purification of water bodies can be divided into three groups: physical processes, chemical processes and biological processes.

Physical processes contributing to the removal of pollutants from a natural water body include dilution/mixing by inflow by unpolluted water into the water body, diffusion of pollutants in water body, and precipitation/filtration of the pollutants to the sediment (Hanelore, 2013). Chemical processes related to the removal of pollutants from a water body are oxidation by oxidants such as ultraviolet, ozone and oxygen, reduction by reductants and neutralization. The biological processes include degradation/transformation of organic pollutants by bacteria by aerobic or anaerobic conditions, and nitrification and de-nitrification of ammonia and nitrate, respectively (Drinan and Spellman, 2001).

Biological processes play the most important role among the mechanisms of self-purification in natural water bodies. Stimson *et al.* (1996) have pointed out several natural biological filters also contribute in natural purification. Biological removal of pollutants from a natural water body is usually called “true self-purification” and the total purification by physical, chemical and biological processes is called “apparent self-purification”. Prati and Richardson (2003) have shown that the natural dilution process of the river was one of the primary self-purification mechanisms for the restoration of the river. The degree of self-purification in any stream depends on certain factors some of which are: temperature; level of river; river velocity; amount of inorganic compound in the stream; distribution and types of aquatic weeds along the channel.

The organic pollutant can be removed naturally in rivers. The process is performed by microorganisms. Several physicals, chemical, and biological activities involved in the river water organic pollutant degradation. Many of these physical and chemical activities are influenced by the biological condition. De-oxygenation is the process of decreasing the amount of oxygen that occurs due to the use of oxygen by microorganisms to decompose pollutants into the aquatic bodies (Kumarasamy, 2015). The de-oxygenation process is an important process in the effort of the river to self-purification process. The rate of the de-oxygenation process affects the sooner or later self-purification takes place.

2.5.1 Oxygen Sag

The oxygen sag or oxygen deficit in the stream at any point of time during self purification process is the difference between the saturation DO content and actual DO content at that time.

$$\text{Oxygen deficit, D = Saturation DO – Actual DO} \qquad (2.1)$$

The saturation DO value for fresh water depends upon the temperature and total dissolved salts present in it; and its value varies from 14.62 mg L^{-1} at 0 ^{o}C to 7.63 mg L^{-1} at 30 ^{o}C, and lower DO at higher temperatures. The DO in the stream may not be at saturation level and there may be initial oxygen deficit ‘Do’. At this stage, when the effluent with initial BOD load Lo, is discharged in to stream, the DO content of the stream starts depleting and the oxygen deficit (D) increases. The variation of oxygen deficit (D) with the distance along the stream, and hence with the time of flow from the point of pollution is depicted by the ‘Oxygen Sag Curve’ (Fig. 2.2). The major point in sag analysis is point of minimum DO, i.e., maximum deficit. The maximum or critical deficit (D_c) occurs at the inflexion points of the oxygen sag curve.

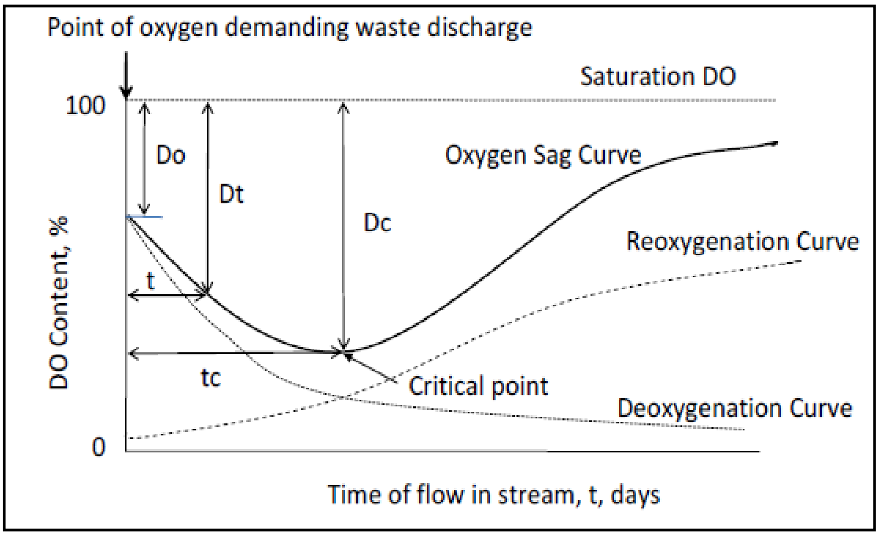

Figure 2.2 De-oxygenation, re-oxygenation and oxygen sag curve

2.5.2 Self-purification capacity: Streeter – Phelps equation

The field of water quality modeling was found by the duo of (Streeter and Phelps, 1925). They proposed the idea of measuring and predicting the dissolved atmospheric oxygen (DO) and biochemical oxygen demand (BOD) dynamics of a water body as a parameter for measuring the self-purification capacity of a water body. Their predicted model was given as,

$$\frac{dD(t)}{dt} = k1L(t) - k2D(t) \qquad (2.2)$$

Where, $dD\ (t)/dt$ = the DO content rate of change of the river with time, *k1* = de-oxygenation rate, *L (t)* = BOD at the instantaneous time, *k2* = re-aeration rate and *D (t)* = DO at an instantaneous time, that described by (Kiely, 1998). Villeneuve *et al.* (1998) have reported basis on further studies which modified the initial equations in order to contain additional variables in nature. By integrating equation (2.2), the equation commonly used for the prediction of DO is obtained (Longe and Omole, 2008).

$$D = \frac{La}{f-1} 10^{k2t} \left[1 - 10^{[-(f-1)k2t]} [1-(f-1)\frac{Da}{La}] \right] \qquad (2.3)$$

Where, *D* = instantaneous DO, *La* = initial BOD, *f is* the self-purification factor, *Da* = initial DO and *t* is the instantaneous time. The value of *f* is determined by dividing computed value of *k2* by the observed or tabulated value of *k1* (Garg, 2006). The range of *f* at 20 °C is given in (Table 2.1).

Table 2.1 The self-purification factor, *F*, of different water bodies at 20 °C.

Description of water body	Range
Small ponds and backwaters	0.5-1.0
Sluggish streams, Large Lakes and impounding reservoirs	1.0-1.5
Large stream of low velocity	1.5 - 2.0
Large streams of normal velocity	2.0 – 3.0
Swift stream	3.0 – 5.0
Rapids/ Water falls	Over 5.0

2.5.2.1 Time of travel

The time of travel, *t*, was computed from velocity and distance travelled as follows,

$$Time\ (days) = \frac{Distance\ (km)}{Velocity\ (\frac{km}{hr})} * \frac{1\ day}{24\ hrs} \qquad (2.4)$$

2.5.2.2 Dissolved oxygen saturation

The DO saturation values, for various water temperatures can be calculated using the method of (Elmore and Hayes, 1960),

$$DO_{saturation} = 14.652 - 0.41022T + 0.0079910T^2 - 0.000077774T^3 \qquad (2.5)$$

2.5.2.3 De-oxygenation coefficient *k1* and re-oxygenation coefficient *k2*

The de-oxygenation coefficient, *k1* (day^{-1}), was computed from the follow equations (Weiner and Matthews, 2003),

$$Lo = \frac{L}{1-10^{(-ki*t)}} \qquad (2.6)$$

$$\text{Ki}= 0.1*(1.047)^{(T-20)} \qquad (2.7)$$

$$L = Lo10^{-k1t} \qquad (2.8)$$

Where, *L* = instantaneous BOD, *Lo* = ultimate BOD and *t* = time in days. Therefore,

$$k1 = \frac{1}{t}\, log\, \frac{Lo}{L} \qquad (2.9)$$

The re-oxygenation coefficient, *k2* (day^{-1}), was computed from the follow equations (Agunwamba *et al.,* 2007),

$$k2 = \frac{(logDo - logD)}{t} \qquad (2.10)$$

This is also the same as,

$$k2 = \frac{(log\, Do/D)}{t} \qquad (2.11)$$

Where, *Do* is the initial dissolved oxygen; *D* is the deficit DO is equal to difference between saturation DO and the observed DO. When these two coefficients are known, then the self-purification capacity, *f*, of any stream can be derived by the following equation,

$$f= k2/k1 \qquad (2.12)$$

2.5.3 Factors affecting self-purification

Water quality of a river depends on its self-purification and several factors influence the self-purification capacity of a river. The purification capacity of a lake/stream is directly proportional to the volume of run-off. Therefore, according to the studied was done by (Agunwamba, 2007) factors that normally influence the quantity of run-off such as wind, velocity, precipitation, vegetative cover, topography and temperature affect its adjustment capacity. Temperature also affects the rate of organic waste adjustment. Increase in temperature means increase in rate of oxidation, decrease in oxygen saturation capacity and rate of diffusion. Agunwamba (2001) showed that higher respiratory and metabolic rate due to increase temperature may destroy aquatic life.

Navanita *et al.* (2016) noted that if the sewage is discharge into natural water course, then the organic compounds are oxidized by the dissolved oxygen in water and water gets purified. Thus, a deficiency of DO is created in flowing water. But that deficiency is immediately replenished by the atmospheric oxygen. This phenomenon of de-oxygenation (loss of oxygen) and re-oxygenation (gain of oxygenation) for maintaining the purification process is known as self-purification of natural water. The various actions involved are physical, chemical and biological, and may be explained as due to: (dilution, sedimentation, sunlight, oxidation, reduction, water current and temperature).

2.6 Water Quality Assessment

To minimize water quality challenges, a number of countries have developed water quality management programs (Silberbauer, 1997) which include assessment, monitoring, mitigation and prevention of water pollution in order to ensure safe and healthy water resources. Dicken and Graham (2002) stated that depending on the selected indicators of water quality, there are anumber of methods used in the assessment of water quality. Those methods with a focus on the direct physical, chemical and biological parameters are commonly implemented in different parts of the world. There are a number of international and regional water quality guidelines and standards. Most of the developing countries have water quality standards for different water uses which are in line with international guidelines.

2.6.1 Drinking water quality assessment

The importance of drinking water quality has been enhanced in the last few years by the increased awareness and attendant publicity afforded to the pollution of water sources. Boe-Hansen (2001) reported that the quality of drinking water has a direct link with the human health and providing clean water to the consumers is one of the most important public health priorities. Curtis and Morgenroth (2013) have indicated that water quality depends on the local geology and ecosystem and human activities can negatively affect water quality.

Kirmeyer *et al.* (2001) have established water quality for drinking can be assessed according to chemical, physical and microbiological characteristics. As chemical and physical parameters characterize the physicochemical water quality, microbial water quality involves the measurement of microorganisms (Gerardi, 2006). This study considers the following indicators:

2.6.1.1 Temperature

Dallas and Rivers-Moore (2011) mentioned that natural variations of the water temperature often are influenced by factors such as hydrological, climatilogical, spatial and temporal scale and catchment areas. The development of temperature criteria is important for the effective protection and management of aquatic ecosystems. Numerous studies by (Dallas and Day, 2004; Rivers-Moore *et al.*, 2008 and CWT, 2010) were explained that, the rise of water temperature alter many physicochemical characteristics of water including the solubility of oxygen and other gases, chemical reaction rates and toxicity, and microbial activity. In freshwater the physical environment in terms of a reduction in density of water, a decrease in pH, a reduction in solubility of DO followed by an increase in BOD by stimulating organic decomposition by microorganisms are observed as temperature increases. Zhang (2008) shown that water temperature is therefore a critical parameter for any water resources management programmes. Temperature is influenced by many factors such as latitude, altitude, season, and time of day, air circulation, cloud cover and the flow depth.

2.6.1.2 Turbidity

Turbidity may be classified as both as physical and microbiological parameters. Water turbidity is an optical property of water, which scatters and absorbs the light rather than transmit it in straight lines and it is commonly measured in nephelometric turbidity units (NTU). Suspended sediments are responsible for most of the scattering (Myint and Walker, 2002). APHA (1998) estimated that turbidity in water is caused by suspended matter such as clay, silt, and organic matter and by plankton and other microscopic organisms that interfere with the passage of light through the water. In addition, soil erosion, urban runoff, high flow rate, wastewater, and bottom-feeding fish may result in turbidity in rivers.

The (USEPA, 2010) observed that higher turbidity increases water temperatures because suspended particles absorb more heat. Turbidity levels in surface waters have been found to vary due to variations in precipitation and the percentage of impervious surface in a watershed. Volk *et al.* (2002) observed that turbidity levels in a stream could increase by as much as 300 fold during or following precipitation events. High turbidity levels in surface waters is linked to high percentages of impervious surfaces within a watershed caused by sediment loading from runoff and erosion (Mehaffey *et al.*, 2005). In contrast, (Schoonover *et al.*, 2006) found that during base flow, turbidity concentrations were lower within watershed with higher percentages of impervious surfaces. John *et al.* (2012) recommended that, for water to be clean, the turbidity should be reliably less than 5 NTU and preferably have a median value of less than 1 NTU.

2.6.1.3 Color

Good water should be transparent and clear. The color of water is expressed in Hazen units. Physically, the color of water is affected by factors like the light source, absorption and scattering of light, as well as suspended materials in the water. WHO (2008) reported that drinking water quality should be colorless. WHO (2003) estimated that the drinking water color may possibly be due to the existence of the colored organic matter, typically humus metals from industrial effluents such as manganese. WHO (2011) reported that normally changing in color is not harmful unless it is associated with toxic chemical. In case of the changes in color of water was observed mainly because of the mixing of mud during the rainy season which may indicate the mixing of microbes present in the mud.

2.6.1.4 pH

RAMP (2010) has shown the pH of most natural waters is between 6 and 8.5. Similarly, the range of pH in water for domestic use is 6.5 to 8.5 according to (WHO, 2011). pH can be affected by acid rain, wastewater discharges, agriculture runoff, decomposing organic matter, drainage from mines and the type of rock naturally found in the area. pH influences some chemical and biological processes in water resources such as salinity, conductivity, permeability and toxicity (Mazlum *et al.*, 1999).

Calles *et al.* (2007) expressed that surface water pH can be relatively higher in low discharge since water is rich in solutes characteristic of ground water. Low pH increases solubility of metals and nutrients such as phosphates and nitrates making them available for uptake by plants and animals (WHO, 2002). Water pH is generally not a problem itself, but it is an indicator of other problems such as sodium and carbonates. Belcher (2009) estimated that important factors that influence pH include geology, biotic activities, type of vegetation, atmospheric influences, and cation exchange capacity. According to (Gueade *et al.*, 2009) lower pH values often are related to higher conductivity. Klerk *et al.* (2012) reported that an increase in pH in spring for instant may be attributed to increased photosynthesis activities of aquatic plants, namely macrophytes and algae.

2.6.1.5 Electrical Conductivity (EC)

Conductivity is the capacity of water to conduct an electrical charge (Dougall, 2007). EC is a function of total dissolved solids (TDS) known as ions concentration, which determines the quality of water according to the (Tariq *et al.*, 2006). Mosley *et al.* (2004) described EC or a TDS is a measure of how much total salt (inorganic ions such as sodium, chloride, magnesium, and calcium) is present in the water, the more ions the higher the conductivity. Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Dougall (2007) was obtained streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water. On the other hand, streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water.

Mehaffey *et al.* (2005) showed that areas with a high percentage of impervious surfaces, such as urban areas, can yield runoff containing oils that may lower the conductivity of nearby surface water. Other human activities in a watershed that may raise the conductivity of surface waters include agricultural and residential land uses. During snow melt periods, it has been shown that surface waters surrounded by agricultural lands have a higher specific conductivity when compared to other land uses as emphatic by (Detenbeck *et al.*, 1996).

2.6.1.6 Dissolved Oxygen (DO)

Dissolved oxygen plays a key role in the assessment of water quality. Its affects the taste of water and high concentrations of DO in domestic supplies are encouraged by aeration (Shaw, 1994). Vigil (2003) shown that oxygen gas naturally mixes with water through surface contact. Fast moving waters typically have a higher DO due to mixing with air when the water hits debris such as rocks and logs. Dissolved oxygen can be depleted by the demand from organic decomposition and use from plant and animal respirationas as revealed by (Jacobsen, 2008).

Reckhow (1994) indicated that DO is one of the parameters that influence the biodegradation rate in water bodies. It is affected by entry of organic matter into rivers especially from runoff during and after a rainfall event (Kannel *et al.*, 2007). Numerous studies showed that solubility of oxygen increases as temperature decreases and decreases with decreasing atmospheric pressure (Jacobsen, 2008). Jacobsen and Marin (2008) have investigated tropical high mountain streams are more oxygen rich than warmer lowland streams.

Based on (Dallas, 2008) the structure of a stream or river may also affect DO contents. Turbulence of water, depth and degree of contact of the rock layer on surface water influence the re-aeration of water. Seasonally, DO concentrations are usually higher in the winter than in the summer. Mason (2002) noted that during rainy seasons, oxygen concentrations tend to be higher because the rain interacts with oxygen in the air as it falls. Whereas during dry seasons, water levels decrease and the flow rate of a river slows down. As the water moves slower, it mixes less with the air, and the DO concentration decreases.

2.6.1.7 Biochemical Oxygen Demand (BOD)

Biological oxygen demand is a measure of how much oxygen is used by microorganisms in aerobic oxidation, or the breakdown of organic matter. Usually, the higher the amount of organic material found in the stream, the more oxygen is used for aerobic oxidation. According to the study by (Chapman, 1996) BOD depletes the amount of DO available to other aquatic life. The level of BOD in receiving waters is directly increased by the discharge of wastes high in organic matter, resulting in localized areas of DO depletion.

BOD also directly affects the amount of DO in rivers and streams. The greater the BOD, the more rapidly oxygen is used up in the stream. This measurement is obtained over a period of five days, and is expressed in mg L^{-1}. Harrison (1992) mentioned that unpolluted river waters are likely to have BOD values of <3 mg L^{-1} and values above 5 mg L^{-1} indicate possible pollution. As noted by (Weiner and Matthews, 2003) very low oxygen demand indicates either clean water or the presence of a non-biodegradable pollutant.

2.6.1.8 Total Solids (TS)

The term "total solids" refers to matter suspended or dissolved in water, and is related to both specific conductance and turbidity. A total solid (also referred to as total residue) is the term used for material left in a container after evaporation and drying of a water sample. A total solid includes both total suspended solids, the portion of total solids retained by a filter and total dissolved solids, the portion that passes through a filter.

2.6.1.9 Total Dissolved Solids (TDS)

The expression “total dissolved solids” refers to the total amount of all inorganic and organic substances-including minerals, salts, metals, cations or anions that are dispersed within a volume of water. Wellcare (2007) explored that TDS concentrations are used to evaluate the quality of freshwater systems. TDS is usually concerned with river water quality as it is related to salinity and water hardness, especially its ionic constituents. WHO (2003) showed that the primary sources for TDS in receiving waters include agricultural run-off, urban run-off, industrial wastewater, sewage, and natural sources such as leaves, silt, plankton, and rocks. According to (Nadia, 2006) discharge of wastewater with a high TDS level would have bad impact on aquatic life; make the receiving water unfit for drinking and domestic purposes.

2.6.1.10 Total Suspended Solids (TSS)

A total suspended solid is the amount of material, by weight that is suspended (not dissolved) in a given volume of water. Cunningham (2003) shown that the solids mainly consist of living and dead phytoplankton, sand, silt, clay, human sewage, animal manure, portions of decaying plants and animals and a huge range of industrial wastes moving with the water or along the bed of the stream. TSS describes how much of the organic or inorganic matter is not dissolved in water and contains settle-able solids that sink to the bottom in a short time and non settle-able suspended solids. It is an important parameter because suspended solid causes turbidity in the water as clearly described by (Sasse, 1998).

2.6.1.11 Nutrients

Nutrients can be referred to as those chemical elements or compounds that are essential in the system of plants and animals for normal growth and development, such as nitrogen and phosphorus. However, if these nutrients are present in excess in water, they over stimulate the growth of aquatic plants, leading to water quality problems. It may also enter through diffused sources such as nutrient losses from manure and waste products applied over large agricultural fields, sediments from eroded soils, and runoff from residential or agricultural areas. Most nutrients are not toxic; however high concentrations affect the structure and functioning of biotic communities (Neda *et al.*, 2011).

2.6.1.11.1 Nitrogen

Total nitrogen represents the summation of ammonia nitrogen, nitrite plus nitrate nitrogen, and organic nitrogen as studied by (Lutz, 2004). However nitrite and nitrate are known to be the most significant in biochemical processes because they rapidly dissolve in water. Nitrogen is an essential requirement for photosynthetic processes in plants. In agriculture, the amount of nitrogen which is not taken by plants is washed away by runoffs to the river, whereby excess release can have bad effects on aquatic life (Jordan *et al.*, 1997). The excess nitrogen may accumulate in soils, leach into surface and ground water, or enter the atmosphere. In addition, as noted by (Wetzel, 2001) surface runoff, especially in agricultural areas, is most likely the dominant input of nitrogen to aquatic systems.

Cooke and Prepas (1998) have showed that agricultural watersheds exported upto 50 times more nitrogen than forested watersheds. Nitrate comes into water supplies through the nitrogen cycle rather than through dissolved minerals. Other secondary sources of nitrogen compounds include fertilizers, manure and urine from feedlots and pastures, sewage, and landfills these views were also supported by (ODNR, 2011). DWAF (1996a) highlighted the ammonium ion (NH_4^+) is a reduced form of inorganic nitrogen derived mostly from aerobic and anaerobic decomposition of organic material.

2.6.1.11.2 Phosphorus (PO_4^{3-})

Phosphorus is a nutrient essential for all organisms and plants for the basic processes of life, but in excess, it results in the excessive growth of algal and aquatic plants which has both direct and indirect impacts to water quality. The increase of phosphorous in water bodies can be attributed to artificial introduction due to human activity as shown by (Chen *et al.*, 2007). Hochanadel (2010) shown that manmade sources of phosphate include human sewage, agricultural run-off from farms, sewage from animal feedlots, vegetable and fruit processing, chemical and fertilizer manufacturing, and detergents.

According to (Geneviève and James, 2006) phosphates can enter aquatic environments from the natural weathering of minerals in the drainage basin, from biological decomposition. Wetzel (2001) pointed out in heavily fertilized agricultural regions; the phosphorus content of precipitation is much higher during the active growing season than in winter. According to the studies were conducted by (Sharpley *et al.*, 1994b) phosphates bound to soil particles enters aquatic systems by way of runoff and is a major source of phosphates to surface waters.

2.6.1.12 Calcium (Ca^{2+})

According to (Annalakshmi and Amsath, 2012) calcium is an important macronutrient in an aquatic environment. Day (1963) has studied the calcium enters the freshwater system through the weathering of rocks, especially limestone and gypsum, and from the soil through seepage, leaching and runoff. The leaching of calcium from soil has been found to increase significantly with the acidity of rainwater as studied by (Overrein, 1972). Calcium compounds are stable in water when carbon dioxide is present, but its concentration falls when calcium carbonate precipitates due to increase in water temperature, photosynthetic activity and loss of carbon dioxide due to increase in pressure. Calcium concentration in natural waters are typically less than 15 mg L^{-1} , for waters associated with carbonate-rich rocks concentrations may reach 30 to100 mg L^{-1} although has estimated by (Chapman, 1996).

2.6.1.13 Magnesium (Mg^{2+})

Chapman (1996) has given an overview of magnesium is common in natural waters and along with calcium are the contributors to water hardness. Magnesium arises principally from the weathering of rocks containing Ferro magnesium minerals and from some carbonate rocks. Magnesium generally is a slow-reacting element, but reactivity increases with oxygen levels. Natural concentration of magnesium in fresh waters may range from 1 mg L^{-1} to less than 100 mg L^{-1}, depending on the rock types in the catchment. Muhammad *et al.* (2013) have studied according to the WHO standards; the allowable limit of magnesium in water should be 150 mg L^{-1}. However (NAMWATER, 2008) has a set limit of 200 mg L^{-1}.

2.6.1.14 Water hardness

Water hardness is the measurement of the amount of ions which have lost two electrons dissolved in tested water. The more divalent cations dissolved in water the "harder" the water as shown by (Global water, 2011). Sheila (2007) recommended that hardness generally represents the concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, because these are the most common polyvalent cations. Other ions, such as iron (Fe^{2+}) and manganese (Mn^{2+}) may also contribute to the hardness of water, but are generally present in much lower concentrations. Generally, the hardness of stream or river water may come from natural source and human activities.

2.6.1.15 Sodium (Na^{+})

All natural waters contain some sodium. Sodium salts are highly soluble in water and it is one of the plentiful elements on earth as investigated by (Chapman, 1996). Increased sodium concentrations in surface water may arise from sewage and industrial effluents. Chapman (1996) has presented concentrations of sodium in natural surface waters may vary considerably depending on local geological conditions and wastewater discharges. Values can range from 1 mg L^{-1} or less to 105 mg L^{-1} or more in natural salines. The sodium ion is everywhere in water; most water supplies contain less than 20 mg L^{-1}. Although concentrations of it in potable water are typically less than 20 mg L^{-1} but in some courtiers levels can exceed 250 mg L^{-1}. Sodium salts are generally highly soluble in water and are leached from the earthly environment to ground water and surface water, also sodium salts are found in almost all drinking water as explored by (WHO, 2006).

2.6.1.16 Potassium (K^+)

Potassium occurs generally in the environment, together with all natural waters as reported by (WHO, 2009). The natural resource of potassium ion in water is weathering of mineral like K-Feldspar and Biotite etc. The potassium substance of drinking water changes extremely depending upon its source. It has trend to be higher in sea water and minerals than tap water. K^+ levels in water bodies are in general very low as compared to Na^+ since potassium salts are limited in rocky deposits. Potassium deposits enter freshwaters through industrial discharges and run-off from cultivated fields as investigated by (Mustapha and Usman, 2014). Two factors are responsible for the lack of potassium in water one being the resistance of potassium minerals to decomposition by weathering and the other being the fixation of potassium in clay minerals formed due to weathering. Potassium salts, being more soluble than sodium salts, are the last to crystallize during evaporation.

2.6.1.17 Chlorides (Cl^-)

According to (Rajkumar *et al.*, 2004) chlorides occur naturally in all types of waters, high concentration of chlorides is considered to be the indicators of pollution due to organic wastes of animal or industrial origin and chlorides are troublesome in irrigation water and also harmful to aquatic life. Chlorides are commonly found in sewage, streams and wastewater. Chlorides are leached from various rocks into soil and water by weathering. The chloride ions highly mobile and is transported to closed basins. Chloride increases the electrical conductivity of water. However, (APHA, 1998) noted that metabolic utilization does not cause large variations in the spatial and seasonal distribution of chlorides within most lakes, but high chloride content may indicate the pollution by sewage/industrial waste or intrusion of the saline water.

2.6.1.18 Sulfate (SO_4^{2-})

In water, sulphate naturally occurs as a result of weathering of rocks and other geological formations particularly gypsum, and anhydrites studied by (Alexander, 1985). As an anthropogenic compound, it may occur as a result of municipal, agricultural or industrial discharges in water. Sulphate is used in the manufacture of fertilizers, hence its concentration is found in agricultural runoff to the rivers. Sulfate in drinking water has a secondary maximum contaminant level of 250 mg L^{-1}, based on aesthetic effects (taste and odor). USEPA (2012a) underscored the presence of sulfate in drinking-water may also cause noticeable taste**.** The major effect of higher sulfate levels in water to people is the laxative effect which may lead to dehydration. It was also emphasized by (Kanu *et al.*, 2011) being used as a fertilizer, sulphate levels in water have increased in anumber of rivers over time increasing risk to aquatic ecosystem health.

2.6.1.19 Alkalinity (HCO_3^-)

USEPA (2010) investigated that alkalinity is not a pollutant. The main sources of alkalinity are rocks, which contain carbonate, bicarbonate, and hydroxide compounds. Limestone is rich in carbonates, so waters flowing throughout limestone regions generally have high alkalinity- thus its good buffering capacity. Conversely, granite does not have minerals that contribute to alkalinity. Therefore, areas rich in granite have low alkalinity and poor buffering capacity. Alkalinity in streams is therefore influenced by rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges. Alkalinity is affected by changes in flow regimes (Brydsten *et al.,* 1990) and its natural variability is linked to the presence or absence of carbonate rock (Kney and Brandes, 2007).

2.6.1.20 Heavy metals and metal pollution indices

Heavy metals are generally defined as metals required in trace amounts and considered as toxic (Maitra, 2016). Carlos *et al.* (2016) have explored these metals have been widely investigated by many researchers due to their significant hazardous impact on human health and environment. Hesse *et al.* (2018) have carried out these are considered as major source of environmental contamination due to their toxic nature and their ability to accumulate. Industrialization, urbanization, and agricultural activities resulted in increase of heavy metal concentrations in different habitats compared to their natural background levels as investigated by (He *et al.*, 2016).

Most heavy metals such as chromium (Cr), iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) are essential elements because they have biological functions; while others such as cadmium (Cd) and lead (Pb) are non-essential because they do not have any biological function. Essential heavy metals become toxic when their concentration exceeds tolerable limits, while non-essential metals are highly toxic even at low concentration. Seiyaboh *et al.* (2017a, b) have worked on heavy metals enter the surface water through both natural (volcanic activity, weathering, geology of the area) and human activities (through careless discharge of untreated wastes into the surface water and runoff resulting from rainfall).

According to (Anim-Gyampo *et al.*, 2013) heavy metals tend to accumulate in soils and sediments after weathering processes and can be deposited in water bodies due to surface run-offs. According to (WHO, 2017) zinc, copper and cadmium are among 10 toxic heavy metals with major issue. Heavy metal pollution in river is primarily caused due to industrialization (Nguyen *et al.*, 2016). Wang (2017) has focused on the river sediments become the storage of heavy metals, which in turn becomes the possible secondary source of metal pollution to the connected aquatic systems. Raju *et al.* (2012) have evaluated that the chemical leaching of bedrocks and runoff from river banks are the primary sources of heavy metals in river water. Consumption of heavy metals is linked to many serious health concerns (Benham *et al.*, 2011). Hence there is the need to investigate the heavy metals in surface water frequently to find out the level of pollution. To this effect several studies have been conducted with regard to water quality at different locations including (Seiyaboh *et al.*, 2016b and Seiyaboh and Izah, 2017a).

Bhuiyan *et al.* (2010) underscored metal pollution indices are an important device for assessment quality of water and have been successfully used around the world. The contamination of surface water by metals is a serious ecological problem according to the studied has shown by (Nair *et al.*, 2010). Three various pollution indices, namely heavy metal pollution index (*HPI*), heavy metal evaluation index (*HEI*) and degree of contamination (*Cd*) are used to evaluate quality water for drinking as well as irrigation purposes. The (*HPI*) and (*HEI*) methods provide an overall quality of the water with regard to heavy metals. On the other hand, in the (*Cd*) method, the quality of water is evaluated by computation of the amount of contamination.

2.6.1.20.1 Heavy Metal Pollution Index (*HPI*)

HPI was developed by assigning a rating (*Wi*) for each chosen parameter. The rating is value from (0 to 1) and its selection depends upon the importance of individual quality considerations or it can be defined as inversely proportional to the standard permissible value ($Wi = 1/Si$) (Mohan *et al.*, 1996). In computing the *HPI* for the present water quality data, the standard permissible value (*Si*) and highest desirable value (*Ii*) for each parameter were taken from the WHO and Iraqi standards. The *HPI* is determined by using the below expression (Mohan *et al.*, 1996),

$$HPI = \sum_{i=1}^{n} \frac{WiQi}{Wi} \qquad (2.13)$$

Where, *Qi* is the sub-index of the *i*-th parameter. *Wi* is the unit weightage of the *i*-th parameter and *n* is the number of parameters considered. The sub-index (*Qi*) is calculated by equation below,

$$Qi = \sum_{i=1}^{n} \left[\frac{Mi(-)Ii}{Si - Ii}\right] * 100 \qquad (2.14)$$

Where, *Mi*, *Ii* and *Si* are the monitored value of heavy metal, desirable and permissible standard values of the *i*-th parameter, respectively. The sign (-) indicates algebraic differences of the two values, ignoring the algebraic sign.

2.6.1.20.2 Heavy Metal Evaluation Index (*HEI*)

Similar to *HPI*, *HEI* assigns an overall water quality with respect to heavy metals (Edet and Offiong, 2002) and is computed as,

$$HEI = \sum_{i=1}^{n} \frac{Hci}{Hmaci} \qquad (2.15)$$

Where, *Hci* is the observed value of the *i*-th parameter and *Hmaci* the maximum proper concentration of the *i*-th parameter. Edet and Offiong (2002) for easily interpret the pollution index and level of pollution the *HEI* was used. For better understanding the pollution indices we can use this index.

2.6.1.20.3 Degree of contamination (*Cd*)

Cd summarizes the combined effects or degree of contamination of several parameters considered potentially harmful to domestic water (Backman *et al.*, 1997). *Cd* is asum of the contamination factors of the individual parameters that exceed their respective permissible values and calculated as follow,

$$Cd = \sum_{i=1}^{n} Cfi \qquad (2.16)$$

Where,

$$Cfi = \frac{CAi}{CNi} - 1 \qquad (2.17)$$

Where, *Cfi*, *CAi* and *CNi* stand for contamination factor, analytical value and upper permissible concentration of the *i*-th component, respectively.

2.7 Irrigation Water Quality Assessment

Irrigation water quality refers to the suitability for its use for irrigation purposes. Good quality water has the possible to maximize crop yield under good soil and water management practices. However, with poor quality water, soil and cropping problems can be expected to reduce yield unless special management practices are assumed to correct these problems. CSU (2015) has investigated that the effects of irrigation water on crop production and soil quality are described by salinity hazard, sodium hazard and alkalinity hazard. For assessing the irrigation water quality in the study area, some important criteria such as salinity, soluble sodium percent (SSP), sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) are used.

2.7.1 The salinity hazard

There are dissolved salts in all major water irrigation sources. Porter and Marek (2006) to describe the concentration of salt species, the term salinity is used. The salinity hazard can happen when salts accumulate in the root zone of the crop to reduce the sum of water existing at the roots. Salinity of water irrigation is expressed in terms of both indicators of (EC) electrical conductivity and (TDS) total dissolved solids.

2.7.1.1 Electrical Conductivity (EC)

Electrical conductivity has been generally accepted as a standard measure of irrigation water quality, but there is a great degree of variability in choosing the water classes on this basis. EC is an index of degree of mineralization. Sarathbabu (2015) has indicated EC varies with concentration, degree of ionization of the components and temperature. It is closely related to TDS (Wlicox, 1955). As mentioned by (Ayres and Westcot, 1994) the usual range of EC is from (0 to 3000) $\mu S\ cm^{-1}$.

2.7.1.2 Total Dissolved Solids (TDS)

Total dissolved solids, is another expression used in description water quality for irrigation that is used to assess the mass concentration of soluble components in water. As mentioned by (Ayres and Westcot, 1994) usual range of TDS for irrigation water from (0 to 2000) $mg\ L^{-1}$.

Therefore, (Balakrishnan *et al.*, 2011) underscored that the TDS in water is a universal indication of the over-all suitability of water for various uses.

2.7.2 Sodium hazard

There are large amounts of sodium in irrigation water which is special concerns because of sodium effects on the soil and forms a sodium hazard as founded by (Fipps, 2003). A problem to occur with the high sodium concentrations when the infiltration rate is reduced to such a rate that the availability of the water for a crop is not enough or when the hydraulic accessibility of the soil profile is very low to supply sufficient drainage. There are several factors related to these problems such as the rate of salinity and soil type. Fipps (2003) indicated that sodium risk is usually expressed in terms of (SAR) sodium absorption ratio and (SSP) soluble sodium percent.

2.7.2.1 Sodium Absorption Ratio (SAR)

According to the study by (Asadollahfardi *et al.*, 2013) SAR is the effective factor used for assessing the suitability of water for irrigation purposes, because sodium concentration can reduce the soil permeability and soil structure. Toumi (2015) regarded based on SAR values, irrigation water is classified into different classes. According to (Collins and Jenkins, 1996) SAR was calculated using the following formula and all concentrations were expressed in meq L^{-1},

$$\mathrm{SAR} = \frac{\mathrm{Na}^{+}}{\sqrt{\frac{\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}}{2}}} \qquad (2.18)$$

2.7.2.2 Soluble Sodium Percent (SSP)

Sodium content is also referred to as soluble sodium percentage. Fipps (2003) investigated that when water with a SSP more than 60% it product in sodium cumulation that will give rise to a collapse in the physical properties of soil. It is a computed by the following equation and all concentrations were expressed in meq L^{-1} (Wilcox, 1955),

$$\mathrm{SSP} = \frac{(\mathrm{Na}^{+} + \mathrm{K}^{+})}{(\mathrm{Na}^{+} + \mathrm{K}^{+} + \mathrm{Ca}^{2+} + \mathrm{Mg}^{2+})} * 100 \qquad (2.19)$$

Raju (2007) showed that sodium percentage is an important parameter for studying sodium hazard. Naseem *et al.* (2010) also indicated that the irrigation water having sodium percentage greater than 60% may lead to sodium accumulation and probably damage of soil structure, infiltration and aeration. Bhat *et al.* (2016) pointed out the higher Na^+ in the water may be due to long residence time of water, dissolution of minerals from lithological composition and addition of chemical fertilizers with irrigation waters.

2.7.3 Alkalinity hazard [Residual Sodium Carbonate (RSC)]

Richard (1955) has measured that RSC is a useful parameter for the determination of bicarbonates and carbonates hazard. In addition to the SAR and SSP, the excess sum of carbonate and bicarbonate in water over the sum of calcium and magnesium also influences the unsuitability of water for irrigation; this is termed as RSC. Toumi *et al.* (2015) indicated that the continuous usage of water having high RSC will cause burning of plant leaves and reduces the yield of crops. Because of high concentration of bicarbonate in the water, the tendency for calcium and magnesium to precipitate increases as the water in the soil becomes more concentrated ensuing the decrease of permeability and finally leads to poor internal drainage of the soil as founded by (Purushothaman *et al.*, 2012). RSC is calculated as follow and all concentrations were expressed in $meqL^{-1}$ (Landschoot, 2007),

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \qquad (2.20)$$

Strawn (2015) shown a negative RSC is the best condition because the total concentration of carbonate and bicarbonate is lower than the concentration of calcium and magnesium combined which implies that there is no residual carbonate to react with sodium to enhance the sodium hazard in the soil.

2.8 Erosion Processes

Erosion is the detachment and transportation of material from a surface of soil. Erosion is the process whereby earth or rock material is loosened or dissolved and removed from any part of the earth’s surface. Whereas weathering involves only the breakdown of rock, erosion additionally entails the detachment and transport of weathered material from one location to another, erosiving the earth’s surface and delivering sediment to the fluvial system. There are really two types of erosion, natural and accelerated erosion, also called man-made erosion (Kuypers *et al.*, 2005),

- Natural erosion is going on all the time; the weathering of mountains, hills caused by the influences of nature. New landscapes are formed, but the process is very slow.
- Man-made erosion occurs when people cause the soil to become capable to be carried away by rain or wind. Cutting trees and burning vegetation are examples of practices that destroy the natural protection of the soil.

Tangtham (2002) classified soil erosion according to the erosive agent (water and wind), the erosion site (splash, sheet, rill, gully and channel) or the erosive process (raindrop, channel, mass wasting). Once the rainfall amount accumulating on the land surface exceeds the infiltration capacity of the soil, surface runoff or overland flow is generated. The loosened soil particles will then be removed by surface runoff in a thin layer, flowing down to a point of deposition (called sheet erosion). While sheet erosion is difficult to see due to the fact that water does not cut any channel when carrying away soil particles, rill erosion leaves visible scouring on the landscape.

Rill erosion is formed when runoff from sheet erosion begins cutting small, separate channels as it travels a downward slope. Gully erosion is an advanced stage of rill erosion, it occurs when the water in rill concentrates to form larger channels. Unlike rill erosion, the gully cannot be removed by normal cultivation methods as described by (Morgan, 2005). Gully erosion and channel erosion may refer to either the gradual or the massive erosion of the beds and banks of gullies and stream channels. Mass wasting refers to erosion associated with slope failures, including landslides and similar slope movements.

According to explored by (Rooseboom, 1992) wind erosion refers to movement of soil particles by wind. Wind erosion may be important in arid or semi-arid regions as an agent that can transport sediment from ridges into valleies from which it can subsequently be transport by runoff. Arid and semi-arid regions with less than 600 mm precipitation per year and strong winds are especially open to wind erosion. Jones *et al.* (2013) proved that low vegetation cover and poorly developed soils intensify wind erosion. Saltation, soil creep and suspension are the forms of sediment transport due to wind erosion. Jones *et al.* (2013) indicated that several factors control overland flow phenomenon, including: Morphological conditions, soil texture and structure, initial moisture content, flow depth and rate, presence of cracking and swelling on soils, vegetation density and organic matter content.

Depending on a study conducted by (Ochoa *et al.*, 2016) soil erosion by water is the most serious form of land degradation in many areas of the world particularly in arid and semi-arid regions, where the soil formation rate is usually lower than the rate of soil erosion by water due to the accelerated soil erosion as a consequence of human misuse and abuse of the soils as proved by (Seutloali and Beckedahl, 2015). Gentile and Jones (2013) indicated that erosion is a natural process intensified and accelerated by human action. Natural erosion rates increased due to anthropogenic influences up to permanent levels, more than 1 t ha^{-1} yr^{-1} within duration of 50 to 100 years. Soil erosion is considered to be the most widespread and severest form of land degradation. Consequences of soil erosion are various and induce on-site as well as off-site effects. While on-site effects are mainly related to a reduction in top soil and soil productivity, off-site effects occur due to deposition of transported sediments and chemicals causing sedimentation, silting of water resources, alteration of the landscape, reduction of habitats and infrastructure damages (Blanco-Canqui and Lal, 2008).

Many predictive equations have been developed to estimate soil loss from drainage basins. However, the most accepted, used, convenient and suitable technique for assessing soil loss from smaller areas such as hill slopes and fields is the (USLE) Universal Soil Loss Equation and its Revised version (RUSLE) are used for prediction of soil erosion and design of protective programs (Sadeghi *et al.*, 2004). The RUSLE model is a water erosion estimation model that related to the following six erosion factors as mentioned by (Wischmeier and Smith, 1978).

$$A = R.K.LS.C.P \qquad (2.21)$$

Where,

R, Rainfall erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1}), equals E, the kinetic energy of rainfall, multiplied by I30 (maximum intensity of rain in 30 minutes expressed in cm per hour). This index corresponds to the potential erosion hazard in a given region where sheet erosion appears on a bare plot with a 9% slope.

K, Soil erodibility factor (t ha h ha^{-1} MJ^{-1} mm^{-1}) depends on the organic matter and texture of the soil, its permeability and profile structure. It varies from 70/100 for the most breakable soil to 1/100 for the most stable soil. It is measured on bare reference plots 22.2 m long on 9% slopes, tilled in the direction of the slope and having received no organic matter for three years.

SL, the topographical factor [Slope length-gradient factor (dimensionless)], depends on both the length and gradient of the slope. It varies from 0.1 to 5 in the most frequent farming contexts in West Africa, and may reach 20 in mountainous areas.

C, the plant cover factor (dimensionless), is a simple relation between erosion on bare soil and erosion observed under a cropping system. The C factor combines plant cover, its production level and the associated cropping techniques. It varies from 1 on bare soil to 1/1000 under forest, 1/100 under grasslands and cover plants, and 1 to 9/10 under root and tuber crops.

P, Conservation practice factor (dimensionless) is a factor that takes account of specific erosion control practices such as contour tilling, or contour ridging. It varies from 1 on bare soil with no erosion control to about 1/10 with tied ridging on a gentle slope.

2.8.1 Estimation of rainfall erosivity factor (R)

Due to the lack of rainfall intensity data required for computing rainfall erosivity factor. There were many empirical formulas proposed based on the average monthly and annual data of rainfall. The most reasonable formulas for estimation rainfall erosivity factor are as follow:

2.8.1.1 Merritt's model

Rainfall data was processed into average annual rainfall. Rain erosivity factor was calculated from the rainfall point map using the model proposed by (Merritt *et al.*, 2003),

$$R = 38.5 + 0.35 * P \qquad (2.22)$$

Where,
R = Rain erosivity factor (Joule m^{-2}), P = Mean annual rainfall (mm yr^{-1})

2.8.1.2 Lo's model

This model was proposed by (Lo *et al.*, 1985) as follow,

$$R= 38.46 + 3.84 * P \qquad (2.23)$$

Where, P = Mean annual rainfall in mm yr^{-1}.

2.8.1.3 Hengl's model

This model was intended by (Hengl *et al.*, 2015) as follow,

$$R= 0.26\ F\text{^}1.5 \qquad (2.24)$$

Where, R in MJ mm ha^{-1} hr^{-1} yr^{-1}, F = Fournier’s Index

$$Fournier\text{'}s\ Index\ (F) = \frac{1}{P}\sum_{i=1}^{n}(Pi)^2 \qquad (2.25)$$

2.8.1.4 Ferrari's model

Rain erosivity factor was proposed by (Ferrari et al., 2005) as follow,

$$R = 4.0412 * P - 965.53 \qquad (2.26)$$

Where, P = Mean annual rainfall in mm yr^{-1}.

2.8.1.5 Arnoldus's model

This model was proposed by (Arnoldus, 1980) as follow,

$$R = 4.17 * F-152 \qquad (2.27)$$

Where, R in MJ mm ha^{-1} hr^{-1} yr^{-1}, F = Fournier's Index as described before.

2.9 Sedimentation Process

Sediment is defined as any fragmental materials transported by suspended in or deposited by water. The deposited gravel, sand, silt, clay or boulders in river bed or finer particles in suspension constitute the suspended load. Sedimentation continues to be one of the most important threats to river ecosystems around the world. Sedimentation processes may be complex. Although sedimentation in ponds and wetlands is important, for removing the sediment, nutrients and contaminants which are readily attached to fine particles (Raisin *et al.*, 1997), excess sedimentation can lower wetlands lifespan and thus degrade wetland function which generally reduce wetland retention time. As sediment is a major pollutant and also a transporter of pollutants, the need for assessments and estimations on catchment's surface runoff, sediment delivery and sediment yield are very important through water resources analyses, modeling, and engineering methodology.

2.9.1 Sediment yield

Sediment yield is the amount of eroded material that moves from a source to a downstream control point, such as a reservoir or to the edge of catchment outlet, per unit time (Chow, 1964). The fate of eroded material within a watershed is influenced by hydrologic, topographic, vegetative and ground cover characteristics. Lane *et al.* (1997) defined the sediment discharge from a watershed as the total quantity of sediment moving out of the watershed in a given time interval (mass/time). This sediment discharge is often termed sediment yield (ASCE, 1970). ASCE (1982) pointed out the total sediment discharge from a watershed relative to the watershed area is also called sediment yield (mass/area/time).

2.9.2 Sediment predictive

In a number of instances, data to insert in the gross erosion equations is not available or perhaps only an estimate of sediment yield is required. If this is the case, there were many empirical equations which had proven reliable in a limited number of cases in different regions. These equations are based on watershed parameters.

2.9.2.1 Sediment yield predictive equation

One of these equations is sediment yield predictive equation which was proposed by (Bali *et al.*, 1972). It is expected that this equation will give reasonable results in the arid and semi-arid and sub humid meteorological zones. The sediment yield predictive equation with source from only sheet erosion (excluding that from channels and slide) is of the following form,

$$\text{Log}\,(100+Y) = 6.63792 - \text{Log}\,(100+X1)^{2.40504} + \text{Log}\,(100+X2)^{0.06567} - \text{Log}\,(100+X3)^{0.01820} + \text{Log}\,(100+X4)^{0.04019} \qquad (2.28)$$

Where,

Y = sediment yield in (acre ft mi^{-2} yr^{-1}).

X1= is an indirect expression of the natural response of vegetations to climate.

= average annual precipitation (inches)/average annual temperature (degree F°).

X2 = average slope of the watershed.

X3 = the percent of soil particles coarser than (1mm) in the surface two inches.

X4 = erodibility index for the surface 2 inch soil and represents the percent of soil particles < 2 µm. When the soil pH is alkaline a positive sign is assigned to it, otherwise a negative sign is assigned to it. The soil pH is the indicator of dispersion and aggregation in alkaline and acidic soils respectively.

2.9.2.2 Factorial scoring model (FSM)

Application of empirical models is the most practical methods for regions of lack recorded data. During the past decades, several empirical models regarding sediment yield estimation have been presented. Such empirical models are prepared based on the specific basin properties for different regions; FSM proposed by (Verstraeten *et al.*, 2003) related sediment yield to basin properties. As the regression method developed, (Avendano Salas *et al.*, 1995), by using 60 reservoirs data, present an equation to define a relation between the area of basins and sediment yield and as follow,

$$\mathbf{SSY = 4139 \times A^{-0.43}} \qquad (\mathbf{2.29})$$

Verstraten *et al.* (2003) predicts non linear equation for estimate annual specific sediment yield by adding five weighted additional factors: topography, vegetation cover, gullies, lithology and slope to the basin area of the equation (2.31). The following equation shows the model presented by (Verstraeten *et al.*, 2003). This equation is based on the data from 19 reservoirs (out of 60), (Atapourfard *et al.*, 2012).

$$\mathrm{SSY} = 4139 \times A^{-0.43} + 4.55 \times \mathrm{I} + 21 \qquad (2.30)$$

Where,

I= is the total scoring index (product of scores of each factor).

The method consists scoring of each five factors description given in (Table 2.2) with a score of 1, 2, and 3 for low, moderate and high sediment yields, respectively. Then, the index I is calculated by multiplying the score given to each factor. The index can vary between 1 and 243 (when all factors are assigned 3). In this study the following equation which was proposed by (Verstraeten *et al.*, 2003) has used and the proposed equation was,

$$\mathrm{SSY} = 4139 * A^{-0.44} + 7.77 * \text{FSM-Index} - 310.99 \qquad (2.31)$$

FSM-Index = Score1 * Score2 * Score3 * Score4 * Score5

A= area in km^2

SSY = sediment yield in t km^{-2} yr^{-1}

Table 2.2 Description of the scores for each of five factors used in FSM (Verstraeten *et al.*, 2003).

Factor	Score	Description
Topography	1	Very gentle slopes near reservoir and main rivers; elevation difference <200 m within 5 km
	2	Moderate slopes near reservoir and main rivers; elevation difference 200-500 m within 5 km
	3	Steep slopes near reservoir and main rivers; elevation difference >500 m within 5 km
Vegetation cover	1	Good contact cover of the soil (>75% surface protected)
	2	Moderate contact cover (25–75% protected surface)
	3	Poor contact cover (<25% protected)
Gullies	1	Bank and ephemeral gullies are very rare
	2	Few bank and/or ephemeral gullies can be observed
	3	Many bank and/or ephemeral gullies can be observed
Lithology	1	Dominant limestone, sandstone or conglomerate (low weathering degree)
	2	Dominant Neogene sedimentary deposits (gravels, etc.)
	3	Strongly weathered (loose) material loams and/or marls
Basin shape	1	Elongated basin shape with one main river channel draining to the reservoir. No significant direct runoff from slopes into the reservoir
	2	Between elongated and (semi-) circular basin shape
	3	(Semi-) circular basin shape with many rivers draining into the reservoir and/or much direct runoff from hill slopes to the reservoir

2.9.2.3 Estimation of sediment yield based on gross erosion and sediment delivery ratio

The estimation of sediment yield is made by use of the following equation,

$$Y = \mathrm{SDR} * E \qquad (2.32)$$

Where,

Y = sediment yield, SDR = sediment delivery ratio (<1.0)

E = gross erosion, it includes sheet, rill and channel (gullies, valley trenches and stream bank) erosions.

Julien (2010) defined the sediment delivery ratio is the ratio of the sediment yield (Y) at a given stream cross-section to the gross erosion (E) from the watershed upstream of the measuring point. The gross erosion (E) is the total soil eroded in a drainage area or watershed through inter-rill, rill, gully, and stream erosion processes. Therefore, the sediment delivery ratio is given by the expression as expressed by (Ouyang and Bartholic, 1997),

$$\mathrm{SDR} = \frac{\mathrm{Y}}{\mathrm{E}} \qquad (2.33)$$

Where,

SDR = sediment delivery ratio, Y = average annual sediment yield per unit area, and

E = total gross annual erosion for the same area

The SDR often has a value between (0 and 1) due to sediment deposition caused by change of flow regime and reservoir storage. However, values larger than 1 were also found at event basis or when bank or gully erosion predominates (Lu *et al.*, 2005). According to the upland theory of (Boyce, 1975) SDR generally decreases with increasing catchment size area because average slope decreases with increasing catchment size, and large catchment also have more sediment storage sites located between sediment source areas and the basin outlet. At catchment scale, the most widely used method to estimate SDR is through an SDR-area power function given by (Roehl, 1962) as follow,

$$\mathrm{SDR} = \alpha A^{\beta} \qquad (2.34)$$

Where,

A = catchment area (km^2), α = constant, β = scaling exponent, and

α and β empirical parameters

Field measurements using the statistical regression technique suggest that β is in the range (0.01 to -0.025) as published by (Richards, 1993), which means that SDR decreases with increasing catchment area. The relationship for SDR and catchment size is known as the SDR curve (USDA, 1972). Lim *et al.* (2005) noticed that the SDR curve based on watershed size is widely used because of its ease. USDA (1972), (Boyce, 1975) and (Vanoni, 1975) also developed SDR curves expressed as,

$\mathrm{SDR} = 0.4724\ A^{-0.125}$ (2.35) (Vanoni, 1975)

$\mathrm{SDR} = 0.3750\ A^{-0.2382}$ (2.36) (Boyce, 1975)

$\mathrm{SDR} = 0.5656\ A^{-0.11}$ (2.37) (USDA, 1979)

Where, A = catchment area (km^2)

The differences in SDR equation above are because of the amount of data used to derive such equation.

CHAPTE THREE

3. MATERIALS AND METHODS

3.1 Study Area Location

Dukan Lake is a large reservoir in the Iraqi Kurdistan region, covers an area of about (25000 hectare) that is fed by Lesser Zap River from the northeast, Qadrawa stream from the north and the Hizop stream from the northwest. It is surrounded by mountains (Kosrat, Qarasrd, and Sara), hills, and lowland areas characterized by steppe grasslands and some oak forests. Villages and towns with agricultural lands (Ranya, Chwarqurna, and Qaladza) surround the lake, with the most dense populations and agricultural development to the northwest of the large lake. Geographically, the study area is situated between (35º 41' 03'' N to 36º 14' 31'' N) north and (44º 36' 34'' E to 45º 32' 29'' E) east. The elevation ranges between (412 to 868) meters (m.a.s.l.) and it is located to the south of Ranya town, about (60 kilometers) northwest of Sulaimanyah city is located northern of Iraq, between latitude (35° 31' 26'' N to 35° 35' 37'' N) and longitude (45° 22' 10'' E to 45° 28' 48'' E).

3.2 Hydrology

The study area covers all rivers, streams and tributaries supplying water to the Dukan reservoir. Many tributaries enter the Dukan reservoir from its northwestern part; the nearby one is Hizop and Khdran streams. The important tributaries that join the Hizop stream before Dukan reservoir are Smaquli and Jali streams. A number of smaller streams join the Dukan reservoir in Ranya plain, the noted one Qarani-Agha and Bosken. The upper portion of the Lesser Zab River from the Iranian-Iraqi border near Kawe village to the Dukan Lake inlet. Four major tributaries join the Lesser Zab River coming from its northeastern part of the Dukan reservoir before the Darbany-Ranya. These tributaries which are mostly ephemeral are located in areas around Sangasar, Zharawa and Qaladza. The important tributaries that join the Lesser Zab River in Iraq before Dukan reservoir are: Hallsho, Zharawa, Dolabafra, and Doli-Shahidan streams.

The Qalachwalan River, which flows northward and joins the Lesser Zab River near an area called Du Choman (Two Rivers), has two major tributaries, the Siwayl that forms from Shalair and Kiziljeh tributaries, and Joga-Sur. The origins of the Lesser Zab River before entering Iraqi border forms the boundary between Iran and Iraq for about (33 kilometers).

The Qalachwalan River and its tributaries drain areas around the cities of Penjwin, Chwarta and Mawat. The Qalachwalan River which originates in Howran Mountain in Iran is (39 kilometers) long and covers a catchment area of (1506 km^2) (15% in Iran and 85% in Iraq) and forms (35%) of the Lesser Zab River in this area. The Joga-Sur is about (64 kilometers) in length and has a catchment area of (402 km^2). They are the last bodies of water that contribute to the river. The Qalachwalan and Lesser Zab River in the study area passes through many villages, towns, and agricultural lands where possible man-made pollution sources could affect its water quality, in addition to the natural pollution causes such as spring waters, erosion and weathering of rocky outcrops.

The major source of water for the Lesser Zab River is rain and snow melts, supplied mainly from its two sub-basins, Baneh River and Qalachwalan. A number of smaller streams joined the Lesser Zab in the Ranya plain, which is now partly inundated by Lake Dukan. The river is in a peak discharge in the period (February to May) and low water levels are recorded for the period (July to October). The drainage basin of the Little Zab from the location where the Dukan dam has been constructed, it measures (11.700 km^2) (Fink and Ostrizhnov, 1984) and (Ezz-Aldeen *et al.*, 2018) it drains an area of (11.690 km^2). The larger part of the basin (74%) is located within Iraqi borders; the remainder is in Iran (Frenken, 2009). SMEC International Pty. Ltd. (2006) mentioned Dukan catchment area about (11.690 km^2).

3.3 Climate of the Study Area

Generally, Kurdistan climate is of semi-arid region, designated as continental and subtropical which is characterized by a wide diurnal and annual ranges of temperature, low relative humidity, cloudless summer months and northwest prevailing wind direction (FAO, 2001). The Mediterranean type climate prevails in the catchment of the Lesser Zab River. It is hot and very dry in summer, while the winter season is cold and has high annual precipitation, which is more rainy and snowy towards northeast (Stevanovic and Markovic, 2003).

The area receives an annual rainfall of (700 to 800) mm. Generally, the climate of the studied area around Dukan, Ranya, Qaladza, Mawat, and Chwarta towns is characterized by high rainfall, relatively cold weather during the winter although it was affected by drought during the past several years. These areas mostly represent the high mountain regions. Climate has a direct influence on water quality of the study area; and it is one of effective factors in hydrological cycle. The obtained data from the Dukan meteorological station for the periods of study including precipitation, temperature, humidity, and wind speed with direction are used to evaluate the weather of the study area (Table 3.1).

Table 3.1 Metrological data of Dukan station for the studied area.

Months	Dukan								Rain fall					
	Air temperature C^{o}			Humidity %			Wind		Dukan	Chwarta	Mawat	Ranya	Qaladza	Chwarqurna
	Avg.	Max.	Min.	Avg.	Max.	Min.	Speed m s^{-1}	Direction	mm					
August 2016	36.0	44.4	28.8	16.5	38.2	6.4	2.4	112.2	0.0	0.0	0.0	0.0	0.0	0.0
September	29.8	37.8	22.7	20.7	38.5	9.8	2.1	157.9	0.0	0.0	0.0	0.0	0.0	0.0
October	24.3	30.5	19.1	29.9	46.8	17.6	3.5	230.1	1.1	4.5	0.0	0.0	0.2	0.0
November	15.3	21.5	10.6	34.5	54.7	18.8	3.7	230.2	34.0	50.0	44.6	36	25.2	22.8
December	7.7	11.3	4.6	68.0	83.3	50.8	3.7	204.9	235.0	197.0	273.9	237.5	213.8	222.2
January 2017	7.0	11.3	3.4	66.2	82.5	47.0	2.8	222.3	48.2	63.8	69.1	56.5	55.2	57
February	6.4	10.8	2.7	62.1	79.3	42.0	2.7	247.6	58.8	122.7	95	45	61.9	52.5
March	12.4	16.9	8.9	63.2	81.5	41.9	3.4	241.1	120.8	178.2	138.8	128	143.3	129.5
April	17.6	23.5	13.0	57.1	77.5	32.7	2.5	217.7	48.0	74.0	72.1	61	48.1	40.2
May	25.1	33.6	18.4	31.4	54.4	13.4	2.7	234.3	5.6	25.5	14	6	11.1	10
June	31.6	40.0	24.1	18.5	38.0	9.1	2.7	192.1	0.2	2.5	0.0	0.0	0.0	0.0
July	36.2	44.5	28.9	14.7	36.6	6.4	3.1	222.0	0.0	0.0	0.0	0.0	0.0	0.0

3.4 Northern Iraq Geology Description

The Lesser Zab River and its tributaries, and the Dukan reservoir pass through, the Zagros suture and the unstable shelf tectonic zones of northeastern Iraq as shown in (Fig. 3.1). The Zagros suture zone which is shared between Iran and Iraq consists dominantly of igneous and metamorphic rocks belonging to (Shalair, Penjwin-Walash, and Qulqula-Khuwakurk zones) (Jassim and Golf, 2006).

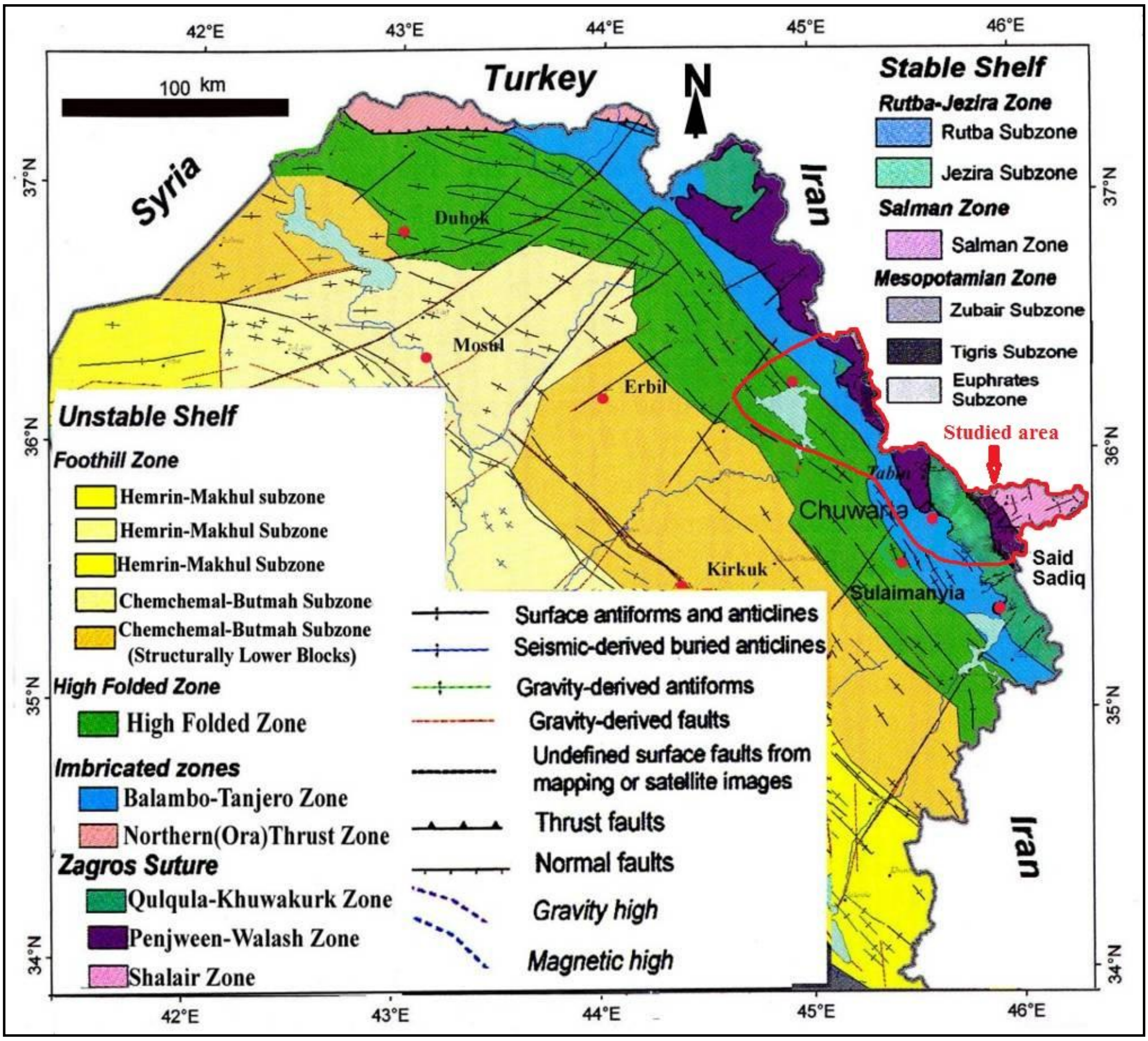

Figure 3.1 Geological map shows the study area (after Stevanovic and Markovic, 2003).

Depending on minerogenic map of Iraq by (Al-Bassam, 2007), the dominant mineral in the studied area were (Limestone, Dolostone, and Halite Saltern) as shown in (Fig. 3.2).

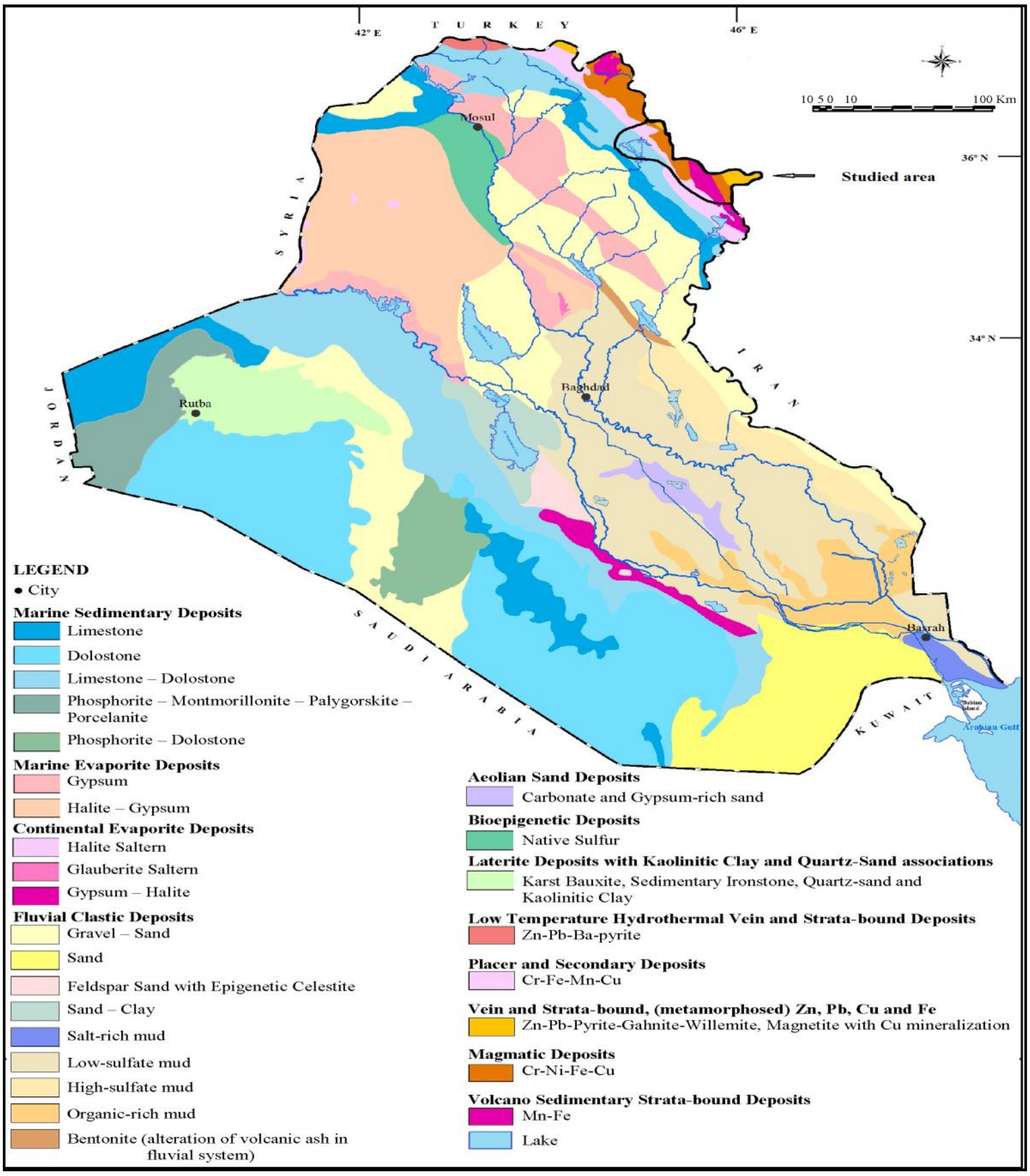

Figure 3.2 Minerogenic map of Iraq (Al-Bassam, 2007).

3.5 General Situations and Sampling

To achieve the destinations of this investigation, field and laboratory works are conducted out. The physiochemical and hydrological analyses were conducted in different laboratories in college of agricultural engineering sciences, Kurdistan institution for strategic studies and scientific researcher, and Bakrajo agricultural researcher. Many field trips and surveillance were recored and conducted to setting study area and detecting site stations. Based on the land use pattern differences, including agricultural and residential areas, the sampling sites were selected. Water samples were collected during four seasons at six different periods; during (August, November, February, March, April, and May) the period sampling were chosen situated on the hydrological regime of the area was studied and it was affected by seasonal variations due to rainfall specimen. The collected water samples were determined by using the procedures indicated in the standard methods for the examination of water and wastewater (APHA, 2005).

A total of 21 water samples were collected from the studied area in each sampling period (Table 3.2 and Fig. 3.3) and 34 samples of soil were collected from the plains and hilly areas of the studied locations around the studied area by hand auger at depth (0 to 15 cm); among them eleven were selected at Mawat-Chwarta side, while the other twenty three were collected at the north, east and west sides of Dukan lake (Table 3.3 and Fig. 3.3). The samples were placed in a plastic bag sack then stored to laboratory for analysis (Carter and Gregorich, 2008).

3.6 Pre-field Work

In order to prepare the fieldwork, available basic data from different sources were collected, topographic and geological maps with relevant scale were selected, and satellite images suitable for background map were made available. Relevant data from site on land use/land cover, soil type, water resource, vegetation type, size of cultivated area, and relevant meteorological data were gathered from the respective offices (Dukan dam directorate, agricultural directorates, and municipality within the studied areas).

Table 3.2 GPS reading of water sampling sites.

Site codes	Sites	Elevation (m)	Latitude (N)	Longitude (E)
W1	Joga-Sur	849	35º 41' 46"	045º 32' 29"
W2	Mawakan	868	35º 41' 03"	045º 31' 49"
W3	Shakha-Sur	836	35º 42' 49"	045º 30' 32"
W4	Siwayl	832	35º 45' 04"	045º 29' 59"
W5	Kuna-Masi	792	35º 47' 32"	045º 24' 27"
W6	Qashan	736	35º 52' 02"	045º 24' 14"
W7	Kawe	537	36º 06' 37"	045º 10' 36"
W8	Hallsho	604	36º 10' 36"	045º 09' 31"
W9	Sndollan	501	36º 10' 21"	045º 03' 10"
W10	Zharawa	501	36º 12' 59"	045º 04' 28"
W11	Dolabafra	523	36º 13' 55"	045º 03' 12"
W12	Doli-Shahidan	506	36º 14' 31"	044º 59' 56"
W13	Darbany-Ranya	493	36º 12' 51"	044º 59' 14"
W14	Bosken	514	36º 13' 35"	044º 55' 03"
W15	Dukan-Lake	501	36º 10' 9"	044º 55' 20"
W16	Qarani-Agha	506	36º 11' 56"	044º 45' 20"
W17	Khdran	540	36º 07' 56"	044º 46' 54"
W18	Hizop	531	36º 10' 19"	044º 41' 10"
W19	Smaquli	625	36º 10' 09"	044º 37' 16"
W20	Jali	592	36º 11' 23"	044º 36' 34"
W21	Qashqoli	412	35º 55' 31"	044º 57' 42"

Table 3.3 GPS reading for soil sampling sites

Site codes	Site names	Elevation (m)	Latitude (N)	Longitude (E)
S1	Ashi-Qazi	879	35º 39' 29"	45º 32' 14.4"
S2	Mawakan	854	35º 41' 00.9"	45º 31' 44.9"
S3	Joga-Sur up	862	35º 41' 48.9"	45º 32' 59.3"
S4	Joga-Sur near bridge	862	35º 41' 29.8"	45º 32' 34.8"
S5	Shakha-Sur	834	35º 42' 53.3"	45º 30' 34.3"
S6	Kanarwe	961	35º 41' 18.5"	45º 35' 01.1"
S7	Wazha	854	35º 45' 09.8"	45º 29' 58.2"
S8	Kuna-Masi	798	35º 47' 36"	45º 24' 26.9"
S9	Kuna-Masi up	919	35º 46' 40.4"	45º 24' 01.6"
S10	Zainal village	796	35º 51' 00.2"	45º 26' 08.9"
S11	Qashan near bridge	765	35º 51' 59.1"	45º 24' 19.9"
S12	Kawe	567	36º 06' 58.1"	45º 10' 42.9"
S13	Hallsho near Allawa village	934	36º 12' 12.1"	45º 13' 12.1"
S14	Hallsho near bridge	709	36º 10' 33.9"	45º 09' 33.4"
S15	Sndollan	502	35º 41' 29.7"	45º 32' 34.8"
S16	Zharawa up	565	36º 13' 21.2"	45º 05' 04.0"
S17	Zharawa near grideg	529	36º 12' 58.2"	45º 04' 36.4"
S18	Dolabafra up	552	36º 14' 31.3"	45º 03' 50.7"
S19	Dolabafra near bridge	536	36º 14' 31.4"	45º 03' 50.8"
S20	Qadrawa village	615	36º 16' 48.3"	45º 00' 48.4"
S21	Doli-Shahidan near bridge	524	36º 14' 34.8"	45º 00' 00.4"
S22	Twasuran	519	36º 14' 11.3"	44º 58' 54"
S23	Darbany-Ranya	522	36º 13' 23.9"	44º 57' 24.2"
S24	Bosken	515	36º 13' 36.4"	44º 55' 04.6"
S25	Chwarqurna	522	36º 12' 00.0"	44º 49' 01.6"
S26	Sarwchawa	567	36º 15' 53.8"	44º 46' 12.2"
S27	Qarani-Agha near bridge	526	36º 11' 58.3"	44º 45' 13.5"
S28	Khdran up	552	36º 07' 29.1"	44º 46' 34.6"
S29	Khdran near bridge	529	36º 07' 58.2"	44º 46' 52"
S30	Hizop near bridge	549	36º 10' 16.7"	44º 40' 55.5"
S31	Smaquli near bridge	629	36º 10' 02.8"	44º 37' 15.1"
S32	Smaquli up	669	36º 09' 43.3"	44º 36' 15.2"
S33	Jali low	595	36º 11' 19.3"	44º 36' 36.4"
S34	Jali up	599	36º 10' 57.9"	44º 36' 28.2"

3.7 Data Collection

3.7.1 Flow measurements

The discharge rates for the rivers are measured at the sampling sites at every sampling period concurrently with water quality measurements.

3.7.1 Methodologies for open channel hydraulics

Where direct volumetric measurement is impossible or unreliable, there are a number of hydraulic relationships that can be used to determine discharge with varying degrees of certainty. These relationships are discussed and include the area-velocity-discharge relationship and Manning’s equation.

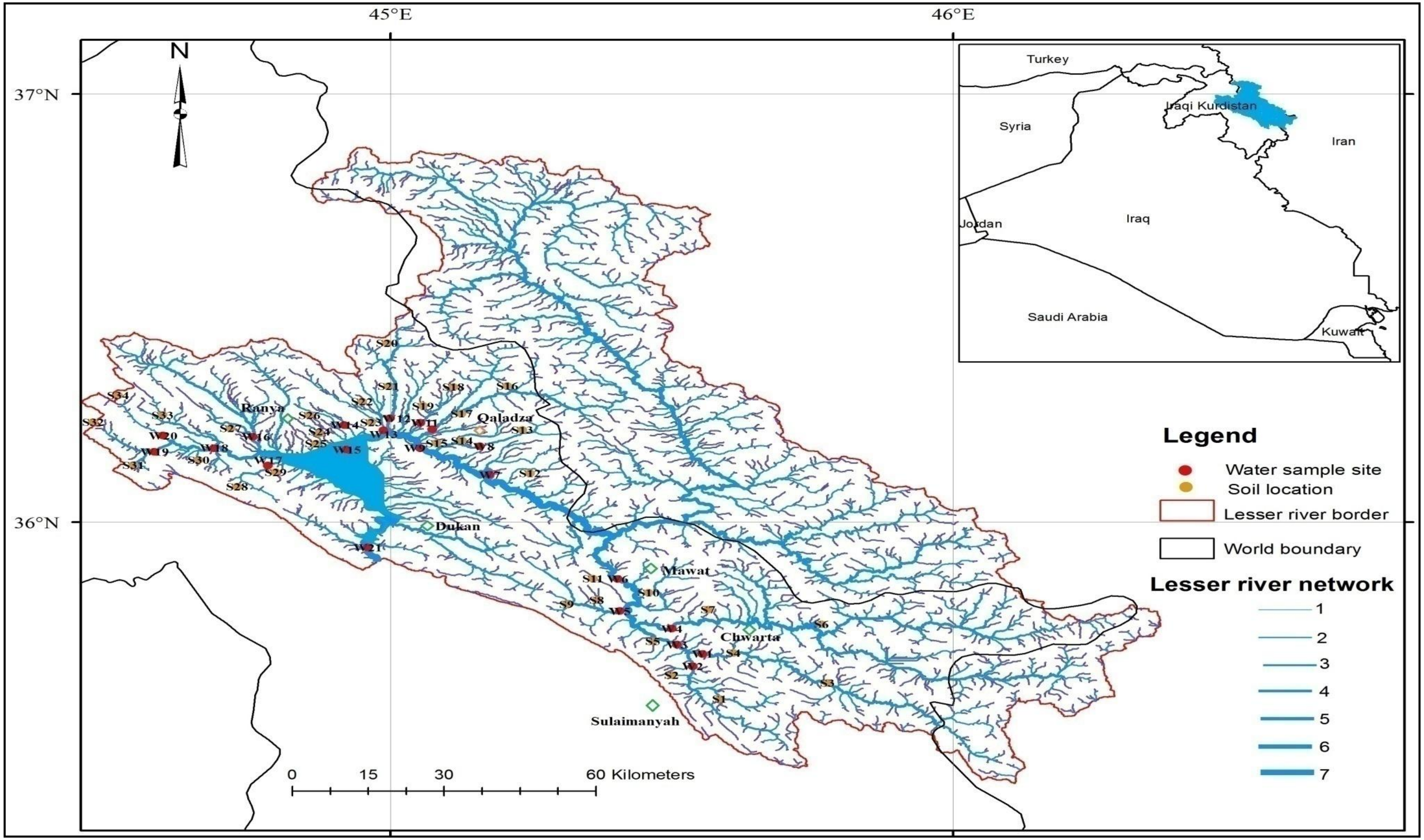

Figure 3.3 Map of the study area showing the water and soil sampling sites.

The method applied will depend on channel geometry and flow characteristics: principally, whether flow is open or closed channel. Open channel flow occurs when flow has a free surface. It most commonly occurs in open-air channels of various scales, both man-made and natural. It also occurs in pipes flowing partially full.

3.7.1.1 Stream area/velocity methods

Where spring discharge flows into an open stream or man-made channel, the stream area/velocity method is commonly employed to estimate discharge as follow,

$$Q= V * A \qquad (3.1)$$

Q = discharge ($m^3\ s^{-1}$), V = average flow velocity ($m\ s^{-1}$), and
A = cross-sectional area of flow (m^2)

3.7.1.2 Determining cross-sectional area

Where channel morphology varies in the direction of flow, at least three cross-sections perpendicular to flow have measured along the channel section.

3.7.1.3 Determining velocity

3.7.1.3.1 Float method

The float method is likely to be most accessible, though the float method was used to compute water velocity although its accuracy is limited. Where there is significant wind, large ripples, or back currents on the channel, the method will be considerably less accurate. As flow velocity will vary from flow surface to bottom of the channel, the averaged surface velocity should be multiplied by a correction coefficient (Table 3.4) depending on the depth of the channel where the float velocity has been measured.

Table 3.4 Correction coefficients for float velocity based on channel depth (Dodge, 2001).

Average depth (ft)	Correction coefficient
1	0.66
2	0.68
3	0.70
4	0.72
5	0.74
6	0.76
9	0.77
12	0.78
15	0.79
>20	0.80

3.7.1.3.2 Manning's equation

The velocity of open channel flow can also be estimated using Manning's equation (Chanson, 2004). This requires measurement of the water surface slope and an estimate of channel roughness, as well as measurement of cross-sectional area of flow,

$$V = 1/n * R^{2/3} * S^{1/2} \qquad (3.2)$$

V = velocity (m s^{-1})
n = roughness coefficient (sec $m^{-1/3}$)
Km = 1/n =Manning's coefficient
R= hydraulic radius
[Note: A/P = R, hydraulic radius] m
S= slope of water surface (m m^{-1})
A = cross-sectional area of flow (m^2)
P= wetted perimeter of flow (m)

3.8 Sample Collection and Storage

Sample collection should be simple with avoiding the possibility of contamination or interference from foreign substances. Surface water was collected during different periods of discharge. Six sampling campaigns were conducted from August 2016 to May 2017. Grab water samples were collected from twenty one sampling sites along the main river and its tributaries. Two samples in 300 ml bottles were collected at each site. One sample was for heavy metal analysis and the other sample was fully topped up for analysis for BOD_5 and one 1.5 liters bottle sample for other parameters and measuring suspension solids, according to the procedure described by (APHA, 2005).

The bottles were washed (2 to 3) times with water of interest prior to collection for analysis and filled to the neck to expel air which leads to preventing iron deposition and consequent loss of phosphate and carbon dioxide with consequent calcium precipitation (Höll, 1972). The samples were then stored in the cooler box with ice cubes, waiting to be transported to the laboratory for analysis. The samples were filtered through 0.45 µm filters and done analyzed, while some parameters such as temperature, EC, DO and pH were measured on site, using the portable instrument. Samples collected for heavy metals analysis were filtered and preserved with dilute nitric acid (2 ml) in 300 ml before transporting to the laboratory for analysis. The bottles were kept in the refrigerator at (4-6 °C) temperature for subsequent analysis (Sanders, 1998).

3.9 Analytical Methods (Physicochemical analyses):

3.9.1 Temperature (^{o}C)

Surface water temperature was determined on site using temperature sensor of a dissolved oxygen probe (InoLab.OXi730, WTW Company-Germany), as described in the field method according to (APHA, 2005).

3.9.2 Hydrogen ion concentration (pH)

The pH of the water was measured on site using a portable pH meter (Multi 340i/SET multi-parameter instrument WTW Company-Germany), equipped with pH probes, the probe was calibrated using appropriate standard solutions before sampling as described by (APHA, 2005).

3.9.3 Electrical Conductivity (EC)

Electrical Conductivity was measured in the field by electrometric method, using portable EC-meter (Cond 330i, 82362 Weilheim WTW Company-Germany). Final result corrected at (25°C) and expressed in (μS cm^{-1}), (APHA, 2005).

3.9.4 Total Solids (TS)

The total solid was determined using the procedure described by (Hussein, 2013). A known volume of well-mixed unfiltered sample was evaporated in a weighed dish and dried to constant weight in an oven at (103 to 105) ^{o}C. The increase in weight over that of the empty dish represents the total solids. TS was calculated as,

$$\mathrm{TS\ (mg\ L^{-1})} = \frac{(\mathrm{A} - \mathrm{B}) * 1000\,000}{\text{Volume of sample, ml}} \qquad (3.3)$$

Where, A = weight of dried residue + dish, (grams), and B = weight of dried dish, (grams)

3.9.5 Total Dissolved Solids (TDS)

The total dissolved solid was determined using the procedure describe by (Hussein, 2013). A known volume of sample was filtered through a standard 0.45 μm filter membrane, and the filtrate was evaporated to dryness in a weighed dish and dried to constant weight. The increase in dish weight represents the total dissolved solids. TDS was calculated as,

$$\mathrm{TDS\ (mg\ L^{-1})} = \frac{(\mathrm{A} - \mathrm{B}) * 1000\ 000}{\mathrm{Volume\ of\ sample,\ ml}} \qquad (3.4)$$

Where, A = weight of dried residue + dish, (grams) and B = weight of dried dish, (grams)

3.9.6 Total Suspended Solids (TSS)

The total suspended solid was determined using the procedure described by (Hussein, 2013). A known volume of well-mixed sample was filtered through a pre-weighed 0.45 μm filter membrane and the residual retained on the filter were dried to constant weigh at (103 to 105) ºC. The increase in the weight of the filter represents the total suspended solids in (mg L^{-1}). TSS was calculated as,

$$\mathrm{TSS\ (mg\ L^{-1})} = \frac{(\mathrm{A} - \mathrm{B}) * 1000\ 000}{\mathrm{Volume\ of\ sample,\ ml}} \qquad (3.5)$$

Where, A = weight of filter + dried residue, (grams) and B = weight of filter, (grams)

3.9.7 Turbidity

The turbidity of water in all sampling sites was determined by using a portable turbidity-meter (Photo Flex/Photo Flex Turb.WTW Company-Germany), and the measurements were read in Nephelometric Turbidity Units (NTU) (APHA, 2005).

3.9.8 Color

In laboratory color variability of each water sample was measured by photoLab spectral model (82362 Weilheim) WTW company-Germany as described in the (APHA, 2005).

3.9.9 Dissolved Oxygen (DO)

Dissolved oxygen was measured at the field using a special oxygen-sensitive membrane electrode (InoLab.OXi730, WTW Company-Germany). The readings were allowed to stabilize and DO read in mg L^{-1}, as described in the (APHA, 2005).

3.9.10 Biochemical Oxygen Demand (BOD)

BOD was measured by a special oxygen sensitive membrane electrode (InoLab.OXi730, WTW Company-Germany), as described in the (APHA, 2005). Samples were analyzed after 5-days incubation period, then the final dissolved oxygen concentration (DO_5) was determined, if the original sample contained (DO) mg L^{-1} of oxygen and the incubated sample DO_5 mg L^{-1} after 5- day at 20 ^{o}C then the five-day BOD is,

$$BOD_5\ (mg\ L^{-1}) = (\text{Original DO of sample - } DO_5 \text{ sample after 5 day incubation}) \qquad (3.6)$$

Samples were diluted prior to incubation, then were incubated for five days, the measurement of the loss oxygen from the beginning to the end of the test were taken. The BOD levels were then determined by comparing the initial and the final DO level of the sample.

$$BOD_5\ (mg\ L^{-1}) = (DO_1-DO_5)/P \qquad (3.7)$$

Where,

DO_1 = initial DO of the diluted water sample.

DO_5= final DO of the diluted water sample after five days incubation.

P= decimal volumetric fraction of sample.

3.9.11 Major cations and anions:

3.9.11.1 Calcium and magnesium (Ca^{2+} and Mg^{2+})

These were estimated by using a titrimetric method with EDTA (0.01N) according to (Maiti, 2004).

3.9.11.2 Sodium and potassium (Na^{+} and K^{+})

These were measured by flame photometric methods as described by (APHA, 2005); using flame-photometer, model JENWAY, PEP7.

3.9.11.3 Chloride ion (Cl^{-})

The ion of chloride was determined by titrimetric method (APHA, 2005). The method is based on the titration of the water sample with $AgNO_3$ (0.01N) using potassium chromate (K_2CrO_4) as indicator.

3.9.11.4 Alkalinity as bicarbonate contents (HCO_3^{-})

The alkalinity of water was determined by titration against a standard sulphuric acid (0.02N) (APHA, 2005).

3.9.11.5 Nitrate and Sulphate (NO_3-N and SO_4^{-2})

NO_3-N and SO_4^{2-} were determined using a spectrophotometer 220 and 420 nm (UV-1800, Japan) respectively according to (Maiti, 2004).

3.9.11.6 Phosphorus, ammonium, and nitrite (PO_4-P, NH_4-N and NO_2-N)

These were determined by using a photoLab spectral model (82362 Weilheim) WTW company-Germany according to (APHA, 2005). The results were expressed in (mg L^{-1}).

3.9.12 Total hardness

An accurate method was used for determination of total hardness and calcium hardness depending on the procedure given by (Theroux *et al.*, 2001). The measurements of total hardness were done depending on the mathematical model below,

$$(\text{mg L}^{-1}\ \text{Ca}^{2+} \times 2.496) + (\text{mg L}^{-1}\ \text{Mg}^{2+} \times 4.115) = \text{mg L}^{-1}\ \text{Total hardness as CaCO}_3 \qquad (3.8)$$

3.9.13 Irrigation water quality measuring:

To evaluate water quality for irrigation purpose, following indices were calculated using the shown equations.

3.9.13.1 Salinity (Total Soluble Salt)

Electrical conductivity measured on the field was also used to assess salinity hazards as following,

$$\text{TDS}=\text{EC}*\text{K} \qquad (3.9)$$

Where, K = 0.640 in most cases (for EC: 0.5-5 dS m^{-1}) or
K = 0.735 for mixed waters or
K = 0.800 for EC > 5 dS m^{-1}

3.9.13.2 Soluble Sodium Percentage (SSP)

This was calculated employing the equation (Todd, 1995) as,

$$\text{SSP} = \frac{(\text{Na}^{+} + \text{K}^{+})}{(\text{Na}^{+} + \text{K}^{+} + \text{Ca}^{2+} + \text{Mg}^{2+})} * 100 \qquad (3.10)$$

Where, all concentration is in meq L^{-1}.

3.9.13.3 Sodium Adsorption Ratio (SAR)

This was calculated employing the equation (Ryan *et al.*, 2001) as,

$$\mathrm{SAR} = \mathrm{Na}^{+}/\sqrt{(\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+})/2} \qquad \text{Concentrations are in meq L}^{-1}. \qquad (3.11)$$

3.9.13.4 Residual Sodium Carbonate (RSC)

This was calculated employing the equation (Eaton, 1950) as,

$$\mathrm{RSC} = (\mathrm{CO_3}^{2-} + \mathrm{HCO_3}^{-}) - (\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}) \qquad (3.12)$$

Where, all concentration is in meq L^{-1}.

3.10 Heavy Metal Analysis

The trace metals were tested by using the analytical methodologies as per (APHA, 2005). The collected water samples immediately transported to the laboratory for doing analysis by placing in a cooler at 4 °C. The collected samples were filtered with filter paper (pore size 0.45 µm) and to minimize adsorption and precipitation metals on the walls of the bottles the samples were preserved by correcting the pH below 2 with nitric acid as described the standard procedure. The heavy metals concentrations, iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), lead (Pb), cadmium (Cd), and chromium (Cr) were determined using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) Optima 2100 DV Series (Perkin-Elmer). It comes with WinLab32 Software which optimizes the workflow and accuracy.

3.11 Soil Analysis (Physical and chemical analyses):

Some physical and chemical properties of the soils were determined as follows:

3.11.1 Particle size distribution

The particle size distribution was carried out by using pipette method according to (Klute, 1986).

3.11.2 Bulk density

Bulk density was determined by using a clod method according to (Bonsu and Laryea, 1989).

3.11.3 Saturated hydraulic conductivity

It was measured by constant and falling head method as modifieded by (Fattah, 2004).

3.11.4 Electrical Conductivity (EC)

Was determined by using portable EC-meter (Cond 330i, 82362 Weilheim WTW Company-Germany), according to (Hesse, 1971).

3.11.5 pH

The pH of soil extract was determined by using a pH-meter, model (Multi 340i/SET multi-parameter instrument WTW Company-Germany), according to (Wang and Anderson, 1998).

3.11.6 Calcium and magnesium (Ca^{2+} and Mg^{2+})

They were determined by titremetric method by using (0.02M) EDTA di-sodium salt as described in (APHA, 1998).

3.11.7 Sodium and potassium (Na^{+} and K^{+})

Were measured by flame photometer model (JENWAY, PEP7), according to (Allen, 1974).

3.11.8 Alkalinity as bicarbonate (HCO_3^-)

Was determined by titremetric method by using (0.01M) HCl as described in (Richards, 1954).

3.11.9 Chloride (Cl^-)

The chloride concentration was determined by titration method by using (0.01M) $AgNO_3$ as described in (Richards, 1954).

3.11.10 Nitrate and Sulphate (NO_3-N and SO_4^{-2})

They were determined by using a spectrophotometer (UV-1800, Japan) 220 nm for NO_3-N and 420 nm for SO_4^{2-} according to (Tabatabai, 1974).

3.11.11 Phosphorus (PO_4-P)

Was determined by (Olsen's method) as described in (Rowell, 1996).

3.11.12 Ammonium and nitrite (NH_4-N and NO_2-N)

These were determined by using a photoLab spectral model (82362 Weilheim) WTW company-Germany according to (APHA, 2005).

3.11.13 Organic matter (O.M)

This was determined by using the Walkly Black method as described in (Ryan *et al.,* 2001).

3.12 Soil Heavy Metal Analysis (Nitric acid extraction)

The sieved and air-dried soil sample (<2 mm) is extracted with (0.43 M HNO_3) at room temperature according to modified versions of the extraction procedure by (Houba *et al.,* 1995). The extraction solution is obtained by dilution of 30 mL concentrated HNO_3 (65%, analytical grade) in 1000 mL ultrapure water. The soil material together with the extracting solution at a 1:10 weight to volume ratio are shaken during 2 (standard), 4 or 48 h (according to procedure). After centrifugation and filtration dissolved concentrations are measured using ICP-AES. The pH after extraction is usually between 0.5 and 1.

3.13 Statistical Analysis

The results were statistically analyzed and tabulated by using the Microsoft Excel Software. Error-Bar was used to compare the treatment means at the $P \leq 0.05$ which is represented by standard error of the mean (SE). Finally correlation between the variables was calculated using NCSS 12 Software.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Physicochemical and Hydrological Parameters:

4.1.1 Temperature (^oC)

Water temperature readings ranged from (7.7 to 31.4) ^oC during the study period. The monthly average values were ranged from (11.4 to 25.5) ^oC has been shown in (Fig. 4.1.1a), the temperature obtained in August was higher than those other months with significant differences between months and similar results were founded by (Goran, 2014). This could lead to increase in rate of chemical reaction and nature of biological activities in August. Guidelines for drinking-water quality value none sets but number of countries were setting a guideline value (Appendex1: Table 4.1.1). However, the wide temperature variations that could be attributed to the slight variations in the sampling time at each site and the different sampling days.

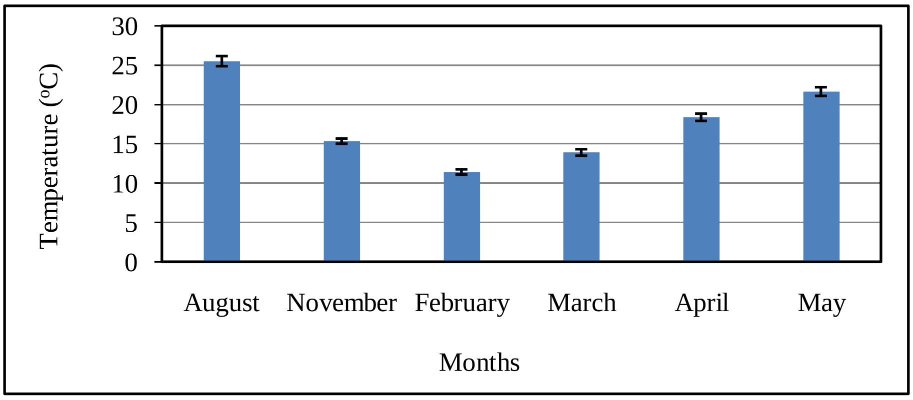

Figure 4.1.1a Standard error of mean of water temperature (^oC) for studied months.

The maximum water temperature 31.4 ^oC was recorded at sampling site (W13-Darbany-Ranya) during August and the minimum of 7.7 ^oC was recorded during February at sampling site (W4-Siwayl) with significant differences between among sites has been revealed in (Fig. 4.1.1b). The monthly variations in water temperature could be attributed to the seasonal dynamics of weather within the study area. The lowest water temperature in the February might be due to high water levels and lower solar radiation whereas maximum in the August might be due to low water level, greater solar radiation and clear atmosphere. Temperature controls the hydrochemistry of parameters like DO, BOD, solubility, pH, conductivity, etc. (Patil *et al.*, 2011). In general water holds lesser oxygen as the temperature increases (Kulkarni *et al.*, 2007).

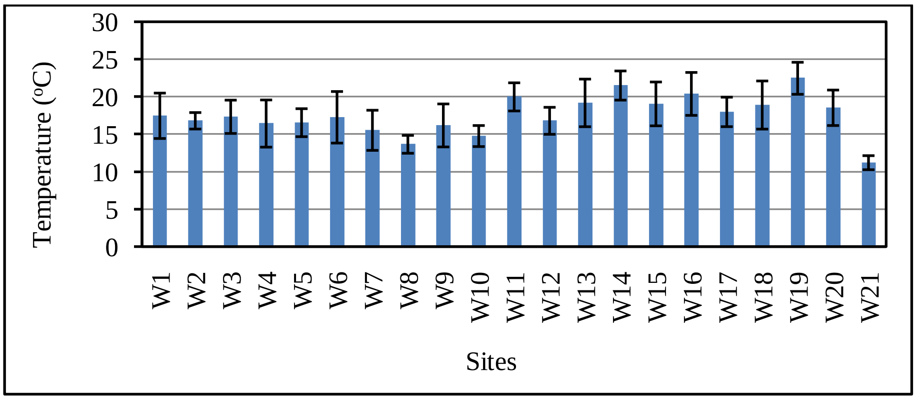

Figure 4.1.1b Standard error of mean of water temperature (°C) for studied sites.

4.1.2 Turbidity

The turbidity values ranged from (< 0.01 to 659) NTU. The monthly average turbidity ranged from (18.4 to 52) NTU with significant differences between months has been exposed in (Fig. 4.1.2a). The results show that it is much greater than mean value recommended by number of countries (5 NTU) especially during rainy season (Appendex1: Table 4.1.2). Very high turbidity values were obtained in March and April which is the wet season of the study area than the dry season and keeping with results were noted by (Farka, 2006). This could be due to more frequency of rainfall in the wet season. Rainy season generally causes high turbulence and mixing of water leading to an increase in the suspended particulate matter. Turbidity of water has an influence on other parameters such as color and even chemical parameters which affect water quality (Olumuyiwa *et al.*, 2012).

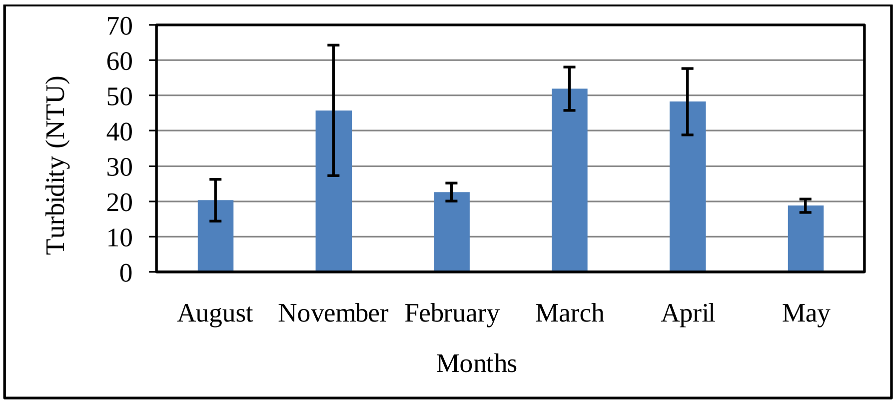

Figure 4.1.2a Standard error of mean of water turbidity (NTU) for studied months.

Comparatively low water turbidity < 0.01 NTU is found at sample site (W21-Qashqoli) and sample site (W2-Mawakan) during August and November respectively. The highest value 659 NTU was founded at sample site (W12-Doli-Shahidan) during November with significant differences between sites has been shown in (Fig. 4.1.2b) due to the effect of sand washer activates at the upstream of the river can lead to increased suspends of the river in this site and turbidity can also rise sharply during dry weather if earth-disturbing activities are occurring in or near a stream without erosion control practices in place. During rainy season silt, clay and other suspended particles contribute towards high turbidity values, while during winter and summer seasons settlement of silt, clay results low turbidity (Thirupathaiah *et al.*, 2012). In March, high turbidity values can be attributed to high incidences of rainfall, sand washer and agricultural lands, which lead to increased erosion and surface runoff carrying a lot of suspended materials into the river.

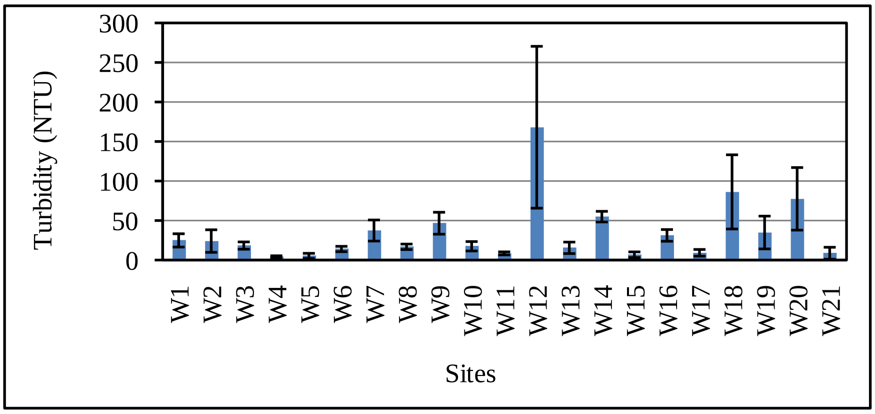

Figure 4.1.2b Standard error of mean of water turbidity (NTU) for studied sites.

4.1.3 Color (Hazen unit)

The minimum and maximum color values were (0.2 and 93.2) Hazen unit measured at sampling site (W5-Kuna-Masi) and (W14-Bosken) during August respectively, with significant differences among sites has been revealed in (Fig. 4.1.3a). The monthly average concentrations were ranged from (7.7 to 56.9) a Hazen unit with significant differences between months has been shown in (Fig. 4.1.3b). Throughout the sampling periods, measured concentrations were greater than the maximum permissible limit value for drinking standard guideline in most of the sites as a result of erosion and runoff into the river, it should not be more than (15 Hazen unit or TCU) (Appendix 1: Table 4.1.3). In terms of time, March showed higher values of color than other months, owing to the river characteristics during the beginning of the rainy season. Rivers tend to collect solid and liquid wastes in the catchment lands during this period (Abowei, 2010). We can see that the main causes of color in the study area may be due to decaying of organic material, sand washer effects, agricultural activities (runoff) which are practiced at different sites along the river and might be due to high iron concentration.

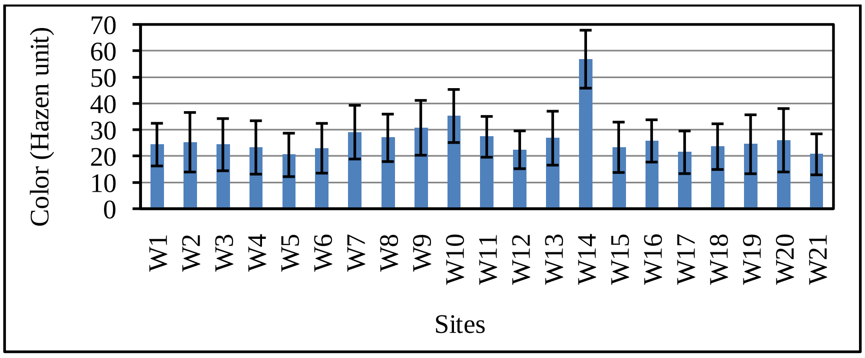

Figure 4.1.3a Standard error of mean of water color (Hazen unit) for studied sites.

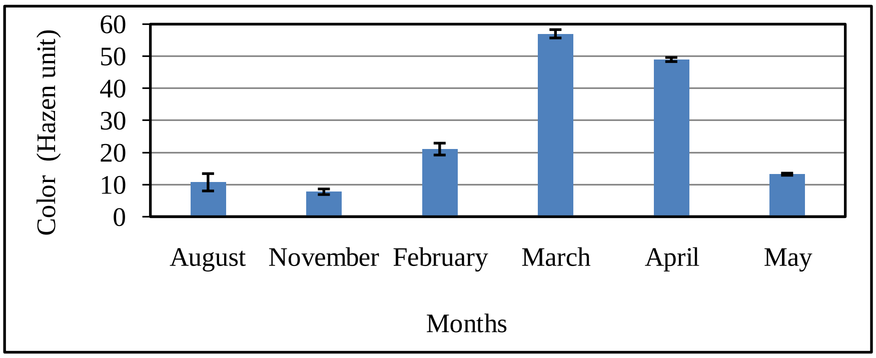

Figure 4.1.3b Standard error of mean of water color (Hazen unit) for studied months.

4.1.4 pH

The values of pH in natural water are affected by geological shed water and balance of CO_2, H_2CO_3 and CO_3^{2-}. It ranged from (7.45 to 8.70). High water volume, greater water retention, high carbon dioxide concentration occurring from organic decomposition, and good buffering capacity of total alkalinity may have been the reason why pH was fluctuated in weak or moderate alkaline medium during all the study and for most part of the study and similar results was observed by (Rasul, 2013). The monthly average values were ranged from (8.09 to 8.27) with significant differences between months has been shown in (Fig. 4.1.4a).

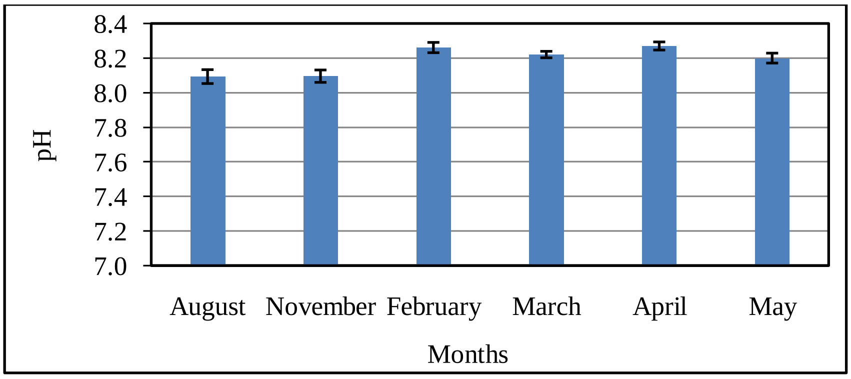

Figure 4.1.4a Standard error of mean of water pH for studied months.

Ezekiel *et al.* (2011) associated low pH value to the rise of CO_2 production and humic acid formation with bacterial respiration in decomposition of organic matter. Among the sites, the highest value 8.70 was found at sampling site (W10-Zharawa) during February. High value of pH in February is due to the rainfall, which may dilute the alkaline substances or the dissolution of the atmospheric carbon dioxide (Sheikh and Yaregi, 2003), whilst the least pH value 7.45 was noted from the sampling site (W21-Qashqoli) during November with significant differences between sites has been given away in (Fig. 4.1.4b). These values are indicative of alkaline conditions, and may be attributable to geological characteristics of the soil over which the rivers flows (Dallas and Day, 2004). In comparison to drinking water quality standards, all the pH values measured were within the permissible limits, although there is no health-based guideline (Appendix 1: Table 4.1.4).

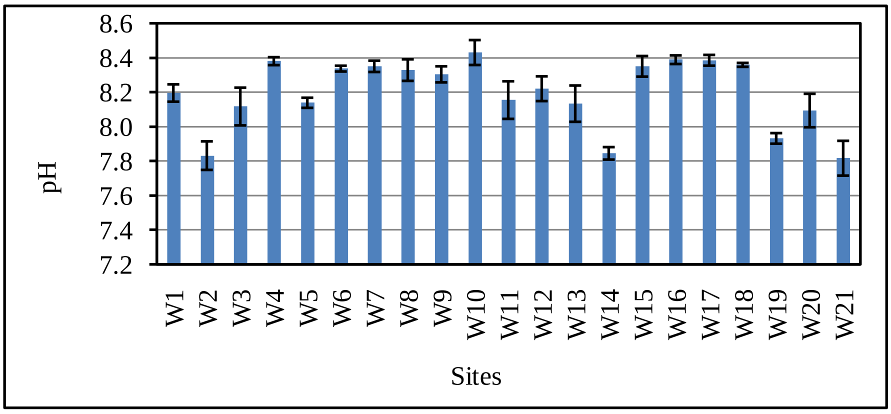

Figure 5.1.4b Standard error of mean of water pH for studied sites.

During the study period in the summer season and during August, photosynthetic activity was reduced due to higher temperature which resulted in the accumulation of carbon dioxide and the subsequent decrease in the pH or higher pH value of summer is due to utilization of bicarbonate and carbonate buffer system (Mehrotra, 1988). Higher pH values during rainy season could be due to discharges of waste into the water. The weakly low pH of water in some sites during the dry season could be due to dissolved carbon dioxide and organic acids resulting from the decayed matter which then eventually leach into the waters. The variations in pH values may be due to increase or decrease of human and other biological activities. The slight alkalinity could be possibly from calcium carbonate bedrock weathering or may reflect the importance of dissolution of limestone and dolomites in the watershed. The presence of higher concentration of bicarbonates in this study caused the rivers water in to alkaline nature.

4.1.5 Electrical Conductivity at field temperature (EC$_t$)

The electrical conductivity values of water samples varied due to different sites and seasons or could be due to content of available soluble ions during months of sampling. Generally the EC$_t$ values ranged from (218 to 976) µS cm^{-1}. The monthly average values were ranged from (410 to 479) µS cm^{-1} with significant differences among months has been shown in (Fig. 4.1.5a). The lowest value 410 µS cm^{-1} was founded in April and May due to the rainfall dilution effect and highest value 479 µS cm^{-1} was detected in August due to high temperature and ionic concentration, same accord was mentioned by (Zewayee, 2011). The main reason behind fluctuation of mean EC values in one month is dumping of huge volumes of toxic wastes into water.

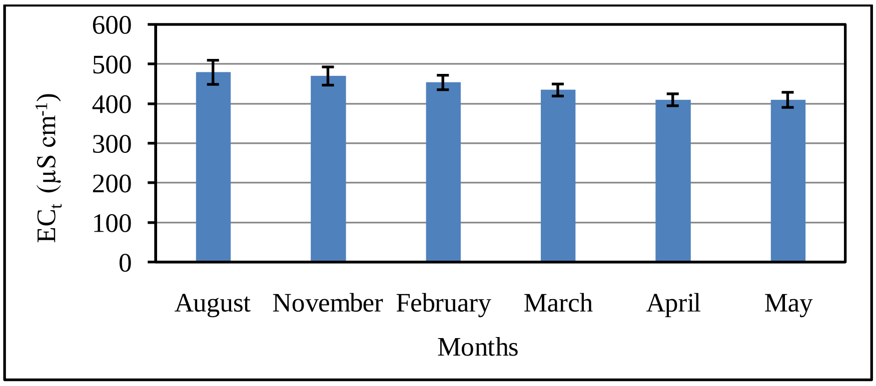

Figure 4.1.5a Standard error of mean of water EC$_t$ (µS cm^{-1}) for studied months.

Among different sites, maximum EC$_t$ value was 976 µS cm^{-1} at sampling site (W18-Hizop) during August might be attributed to the presence of high dissolved ions in the water, which influenced by (W20-Jali) sulfur spring effluents, however concord results were obtained by (Al-Barzingy *et al.*, 2009). Surface and agricultural run-offs might have contributed to the increased concentration of ions in the surface water. However, the high conductivity values may be attributed to high ionic transfer between the water and the surrounding land use as a result of the human activities as well as the temperature also have an effect on the conductivity.

The minimum EC$_t$ value was 218 µS cm^{-1} which was noted at sampling site (W15-Dukan-Lake) during May with significant differences among sites has been exposed in (Fig. 4.1.5b), which might be due to the high dilution effects. There is currently no official guideline as to what is considered safe level for conductivity (Karikari *et al.*, 2007). However, the conductivity of most freshwaters ranged from (10 to 1000) µS cm^{-1}, but many exceed (1000) µS cm^{-1}, especially in polluted waters or those receiving large quantities of land run-off (Chapman, 1992). The EC of natural water is between (170 and 2700) µS cm^{-1} according to number of countries (Appendex1: Table 4.1.5). EC was generally within permissible limits and this attributed to the dilution effect and other natural processes. Conductivity in rivers could be affected primarily by natural factors such as the geology underlying the formation of the catchment through which the water flows. Others include anthropogenic activities such as agriculture that could possibility discharge fertilizers runoff affecting the conductivity of the water as detected in (W14-Bosken, W18-Hizop, W19-Smaquli, and W20-Jali) sites. Dougall (2007) found that streams that run through areas with clayey soils tend to have higher EC because of presence of materials that ionize when washed into water.

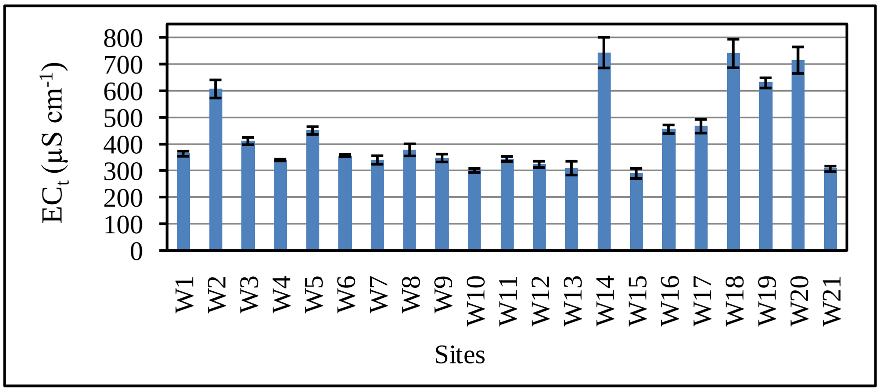

Figure 4.1.5b Standard error of mean of water EC_t (µS cm^{-1}) for studied sites.

4.1.6 Electrical Conductivity at lab temperature (EC_{25} ^{o}C) and salinity

The monthly mean salinity shows similar patterns of monthly distribution in $EC_{25}$$^{o}C$ concentrations. The salinity were ranged (140.88 to 716.97) mg L^{-1} with significant differences among sites (Fig. 4.1.6a1). In comparison to drinking water quality standards WHO and IQS, the optimum acceptable salinity value (1000 mg L^{-1}). All the values measured were within the permissible limits (Appendex1: Table 4.1.6a). The highest monthly mean of salinity 393.80 mg L^{-1} was recorded on the February, this result revealed that the river was alkaline and the lowest mean of 278.55 mg L^{-1} was obtained on the May with significant differences between months (Fig. 4.1.6a2).

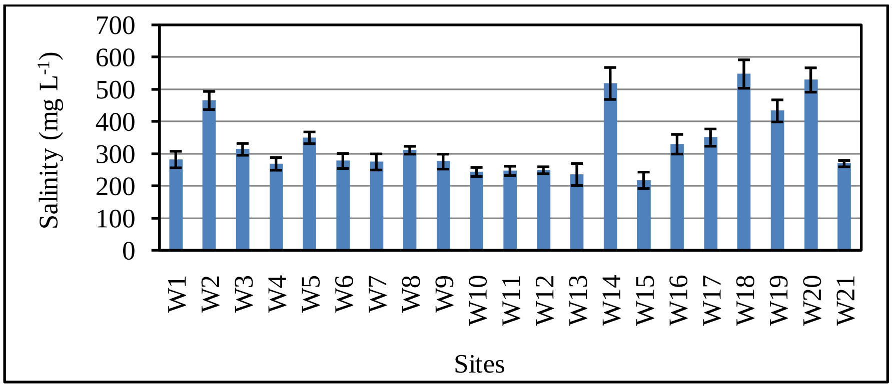

Figure 4.1.6a1 Standard error of mean of water salinity (mg L^{-1}) for studied sites.

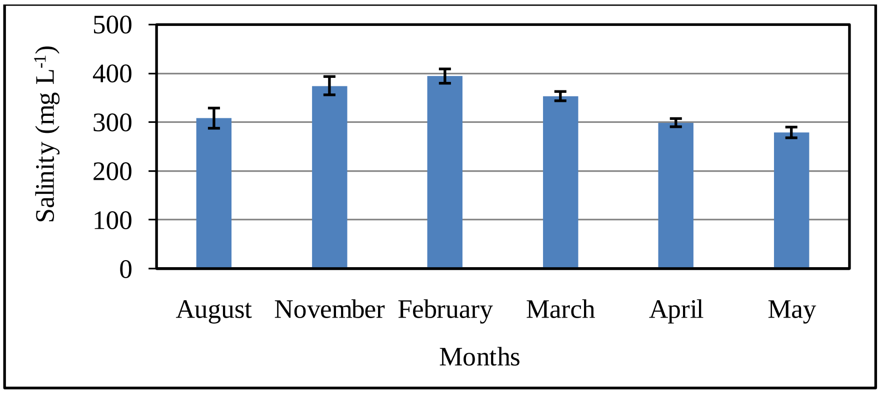

Figure 4.1.6a2 Standard error of mean of water salinity (mg L^{-1}) for studied months.

The electrical conductivity ranged between (220.12 to 1120.26) µS cm^{-1}, while the highest monthly mean of EC$_{25}{}^{o}{}_{C}$ 615.32 µS cm^{-1} was recorded on the February and the lowest mean of 435.23 µS cm^{-1} was obtained on the May (Fig. 4.1.6b1) with significant differences between months. Throughout the sampling periods, measured EC$_{25}{}^{o}{}_{C}$ values were within the permissible limits for drinking water (Appendex1: Table 4.1.6b).

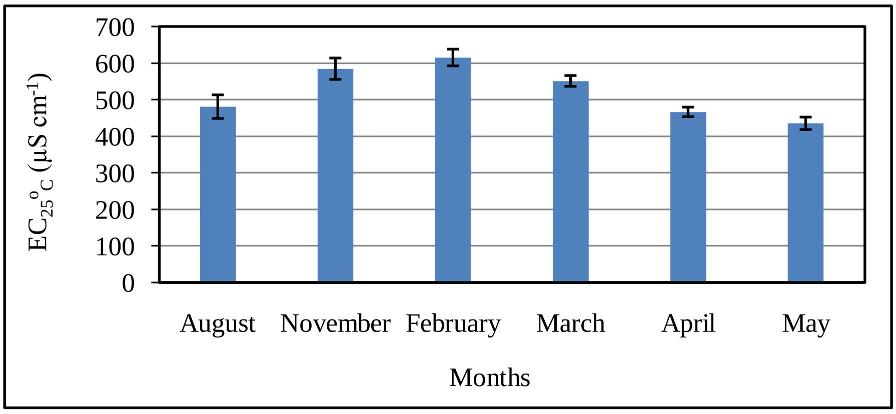

Figure 4.1.6b1 Standard error of mean of water EC$_{25}{}^{o}{}_{C}$ in (µs cm^{-1}) for studied months.

It can be seen that the value of conductivity is more in the samples collected in the month of February as compared to other months. It is depends on the total amount of soluble salts. The highest monthly mean value of $EC_{25}{}^{o}{}_{C}$ was recorded during cold season which probably related to high precipitation and soil leaching processes or due to effluent loaded by salts and dissolved material and same results was observed by (Rasul, 2013). Generally the higher amount of $EC_{25}{}^{o}{}_{C}$ and salinity were recorded during November at sampling site (W14-Bosken) which influenced by (Bosken) village wastewater and higheast mean value of them at (W18-Hizop) site with significant differences between sites as shown in (Fig. 4.1.6b2).

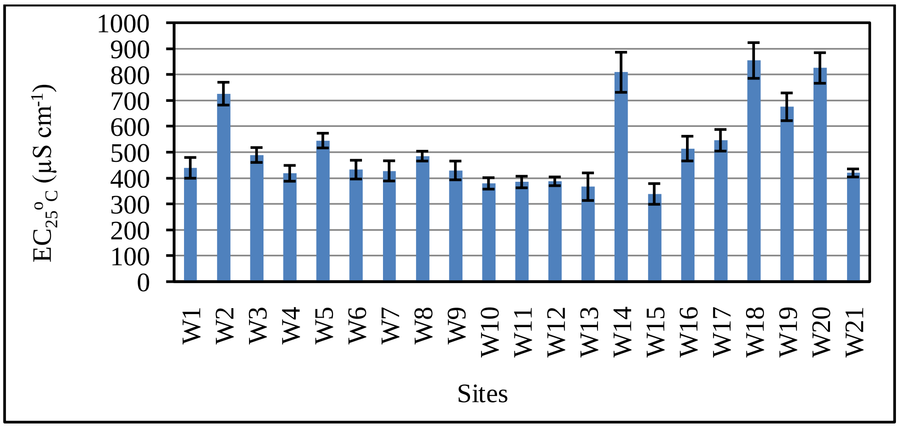

Figure 4.1.6b2 Standard error of mean of water $EC_{25}{}^{o}{}_{C}$ in (µs cm^{-1}) for studied sites.

4.1.7 Dissolved Oxygen (DO)

As shown in (Appendex1: Table 4.1.7) the DO was ranged (4.30 to 10.35) mg L^{-1}. In general, DO level of 3 mg L^{-1} are stressful to most aquatic organisms. The highest amount was recorded during February wich was 10.35 mg L^{-1} at sampling site (W9-Sndollan) due to the high turbulence of water facilitating the diffusion of atmospheric oxygen and the increased solubility of oxygen at lower temperature (Yadav *et al.*, 2014). The lowest value was recorded during May wich was 4.30 mg L^{-1} at water sampling site (W14-Bosken) due to the high temperature and addition of sewage and other waste which can be responsible for low value of DO (Pradeep *et al.*, 2012). The monthly average values were ranged from (5.71 to 8.92) mg L^{-1} with significant differences among months has been shown in (Fig. 4.1.7a). Its highest and lowest values were recorded in February and May months respectively conformity results were revealed by (Goran, 2014).

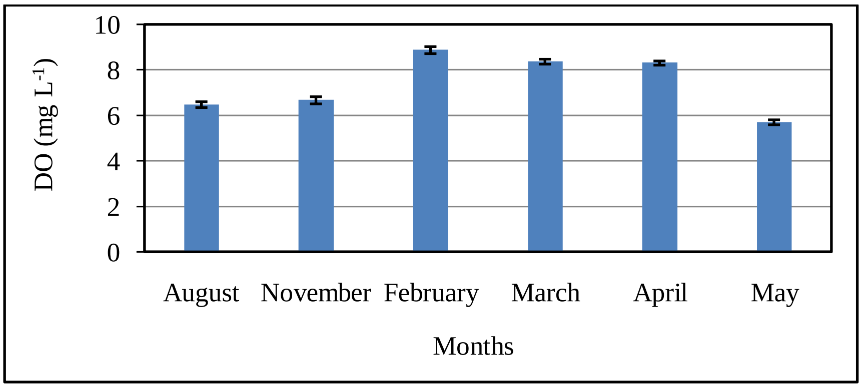

Figure 4.1.7a Standard error of mean of water DO in (mg L^{-1}) for studied months.

DO levels fluctuate seasonally and over a 24-hour periods. They vary with water temperature and altitude. The reduction of DO at some sites (W2-Mawakan), (W14-Bosken) and (W19-Smaquli) during summer and autumn seasons with significant differences among sites has been shown in (Fig. 4.1.7b) can be due to the increasing in the untreated domestic sewage which polluted the water or due to organic pollutants which fasten the consumption of DO in water during warm months (ALHejuje, 2015). Rani *et al.* (2004) also reported lower values of DO in summer season due to higher rate of decomposition of organic matter and limited flow of water in low holding environment due to high temperature.

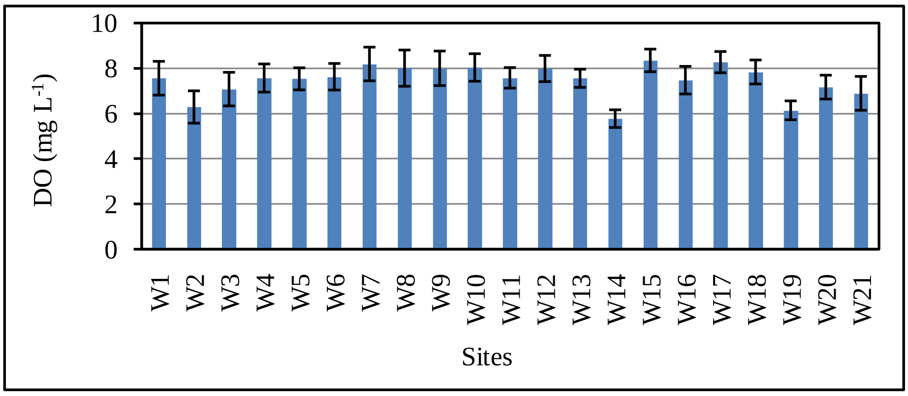

Figure 4.1.7a Standard error of mean of water DO in (mg L^{-1}) for studied months.

4.1.8 Biochemical Oxygen Demand (BOD)

The biochemical oxygen demand values were generally ranged from (0.13 to 78.3) mg L^{-1}. The possible reason for difference observed between the ranges obtained in this study is increase in anthropogenic activities in the river and its tributaries. The monthly average BOD values were ranged from (4.96 to 7.54) mg L^{-1}. The lowest value 4.96 was founded in May, whereas the higher value 7.54 was recorded during March with significant differences between months as shown in (Fig. 4.1.8a).

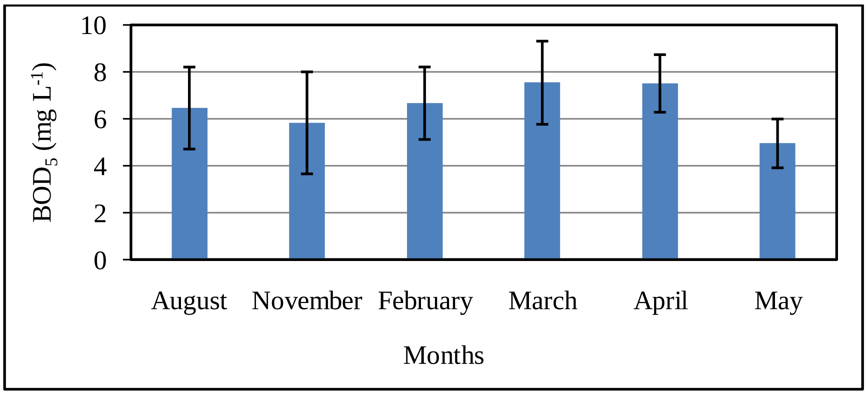

Figure 4.1.8a Standard error of mean of water BOD in (mg L^{-1}) for studied months.

The highest mean BOD concentrations were recorded during the wet season, and coincided with results obtained by (Shekha *et al.*, 2013 and Salman, 2006). An increase in BOD during the rainy season March might have been caused by increased runoff, which transports organic matter and sediments from the catchment into the river (Masese *et al.*, 2009). Conversely, during the dry season May, lower mean concentrations of BOD were recorded, suggesting that there were little or no movement of organic matter from the land, in other side due to self purification action. The slightly low levels of BOD at sampling sites (W3-Shakha-Sur, W10-Zharawa, W13-Darbany-Ranya, W15-Dukan-Lake and W21-Qashqoli) (Fig. 4.1.8b) could be due to dilution effect and natural purification systems along the river system. The highest BOD values recorded in all over the periods at sampling site (W14-Bosken) with significant differences between sites as shown in (Fig. 4.1.8b). This increasing related to organic matter loads discharged in to river from the area near the sewage effluents and agricultural lands, contain different types pollutants and detergents in additional to residual dead algae through the stream (Osibanjo *et al.*, 2011). Additionally, with the exception of some collection points during different periods, all other samples recorded BOD values higher than the WHO limit of (< 3) mg L^{-1} (Appendex1: Table 4.1.8).

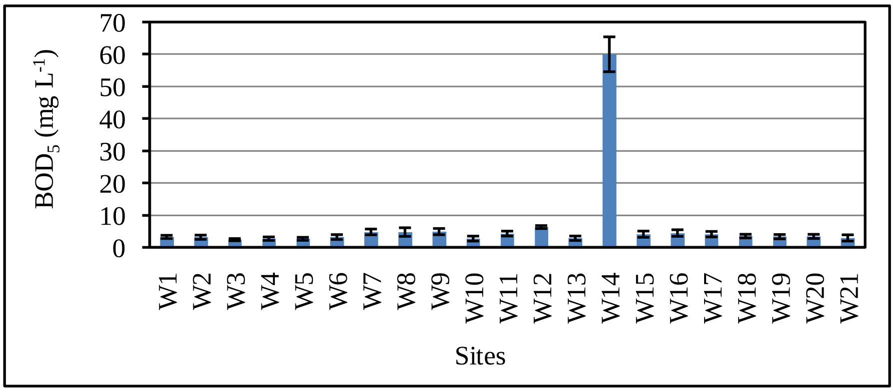

Figure 4.1.8b Standard error of mean of water BOD in (mg L^{-1}) for studied sites.

4.1.9 Total Solids (TS)

The levels of total solids in present study were ranged from (145 to 1449) mg L^{-1}. The monthly mean TS concentrations were ranged from (279 to 357) mg L^{-1} with significant differences between months as stated in (Fig. 4.1.9a). The fluctuations of TS between the sites as well as the months were at the moderately case. Minimum value of TS 145 mg L^{-1} at sampling site (W15-Dukan-Lake) was evident with the high water level of May due to the excessive dilution, stagnation and low rate of evaporation. Maximum TS 1449 mg L^{-1} was recorded at sampling site (W12-Doli-Shahidan) during November, with significant differences between months as stated in (Fig. 4.1.9b) may be due to the presence of silt and clay particles in the river water as aresult of earth-disturbing activity and erosion process due to the steep slope of the area (Sarwar, 2010). Comparison to drinking water quality standard, all the TS values measured were within the permissible limit except sampling site (W12) during November (Appendex1: Table 4.1.9).

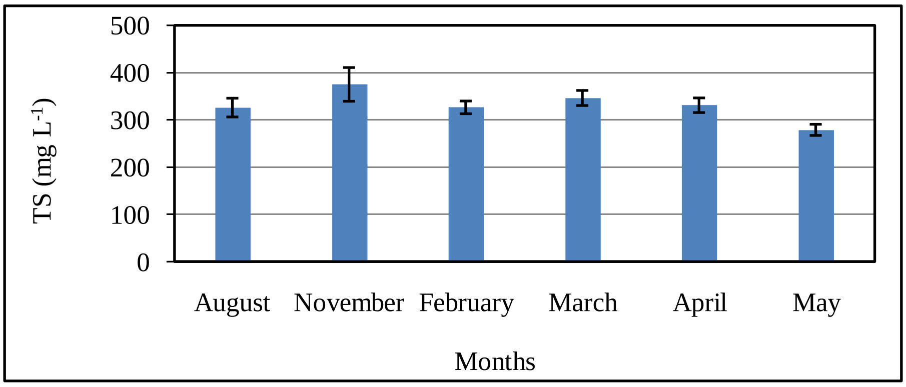

Figure 4.1.9a Standard error of mean of water TS in (mg L^{-1}) for studied months.

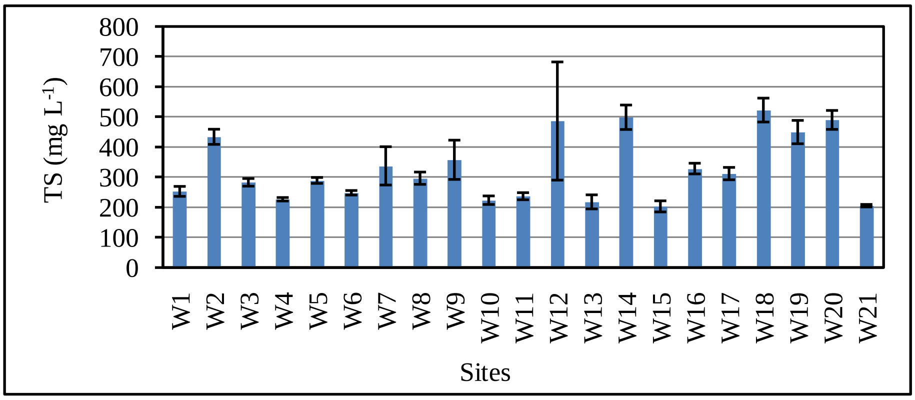

Figure 4.1.9b Standard error of mean of water TS in (mg L^{-1}) for studied sites.

4.1.10 Total Dissolved Solids (TDS)

The total dissolved solids values were fluctuated from (126 to 611) mg L^{-1}. The monthly average values were ranged from (236 to 299) mg L^{-1} with significant differences between months has been shown in (Fig. 4.1.10a). Increasing and decreasing of TDS values were possibly related to the agricultural run-off, rapid urbanization, over utilization of the catchment, and water-erosion from catchments watershed. High values of TDS recorded during August and November as a result of high ionic concentration and temperature. Lower value of TDS recorded in May might be due to sedimentation of suspended solids and slow decomposition rate during May (Imnatoshi and Sharif, 2012). The observed values were within the permissible limit as revealed in (Appendex1: Table 4.1.10).

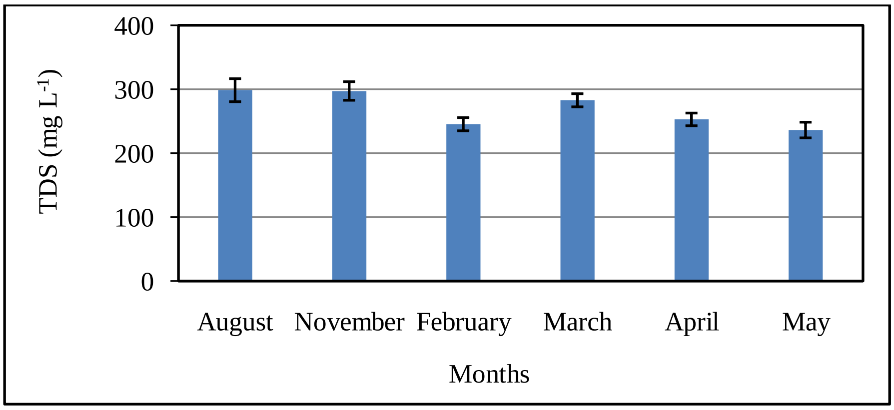

Figure 4.1.10a Standard error of mean of water TDS in (mg L^{-1}) for studied months.

The major reasons for the highest TDS 611 mg L^{-1} at sampling site (W18-Hizop) river during the August, with significant differences between sites has been shown in (Fig. 4.1.10b) it is related to the study area is known for heavy agricultural activities and high ionic concentration in water. Land fertilizing, would be the reason for the highest TDS value. In addition to natural salinity attributable to geology, anthropogenic input in aquatic ecosystems and high water evaporation also lead to high TDS concentrations (Van der Laan *et al.*, 2012). Perhaps, runoff and storm water from residential areas may also contribute to increased salts in the water body, while the lowest values 126 mg L^{-1} were found at sampling sites (W8-Hallsho) during April, (W13-Darbany-Ranya) and (W15-Dukane-Lake) during May are attributable to the geological characteristics of soil over which the river flows and due to rainfall dilution effects.

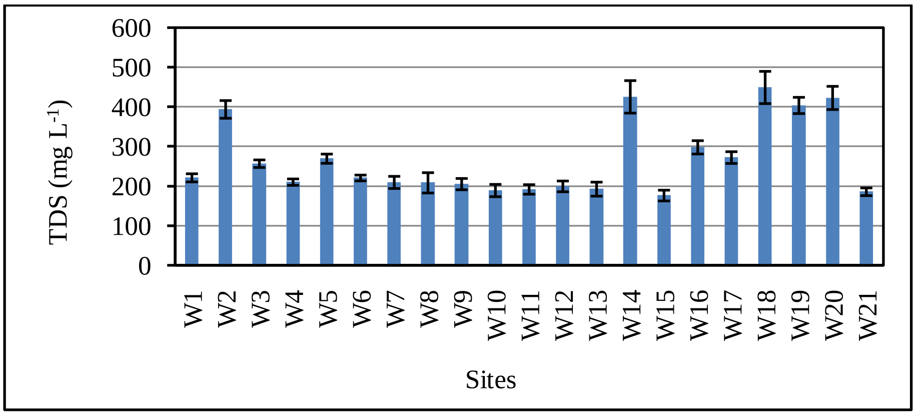

Figure 4.1.10b Standard error of mean of water TDS in (mg L^{-1}) for studied sites.

4.1.11 Total Suspended Solids (TSS)

The TSS values ranged from (1 to 1228) mg L^{-1}. The monthly average values were ranged from (27 to 81) mg L^{-1} with significant variation between months as shown in (Fig. 4.1.11a). The lowest monthly mean value of TSS was recorded during August due to low rainfall and low levels of water in the rivers; on the other hand highest monthly mean value of TSS was founded during February due to effects of soil erosion and surface runoff by high intensity of water in the rivers and the same results were recorded by (Duru *et al.*, 2018). Generally the value of TSS should be between (25-40) mg L^{-1} according to WHO, if we are using water for drinking purposes. But here it can be clearly seen that the values are much more than that (Appendex1: Table 4.1.11).

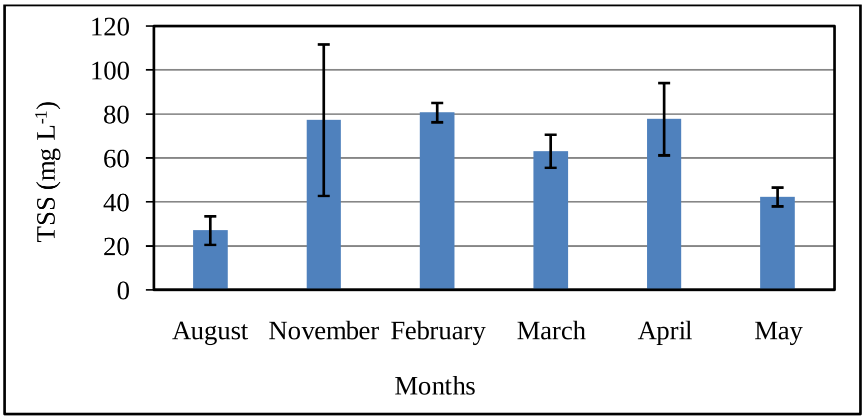

Figure 4.1.11a Standard error of mean of water TSS in (mg L^{-1}) for studied months.

Normally, soil erosion considers the source for suspended solids that comes from the surrounding area caused by human activities. It can be seen that sampling site (W12-Doli-Shahidan) has the highest observed TSS value 1228 mg L^{-1} during November due to earth-disturbing activities and construction work like sand washers without erosion control with significant variation among sites as exposed in (Fig. 4.1.11b). The lowest observed TSS 1 mg L^{-1} can be seen at sampling site (W20-Jali) and (W21-Qashqoli) during November and August due to low soil erosion. In general, there was a decreasing trend of TSS values from the upstream to the downstream sites due to the settlement processes of suspended.

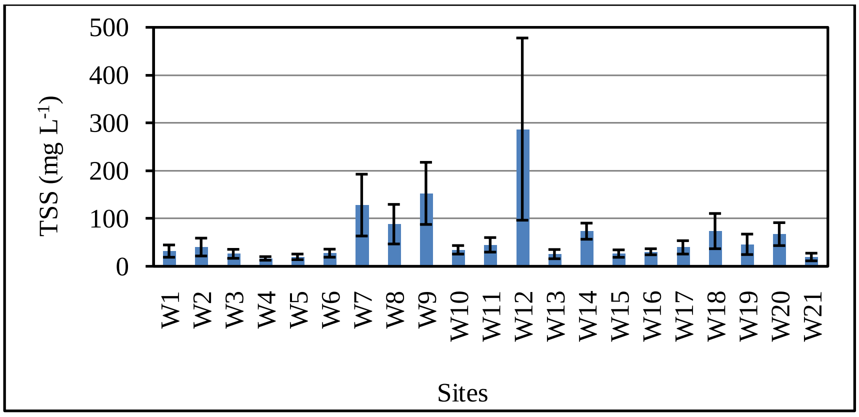

Figure 4.1.11b Standard error of mean of water TSS in (mg L^{-1}) for studied sites.

4.1.12 Nitrate-Nitrogen (NO_3-N)

The NO_3-N values were ranged from (1.1 to 7.9) mg L^{-1}. The monthly average values were ranged from (2.1 to 5.6) mg L^{-1} with significant monthly variation as shown in (Fig. 4.1.12a). The lowest amount of nitrate was recorded during November by the utilization of nitrate by plankton and aquatic plants (Verma *et al.*, 2012), or due to low surrounding runoff and high microbial activity in the rivers; on the other hand the highest amount of nitrate was recorded during March because of high vegetation during rainy which supported the growth of plankton (Pandit and Solanki, 2004), or due to the effects of agriculture activities and surface waste runoff by high rainwater. A same result was indicated by (Rasul, 2013).

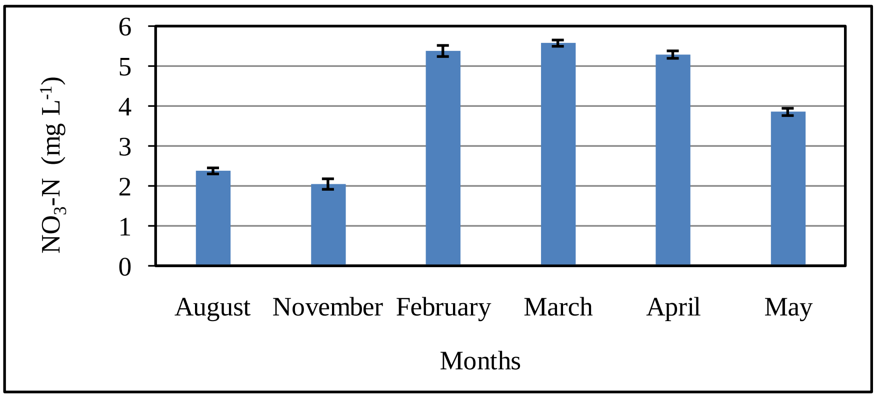

Figure 4.1.12a Standard error of mean of NO_3-N in water (mg L^{-1}) for studied months.

The nitrate content was fluctuated between the sites with significant differences as revealed in (Fig. 4.1.12b). Among different sites, maximum concentration was found as 7.9 mg L^{-1} at sampling site (W6-Qashan) during February. Minimum concentration was noted as 1.1 mg L^{-1} at some sites during November. Nitrogen is the chief constituent of organic matter. When this organic matter gets decomposed, release ammonia which in turn converted to nitrate if there is oxygen (Boyd and Tucker, 1998). The nitrate content of studied sites was well within the WHO and IQS standard guidelines permissible limits (<50 mg L^{-1}), and therefore not polluted with nitrate (Appendex1: Table 4.1.12).

The levels of nitrate recorded at the study area could be as a result of certain natural processes like decomposition of vegetation and activities of nitrogen fixing by bacteria and precipitation. The time of the study could be a factor for the nitrate levels recorded because during rainy seasons concentrations of nitrate were likely to rise since the volume of waste in the stream increased. Most importantly, the major causes of high nitrate concentration could be due to the continuous human activities nearby the studied catchments. The location of a landfill, a waste and a refuse dump very close to the rivers and coupled with runoffs from residential areas and agricultural fields input nitrate into the rivers.

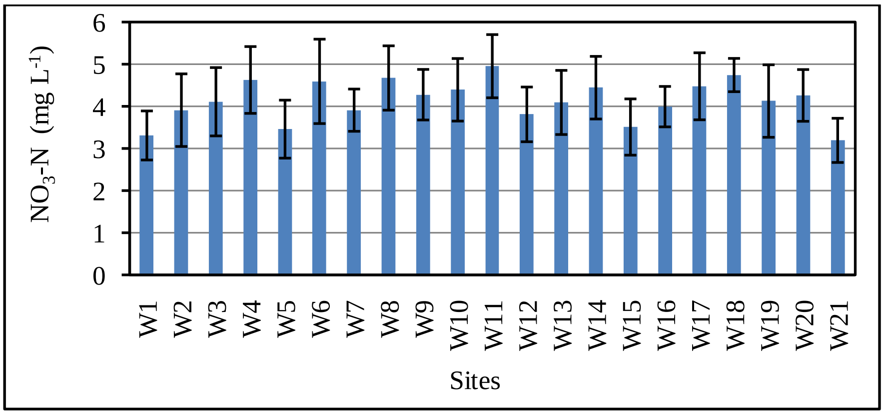

Figure 4.1.12b Standard error of mean of NO_3-N in water (mg L^{-1}) for studied sitess.

4.1.13 Nitrite-Nitrogen (NO_2-N)

The NO_2-N concentration values were ranged from (0.01 to 0.22) mg L^{-1}. The monthly average concentrations of nitrite ranged from (0.02 to 0.05) mg L^{-1} with significant differences between months (Fig. 4.1.13a). Also it is clear from the results that high concentration of nitrite was recorded in March compared to other months. Organic matter and dissolved oxygen negatively affect nitrite concentration (Goran, 2006).

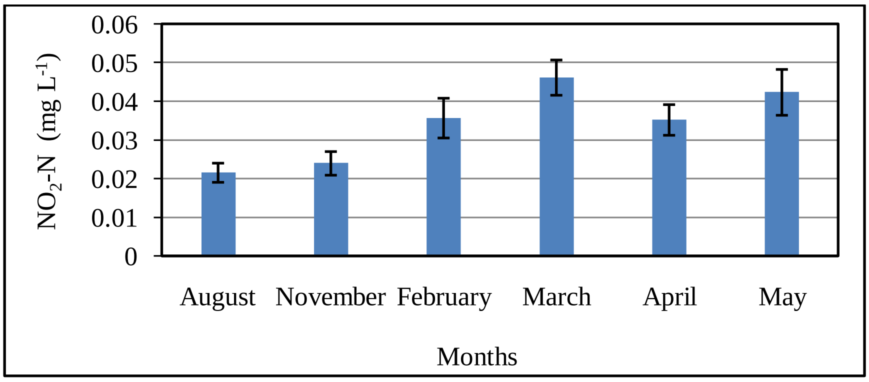

Figure 4.1.13a Standard error of mean of NO_2-N in water (mg L^{-1}) for studied months.

In this study the concentration of nitrite was found in small amount in all sampling sites and to some extent increased in the sampling site (W14-Bosken), with significant differences between sites (Fig. 4.1.13b). These may be due to organic wastes, agricultural fertilizers, intensive livestock operations, surface runoff, sewage discharge and atmospheric deposition into the river (WHO, 2004). In the normal status the lake nitrite level never be greater than 0.001 mg L^{-1} (Chapman, 1996), however, in this study it reaches to 0.22 mg L^{-1} with strongly agreement observes by (Worako, 2015). WHO and IQS guideline value retains the value of (3 mg L^{-1}) as a quality standard for drinking water (Appendex1: Table 4.1.13). However, all observed results were below the permissible limit for drinking water. Nitrate concentrations in surface waters tend to be higher than nitrite because nitrite rapidly oxidizes to nitrate.

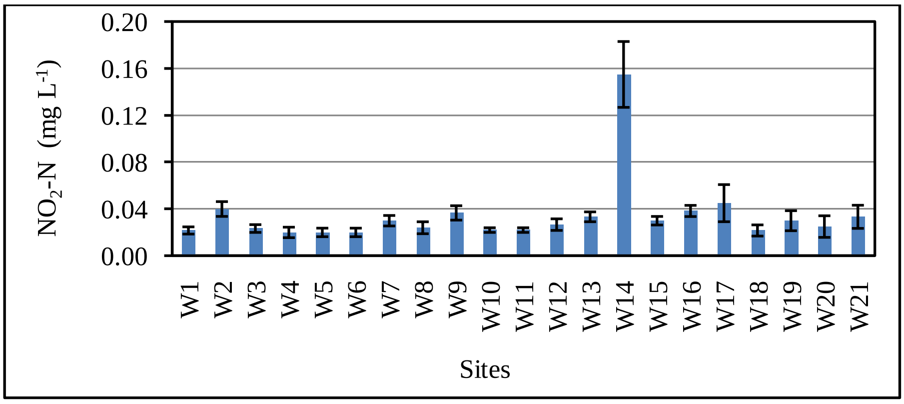

Figure 4.1.13b Standard error of mean of NO_2-N in water (mg L^{-1}) for studied sites.

4.1.14 Ammonium-Nitrogen (NH_4-N)

Ammonia is one of the most important water pollutants in the aquatic environment because it is highly toxic and presence in surface water. The NH_4-N values ranged from (0.03 to 5.1) mg L^{-1}. The monthly mean concentrations of NH_4-N have been presented in (Fig. 4.1.14a) ranged from (0.59 to 0.91) mg L^{-1} with significant differences among months. However, the mean value of river water samples exceeded the admissible level of WHO guideline value for safety drinking water (1.5 mg L^{-1}) at few sites (Appendex1: Table 4.1.14) and they were strongly agreed with same findings of (Maulood and Hinton, 1978a). These high values could be explained by anthropogenic activities, use of animal waste as fertilizer for agricultural land. The highest values of NH_4-N during August and May in all sites were probably related to high values of temperature and the increase in bacterial growth. While the lowest levels of NH_4-N during March and April correlated with great dilution effect capacity of the water by rainfall, highest water velocity as well as to lower water temperature (Goran, 2014).

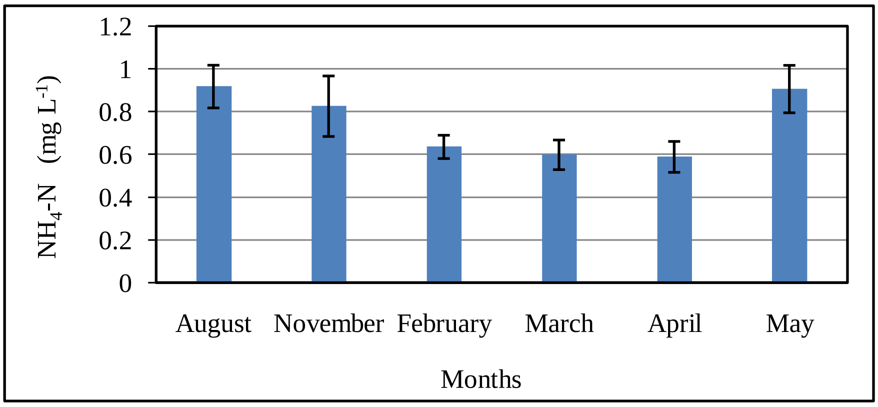

Figure 4.1.14a Standard error of mean of NH_4-N in water (mg L^{-1}) for studied months.

Among the sites, the highest average NH_4-N concentration was found at sampling site (W14-Bosken) 5.10 mg L^{-1} with significant differences as shown in (Fig. 4.1.14b) due to leaching or run-offs from agricultural land and contamination from human waste or animal waste from (Bosken village); while the lowest average NH_4-N concentration was noted from the sampling site (W6-Qashan) 0.03 mg L^{-1}. This is probably attributed to the utilization of NH_4-N by phytoplankton along the river.

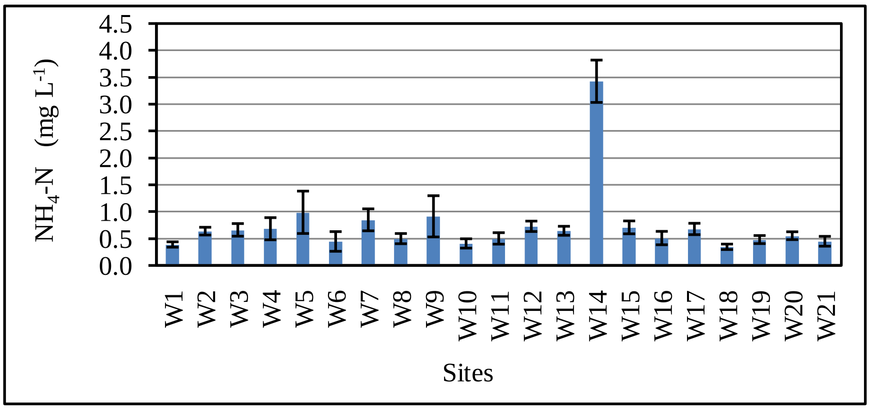

Figure 4.1.14b Standard error of mean of NH_4-N in water (mg L^{-1}) for studied sites.

4.1.15 Phosphates (PO_4-P)

As mentioned by (Girija *et al.*, 2007) the natural sources of phosphorus in water were from the leaching of phosphates being rocks and organic matter decomposition as well as anthropogenic activities. From the results it was observed that PO_4-P concentrations were ranged from (0.01 to 1.16) mg L^{-1}. The monthly average concentrations of PO_4-P ranged from (0.09 to 0.15) mg L^{-1} with significant differences between months (Fig. 4.1.15a).

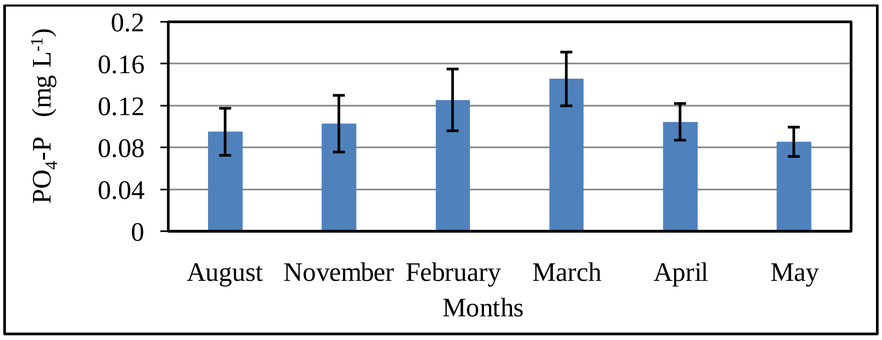

Figure 4.1.15a Standard error of mean of PO_4-P in water (mg L^{-1}) for studied months.

High phosphorus values were recorded during rainy season and winter in comparison to other seasons which characterized by lower phosphorus concentrations, possibly related to the effect of rainfall (Fattah, 2010). High phosphate values could also be contributed by agriculture runoffs during the beginning of the rainy season (Kuyeli *et al.*, 2009) and the high values of phosphate were mainly due to rain, and surface water runoff. When a river or a creek passes through an agricultural area, for instance, the phosphorus load may show a higher concentration compared to other parameters present in the surface water. Among the sites, the highest average PO_4-P concentration was found at sampling site (W14-Bosken) 1.16 mg L^{-1} during February, while the lowest average PO_4-P concentration was noted from the sampling site (W2-Mawakan) 0.01 mg L^{-1} during May with significant differences (Fig. 4.1.15b).

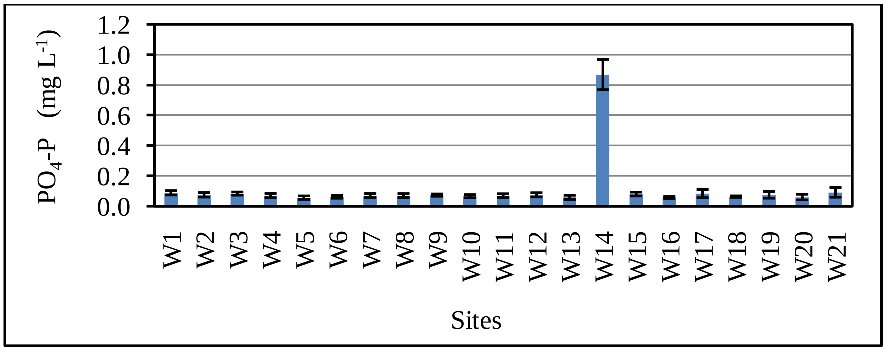

Figure 4.1.15b Standard error of mean of PO_4-P in water (mg L^{-1}) for studied sites.

High phosphorus values can occur due to both natural and human factors. These include the geological characteristics of soil and rocks, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas and detergents. Concrete evidence for sampling site (W14-Bosken) has a high presence of PO_4-P compared with the rest of the sampling sites was that domestic and animal wastes from the (Bosken village) were into to the water source. The high concentration during warm periods May and August could be attributed to decay and subsequent mineralization of dead organic matter, while low concentration during warm periods May and August is attributed to the utilization of nutrients by autotrophs (Kaul *et al.*, 1978).

The lower phosphate values reported during February 0.03 mg L^{-1} (Appendix 1: Table 4.1.15) may be correlated to its locking PO_4-P by macrophytes and phytoplankton during their bloom decreasing their level in water (Kant and Raina, 1990). Hutchinson (1957) has concluded that the quantity of phosphates increases due to sewage contamination in water bodies like at (W14-Bosken) in this study.

4.1.16 Calcium ion (Ca^{2+})

The main source of Ca^{2+} is the chemical weathering of rocks and minerals, such as limestone and dolomite. The source of calcium in the studied area is from the geological units which are dominated by carbonate formations such as (Qamchuqa, Kometan and Sarmord) (Rasul, 2013). Calcium ranged from (24.54 to 97.68) mg L^{-1}. The monthly average calcium ranged from (52.70 to 61.93) mg L^{-1} with significant differences among months as shown in (Fig. 4.1.16a).

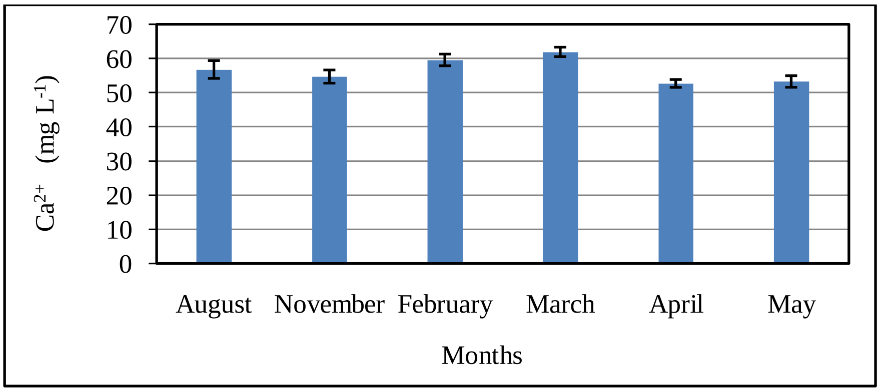

Figure 4.1.16a Standard error of mean of Ca^{2+} in water (mg L^{-1}) for studied month.

The values were small amount higher during rainy season all over sites because of the surrounding rocks and soils in contact with water and weathering increases during the rainy resulting in the increased amount of dissolved material that precipitates downward causing increased values with flow. The lower content observed during dry season might be due adsorption to sediments, and utilization by phytoplankton (Manju *et al.*, 2012). The amount of calcium increased during August and November at sampling sites (W2-Mawakan), (W14-Bosken), (W16-Qarani-Agha), (W19-Smaquli), and (W20-Jali) compared to other months, with significant differences among sites as shown in (Fig. 4.1.16b) due to rapid oxidation/decomposition of organic matter that present in animal and sewage waste was mixed with water resources.

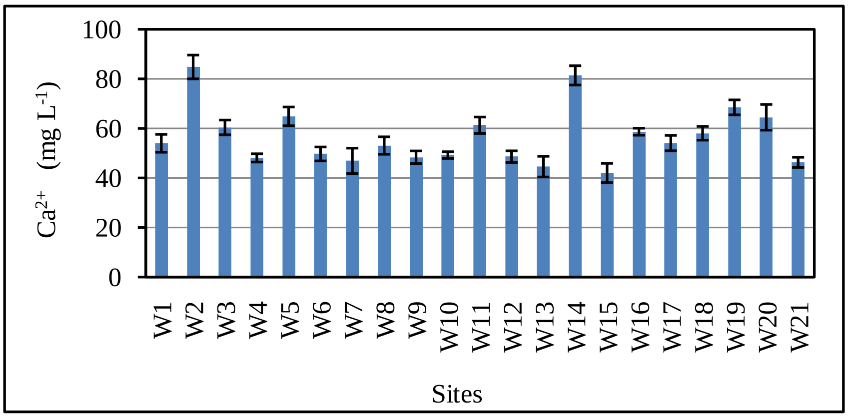

Figure 4.1.16b Standard error of mean of Ca^{2+} in water (mg L^{-1}) for studied sites.

Throughout the sampling periods, measured Ca^{2+} concentrations were within the ranges of drinking standard guidelines (Appendix 1: Table 4.1.16) and same results were founded by (Melaku *et al.*, 2007). The Ca^{2+} values in the rivers are higher than this within the Lake all over periods (Appendix 1: Table 4.1.16) which means that more Ca^{2+} was getting dissolved by the running water as they flow on carbonate dominated rock formations while it was diluting within the Dukan Lake.

4.1.17 Magnesium ion (Mg^{2+})

Magnesium has different uses which end up in the environment originating from carbonate rocks (Greenwood and Earnshaw, 1997). Magnesium is often associated with calcium in all kinds of waters, but its concentration remains generally lower than the calcium due to the fact that the dissolution of magnesium rich minerals is slow process. The amount of magnesium ranged from (7.29 to 54.12) mg L^{-1}. The monthly average magnesium ranged from (18.41 to 25.70) mg L^{-1} significant differences among months as shown in (Fig. 4.1.17a). The highest amount of magnesium was recorded during November due to low levels of water into rivers with high ionic concentration, while the lowest value was recorded during March due to high growth of phytoplankton and more absorbed magnesium in addition to dilution effect when peak rainfall was recorded. According to standards the Mg^{2+} is within the permissible limits and has no any side effect on health (Appendix 1: Table 4.1.17). Mg^{2+} has the same source rocks as Ca^{2+} which is carbonates by the weathering effect which is the dominant in the study area.

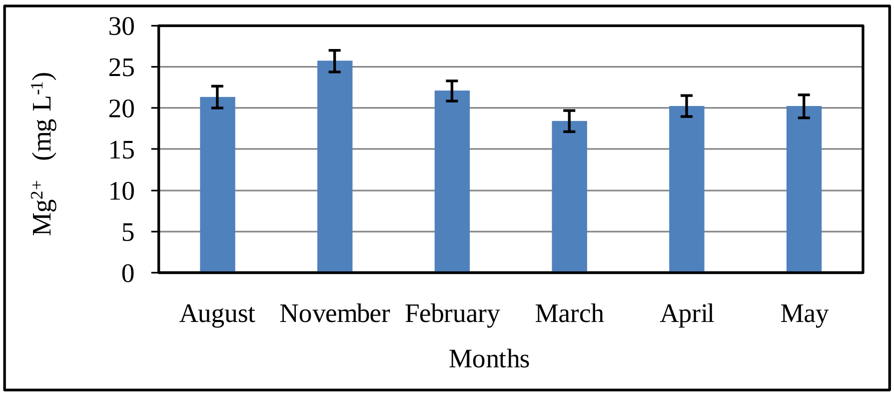

Figure 4.1.17a Standard error of mean of Mg^{2+} in water (mg L^{-1}) for studied months.

From (Fig. 4.1.17b) it is quite evident that the increase levels magnesium concentration and more notably at sampling site (W18-Hizop) which is located in the agricultural and residential environs having the highest concentrations. The present results indicated that concentrations of calcium in water samples were higher than that for magnesium in most studied months, however the solubility of CO_2 by calcium higher than that for magnesium. Magnesium tends to precipitate (Goldman and Horne, 1983) due to the high concentration of sulfate ions as magnesium sulfate (Hakala, 2004). In some months, the concentration of magnesium exceeded calcium concentrations; this may be due to consumption of calcium by organisms (Wetzel, 2001) or may be due to the additional amounts of coming magnesium from agriculture area of river side's (Salman, 2006).

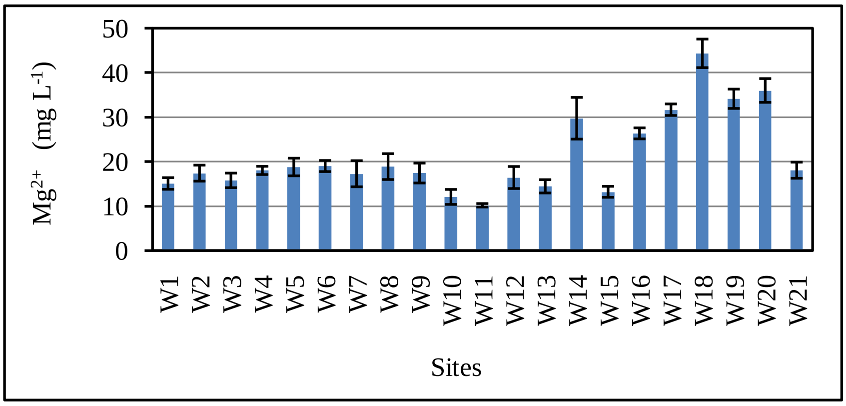

Figure 4.1.17b Standard error of mean of Mg^{2+} in water (mg L^{-1}) for studied sites.

4.1.18 Total Hardness as ($CaCO_3$)

The total hardness sources are from (limestone, dolomite, gypsum, and anhydrite) in the river sediments. TH is due to the presence of bicarbonate, sulfate, chlorides and nitrates of calcium and magnesium. It is total concentration of calcium and magnesium ions (APHA, 1998). The TH ranged from (121.41 to 377.14) mg L^{-1}. The highest amount of TH in the water was recorded during August was 377.14 mg L^{-1} at sampling site (W18-Hizop) due to presence of high content of calcium and magnesium in addition to sulfate and nitrate (Pawar and Pulle, 2005). The lowest amount of TH 121.41 mg L^{-1} was recorded during May at sampling site (W15-Dukan-Lake) due to low concentration of calcium and magnesium by dilution effect (Salve and Hiware, 2006,) with significant differences between sites as shown in (Fig. 4.1.18a).

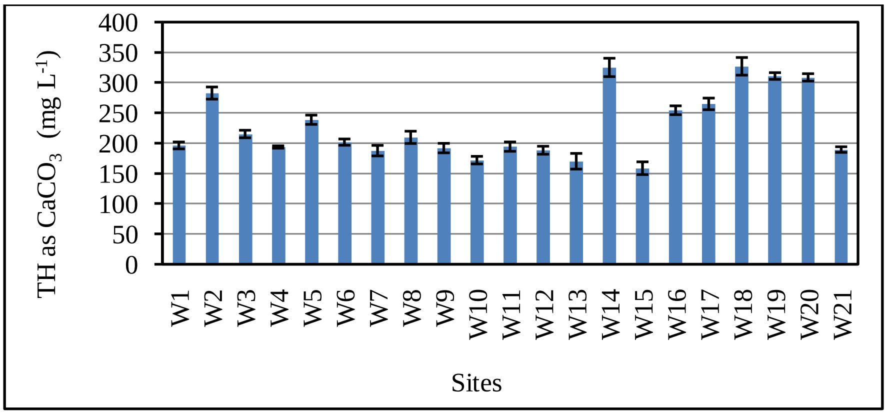

Figure 4.1.18a Standard error of mean of TH in water (mg L^{-1}) for studied sites.

The monthly values of TH ranged from (214.85 to 239.53) mg L^{-1} with significant differences between months as shown in (Fig. 4.1.18b). The differences recorded among months of total hardness caused by the soil wash out and agricultural flow. The results showed an increase in average during February 239.53 mg L^{-1} due to the erosion of soils toward the river as a results of rainfalls and reaching the pollutants to river water from the municipal wastes that close to the river, as well as the agricultural wastes from the nearby lands, all of that lead to raising the rates of hardness in the water. The utilization of calcium and magnesium by organisms and reduced inflow rate of water must have caused the decrease in the concentration of the total hardness in April 214.85 mg L^{-1}. In addition to the growth of algae and phytoplankton in spring season which consume high amounts of CO_2 and reduce hardness values of water.

Moreover, the concentration of hardness in all sites did not create any water quality problems because the hardness concentration was on the recommended limit of guideline standards (Appendix 1: Table 4.1.18).

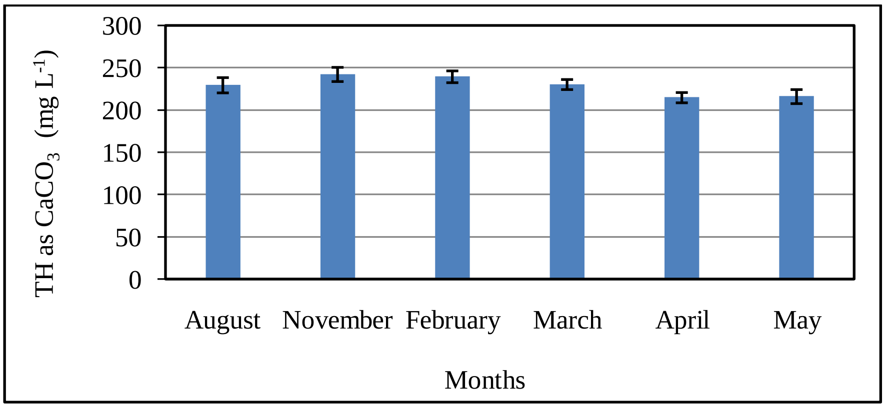

Figure 4.1.18b Standard error of mean of TH in water (mg L^{-1}) for studied months.

4.1.19 Sodium (Na^+)

Sodium concentrations are depending on geological conditions and may also end up in water from industries. The source of Na^+ is the Na-bearing rock-forming minerals. Human activities also can have a significant influence on the concentration of sodium in surface water. The levels of sodium were ranged from (2.89 to 93.25) mg L^{-1}. It is expected that human activities are possible sources for this sodium enrichment in the studied area. The monthly average sodium ranged from (10.46 to 21.32) mg L^{-1} with significant differences among months as shown in (Fig. 4.1.19a). Evaporation of water and high ionic concentration are two important factors in increasing sodium level during August.

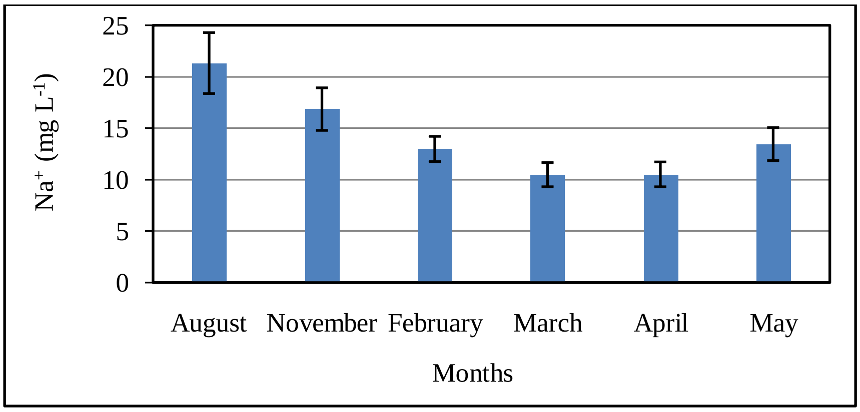

Figure 4.1.19a Standard error of mean of Na^+ in water (mg L^{-1}) for studied months.

The variation was also strongly linked to seasonal fluctuation and higher values were observed during the dry season at sampling site (W18-Hizop) 93.25 mg L^{-1} in August and (W14-Bosken) 67.94 mg L^{-1} in November, with significant differences among sites as shown in (Fig. 4.1.19b). This increase can again be attributed to increased agricultural activities and sewage effluent. According to (Chin, 2006) concentrations of Na^+ in surface waters may arise from sewage and industrial effluents which directly join lake water. Its concentration falls within the permissible limit as prescribed by standard guidelines (Appendix 1: Table 4.1.19).

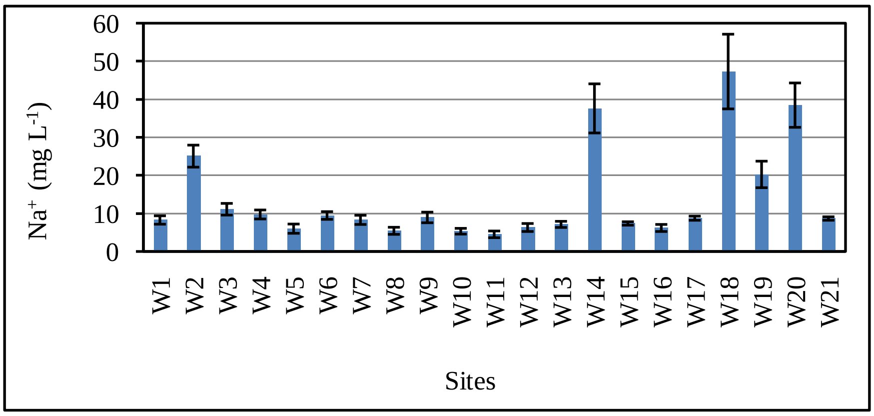

Figure 4.1.19b Standard error of mean of Na^+ in water (mg L^{-1}) for studied sites.

4.1.20 Potassium (K^+)

The main sources of potassium in water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation, its concentration in natural waters is usually quite low. This is due to the fact that potassium minerals offer resistance to weathering and dissolution. Generally, the low concentration of K^+ in water is related to the stability of potassium-bearing alumina-silicate minerals (Hem, 1989). The K^+ concentration values ranged from (0.69 to 9.51) mg L^{-1} (Fig. 4.1.20a). The monthly mean ranged from (1.64 to 2.70) mg L^{-1} with significant differences between months as shown in (Fig. 4.1.20b). The lowest and highest concentration of K^+ in water may be due to the fact that most potassium-bearing minerals are resistant to decomposition by weathering processes and fairly low concentrations of ionic potassium in water (Sravanthi and Sudarshan, 1998). Their ranges are within the standards permissible limit for drinking water (Appendix 1: Table 4.1.20).

Both cations showed similarity in the timing of increase and decrease tough keeping with results observed by (Goran, 2014). This phenomena of declined and raised of (Na^+) and (K^+) during August to April then increased toward May possibly related to increasing rainfall at that seasons, and evaporates as well as human activity like fertilizer and domestic (Owen and Wagner, 1972). Generally, results showed that sodium concentration was higher than that of potassium over the entire periods of study.

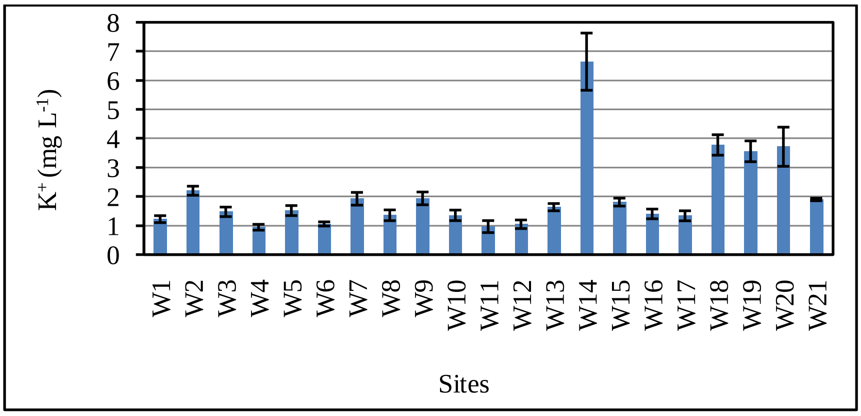

Figure 4.1.20a Standard error of mean of K^+ in water (mg L^{-1}) for studied sites.

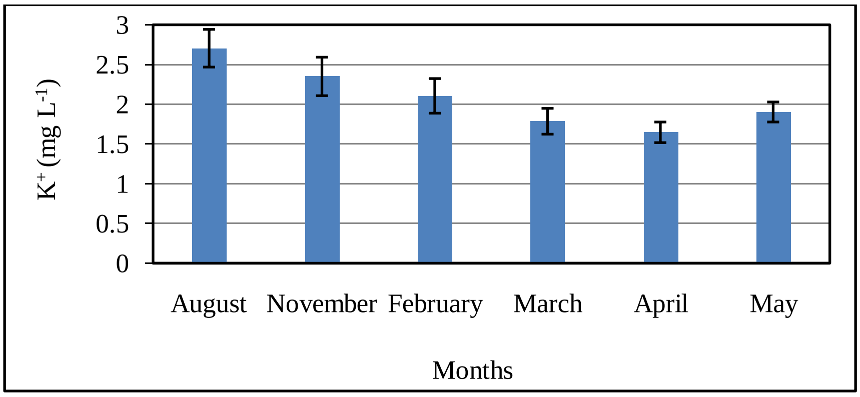

Figure 4.1.20b Standard error of mean of K^+ in water (mg L^{-1}) for studied months.

4.1.21 Chloride (Cl^-)

Chloride is an important quality parameter that affects the aesthetic property of water including taste and makes it unsuitable for drinking purpose if present in high concentration (Abdulrafiu *et al.*, 2011). The sources of chloride in natural water could be attributed to the dissolution of chloride-containing minerals and rocks when water comes in contact with them and due to pollution from discharge of agricultural, industrial and domestic wastewaters which get their way into the water sources (Bohlke, 2002). The chloride concentration values were ranged from (1.87 to 116.09) mg L^{-1}. It was reported from the study area that the monthly average ranged from (10.19 to 29.64) mg L^{-1} with significant differences between months (Fig. 4.1.21a). The high level of Cl^- could be due to discharge from agricultural and domestic wastewaters.

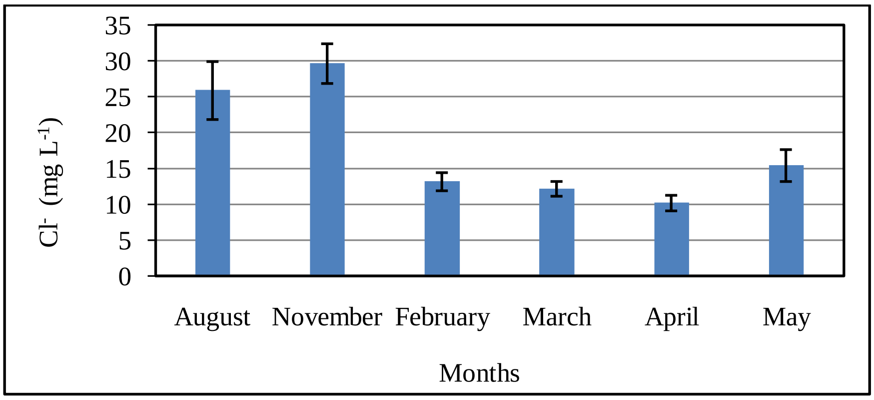

Figure 4.1.21a Standard error of mean of Cl^- in water (mg L^{-1}) for studied months.

As a result of high mineral content in water, agriculture runoff, sewage effluents we were recorded highest values of chloride at sampling site (W14-Bosken), (W18-Hizop), and (W20-Jali) during different months, with significant differences between sites (Fig. 4.1.21b). These can be attributed to mixing of municipal sewage and domestic waste with river water. The highest chloride was reported during August 116.09 mg L^{-1} due to mineral contents in the water with contaminated water from the surrounding area and high evaporation of water (Verman, 2009). The lowest value of chloride was recorded during February 1.87 mg L^{-1} due to the dilution of stream water by rain (Shastry *et al.*, 1972). They are all within the range of values recommended by standard guideline values for drinking water (Appendix 1: Table 4.1.21).

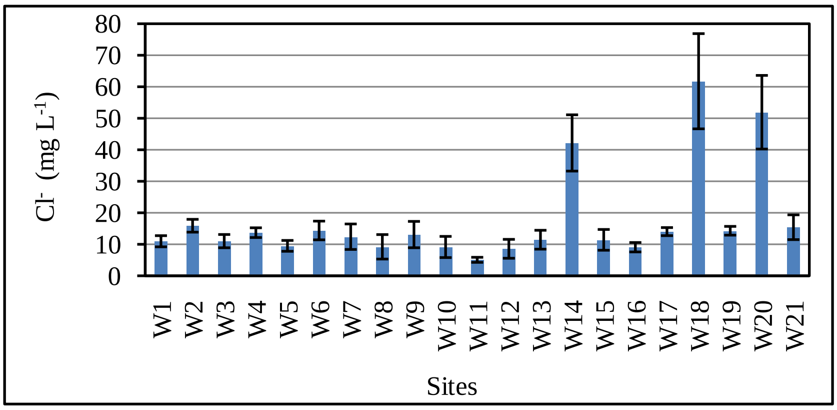

Figure 4.1.21a Standard error of mean of Cl^- in water (mg L^{-1}) for studied sites.

4.1.22 Sulfates (SO_4^{2-})

Sulfates in natural water may originate from many sources such as oxidization of sulfide ores, dissolution of evaporate rocks (gypsum and anhydrite), and anthropogenic source which mainly results from agricultural activities. The litho-logical units of the Fatha formation, which contains gypsum and anhydrite, are believed to be the major source of SO_4^{2-} in the water of study area (Rasul, 2013). Generally, inland waters of Iraqi Kurdistan region usually contain significant amount of sulfate (Goran, 2006). The sulfates were ranged from (18 to 125) mg L^{-1}, which is within the highest desirable limit of sulfate in drinking water standards guideline (Appendix 1: Table 4.1.22). The monthly average SO_4^{2-} ranged from (41 to 48) mg L^{-1} with significant differences among months as shown in (Fig. 4.1.22a). The concentration of SO_4^{2-} was higher during the wet season; because the period is usually the peak of agricultural activities around the study area.

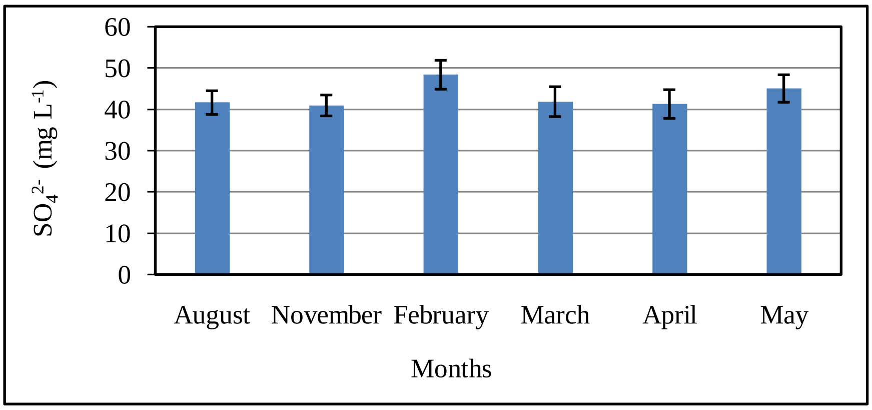

Figure 4.1.22a Standard error of mean of SO_4^{2-} in water (mg L^{-1}) for studied months.

The lower value of sulfate was recorded 18 mg L^{-1} at sampling site (W5-Kuna-Masi) during November could be because sulfate easily precipitates and settles to the bottom sediment of the river. The higher value of sulfate content 125 mg L^{-1} at sampling site (W19-Smaquli) during February was recorded with significant differences among sites as shown in (Fig. 4.1.22b), the sulfide-water it is the main reasons and sulfide concentrations became high and the odor of H_2S was produced and similar results were obtained by (Peterson, 2005). In other sides bio-chemical and anthropogenic sources have great effects on sulfate concentrations.

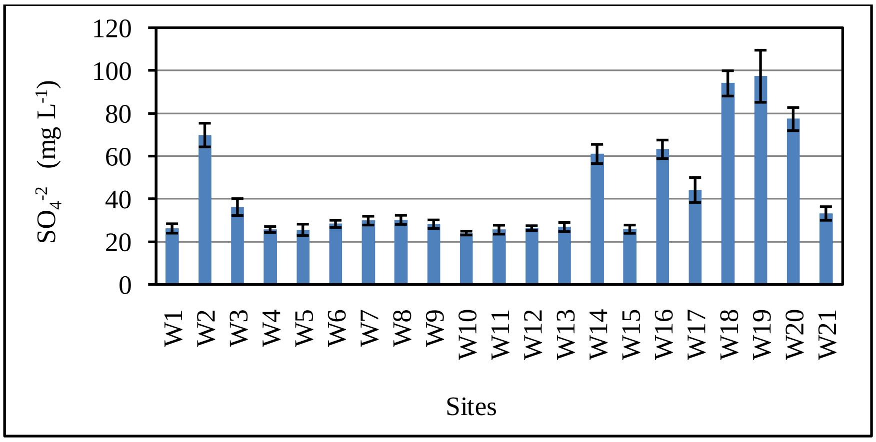

Figure 4.1.22b Standard error of mean of SO_4^{2-} in water (mg L^{-1}) for studied sites.

4.1.23 Alkalinity as (HCO_3^-)

Bicarbonates concentration in water depends on pH. Major sources of bicarbonate are CO_2 in air, chemical weathering of carbonate and silicate minerals by carbonic acid (Langmuir, 1997). The weathering of rocks adds bicarbonate content in water. Mostly bicarbonates are soluble in water (bicarbonate of magnesium and calcium). Carbonate is absent in all the samples we collected and analyzed, so alkalinity of our water samples is only because of bicarbonate. The alkalinity values ranged from (128.41 to 441.15) mg L^{-1}. The monthly alkalinity ranged from (222.76 to 259.49) mg L^{-1} with significant differences as shown in (Fig. 4.1.23a) and much higher than the desirable limits according to standard guideline for drinking water as given in (Appendix 1: Table 4.1.23). Alkalinity was lowest in April and May due to the dilution of water in comparison to other months. The unison results were recorded by (Al-Shwanny, 2009).

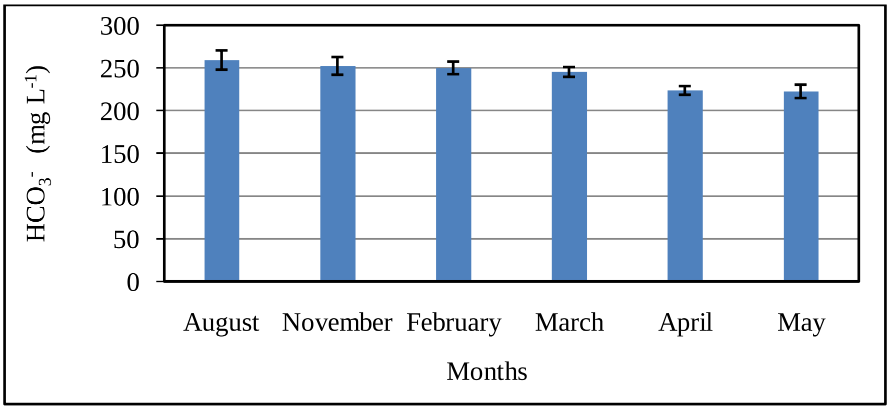

Figure 4.1.23a Standard error of mean of HCO_3^- in water (mg L^{-1}) for studied months.

The highest alkalinity 441.15 mg L^{-1} was recorded at sampling site (W14-Bosken) during November, with significant differences among sites as shown in (Fig. 4.1.23b) due to high nutrients in water (Uduma, 2014) and could be attributed to accelerated rate of photosynthesis leading to greater utilization of carbon dioxide and urban discharge through open drains in the stream, while the lowest value 128.41 mg L^{-1} was recorded during August at sampling site (W15-Dukan-Lake) (Appendix 1: Table 4.1.23) this is due to the dilution of water in comparison to other samples by addition into lake water (Pradeep *et al.*, 2012). The source of bicarbonate ion is minerals such as calcite and dolomite which are dominant minerals in the carbonate formation of the study area (Fatha and Kometan formations) (Rasul, 2013). Dissolution of these rocks by rainwater and irrigation water carries this anion and increases in the studied waters.

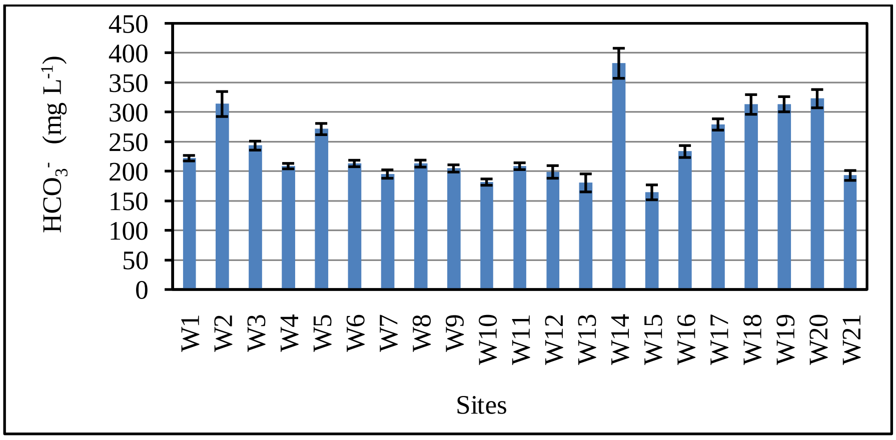

Figure 4.1.23b Standard error of mean of HCO_3^- in water (mg L^{-1}) for studied sites.

4.2 Heavy Metals

The results of the seven studied heavy metal concentrations in the study area such as Fe, Cu, Zn, Mn, Pb, Cd, and Cr have been shown in (Appendix 2: Table 4.2.1 to 4.2.7). The metal concentrations were different between sampling sites and months, except in the cases of copper (Appendix 2: Table 4.2.2) and manganese (Appendix 2: Table 4.2.4) where differences in concentrations were not so large. Heavy metals have been used as indices of pollution because of their high toxicity to human and aquatic life (Omoigberale and Ogbeibu, 2005).

The heavy metal concentrations were ranged (0.088 to 0.389), (0.002 to 0.016), (0.112 to 0.223), (0.001 to 0.067), (0.006 to 0.091), (0.074 to 0.153) and (0.211 to 0.790) mg L^{-1} for Fe, Cu, Zn, Mn, Pb, Cd and Cr respectively (Appendix 2: Table 4.2.1 to 4.2.7). The concentrations of dissolved heavy metals were low in samples collected in autumn, but some heavy metal concentrations in samples collected in spring were above maximum permitted concentrations given in (Appendix 2: Table 4.2.1 to 4.2.7). It was found that the river water heavy metal concentrations at sampling site (W14-Bosken) situated downstream of the general wastewater were higher than concentrations measured at other sites. This was due to the contact of site (W14) to the various types of pollution such as sewage, animal waste and chemicals used in agricultural, because this site was located close to residential areas. Metals concentration can be attributed due to the earth's crust and the geological formation of the area (Senapaty and Behera, 2012). On the other side, the increase of metal concentrations in the water during hot seasons (Spring, Summer) may be attributed to the release of heavy metals from the sediment to the overlying water under the effect of both high temperature and organic matter decomposition due to the fermentation process (Ali and Abdel-Satar, 2005).

From the results, the concentrations of heavy metals such as Cu, Zn and Mn were well below the permissible limits for drinking water standards (Appendix 2: Table 4.2.2, 4.2.3 and 4.2.4). The low concentrations of the heavy metals in the surface water could be due to dilution, adsorption, and precipitation. However, at some sites, the mean concentrations of Fe were above the permissible limits for drinking water, in all periods (Appendix 2: Table 4.2.1). While the mean concentrations of Pb, Cd and Cr (Appendix 2: Table 4.2.5, 4.2.6 and 4.2.7) respectively has been found more than the highest desirable limits of the mentioned guide lines and require continuous monitoring to detect hateful increases as a result of anthropogenic input and prevent possible public health implications of these metals on consumers of water and seafood from the study area.

4.2.1 Iron (Fe)

In waters iron occurs mainly in ferrous or ferric state (Ghulman *et al.*, 2008). Iron is a very common problem in drinking water and has a strong relationship with water hardness typically with both hardness and iron increasing at the same time. Surface water generally contains < 1 mg L^{-1} of Fe. It is a known fact that iron in trace amounts is essential for nutrition. At concentrations most commonly found in drinking water, the presence of iron was not considered a health problem. The monthly average Fe ranged from (0.244 to 0.280) mg L^{-1} with significant differences between months as shown in (Fig. 4.2.1a). In general, the level of Fe was higher during the long rain season across all sites. The observed high values of Fe might be associated with the phenomenon of leaching due to heavy precipitation. Land runoff, anthropogenic activities, agricultural runoff, leachate coming from the landfill and solid wastes dumping are these sources that might have contributed to enhanced levels of Fe at wet season.

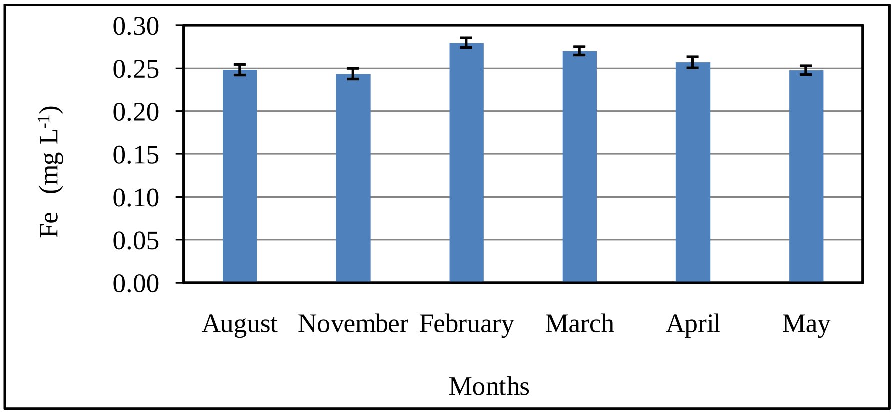

Figure 4.2.1a Standard error of mean of Fe in water (mg L^{-1}) for studied months.

The highest amount of Fe 0.389 mg L^{-1} was recorded during August at sampling site (W14-Bosken), with significant differences between sites as shown in (Fig. 4.2.1b). This may be attributed to the high evaporation and intense anthropogenic activities (agriculture and high degree of human activities) in summer (Olias *et al.*, 2004); while the lowest value 0.088 mg L^{-1} was recorded during April at sampling site (W6-Qashan). Results of this study not fit with (Goran, 2014) and fit with (Rasheed, 2008). The diluting effect owing to heavy rainfall due to rainy season resulted in the consequent reduction of Fe concentration and subsequently dilutes the river pollutants.

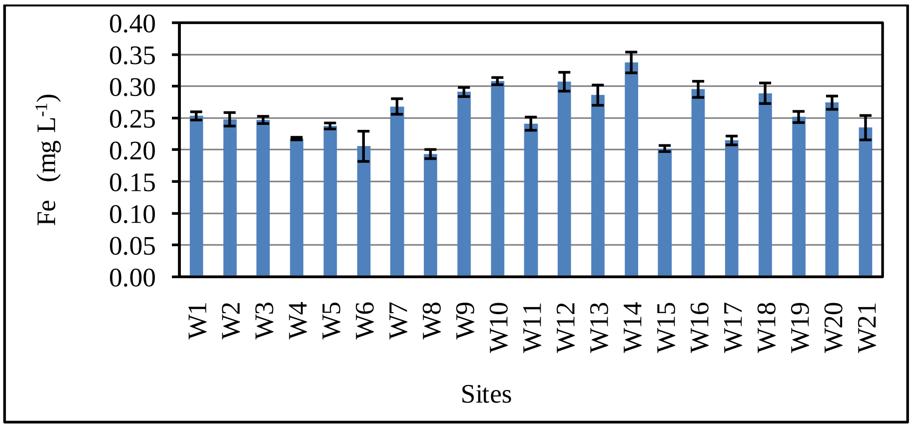

Figure 4.2.1b Standard error of mean of Fe in water (mg L^{-1}) for studied sites.

4.2.2 Copper (Cu)

The presence of copper originates from municipal wastewaters and landfill leachate or it may be attributed to domestic sewage water and runoff from extensive farmed areas. The use of phosphate fertilizers is known to increase copper levels in rivers from runoffs. Significant copper levels may also be added to soils by application of fertilizers, pesticides and fungicides (Pearse, 2002). If the concentration of copper found in water sample is high, then it causes heavy metal pollution (Asaduzzaman *et al.*, 2017).

The monthly average Cu ranged from (0.007 to 0.013) mg L^{-1} with significant differences between months as shown in (Fig. 4.2.2a). Same as the Fe the highest and lowest value of Cu was recorded at sampling site (W14-Bosken) and sampling site (W6-Qashan) during February and August respectively, with significant differences between sites as shown in (Fig. 4.2.2b). Copper is essential for all plant and animal nutrition. Increased quantities of copper make water distasteful to drink. Copper is highly toxic to most forms of aquatic life at relatively low concentrations. The concentration of Cu is within the allowable concentration for drinking water quality standards (Appendix 2: Table 4.2.2) and these results agreed with results obtained by (Ayas *et al.*, 2007 and Rasheed, 2008).

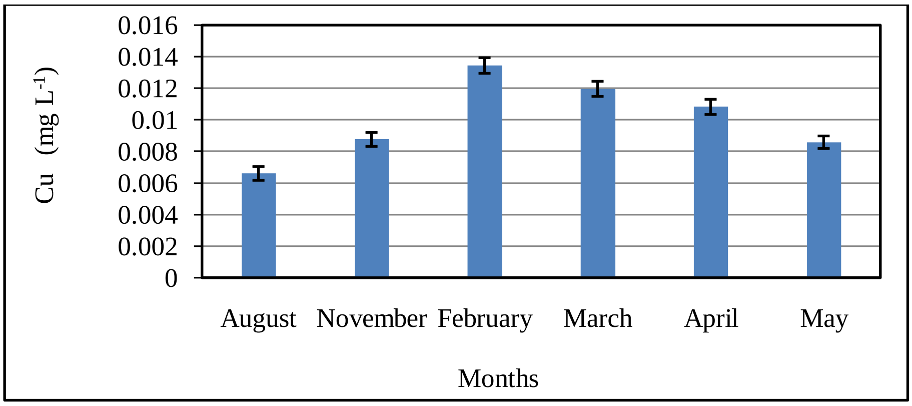

Figure 4.2.2a Standard error of mean of Cu in water (mg L^{-1}) for studied months.

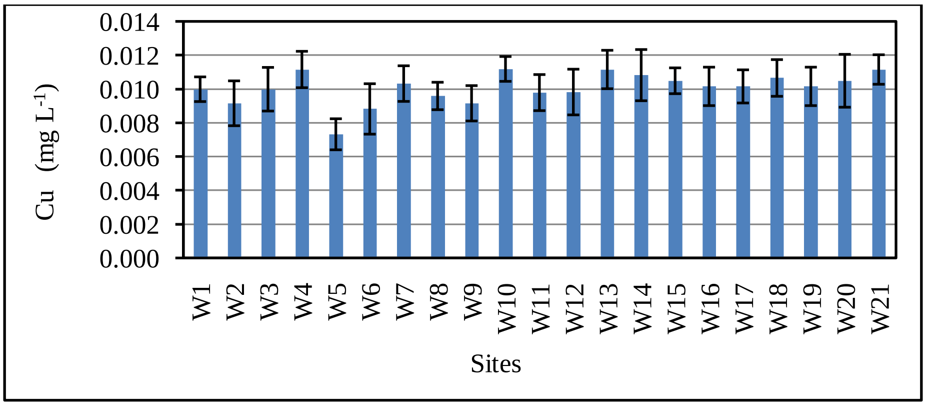

Figure 4.2.2b Standard error of mean of Cu in water (mg L^{-1}) for studied sites.

4.2.3 Zinc (Zn)

Zinc is one of the most abundant and movable of the heavy metals and is transported in natural waters in both dissolved forms and attendant with suspended fragments (Mance and Yates, 1984). Conversely, Zn is less toxic metals. The main sources are the natural source and the use of liquid manure, decomposed materials and agrochemicals such as fertilizers and pesticides in agriculture (Krishna and Govil, 2005). The monthly average Zn ranged from (0.143 to 0.163) mg L^{-1} with significant differences among months as shown in (Fig. 4.2.3a).

Zinc concentrations in analyzed water samples were lower than maximum permitted concentrations (Appendix 2: Table 4.2.3). Results of present study agreed with results obtained by (Rasul, 2013). The relatively higher concentrations of Zn were found in water sample collected at site (W14-Bosken) 0.223 mg L^{-1} during summer and 0.220 mg L^{-1} during autumn, with significant differences among sites as shown in (Fig. 4.2.3b) can be explained by position of the sample near residential area and mix with domestic waste.

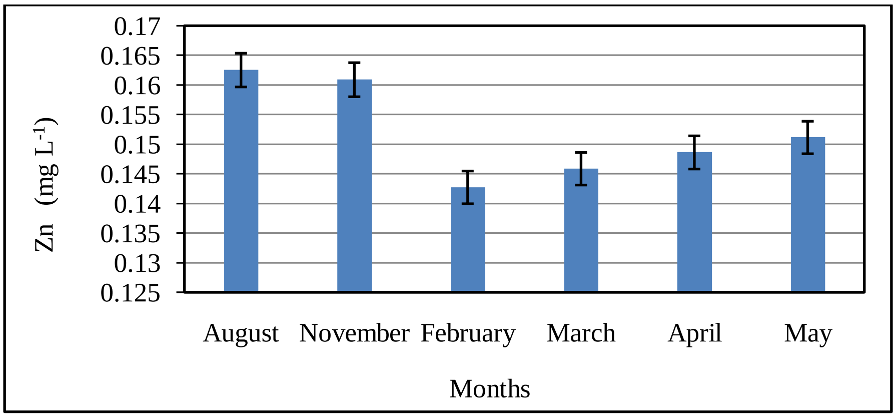

Figure 4.2.3a Standard error of mean of Zn in water (mg L^{-1}) for studied months.

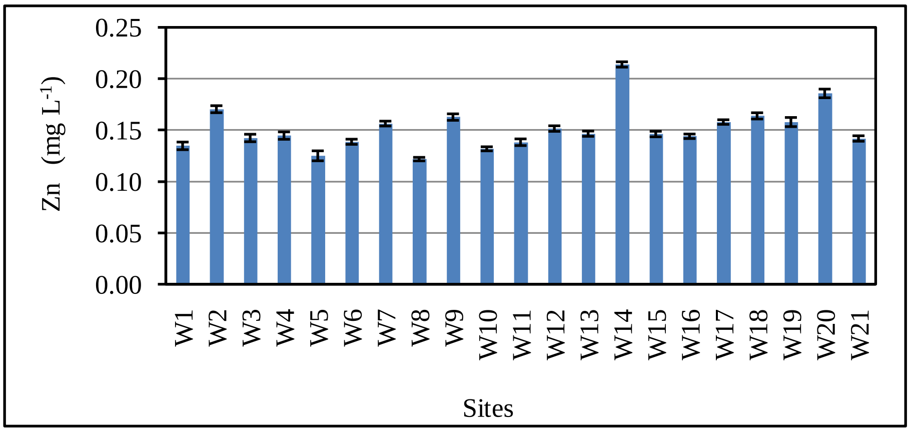

Figure 4.2.3b Standard error of mean of Zn in water (mg L^{-1}) for studied sites.

4.2.4 Manganese (Mn)

Manganese occurs naturally in most surface waters and in soils that may erode into waters. However, human activities are also responsible for much of the manganese contamination in water in most areas (Fianko *et al.*, 2013). The differential levels of Mn in the study area may be due to the soil geology; Mn ranged from (0.001 to 0.067) mg L^{-1} during the sampling periods at all of the sites. The monthly mean values were ranged from (0.003 to 0.007) mg L^{-1} with significant differences among months as shown in (Fig. 4.2.4a). The highest concentration was recorded at sampling site (W14-Bosken) during August, with significant differences among sites as shown in (Fig. 4.2.4b).

The source of high concentration of Mn may be as a result of agricultural activities taking place in the area with the main source from organic fertilizers. In addition, the low variability in the concentrations of Mn obtained in all the sites is an indication of little external inputs of

Mn in the water. The concentration of Mn is within the allowable range for drinking water quality (Appendix 2: Table 4.2.4), while the maximum concentrations of Mn found during summer season and same results was recorded by (Rasul, 2013).

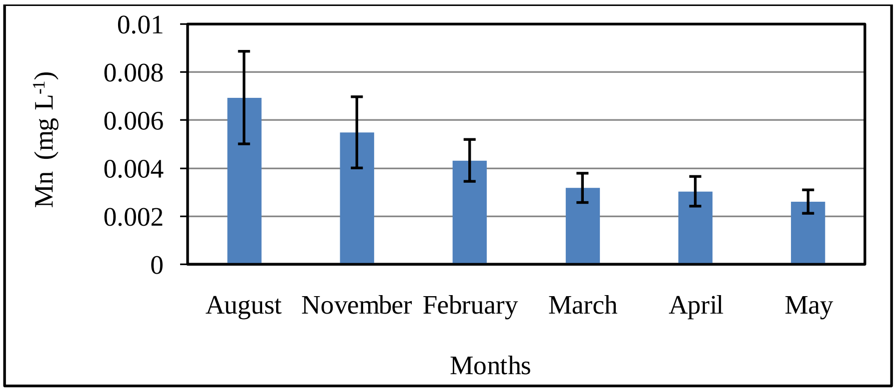

Figure 4.2.4a Standard error of mean of Mn in water (mg L^{-1}) for studied months.

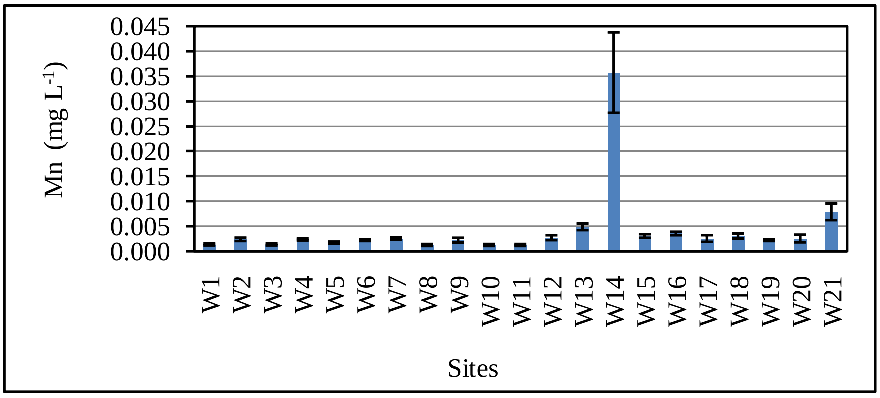

Figure 4.2.4b Standard error of mean of Mn in water (mg L^{-1}) for studied sites.

4.2.5 Lead (Pb)

The concentration of Pb was ranged from (0.006 to 0.091) mg L^{-1} during the periods of study, while a monthly average ranged (0.039 to 0.066) mg L^{-1} with significant differences among months as shown in (Fig. 4.2.5a). The highest concentration of Pb 0.091 mg L^{-1} was observed in November at sampling site (W9-Sndollan) with significant differences among sites as shown in (Fig. 4.2.5b), while the concentrations of Pb in all of the sites has been found more than the highest desirable limits (Appendix 2: Table 4.2.5). Results of present study agreed with results obtained by (Goran, 2014) and disagreed with results by (Rasul, 2013).

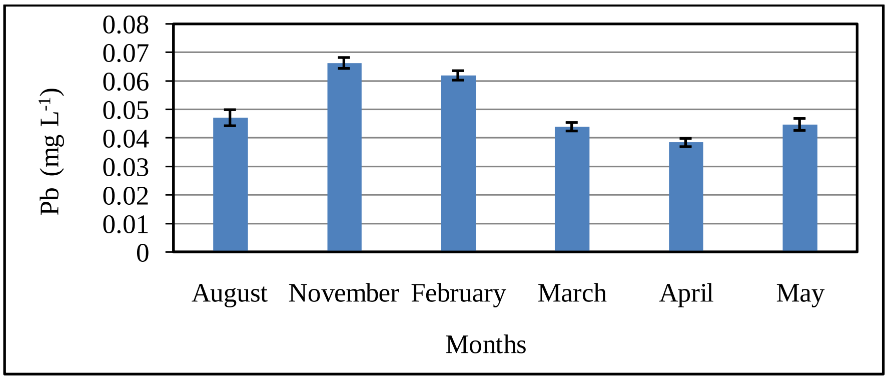

Figure 4.2.5a Standard error of mean of Pb in water (mg L^{-1}) for studied months.

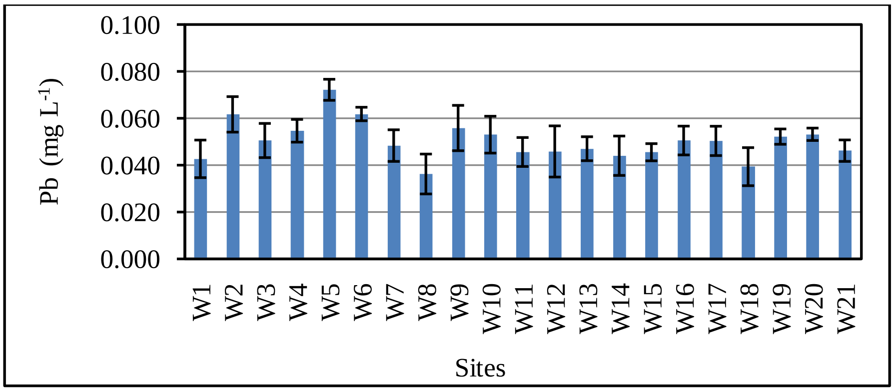

Figure 4.2.5b Standard error of mean of Pb in water (mg L^{-1}) for studied sites.

The abnormal concentration of the lead ion might be due to the increase amount of agricultural, untreated domestic and urban wastewaters (Yilmaz and Sadikoglu, 2011) discharged into the water around the study area which can pose a threat to humans that depends on water for drinking and domestic purposes as it can cause cancer. Additionally, motor vehicle exhaust of leaded gasoline gets adsorbed onto soil surfaces are washed into the streams during rainfall. The added fertilizers to the agricultural soil also supply a significant amount of Pb (Al-Qaraqhuli, 2005).

4.2.6 Cadmium (Cd)

Naturally, about 25000 tons of cadmium is released into the environment per year. About half of this cadmium is released into rivers through weathering of rocks. The rest is released through human activities, such as manufacturing and mining (Damoah, 2007). The concentrations of Cd ranged from (0.074 to 0.153) mg L^{-1} along the river and tributaries. The monthly average of Cd ranged from (0.098 to 0.121) mg L^{-1} with significant differences among months as shown in (Fig. 4.2.6a). The highest concentration was recorded at sampling site (W14-Bosken) during November, with significant differences among sites (Fig. 4.2.6b). Cadmium concentration in this study found to be higher than permissible limit for drinking

(Appendix 2: Table 4.2.6). Same results were obtained by (Hawrami, 2010) and different results by (Rasul, 2013).

The dissolved concentrations of Cd persist at relatively high levels in the area due to additional inputs of contaminated waters that drain from the dumps (Nnabo, 2015). This is supported by the Cd contents of the rocks and the soils (Onyeobi and Imeokparia, 2014). Cadmium is an important factor in aquatic monitoring studies, because it has been found to be toxic to fish and other aquatic organisms (Pascod, 1992).

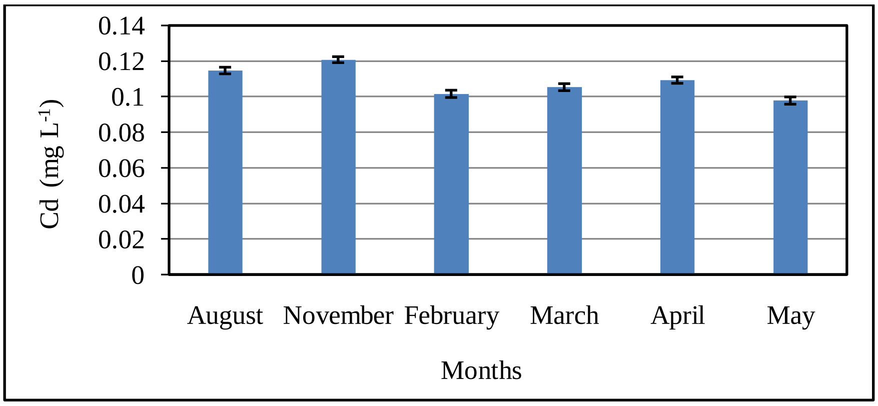

Figure 4.2.6a Standard error of mean of Cd in water (mg L^{-1}) for studied months.

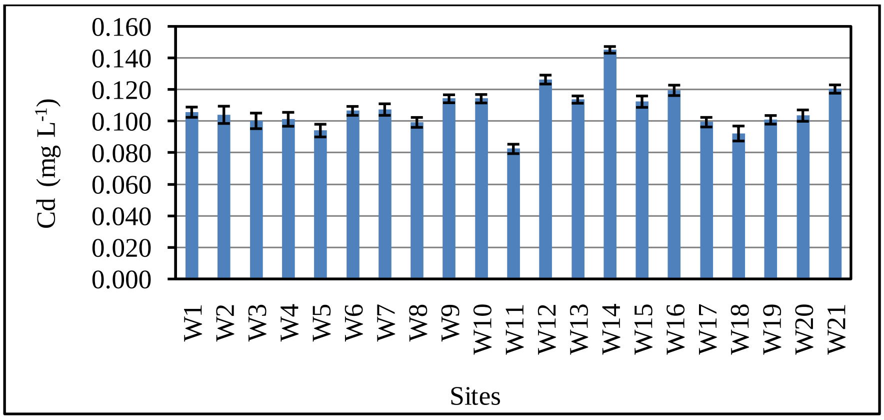

Figure 4.2.6b Standard error of mean of Cd in water (mg L^{-1}) for studied sites.

4.2.7 Chromium (Cr)

The laboratory results of study area were the concentrations of Cr ranged from (0.211 to 0.790) mg L^{-1}. The monthly average value of Cr ranged from (0.483 to 0.604) mg L^{-1} with significant differences among months as reaveled in (Fig. 4.2.7a). The highest result was 0.790 mg L^{-1} recoded at water sampling site (W14-Bosken) during August and lowest 0.211 at sampling site (W15-Dukan-Lake) during November, with significant differences among sites as reaveled in (Fig. 4.2.7b). These values are above the maximum permissible limit

(Appendix 2: Table 4.2.7) and opposed results was recorded by (Rasul, 2013). This result indicates that there is health effect on the users. As is the case with other metals, chromium toxicity to aquatic organisms increases as water temperature increases and as pH and salinity decrease. Additionally, chromium is more toxic in soft water than in hard water.

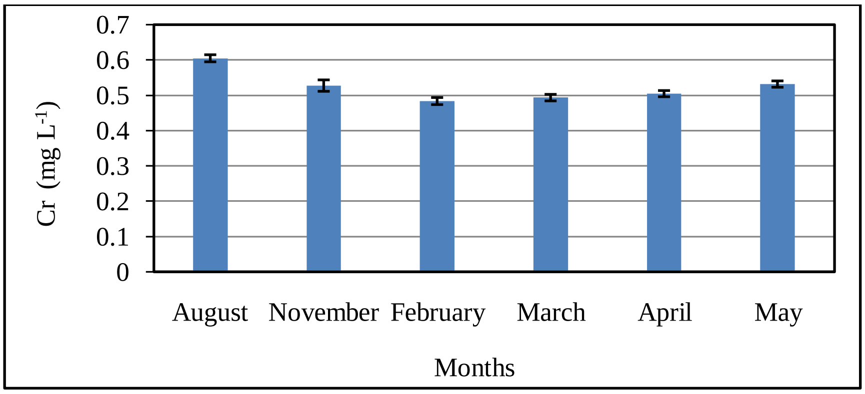

Figure 4.2.7a Standard error of mean of Cr in water (mg L^{-1}) for studied months.

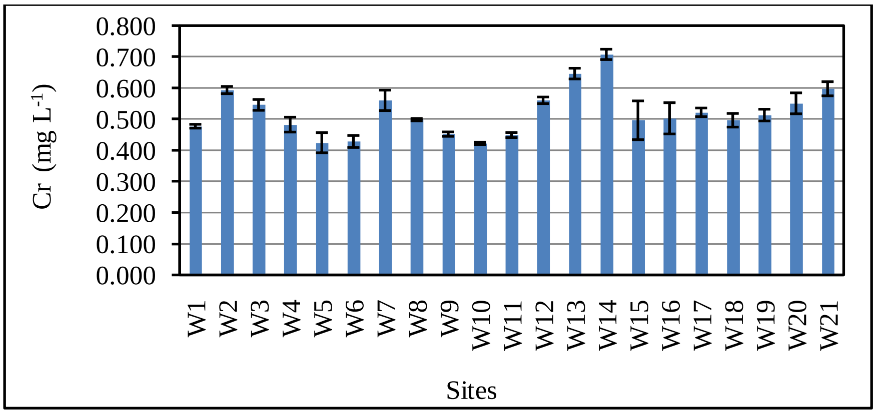

Figure 4.2.7b Standard error of mean of Cr in water (mg L^{-1}) for studied sites.

Heavy metals are usually present at low concentrations in aquatic environments but their concentrations may be raised due to anthropogenic inputs like municipal wastes, fertilizer and pesticides application and industrial effluents (Ntakirutimana *et al.*, 2013). The various anthropogenic activities coupled with land-use pattern (vehicular activities, fertilizer and pesticides use, urban farming and domestic wastes disposals) around these sites must have contributed to the pollution status of Pb, Cr and Cd in the study area. Run-offs into these sites could also increase the metal loads especially (Pb, Cr and Cd) because (Karouna-Renier and Sparling, 2001) have reported that run-offs from developed/built-up can increase metal concentrations in water bodies. Concentration of heavy metals in the studied water samples were ordered as chromium (Cr) > iron (Fe) > zinc (Zn) > cadmium (Cd) > lead (Pb) > manganese (Mn) > copper (Cu).

4.3 Metal Pollution Indices

Today, researchers and various organizations in present time focus on assessment of water quality to reduce the impact of pollutant on human health and its environment. The hydrological study timeline illustrate the development of numerous approaches to identify the source of origin and overall access the quality of water. Extensive literature survey evidences that metal pollution indices is the most convenient and effective approach for water quality assessment. In this study, three documented indices were employed. To identify water quality for drinking, some indices of water pollution were calculated. The heavy metal pollution index (*HPI*), heavy metal evaluation index (*HEI*) and degree of contamination (*Cd*).

4.3.1 Heavy metal pollution index (*HPI*)

The heavy metal pollution index for the study area was calculated individually using the mean concentration values of the selected metals (Fe, Cu, Zn, Mn, Pb, Cd and Cr). *HPI* is an effective method to characterize the surface water pollution. It represents the combined influence of metals on the overall quality of water (Reza *et al.*, 2011). The *HPI* values ranged from (18.87 to 69.75) as show in (Table 4.3.1). The highest *HPI* value 69.75 was observed at water sampling site (W14-Bosken), and the lowest value 18.87 was recorded at sampling site (W15-Dukan-Lake), with significant differences between sites as exposed in (Fig. 4.3.1a). The highest concentrations for metals were measured in sample site (W14-Bosken), which implies the highest value for *HPI* the same results were recorded by (Hoaghia *et al.*, 2016). The monthly average ranged of *HPI* was (42.70 to 53.16) with significant differences between months (Fig. 4.3.1b).

Table 4.3.1 Monthly variation of *HPI* during the periods of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	44.57	41.82	41.02	41.34	41.79	42.44	42.16
W2	Mawakan	56.75	51.32	50.08	50.66	51.45	53.29	52.26
W3	Shakha-Sur	54.35	45.87	44.83	45.68	47.13	50.79	48.11
W4	Siwayl	52.55	40.62	38.47	39.86	40.89	42.79	42.53
W5	Kuna-Masi	50.49	35.07	31.74	33.05	35.21	39.54	37.52
W6	Qashan	46.04	35.85	35.12	35.97	36.14	37.70	37.80
W7	Kawe	56.15	60.18	44.04	44.47	45.60	46.09	49.42
W8	Hallsho	No	43.76	42.88	43.64	44.05	44.87	43.84
W9	Sndollan	42.79	39.36	38.29	39.46	39.91	40.52	40.05
W10	Zharawa	No	37.38	36.80	37.18	37.54	38.72	37.52
W11	Dolabafra	42.10	No	38.21	38.65	39.41	40.02	39.86
W12	Doli-Shahidan	53.37	48.74	47.28	47.99	49.25	50.57	49.53
W13	Darbany-Ranya	63.92	57.41	55.78	54.88	53.91	55.78	56.95
W14	Bosken	69.75	61.27	60.70	60.17	60.93	62.05	62.48
W15	Dukan-Lake	57.45	18.87	42.98	44.95	46.19	51.73	43.70
W16	Qarani-Agha	52.94	60.49	32.74	35.76	39.09	45.82	44.47
W17	Khdran	51.58	44.77	43.46	44.21	44.99	46.65	45.94
W18	Hizop	52.42	42.04	39.18	41.31	43.08	45.49	43.92
W19	Smaquli	52.93	43.44	42.09	42.76	44.38	45.99	45.26
W20	Jali	54.04	60.17	42.84	43.18	43.47	47.95	48.61
W21	Qashqoli	55.80	59.88	48.07	48.65	49.28	53.89	52.60
Mean		53.16	46.42	42.70	43.52	44.46	46.80	46.17

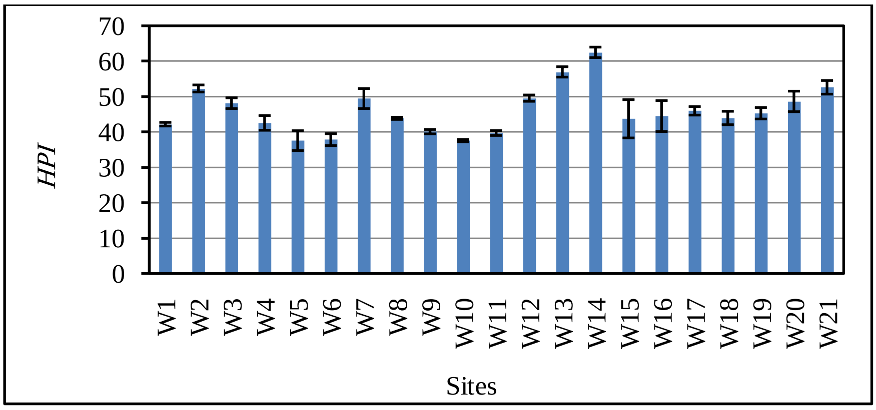

Figure 4.3.1a Standard error of mean of *HPI* in water for studied sites.

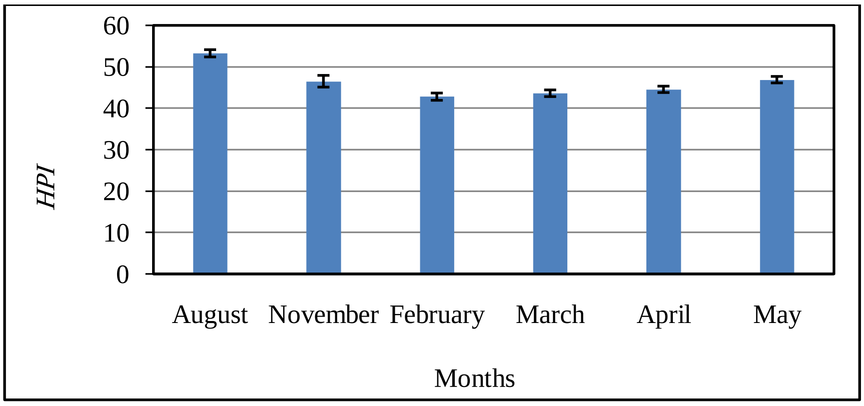

Figure 4.3.1b Standard error of mean of *HPI* in water for studied months.

The results showed that the *HPI* were below the critical limit of 100 proposed for drinking water by (Prasad and Mondal, 2008). Above this value the level of contamination is unacceptable. The *HPI* calculated with mean concentration values of all metals, including all sampling sites is 46.17, which is also well below the critical threshold value of 100, the whole quality of water in respect to metals downfall in the high class (*HPI* > 30) (Table 4.3.2). This result indicates that the influence of the seven studied metals on the river water quality is alarming because of the farmland waste discharge, dump wastes, landfill leachate and soil erosion while appraisement the *HPI* index and the similar results was observed by (Ewaid, 2016).

Table 4.3.2 Categories of metal indices and water quality classes according to sources.

Index method	Category	Degree of pollution	Sources
HPI	< 15	Low	Edet and Offiong (2002); Giri and Singh (2014)
	15–30	Medium	
	> 30	High	
HEI	< 10	Low	Edet and Offiong (2002)
	10 – 20	Medium	
	> 20	High	
Cd	< 1	Low	Edet and Offiong (2002; Goher *et al.* (2014)
	1 – 3	Medium	
	> 3	High	

4.3.2 Heavy metal evaluation index (*HEI*)

The heavy metal evaluation index used for a better understanding of pollution indices. Generally the *HEI* values ranged from (38.81 to 72.15) as shown in (Table 4.3.3). The highest *HEI* value 72.15 was observed at sampling site (W14-Bosken) due to high concentrations of metals in this sampling site, and the lowest value 38.81 was recorded at sample site (W11-Dolabafra) as a result of low met ion concentrations, with significant differences between sites (Fig. 4.3.3a). The monthly average range of *HEI* was (48.55 to 58.25) with significant differences between months as shown in (Fig. 4.3.3b). The highest value 58.25 of *HEI* was recorded in November due to high metals concentration. By following the approach of (Edet and Offiong, 2002), the present level of *HEI* shows that the water quality falls within high zone of pollution (*HEI* > 20) (Table 4.3.2) and comparable results was indicated by (Herojeet *et al.*, 2015).

Table 4.3.3 Monthly variation of *HEI* during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	51.36	55.72	49.42	50.00	48.65	44.39	49.92
W2	Mawakan	60.19	61.17	50.87	49.86	53.05	46.36	53.58
W3	Shakha-Sur	57.07	57.01	47.12	47.13	49.48	43.53	50.22
W4	Siwayl	53.36	56.34	46.01	47.25	49.75	44.96	49.61
W5	Kuna-Masi	53.88	52.95	43.89	44.76	45.60	46.14	47.87
W6	Qashan	54.12	54.12	48.64	49.56	50.79	48.67	50.98
W7	Kawe	53.70	61.33	50.06	51.85	51.78	47.86	52.76
W8	Hallsho	No	53.33	46.95	45.91	47.03	43.47	47.34
W9	Sndollan	54.97	60.37	54.23	51.24	51.72	49.67	53.70
W10	Zharawa	No	57.23	52.74	52.29	52.46	49.71	52.89
W11	Dolabafra	44.34	No	42.54	41.32	42.26	38.81	41.86
W12	Doli-Shahidan	65.13	65.14	55.99	55.97	56.81	54.83	58.98
W13	Darbany-Ranya	58.05	61.64	55.73	54.75	54.44	54.52	56.52
W14	Bosken	72.15	71.31	70.05	65.48	65.88	64.46	68.22
W15	Dukan-Lake	56.57	51.13	51.23	53.05	53.42	50.47	52.64
W16	Qarani-Agha	59.97	66.79	50.27	51.43	54.13	53.24	55.97
W17	Khdran	51.79	53.40	49.92	47.13	47.61	46.22	49.35
W18	Hizop	47.79	51.44	43.82	43.83	45.30	41.43	45.60
W19	Smaquli	53.50	53.56	48.71	47.79	48.72	47.58	49.98
W20	Jali	55.20	59.32	49.18	49.01	50.32	47.79	51.80
W21	Qashqoli	58.52	61.76	56.68	56.32	56.56	55.32	57.53
Mean		55.88	58.25	50.67	50.28	51.23	48.55	52.48

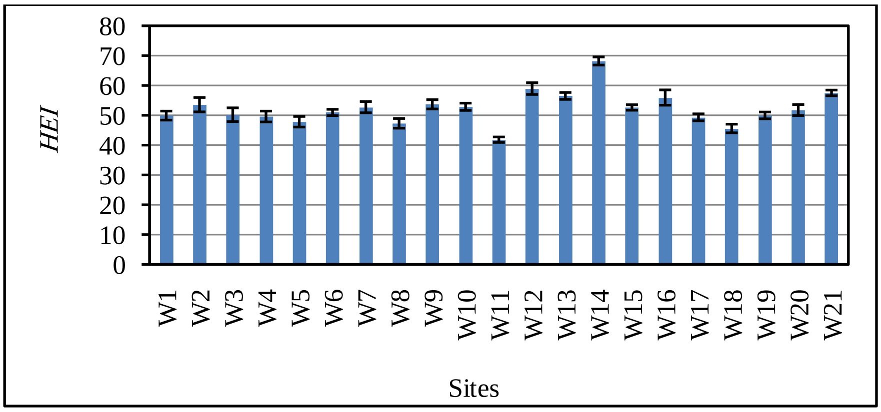

Figure 4.3.2a Standard error of mean of *HEI* in water for studied sites.

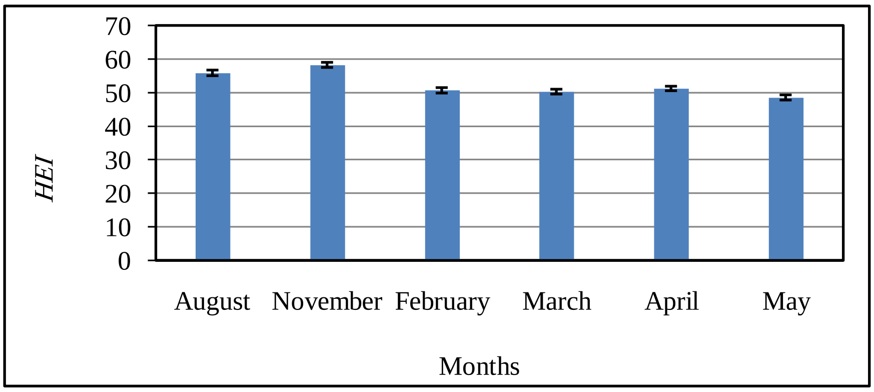

Figure 4.3.2b Standard error of mean of *HEI* in water for studied months.

4.3.3 Degree of contamination (*Cd*)

The degree of contamination was used as reference to estimate the extent of metal pollution (Al-Ami *et al.*, 1987). The *Cd* values ranged from (31.81 to 65.15) as show in (Table 4.3.4). According to the *Cd*, the lowest value 31.81 was obtained at sampling site (W11-Dolabafra), while the highest 65.15 was obtained at sampling site (W14-Bosken), with significant differences among sites (Fig. 4.3.4a). The monthly ranged values of *Cd* were (41.55 to 51.25) with significant differences among months (Fig. 4.3.4b). The studied region was found to have high degree of contamination, as the *Cd* average value 45.48 indicates of all metals. On the light of *HPI*, *HEI*, and *Cd* results the water quality in all sites and months classified under (high degree of pollution).

Table 4.3.4 Monthly variation of *Cd* during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	44.36	48.72	42.42	43.00	41.65	37.39	42.92
W2	Mawakan	53.19	54.17	43.87	42.86	46.05	39.36	46.58
W3	Shakha-Sur	50.07	50.01	40.12	40.13	42.48	36.53	43.22
W4	Siwayl	46.36	49.34	39.01	40.25	42.75	37.96	42.61
W5	Kuna-Masi	46.88	45.95	36.89	37.76	38.60	39.14	40.87
W6	Qashan	47.12	47.12	41.64	42.56	43.79	41.67	43.98
W7	Kawe	46.70	54.33	43.06	44.85	44.78	40.86	45.76
W8	Hallsho	No	46.33	39.95	38.91	40.03	36.47	40.34
W9	Sndollan	47.97	53.37	47.23	44.24	44.72	42.67	46.70
W10	Zharawa	No	50.23	45.74	45.29	45.46	42.71	45.89
W11	Dolabafra	37.34	No	35.54	34.32	35.26	31.81	34.
W12	Doli-Shahidan	58.13	58.14	48.99	48.97	49.81	47.83	51.98
W13	Darbany-Ranya	51.05	54.64	48.73	47.75	47.44	47.52	49.52
W14	Bosken	65.15	64.31	63.05	58.48	58.88	57.46	61.22
W15	Dukan-Lake	49.57	44.13	44.23	46.05	46.42	43.47	45.64
W16	Qarani-Agha	52.97	59.79	43.27	44.43	47.13	46.24	48.97
W17	Khdran	44.79	46.40	42.92	40.13	40.61	39.22	42.35
W18	Hizop	40.79	44.44	36.82	36.83	38.30	34.43	38.60
W19	Smaquli	46.50	46.56	41.71	40.79	41.72	40.58	42.98
W20	Jali	48.20	52.32	42.18	42.01	43.32	40.79	44.80
W21	Qashqoli	51.52	54.76	49.68	49.32	49.56	48.32	50.53
Mean		48.88	51.25	43.67	43.28	44.23	41.55	45.48

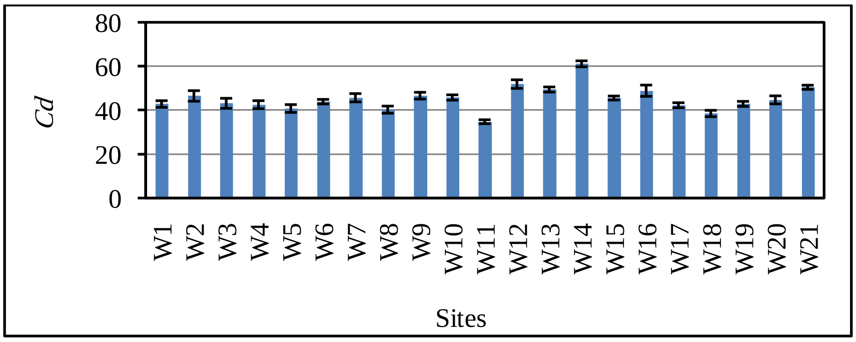

Figure 4.3.3a Standard error of mean of *Cd* in water for studied sites.

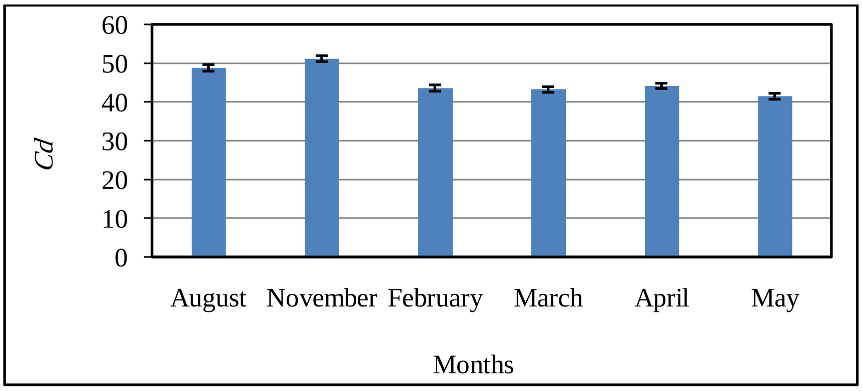

Figure 4.3.3b Standard error of mean of *Cd* in water for studied months.

In order to identify the main contributing parameters to the pollution indices, a correlation was carried out between pollution indices and heavy metal parameters as shown in (Table 4.3.5). This suggests that Fe, Zn, Cd, and Cr were the key contributing parameters. *HPI*, *HEI* and *Cd* show high positive correlations with Fe (0.531, 0.642, and 0.623), Zn (0.756, 0.776, and 0.760), Cd (0.702, 0.970, and 0.971) and Cr (1.000, 0.794, and 0.786) and the similar results was indicated by (Hoaghia *et al.*, 2016). Further, *HPI* shows low correlation with Cu (0.135) and Pb (0.177). The correlation between *HEI* and *Cd* is very high (0.997) and their results show similar trends at various sampling sites. However, *HPI* is high correlated with *HEI* (0.797) and with *Cd* (0.789). Thus, positive relationships between metal concentrations can be observed, such as Zn/ Fe, Cd/Fe, Cd/Zn, and, Cr/Fe, Cr/Zn, and Cr/Cd.

Table 4.3.5 Correlation analysis of different metal concentration and indices values.

	HPI	*HEI*	*Cd*	Fe	Cu	Zn	Mn	Pb	Cd	Cr
HPI	1									
HEI	0.797**	1								
Cd	0.789**	0.997**	1							
Fe	0.531*	0.642**	0.623**	1						
Cu	0.135	0.195	0.172	0.348	1					
Zn	0.756**	0.776**	0.760**	0.630**	0.194	1				
Mn	0.424	0.410	0.435*	0.348	0.020	0.445*	1			
Pb	0.177	0.443*	0.436*	0.228	0.141	0.272	0.011	1		
Cd	0.702**	0.970**	0.971**	0.617**	0.176	0.723**	0.407	0.286	1	
Cr	1.000**	0.794**	0.786**	0.521*	0.132	0.753**	0.421	0.176	0.698**	1

N= 21, df= 19, r 0.05= 0.4329, r 0.01= 0.5487

4.4 Discharge Fuctuation

Discharge of rivers is an extremely important supporting variable in river water quality. Hydrologic behavior of a watershed is greatly influenced by the watershed topography and nature of the soil (Stibinger, 2014). In this study, the river flow discharge was measured at every period, in order to monitor flow discharge throughout the six months period of the field work. During the sampling periods, there was a cut off periods of two months, due to low flow. The discharge was monitored throughout the twenty one sampling events at every period, except August (it managed by only nineteen sampling events) and November (only by twenty sampling events). These three sites had no water during field monitoring, due to the river being dried out towards the lower stretches of the lower catchment during the sampling periods. (Table 4.4) show the estimated temporal variation in discharge of the rivers and tributaries.

Table 4.4 Monthly variation of discharge (m^3 sec^{-1}) during the periods of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	0.40	0.62	6.97	16.96	10.56	4.07	6.60
W2	Mawakan	0.10	0.07	1.12	5.04	2.32	1.78	1.74
W3	Shakha-Sur	0.72	0.73	8.19	23.03	13.66	6.88	8.87
W4	Siwayl	0.66	1.46	11.60	25.28	20.17	11.23	11.73
W5	Kuna-Masi	0.80	0.26	2.44	5.04	3.40	2.43	2.40
W6	Qashan	2.60	2.95	23	58.35	38.23	21.51	24.44
W7	Kawe	8	17.26	43.60	159.57	172.82	60	76.88
W8	Hallsho	No	0.25	7.93	21	16.92	4.87	10.19
W9	Sndollan	7.84	17.51	51.53	180.57	189.74	65	85.37
W10	Zharawa	No	0.37	20.80	75.82	68.72	21.18	37.38
W11	Dolabafra	0.40	No	8.30	25.80	22.91	10.43	13.57
W12	Doli-Shahidan	2.96	2.92	7.59	20.08	12.31	4.46	8.39
W13	Darbany-Ranya	11.17	20.80	88.22	302.27	293.68	101	136.19
W14	Bosken	0.36	0.18	1.86	3.19	0.64	0.37	1.10
W15	Dukan-Lake	13.00	22	98	321	299	102	142.50
W16	Qarani-Agha	1.31	0.44	2.25	6.48	2.76	0.81	2.34
W17	Khdran	0.15	0.10	0.84	1.87	0.48	0.19	0.61
W18	Hizop	0.01	0.48	4.83	7.19	1.44	0.22	2.36
W19	Smaquli	0.16	0.13	0.12	0.50	0.06	0.03	0.17
W20	Jali	0.48	0.33	3.41	2.52	1.67	0.78	1.53
W21	Qashqoli	285	145	74	91	69	73	122.83
Mean		17.69	11.69	22.22	64.41	59.07	23.44	33.20

It was observed that discharge values are varied due to different in places, times and climates. The discharge ranged from (0.01 to 321) m^3 sec^{-1} with significant variations among sites (Fig. 4.4a). It can be clearly seen that the highest monthly mean values of discharge were recorded during March and April, while the lowest mean value was in November, with significant variations among months (Fig. 4.4b), due to high precipitation in March and April.

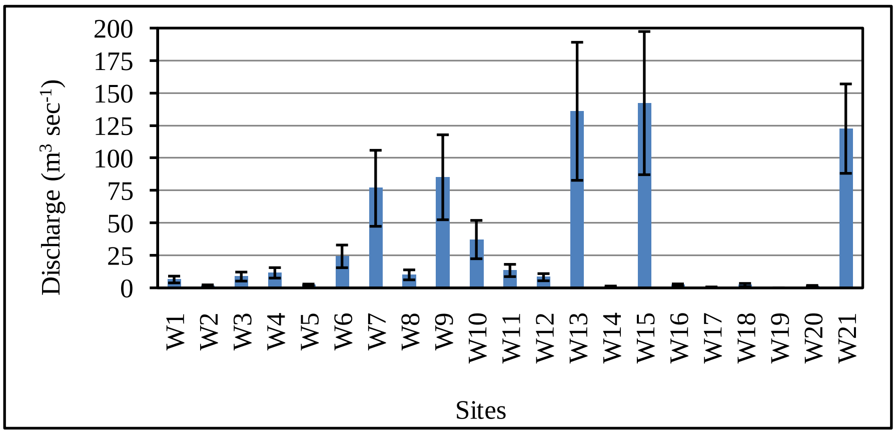

Figure 4.4a Standard error of mean of discharge (m^3 sec^{-1}) for studied sites.

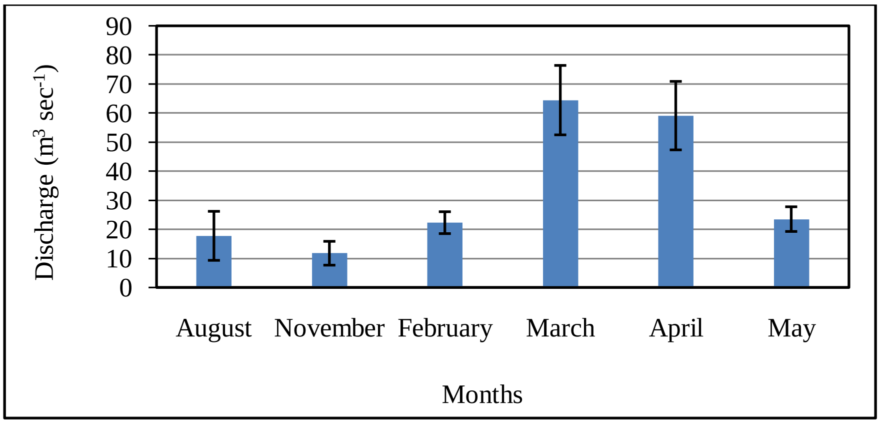

Figure 4.4b Standard error of mean of discharge (m^3 sec^{-1}) for studied months.

4.5 Correlation Analysis Among Water Quality Parameters

The systematic calculation of correlation coefficient between water quality variables provide indirect means for rapid monitoring of water quality. The correlation coefficient measures the degree of association that exists between two variables, one taken as dependent variable. Correlation is the common relationship between two variables. Direct correlation exists when increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of other parameter (Patil and Patil, 2011). The correlation coefficient (r) among various water quality parameters was calculated and the values of the correlation coefficient were given in the (Table 4.5).

From (Table 4.5) it is shown that the idea of bearing a single parameter analyzed has relationship with other parameters. Most of the parameters were found to bear high correlation with each other indicating close association of these parameters with each other. Highly strong positive correlations were observed between ($EC_t/EC_{25}{}^{o}C$) (r=0.938), (EC_t/salinity) (r=0.938), (EC_t/TDS) (r=0.965), (EC_t/Na^+) (r=0.853), (EC_t/HCO_3^-) (r=0.923),

(EC_t/SO_4^{2-}) (r=0.801), (EC_t/TH) (r=0.918), ($EC_{25}{}^{o}C$/salinity) (r=0.999), ($EC_{25}{}^{o}C$/TDS) (r=0.891), ($EC_{25}{}^{o}C/HCO_3^-$) (r=0.883), ($EC_{25}{}^{o}C$/TH) (r=0.883), (salinity/TDS) (r=0.891), (salinity/HCO_3^-) (r=0.883), (salinity/TH) (r=0.883), (TDS/Na^+) (r=0.824), (TDS/HCO_3^-) (r=0.888), (TDS/TH) (r=0.893), (BOD_5/PO_4-P) (r=0.958), (BOD_5/NH_4-N) (r=0.803), (Mg^{2+}/TH) (r=0.813), (Na^+/Cl^-) (r=0.894), and (HCO_3^-/TH) (r=0.916). Thus, the single parameter of EC can give a reasonably good indication of a number of related parameters. The positive moderate correlations were between (EC_t/K^+) (r=0.789), (TDS/SO_4^{2-}) (r=0.796), (TSS/turbidity) (r=0.779), (Ca^{2+}/HCO_3^-) (r=0.796), (Ca^{2+}/TH) (r=0.778), (SO_4^{2-}/TH) (r=0.772), and other parameters were found (Table 4.5).

The weak negative and positive correlations were between (Temperature/DO) (r= -0.161), (Temperature/TSS) (r= -0.095), (Temperature/NO_3-N) (r= -0.160), (Temperature/color) (r= -0.091), (EC_t/TSS) (r= -0.012), and (TDS/TSS) (r= -0.021), it was indicated that inverse relationship between both parameters, and (Temperature/pH) (r=0.395), (Temperature/SO_4^{2-}) (r=0.268), (Ca^{2+}/SO_4^{2-}) (r=0.481), it means straight relationship between both and other parameters were found as shown in (Table 4.5). Discharge showed negative correlation with all the parameters except pH, TSS, DO, NO_3-N, NO_2-N and color with which they had a positive correlation and dissolved oxygen also showed negative correlation with most of the parameters.Thus in this study, discharge and DO can serve as a both useful indexes of water quality of the river because with increase in the value of discharge most of these parameters decreases and DO increase.

Table 4.5 Correlation matrix among the physicochemical parameters of rivers during period of study.

	Discharge	Temperature	pH	EC_t	$EC_{25}{}^{o}{}_{C}$	Salinity	TS	TDS	TSS	DO	BOD_5	Turbidity	Ca^{2+}	Mg^{2+}
Discharge	1	-0.202	0.065	-0.294	-0.225	-0.225	-0.102	-0.249	0.082	0.219	-0.079	-0.044	-0.149	-0.260
Temperature		1	0.395	0.296	0.001	0.001	0.135	0.315	-0.095	-0.161	0.140	0.034	0.173	0.279
pH			1	0.316	0.334	0.334	0.265	0.302	0.085	0.678**	0.025	0.075	0.440*	0.284
EC_t				1	0.938**	0.938**	0.629**	0.965**	-0.012	0.034	0.416	0.111	0.714**	0.747**
$EC_{25}{}^{o}{}_{C}$					1	1.000**	0.614**	0.891**	0.032	0.200	0.362	0.105	0.717**	0.690**
Salinity						1	0.614**	0.891**	0.032	0.200	0.362	0.105	0.717**	0.690**
TS							1	0.645**	0.750**	0.103	0.286	0.694**	0.445*	0.504*
TDS								1	-0.021	0.009	0.352	0.150	0.691**	0.729**
TSS									1	0.127	0.069	0.779**	-0.015	0.028
DO										1	-0.083	0.048	0.195	0.061
BOD_5											1	0.112	0.342	0.215
Turbidity												1	-0.001	0.181
Ca^{2+}													1	0.267
Mg^{2+}														1
Na^{+}														
K^{+}														

N= 21, df= 19, r 0.05= 0.4329, r 0.01= 0.5487

Continue Table 4.5

	Na^+	K^+	HCO_3^-	SO_4^{2-}	Cl^-	NO_3-N	PO_4-P	NH_4-N	NO_2-N	Color	TH
Discharge	-0.233	-0.150	-0.244	-0.282	-0.173	0.167	-0.063	-0.090	0.064	0.294	-0.259
Temperature	0.261	0.313	0.286	0.268	0.198	-0.160	0.103	0.226	0.101	-0.091	0.286
pH	0.086	0.122	0.418	0.200	0.093	0.413	0.032	0.093	0.098	0.196	0.451*
EC_t	0.853**	0.789**	0.923**	0.801**	0.729**	0.135	0.412	0.346	0.301	0.136	0.918**
$EC_{25}{}^oC$	0.763**	0.695**	0.883**	0.743**	0.660**	0.250	0.376	0.276	0.277	0.166	0.883**
Salinity	0.763**	0.695**	0.883**	0.743**	0.660**	0.250	0.376	0.276	0.277	0.166	0.883**
TS	0.528*	0.511*	0.582**	0.540*	0.462*	0.121	0.275	0.246	0.270	0.209	0.597**
TDS	0.824**	0.741**	0.888**	0.796**	0.706**	0.098	0.352	0.286	0.253	0.181	0.893**
TSS	-0.022	0.028	-0.007	0.018	-0.006	0.074	0.056	0.075	0.134	0.117	0.009
DO	-0.152	-0.135	0.113	-0.043	-0.108	0.622*	-0.080	-0.177	-0.033	0.406	0.158
BOD_5	0.385	0.701**	0.457*	0.172	0.302	0.099	0.958**	0.803**	0.719**	0.376	0.347
Turbidity	0.112	0.118	0.073	0.203	0.082	0.051	0.102	0.096	0.141	0.197	0.117
Ca^{2+}	0.427	0.451**	0.796**	0.481*	0.289	0.295	0.356	0.309	0.341	0.256	0.778**
Mg^{2+}	0.653**	0.585**	0.668**	0.738**	0.620**	0.081	0.212	0.147	0.176	-0.006	0.813**
Na^+	1	0.789**	0.702**	0.680**	0.894**	-0.044	0.357	0.325	0.210	-0.021	0.683**
K^+		1	0.700**	0.600**	0.716**	-0.046	0.705**	0.592**	0.479*	0.150	0.653**
HCO_3^-			1	0.660**	0.566**	0.172	0.465*	0.404	0.377	0.175	0.916**
SO_4^{2-}				1	0.484*	0.170	0.181	0.103	0.220	0.074	0.772**
Cl^-					1	-0.154	0.274	0.241	0.116	-0.109	0.579**
NO_3-N						1	0.111	-0.061	0.233	0.627**	0.231
PO_4-P							1	0.746**	0.763**	0.398	0.353
NH_4-N								1	0.567**	0.157	0.282
NO_2-N									1	0.355	0.320
Color										1	0.151
TH											1

N= 21, df= 19, r 0.05= 0.4329, r 0.01= 0.5487

4.6 Dissolved Oxygen Sag Curve and Model Development

In the advance and prediction of the DO sag curve for solving studied river water quality problems, the following essential measures were observed:

(1) Estimating the DO and BOD along the rivers/streams; (2) Estimating time of travel for the rivers/streams; (3) Estimating rate constant necessary; (4) Applying suitable equations to calculate the oxygen deficit at the selected sites; (5) Calculating the critical time; and (6) Calculating the deficit critical.

4.6.1 Oxygen sag curve for main Qalachwalan-Lesser Zab Rive based on distance.

Only five of the sampling sites and their related data are useful for the oxygen sag curve modeling. This is because some of the sites do not fall along the straight path of the river from the reference point. Below the expected the oxygen sag curve developed for studied river on a plot for concentration DO against distance, in the direction of flow. The natural self-purification and oxygen sag curve were calculated for the reach from km (0.0 to 113.48) of main Qalachwalan-Lesser Zab Rive. The major sources of pollution and water inflows to the main river happen at a number of sites along the selected river stretch. The study length of the river is further subdivided into four reaches based on the location of wastes and dumps, surface drains, and freshwater tributaries (Fig. 4.6.1a and Table 4.6). (Appendix 3: Table 4.6.1 to 4.6.6) represented the calculation of natural self-purification using the data set from the reach km (0.0 to 113.48).

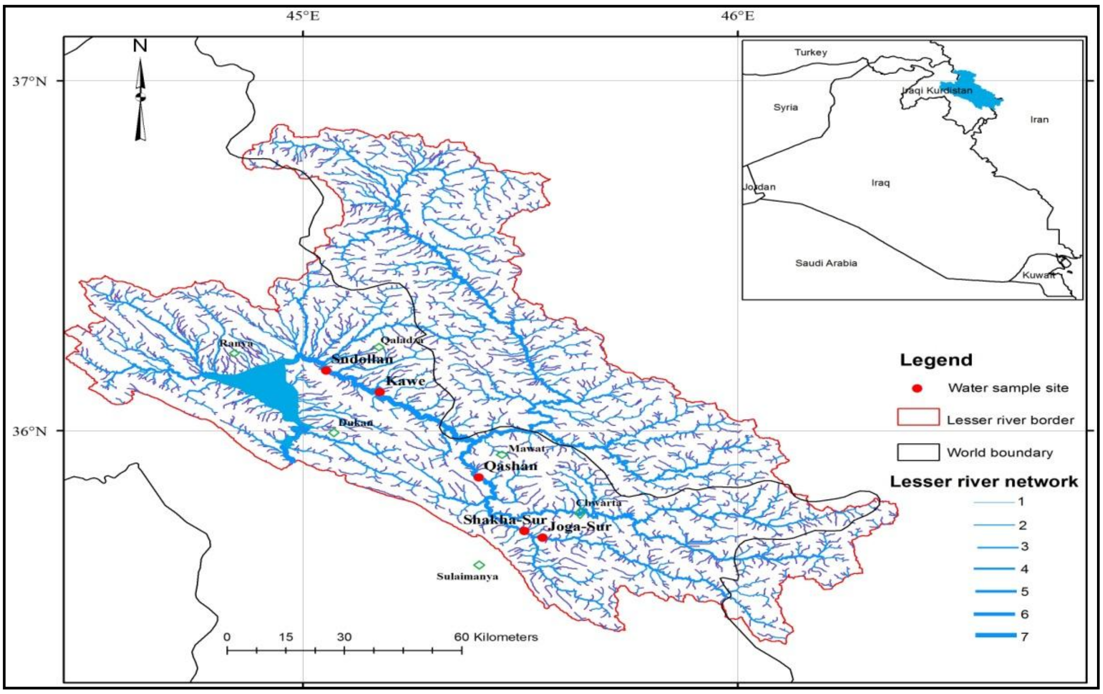

Figure 4.6.1a Map and location of sampling sites in Qalachwalan-Lesser Zab River.

Table 4.6 Details of sampling sites.

Sites	Sites description	Inter-station distance (km)	Distance (km)
Joga-Sur	(1.21 km) before confluence with Mawakan	River beginning	0
Mawakan	(1.52 km) before confluence with Joga-Sur	Off main river	1.52
Shakha-Sur	(2.78 km) after confluence of Mawakan with Joga-Sur	3.99	3.99
Siwayl	(10.90 km) before confluence with Qalachwalan river	Off main river	10.90
Kuna-Masi	(0.46 km) before confluence with Qalachwalan river	Off main river	0.46
Qashan	(37.29 km) far from Joga-Sur point	33.3	37.29
Kawe	(92.06 km) far from Joga-Sur point	58.76	92.06
Hallsho	(10.80 km) before confluence with Lesser Zab river	Off main river	10.80
Sndollan	(113.48 km) far from Joga-Sur point	54.72	113.48
Zharawa	(3.94 km) before confluence with Lesser Zab river	Off main river	3.94
Dolabafra	(5 km) before confluence with Lesser Zab river	Off main river	5
Doli-Shahidan	(2.47 km) before confluence with Lesser Zab river	Off main river	2.47
Bosken	(3.19 km) before confluence with Dukan-Lake	Off lake	3.19
Qarani-Agha	(5.34 km) before confluence with Dukan-Lake	Off lake	5.34
Khdran	(4.52 km) before confluence with Dukan-Lake	Off lake	4.52
Jali	(4.82 km) before confluence with Smaquli point	Off main river	4.82
Smaquli	(3.82 km) before confluence with Jali point	Off main river	3.82
Hizop	(5.84 km) after confluence of Jali with Smaquli	10.66	10.66

(Fig. 4.6.1a1 and 4.6.1a2), illustrated that the oxygen sag curves based on oxygen between (Joga-Sur) point km 0.0, (Shakh-Sur) point km 3.99, (Qashan) point km 37.29, (Kawe) point km 92.06, and (Sndollan) point km 113.48 along the main Qalachwalan-Lesser Zab Rive. The data showed that DO deficit increased with distance and the lowest point of the oxygen sag curve (critical point) is at the (critical distance) km 3.99 in August and November. This point out that the de-oxygenation rate is higher than the re-oxygenation rate, from km (0.0 to 3.99) the oxygen deficit (1.81 to 3.61) mg L^{-1} during August and (2.07 to 3.50) mg L^{-1} during November increased, then DO deficit decreased with distance, consequently after km 3.99 in both months toward the direction of flow. Thus, the re-oxygenation rate is higher than de-oxygenation rate.

The values of re-aeration coefficients, de-oxygenation coefficients, time of travel and self-purification factors for different stretches of Qalachwalan-Lesser Zab River were computed (Appendix 3: Table 4.6.1 and 4.6.2). The maximum de-oxygenation rate were recorded at second site during both months and after that point the re-oxygenation increased with distance, it means self-purification occurred along the river after (Shakha-Sur) point. But at the end point km 113.48 (Sndollan) the de-oxygenation rates increased in November due to the agriculture activities along the bank of the river, sand washers and waste discharge with municipal dump of Qaladza city.

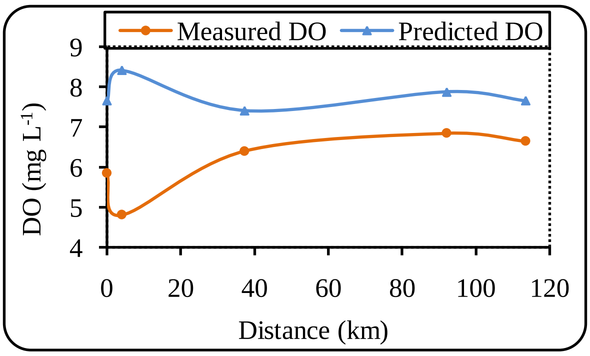

Figure 4.6.1a1 Oxygen sag curve for August.

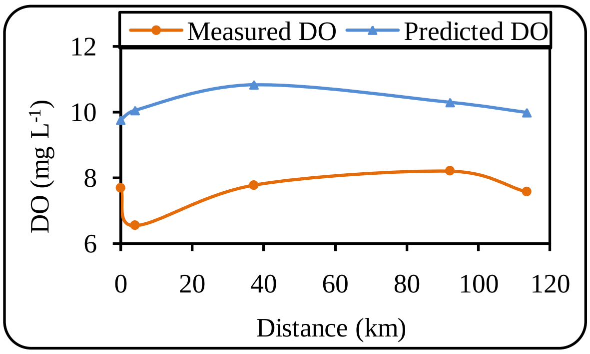

Figure 4.6.1a2 Oxygen sag curve for November.

(Fig. 4.6.1a3) illustrated the oxygen sag curve. The data showed that DO deficit had at the highest at km 0.0 distances and the value of DO deficit 2.44 mg L^{-1} (Appendix 3: Table 4.6.3). This point out that the de-oxygenation rate is higher than the re-oxygenation rate. It is clear that the first point km 0.0 (Joga-Sur) on the oxygen sag curve where the oxygen deficit is high than the other points. Thus, from the point third km 37.29 (Qashan) to fifth point km 113.48 (Sndollan) the re-oxygenation rate was increased. The gradual increase of DO from the lowest value indicated the capacity of the river for self-purification and lack of oxygen demanding wastes being disposed into the river.

(Fig. 4.6.1a4), illustrates the oxygen sag curve. The data showed that DO deficit increased with distance and the lowest point of the oxygen sag curve (critical point) is at (critical distance) km 37.29 in March. This point out that the de-oxygenation rate is higher than the re-oxygenation rate from km (0.0 to 37.29) then DO deficit decreased with distance, consequently after km 37.29. Thus, the re-oxygenation rate is higher than de-oxygenation rate. It is clear that the first point (Joga-Sur) and second point (Shakha-Sur) on the oxygen sag curve where the oxygen deficit is less than the third point (Qashan). It means the maximum DO reduction occurs at km 37.29, after that point the re-aeration increased with distance, but at the end point km 113.48 (Sndollan) the de-oxygenation rates increased a little the reasons were mentioned before.

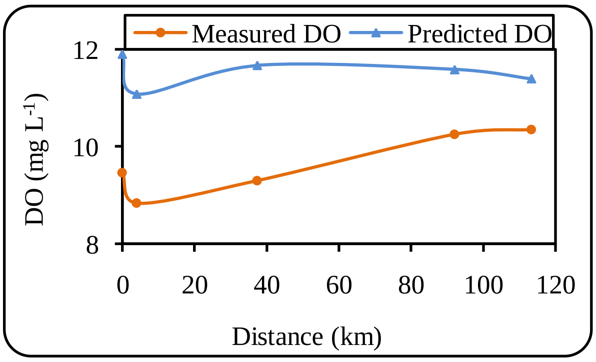

Figure 4.6.1a3 Oxygen sag curve for February.

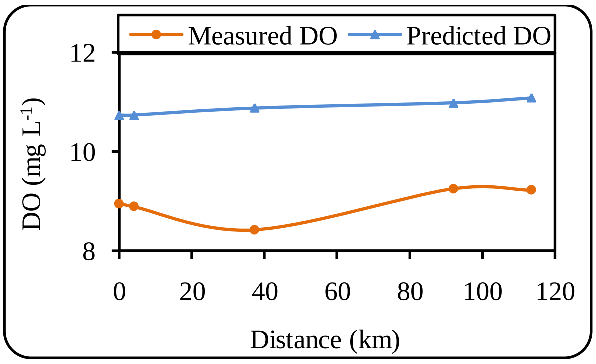

Figure 4.6.1a4 Oxygen sag curve for March.

(Fig. 4.6.1a5) pointed out to the oxygen sag curve and as a result, the same trends for de-oxygenation and re-oxygenation rates, but at the fourth point (Kawe) km 92.06 with increasing distance to fifth point (Sndollan) at km 113.48 the de-oxygenation rate increased and higher than the re-oxygenation rate. It means natural self-purification not occuerd.

(Fig. 4.6.1a6), illustrates the oxygen sag curve. The data showed that DO deficit decreased with distance from (0.0 to 37.29) km and DO deficit increased with distance from km (37.29 to 113.48). It is clear that the fourth point (Kawe) and fifth (Sndolland) on the oxygen sag curve where the oxygen deficit is high than the other points. It obviously cleared that at points fourth and fifth re-aeration decreased due to increased waste and decomposition.

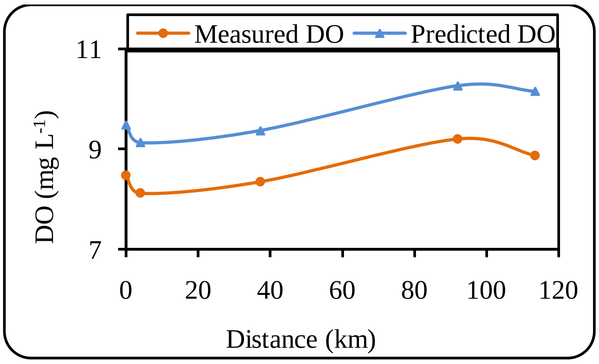

Figure 4.6.1a5 Oxygen sag curve for April.

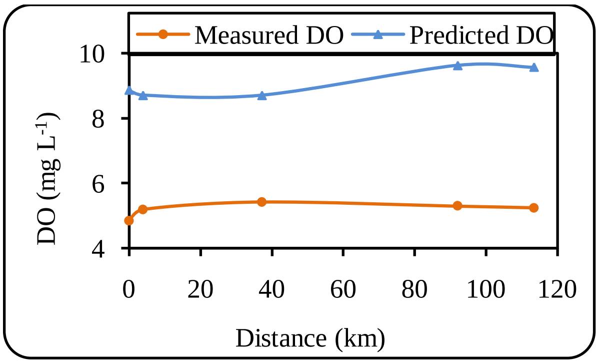

Figure 4.6.1a6 Oxygen sag curve for May.

4.6.2 Oxygen sag curve for main Qalachwalan-Lesser Zab Rive based on time.

Symmetrical sag curves have obtained between oxygen and time as were obtained between oxygen and distance which shown previously in (Fig. 4.6.1a1 to 4.6.1a6). From the (Appendix 3: Table 4.6.1 to 4.6.6), it is clear that the natural self purification process is time dependent. As time progresses, the DO available is used up by the effluent resulting in a drop in DO to the critical level and then rises to the initial status of the stream. This self purification followed the sag curve of polluted water.

4.6.3 The DO model

The plots of measured and predicted DO against sites are presented in (Fig. 4.6.3a1 to 4.6.3a6). The DO curve for river gave reveal sinusoidal shapes and the space between two shapes is deficit DO. From the (Appendix 3: Table 4.6.1 to 4.6.6) and (Fig. 4.6.3a1 to 4.6.3a6) obtained that the highest amount of oxygen deficit (de-oxygenation) during November and May were recorded, due to low discharges, high temperature and activity of bacteria in water and the lowest amount of oxygen deficit (re-oxygenation) during February and April were obtained, due to high dilution and low temperature. The concentration of DO is represented as the resultant of two principal competing progresses; (de-oxygenation and re-oxygenation).

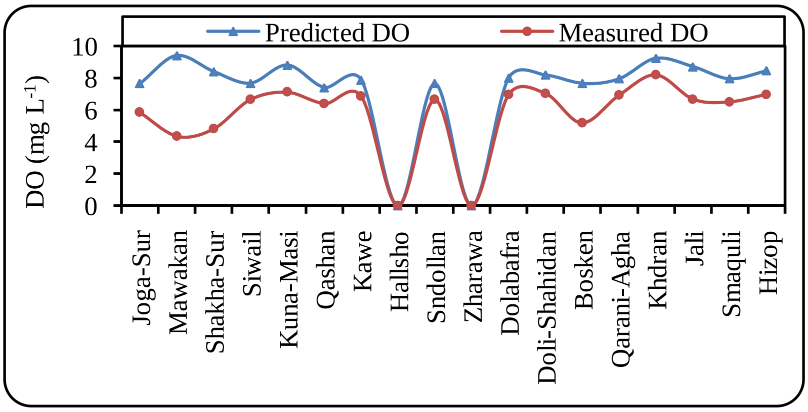

Figure 4.6.3a1 Variation of DO with stations in August.

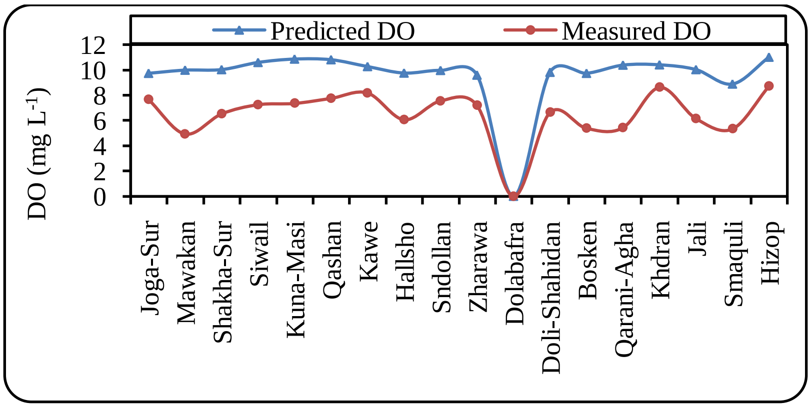

Figure 4.6.3a2 Variation of DO with stations in November.

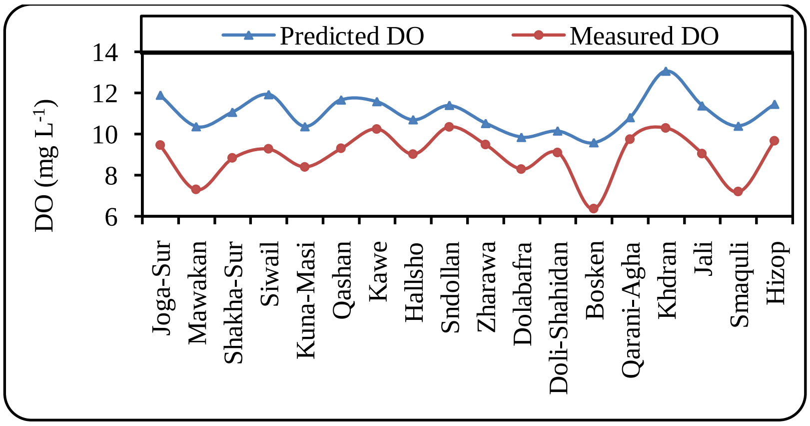

Figure 4.6.3a3 Variation of DO with stations in February.

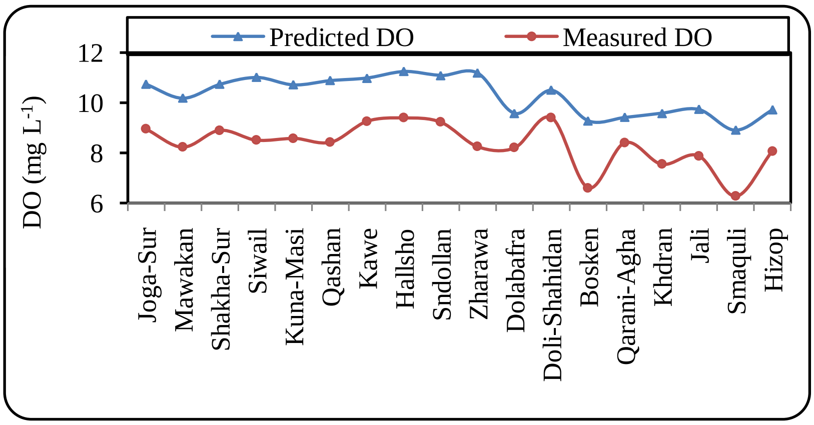

Figure 4.6.3a4 Variation of DO with stations in March.

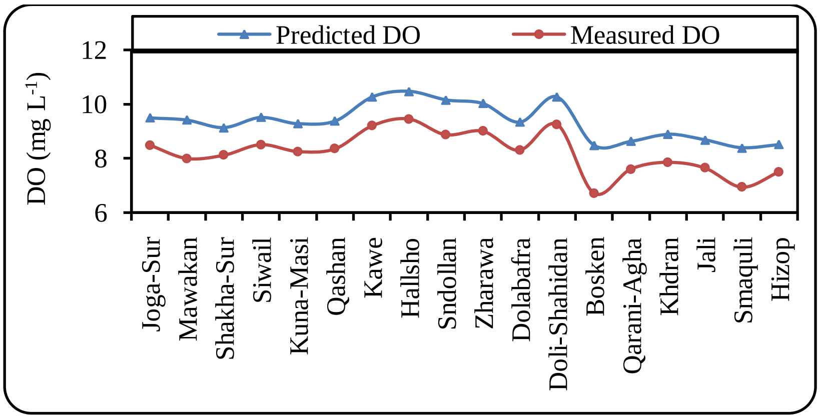

Figure 4.6.3a5 Variation of DO with stations in April.

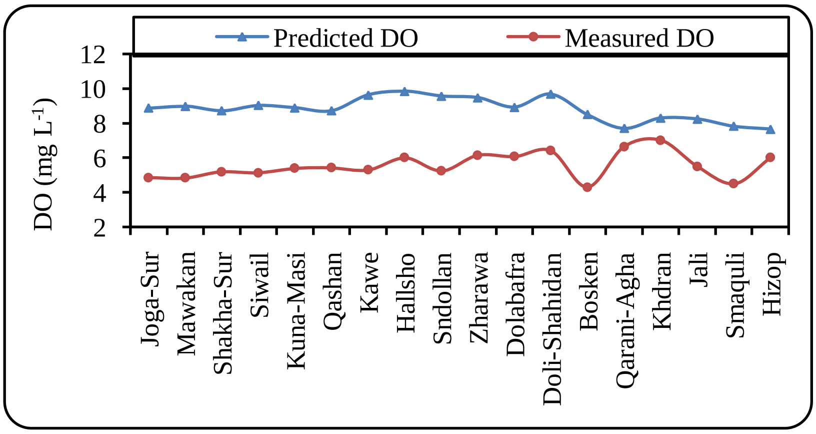

Figure 4.6.3a6 Variation of DO with stations in May.

4.6.4 The BOD model

The plots of measured and predicted BOD against sites are presented in (Fig. 4.6.4a1 to 4.6.4a6). The BOD curve for river gave wavy shapes and the space between two shapes is ultimate BOD. From the (Appendix 3: Table 4.6.1 to 4.6.6) and as shown in (Fig. 4.6.4a1 to 4.6.4a6) that the highest BOD (ultimate) at (Bosken) site during the studied periods were recorded. The reason is attributed to the fact that there was more discharge of effluent in (Bosken) than the others sites. As shown in figures, it was observed that the higher the BOD, the corresponding DO level declines. This shows that progressive increase in the BOD level will lead to an anaerobic condition which may cause death of most aerobic organisms in the river.

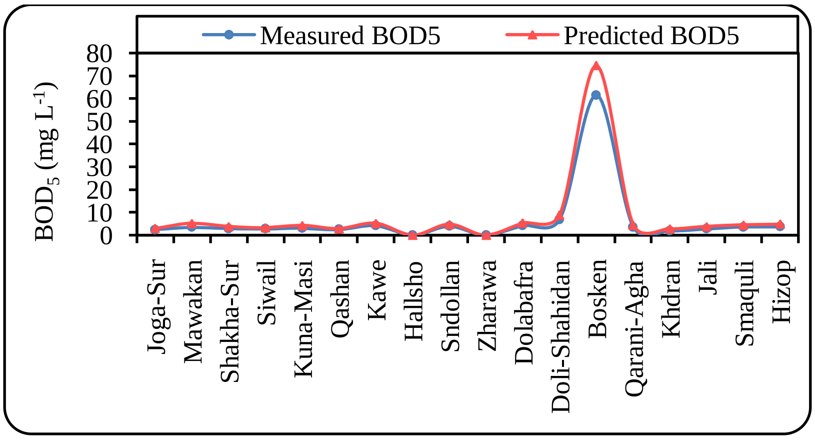

Figure 4.6.4a1 Variation of BOD$_5$ with stations in August.

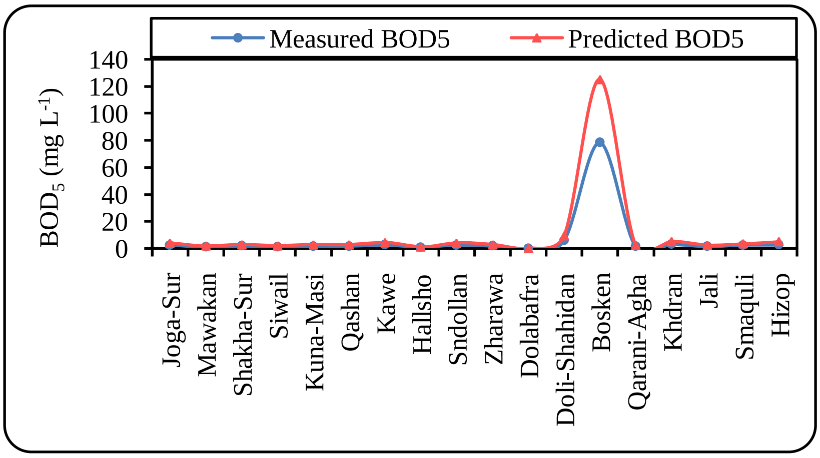

Figure 4.6.4a2 Variation of BOD$_5$ with stations in November.

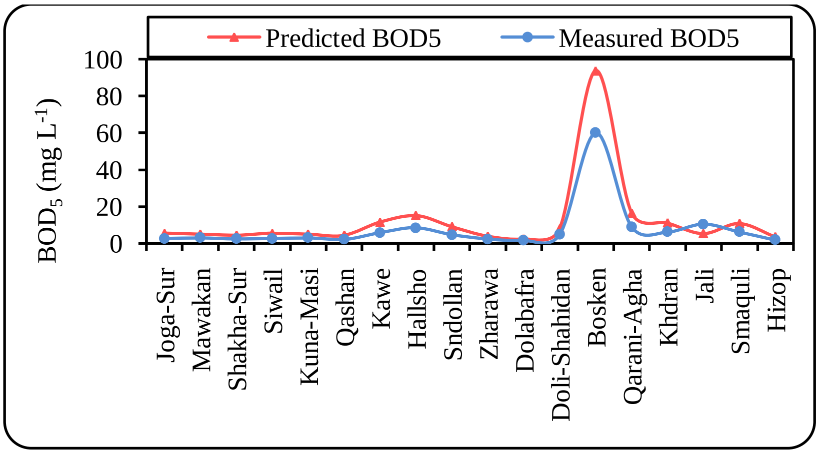

Figure 4.6.4a3 Variation of BOD$_5$ with stations in February.

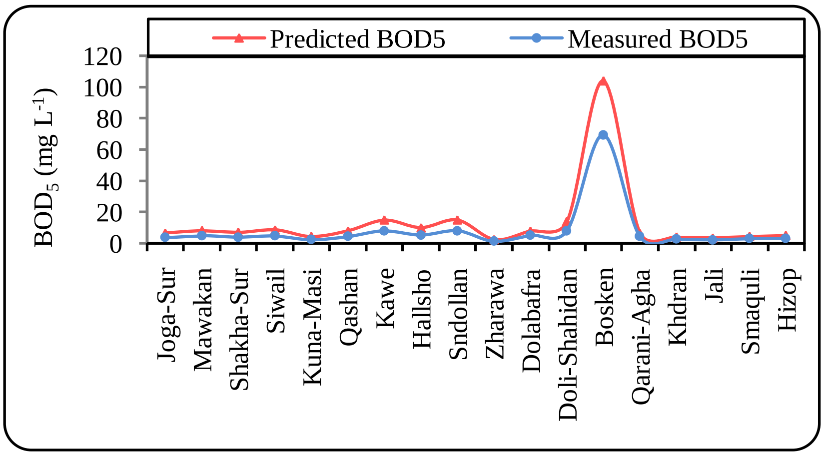

Figure 4.6.4a4 Variation of BOD_5 with stations in March.

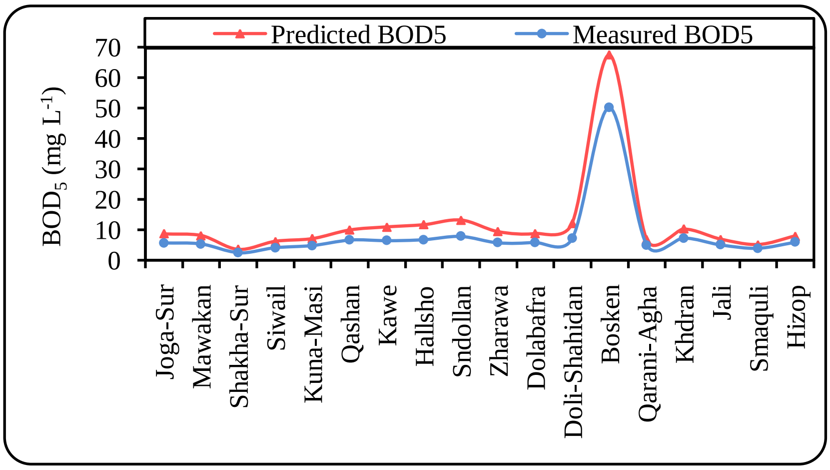

Figure 4.6.4a5 Variation of BOD_5 with stations in April.

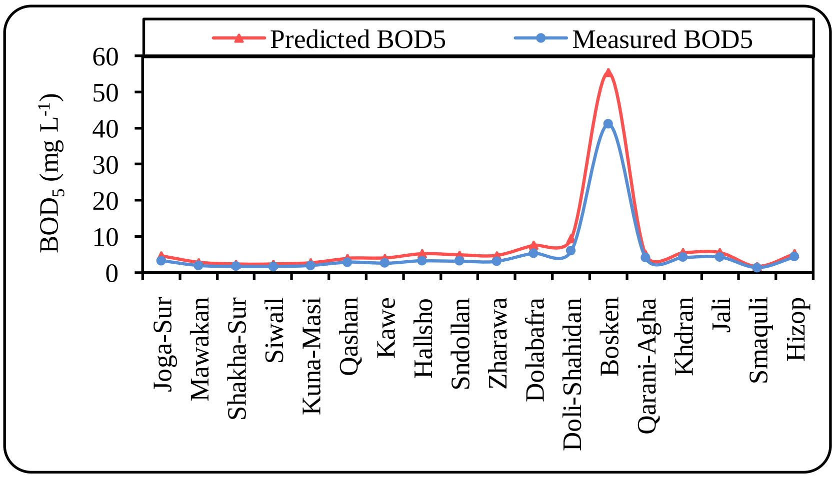

Figure 4.6.4a6 Variation of BOD_5 with stations in May.

The data obtained on a monthly basis include hydraulic, physicochemical properties of the water samples and temperature of the rivers. The de-oxygenation constant *K1* and ultimate

(BOD) *Lo*, re-oxygenation constant *K2* and DO deficit are shown in the same table with fair ratio (*f*) (Appendix 3: Table 4.6.1 to 4.6.6).

4.6.5 Time of travel

The times of travel in days were computed using equation (2.4). The different times of travels were computed for each month. These values were further used in the determination of *K1* and *K2* (Appendix 3: Table 4.6.1 to 4.6.6).

4.6.6 De-oxygenation constant *K1* and re-oxygenation constant *K2*

The computation of the independent variables as stated in equations (2.9 and 2.11) for the consecutive months starting from August 2016 through to May 2017 was carried out by using hydraulic and physicochemical data and these can be seen in (Appendix 3: Table 4.6.1 to 4.6.6). The relationship between *K2* and the time month as shown in tables depends on the rate of waste, the flow velocity of the streams, and the volume of water available during the month. More discharge, generally leads to low DO levels as oxygen demanding material biologically degrades. During the wet season, re-aeration greatly improves compared to dry season. In dry seasons, there are possibilities of decrease in solubility of oxygen and increased biochemical oxidation of organics. High velocity running streams enhances high re-aeration rates, while high discharge favors accelerated dilution and dispersion of concentrated pollutants in water bodies (Garg, 2006).

4.6.7 Average stream velocity

The average stream velocity is an important factor in both the re-aeration constant and the time of travel along the rivers. (Appendix 3: Table 4.6.1 to 4.6.6), we observed that as the velocity increases; the re-aeration coefficient also increases, implying an increased rate of oxygen transfer from the atmosphere to the water. The velocity also affects the temporal distribution of the DO because an increase in velocity implies less time taken for the DO to spread. This transfer occurs at the air/water interface. The transfer of DO from the atmosphere to the surface of the water body is controlled by the transfer rate and the DO deficit.

4.6.8 The fair ratio (*f*)

The fair ratio was used in estimating the self-purification capacity for this study. (Appendix 3: Table 4.6.1 to 4.6.6) shows the model parameters and the self- purification factors (fair ratio) for the studied months from August 2016 to May 2017. The average values of the fair ratio in all the studied months were greater than unity except in April month lower than unity which means that re-aeration predominates but in April de-aeration predominates across the stretch of the rivers studied (Chiejine *et al.*, 2015). The average fair ratio for the month of May was found to be (3.032) which were higher than the other months. The reason for these values could be as a result of less pollution activities (less DO reduction) in the month of May which is suggested by the lower average BOD_5 values generated in that month. The month of April seems to be the most polluted month since most of the fair ratio values in the sampling sites calculated were less than unity which implies that the de-oxygenation rate was greater than the re-oxygenation rate (Omole *et al.*, 2013). Although, the fair ratio of November (2.037) was slightly higher than that of February (1.011), March (1.171) and August (1.173). This could be as a result of increase in waste disposal (high DO reduction) in the months of November, February, March, August and April compare to May at some sampling sites like (Bosken and Doli-Shahidan) which increased the de-oxygenation rates and thereby subsequently affecting the fair ratios.

Generally, the average fair ratios (*f*) of the studied area of rivers were found to be greater than unity which implies that, re-aeration is greater than de-oxygenation except April (0.297). The values, although considered to be still within limits of self-purification capacity (0.5 to 5), (Garg, 2006).

4.7 Irrigation Water Quality

Irrigation water quality varies greatly upon the types and quantity of dissolved salts. Thus, water for irrigation suitability is determined not only by the total amount of salt present but also by the kind of salt. The important irrigation water quality parameters include a number of specific properties of water relevant in relation to the yield and quality of crops, maintenance of soil productivity and protection of the environment. Numerous water quality guidelines have been developed by many researchers for using water in irrigation under different condition (Ayers and Westcot, 1985). In this study the irrigation water quality is judged by the following most applied criteria. Salinity, Sodium Adsorption Ratio (SAR), Soluble Sodium Percent (SSP) and Residual Sodium Carbonate (RSC) (Balachandar *et al.*, 2010).

4.7.1 Salinity hazard versus sodicity hazard

The salinity of irrigation water leads to the accumulation of salt in the root zone of crop, thus reducing the ability of plant to get sufficient water from the soil and causes yield reduction. There are many factors increase salinity in irrigation water such as evaporation, sewage effluent, dissolution of limestone and evaporate bedrock, and agricultural drainage (Al-Shujairi, 2013).

High electrical conductivity in water makes the soils saline (Raju *et al.*, 2009), which is the primary reason for crop loss. The measured value of EC is varied between (220.12 and 1120.26) µS cm^{-1} (Appendix 1: Table 4.1.5b). The increase of salinity in dry season November is due to high rate of evaporation, also the dilution process by rainfall through wet period April reduces the salinity. Irrigation water was qualified by (Richards, 1954) into four categories on the basis of EC values. The zones (C_1 to C_4) have the value of EC < 250 µS cm^{-1} low salinity hazards (C_1-good), 250 to750 µS cm^{-1} medium salinity hazard (C_2-moderate), 750 to 2250 µS cm^{-1} high salinity hazard (C_3-poor) and more than 2250 µS cm^{-1} very high salinity hazard (C_4-very poor), respectively. As per Richards, it is observed that all water samples were fall under (low to high) saline zone (Appendix 1: Table 4.1.5b).

In the present study, the SAR is commonly used as an index for evaluating the sodium hazard associated with an irrigation water supply. The SAR values varied from (0.08 to 2.09) meq L^{-1}, with significant differences among sites have been shown in (Fig. 4.7.1a). Based on the classification of SAR, the result comparison showed that there is no harmful effect from sodium because all the values of SAR are < 10 meq L^{-1} under excellent category (S_1-class) and all the samples are suitable for irrigation (Appendix 4: Table 4.7.1). The monthly average SAR was ranged from (0.29 to 0.57) meq L^{-1} with significant differences among months have been shown in (Fig. 4.7.1b). The increase of sodicity in dry season August and November is due to low flow rate in rivers and high rate of evaporation, also the dilution process by rainfall through wet period March and April reduces the sodicity.

The assessment of irrigation water quality based on the combination of salinity hazard using (EC) and alkalinity hazard using (SAR) is another classification for the suitability of water for irrigation. A more detailed analysis for the suitability of water for irrigation as per the USSL classification diagram (Richards, 1954) (Fig. 4.7.1c), the combined (EC-SAR) classification locates the river water in the (C_1-S_1), (C_2-S_1) and (C_3-S_1) classes. Based on these specifications, the waters of the study area are considered safe for irrigation but high salinity water (C_3) category may not be fit for irrigation purposes in all soil types. Only high-salt tolerant plants can be grown. A result was similarity with resulted by (Rasul, 2013).

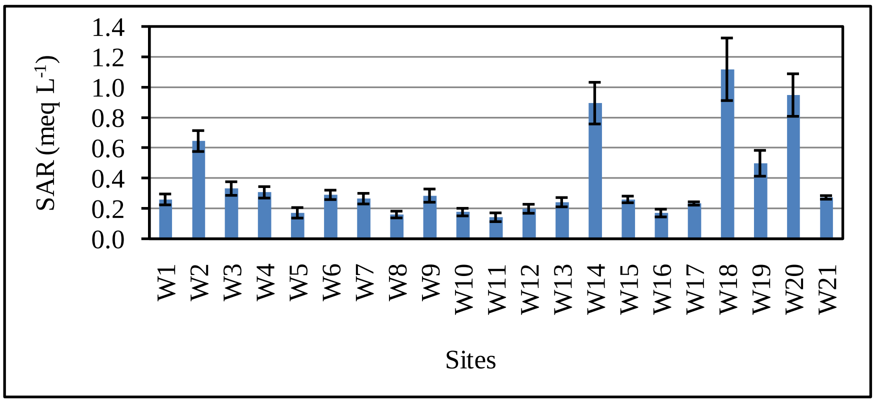

Figure 4.7.1a Standard error of mean of SAR in water for studied sites.

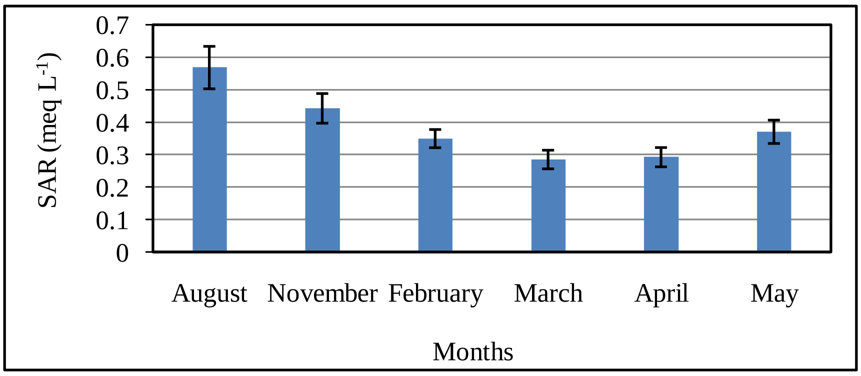

Figure 4.7.1b Standard error of mean of SAR in water for studied months.

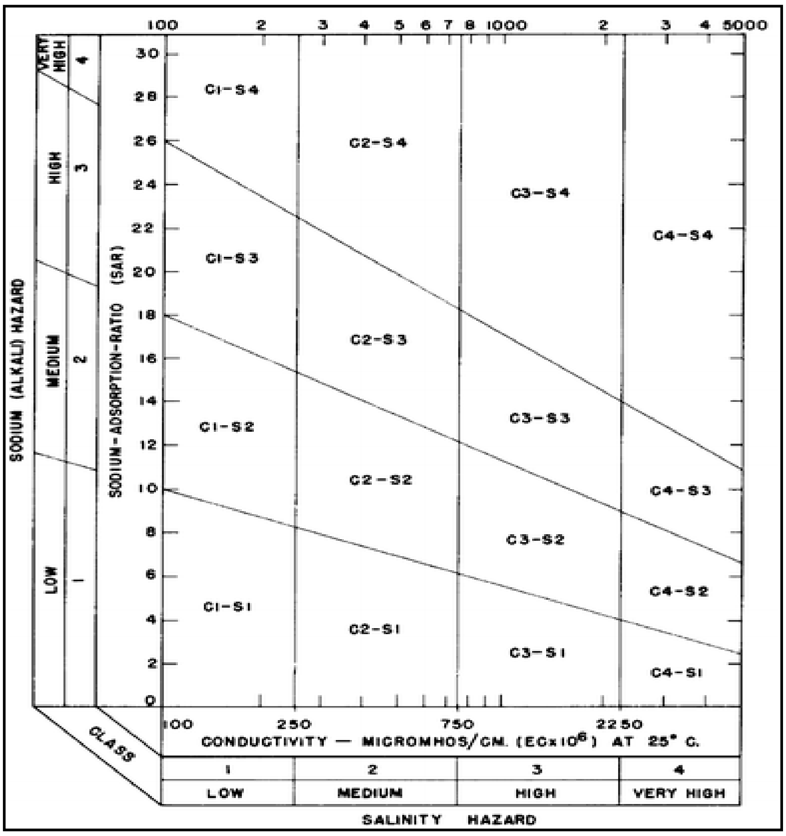

Figure 4.7.1c USSL classification of surface water for irrigation (Richards, 1954).

4.7.2 Soluble Sodium Percent (SSP)

Sodium is also used for adjudging the quality of water for agricultural purposes. Therefore, assessment of water fitness for irrigation purposes is widely done on the percentage of Na^+ (Wilcox, 1955). Water with SSP greater than 60% may result in sodium accumulations that will cause a breakdown of the soil's physical properties (Fipps, 1998). The calculated values of SSP varied from (3.04 to 35.48) % in the study region with significant differences among sites (Fig. 4.7.2a). According to SSP, all of the river water was (excellent to good) for irrigation (Todd and Mays, 2005) (Appendix 4: Table 4.7.2). For the collected surface water the monthly mean SSP values varied from (8.79 to 15.38) % with significant differences among months have been shown (Fig. 4.7.2b). When the concentration of Na^+ is high in irrigation water, sodium tends to be absorbed by clay particles, displacing Mg^{2+} and Ca^{2+} ions. This exchange process of Na^+ in water for Ca^{2+} and Mg^{2+} in soil reduces the permeability and eventually results in soil with poor internal drainage (Singaraja *et al.*, 2014).

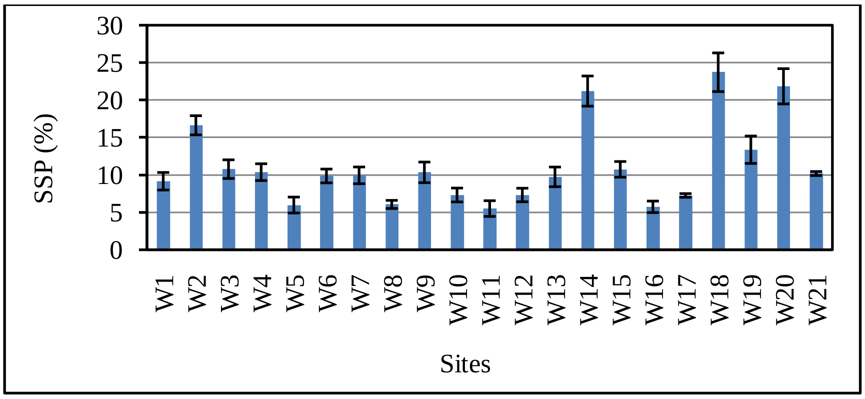

Figure 4.7.2a Standard error of mean of SSP in water for studied sites.

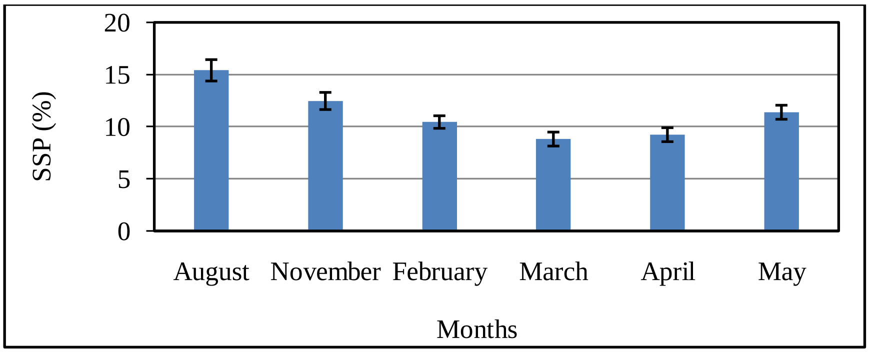

Figure 4.7.2b Standard error of mean of SSP in water for studied months.

SSP values were observed to be in lower range with a non-significant effect on irrigation quality of water. The increased of SSP in dry season August and November is due to high evaporation rate and low flow rate in river, also the dilution process by rainfall through wet period March and April reduces the sodicity.

4.7.3 Alkalinity hazard

The residual sodium carbonate is a valuable parameter that has a great influence on the suitability of irrigation water. Total CO_3^{2-} and HCO_3^- affects the water quality as it causes the precipitation of Ca^{2+} and Mg^{2+}, which in turn increases the percentage of Na^+ (Eaton, 1950). The Na^+ gets combined with the excess carbonates forming $NaHCO_3$, called the residual sodium carbonate (RSC) (Rama Rao *et al.*, 2013). It affects the soil structure. The RSC values were collected ranged from (-2.015 to 0.182) meq L^{-1}, with significant differences among sites (Fig. 4.7.3a). The classification of irrigation water according to the RSC presents in (Appendix 4: Table 4.7.3) all of the river water was suitable for irrigation because those having < 1.25 meq L^{-1} of RSC (Khan and Abbasi, 2013).

The monthly mean value RSC ranged from (-0.736 to -0.363) meq L^{-1} with significant differences among months have been shown in (Fig. 4.7.3b), which RSC remained negative for almost the water samples in this study, showing that the water is of good quality for use in irrigation.

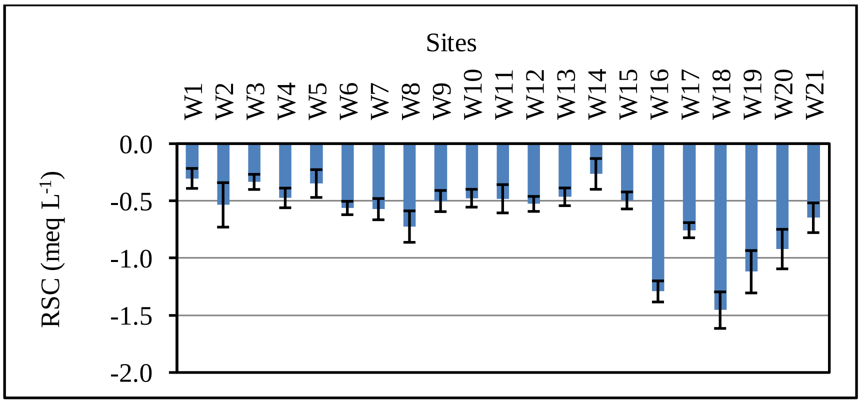

Figure 4.7.3a Standard error of mean of RSC in water for studied sites.

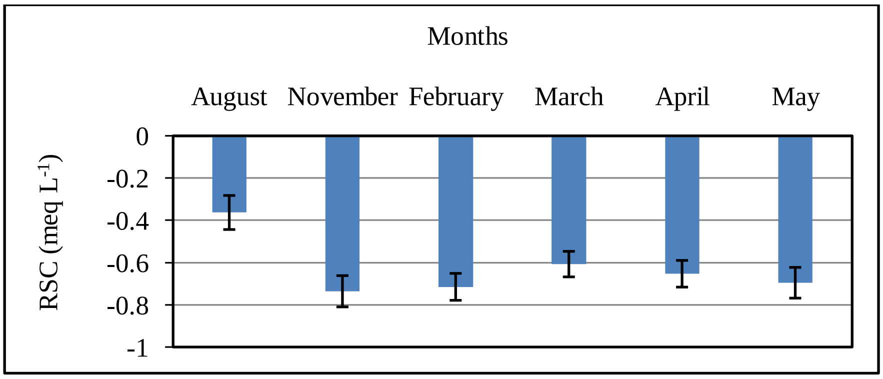

Figure 4.7.3b Standard error of mean of RSC in water for studied months.

Based on all calculated parameters and indexes for irrigation water quality of studied the surface waters were compared with the national and international water quality standards set for irrigation. EC of collected water samples fall in the class ‘low to high’, SAR in ‘excellent’, SSP in ‘good to excellent’ and RSC in ‘good’ for irrigation water quality.

The results of correlation matrix revealed that the very strong positively correlated value was found between (SAR/SSP) (r=0.963). The strong positively correlated value was observed between (EC/SAR) (r=0.739). The moderate positively correlated value was observed between (EC/SSP) (r=0.674). The negative correlated value was appeared between (EC/RSC) (r= -0.254) as shown in (Table 4.7).

Table 4.7 Correlation matrix for different irrigation water quality parameters.

	EC	SAR	RSC	SSP
EC	1	0.739**	-0.254	0.674**
SAR		1	-0.117	0.963**
RSC			1	-0.057
SSP				1

4.8 Soil Analysis

The results of the physicochemical characteristics of the soils from different land uses with statistical analysis are summarized in (Table 4.8a and 4.8b).

4.8.1 Soil pH

Studies have shown that among various environmental factors, pH is important in affecting the surface charge of soils and the availability of plant nutrient and microorganisms (Escobar and Hue, 2008). The data indicated that the soil pH ranged from (7.29 to 8.09). The highest pH value of 8.09 was recorded at soil sample (S31-Smaquli near bridge), while the lowest value of 7.29 was found in the croplands at soil sample (S22-Twasuran) as shown in (Table 4.8a). Overall, the mean value of all soil sites is (7.65). The slightly lower average value of soil pH under the cropland and plantations may be due to the depletion of basic cations in crop harvest and due to its highest microbial oxidation that produces organic acids, which provide H^+ to the soil solution lowers its soil pH value (Chimdi *et al.*, 2014).

4.8.2 Soil EC_e and TDS

The values of EC_e were observed to be in the range from 309.56 at soil sample (S11-Qashan near bridge) to 1305.97 µS cm^{-1} at soil sample (S7-Wazha) with a mean of (645.78) µS cm^{-1} (Table 4.8a). The highest EC_e value under the grazing land might be due to its highest exchangeable Na^+ content, whereas the lowest EC_e value under the cultivated land can be associated with the loss of base forming cations (Ca^{2+} and Mg^{2+}) after deforestation and intensive cultivation. TDS value decreased and increased same as EC_e (Fig. 4.8.1 and Table 4.8a). The values of TDS were observed to be in the range from 198.12 mg L^{-1} at soil sample (S11-Qashan near bridge) to 835.82 mg L^{-1} at soil sample (S7-Wazha) with a mean of (413.30) mg L^{-1}.

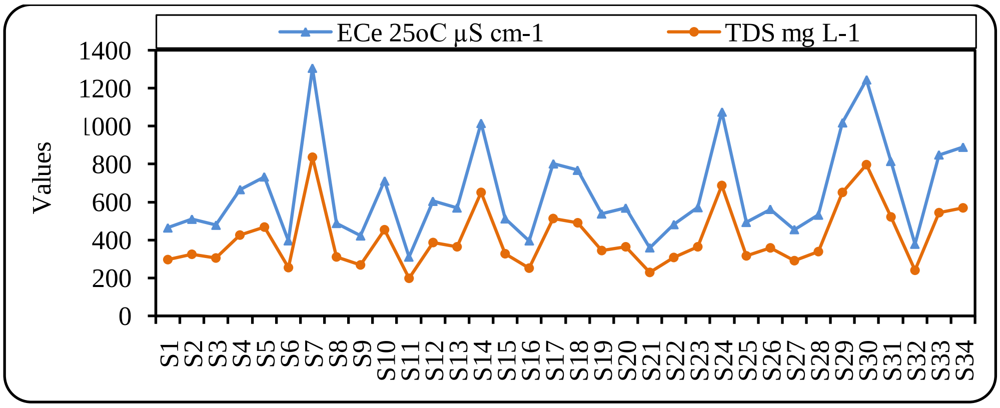

Figure 4.8.1 Soil EC_e and TDS variations in different sampling sites.

4.8.3 Particle size distribution

Particle size distribution analysis allowed classifying the studied soil samples into eight different classes depending on USDA triangle classification: clay, clay loam, silty clay, silty clay loam, loam, silt, silty loam and sandy loam, also the sand, silt, and clay percentages with texture classes of the soil samples are show in (Table 4.8a).

4.8.4 Soil bulk density

The bulk density of soils from the different locations were observed, numerically the highest mean value 1.52 g cm^{-3} of bulk density was recorded on the grazing land at soil sample (S34-Jali up) and the lowest mean value 1.33 g cm^{-3} under the crop land at soil sample (S28-Khdran up) with a mean of (1.42) g cm^{-3} (Table 4.8a). The ranges of bulk density values observed in this study are within the ranges expected in most mineral soils as indicated by (Hillel, 1980).

Table 4.8a Soil physical properties in different sub regions of study area.

Site codes	pH	EC$_e$ µS cm^{-1}	TDS mg L^{-1}	Sand %	Silt %	Clay %	Soil texture	BD g cm^{-3}	SOM %	SHC cm sec^{-1}
S1	7.85	463.10	296.38	30.03	48.89	21.08	Loam	1.38	2.01	4.48E-05
S2	7.78	509.03	325.78	37.68	56.54	5.78	Silt loam	1.47	1.00	7.31E-05
S3	7.56	477.42	305.55	48.55	32.86	18.58	Loam	1.45	1.69	1.54E-05
S4	7.69	665.26	425.77	22.87	46.36	30.77	Clay loam	1.44	1.55	6.97E-06
S5	7.78	732.38	468.72	33.27	43.88	22.85	Loam	1.44	1.72	1.11E-04
S6	7.54	395.28	252.98	10.66	29.79	59.55	Clay	1.47	0.75	5.17E-06
S7	7.74	1305.97	835.82	44.28	50.72	5.00	Sit loam	1.45	1.73	2.63E-05
S8	7.71	487.03	311.70	11.23	38.25	50.52	Clay	1.44	1.70	1.80E-05
S9	7.86	420.98	269.43	5.10	43.88	51.02	Silty clay	1.45	1.10	9.40E-06
S10	7.43	710.68	454.84	28.09	44.93	26.98	Loam	1.45	1.59	3.79E-05
S11	7.52	309.56	198.12	40.19	43.00	16.81	Loam	1.47	0.83	2.84E-05
S12	7.90	603.72	386.38	23.58	62.22	14.20	Silt loam	1.45	1.55	5.85E-06
S13	7.66	568.54	363.87	31.05	57.92	11.03	Silt loam	1.43	1.79	4.21E-05
S14	7.91	1014.79	649.47	40.09	55.47	4.44	Silt loam	1.43	1.88	2.91E-05
S15	7.45	511.06	327.08	29.96	65.95	4.08	Silt loam	1.46	1.18	1.69E-05
S16	7.51	394.94	252.76	14.53	61.89	23.58	Silt loam	1.41	1.58	9.15E-06
S17	7.38	801.15	512.74	22.91	54.05	23.04	Silt loam	1.42	1.37	1.93E-05
S18	8.08	767.36	491.11	12.71	82.31	4.98	Silt	1.43	1.63	8.71E-06
S19	7.73	536.98	343.67	15.42	76.70	7.88	Silt loam	1.38	2.21	2.24E-05
S20	7.54	567.89	363.45	3.75	55.36	40.89	Silty clay	1.48	0.96	3.30E-06
S21	7.50	358.18	229.23	14.93	40.13	44.94	Silty clay	1.50	0.60	2.52E-06
S22	7.29	480.69	307.64	5.72	87.25	7.04	Silt	1.39	1.65	8.09E-06
S23	7.63	570.24	364.95	14.10	54.81	31.09	Silty clay loam	1.37	2.23	1.99E-05
S24	8.01	1074.43	687.64	6.77	38.34	54.89	Clay	1.34	2.21	1.41E-05
S25	7.47	492.48	315.18	32.61	47.11	20.28	Loam	1.42	1.68	1.51E-04
S26	7.60	561.35	359.27	13.11	80.74	6.16	Silt	1.39	1.87	1.01E-05
S27	7.32	454.37	290.80	28.87	48.88	22.25	Loam	1.40	1.72	5.42E-05
S28	8.04	530.83	339.73	8.63	41.38	49.99	Silty clay	1.33	2.62	8.25E-05
S29	7.64	1017.74	651.36	48.86	43.30	7.83	Loam	1.37	2.29	4.38E-05
S30	7.39	1244.50	796.48	4.56	83.23	12.21	Silt loam	1.36	2.45	1.10E-05
S31	8.09	814.23	521.11	4.17	78.10	17.72	Silt loam	1.34	2.98	1.18E-05
S32	7.50	377.19	241.40	20.81	55.42	23.77	Silt loam	1.41	1.84	7.10E-06
S33	7.78	848.47	543.02	20.25	65.22	14.54	Silt loam	1.35	2.39	1.21E-05
S34	7.34	888.84	568.86	68.31	28.26	3.43	Sandy loam	1.52	0.79	6.12E-04
Mean	7.65	645.78	413.30					1.42	1.68	4.6E-04

4.8.5 Soil organic matter (SOM)

The results of the soil organic matter of all the studied locations show that the percentage organic matter of the different land uses ranged from (0.60 to 2.98) % with a mean of (1.68) % (Table 4.8a). The highest SOM value of 2.98 % was recorded in the natural grassland at soil sample (S31-Smaquli near bridge), this may be due to findings that soils underlying native cover. While the lowest value of 0.60 % was found in the croplands at soil sample (S21-Dolishahidan near bridge). The organic matter content is as generally expected higher in the forest and orchard than in farmland fields and vegetable gardens. This is mainly due to large supply of litter fall of leaves, needles and root residues from the trees, while the organic matter content in farmlands and vegetable gardens are lower because they are greatly affected by cultivation speeding up the decomposition and crop removal (Condron *et al.,* 2005). The difference in OM concentration in soil samples of study area is due to the presence of various microorganisms which are capable to decompose such organic matter for their cellular necessities (Rind *et al.,* 2005).

4.8.6 Soil saturated hydraulic conductivity

There were variations in soil saturated hydraulic conductivity values from the soil samples analyzed. From the results obtained, the SHC ranged from (2.52E-06 to 6.12E-04) cm sec^{-1} with a mean of (4.6E-04) cm sec^{-1}. The lowest SHC 2.52E-06 cm sec^{-1} was recorded at soil sample (S21-Dolishahidan near bridge), while the highest 6.12E-04 cm sec^{-1} was recorded at soil sample (S34-Jali up) (Table 4.8a). SHC was increased with increasing sand content and decreased with increasing clay content. The high sand content gives rise to high levels of macro pores which are responsible for saturated water movement (Humble, 1975).

4.8.7 Soluble cations

The four most abundant cations in soils are calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) and potassium (K^{+}). The soluble calcium varied from (43.61 to 213.59) mg L^{-1} with an average value of (109.54) mg L^{-1}. The highest value of Ca^{2+} 213.59 mg L^{-1} was observed at soil sample (S30-Hizop near bridge), the lowest value 43.61 mg L^{-1} of Ca^{2+} was recorded in (S11-Qashan near bridge) (Table 4.8b). The soluble magnesium of all soil sites ranged from (6.71 to 29.04) mg L^{-1}. Overall, the mean of soluble magnesium of all soil sites is (14.20) mg L^{-1}. The highest value was observed in soil sample (S29-Khdran near bridge) 29.04 mg L^{-1}, while the lowest value was recorded in (S6-Kanarwe) 6.71 mg L^{-1} (Table 4.8b). The contents of both Ca^{2+} and Mg^{2+} decreased with soil under the cultivated land. These indicate that there was higher down ward leaching of basic cations in the crop field than in the other land use practices. The lowest value obtained on the cultivated land could be also be related to influence of intensity of cultivation and abundant crop harvest with little or no use of input as reported by (He *et al.*, 1999).

The soluble sodium of all sites indicates the degree of which the soil sites are saturated with sodium. The soluble sodium ranged from (8.24 to 97.25) mg L^{-1} with an average value of (17.02) mg L^{-1}. Soil sample (S33-Jali low) had the highest value of Na^+ 97.25 mg L^{-1}. The least value 8.24 mg L^{-1} of Na^+ was recorded in soil sample (S13-Hallsho near Allawa village) (Table 4.8b); though is not an essential element for plant growth, but is important for diagnosing problem soils that may contain high amounts of sodium. High levels of sodium affect soil structure, soil permeability and may be toxic to sensitive plants (Horneck *et al.*, 2011). Potassium is the third most important plant nutrient along with nitrogen and phosphorus. The potassium of all soil sites ranged from (1.66 to 24.75) mg L^{-1} with an average value of (6.56) mg L^{-1}. Soil sample (S29-Khdran near bridge) had the highest value of K^+ 24.75 mg L^{-1}. The least value 1.66 mg L^{-1} of K^+ was recorded in soil sample (S11-Qashan near bridge) (Table 4.8b). Generally, the lower K^+ contents in the cultivated and the grazing lands than in the forest land might be due to its continuous losses in the harvested and grazed parts of the plants from the cultivated and grazing lands, respectively (Gebeyaw, 2007).

The concentration of soluble cations are in the order $Ca^{2+} > Na^+ > Mg^{2+} > K^+$ in the soils from study area (Table 4.8b). The high values of soluble Ca^{+2} reflect the presence of carbonate minerals such as calcium carbonate (calcite).

4.8.8 Soluble anions

Among the anions, bicarbonate is predominant anion followed by sulfate and chloride in the soils. The bicarbonate content ranged from (142.74 to 590.52) mg L^{-1} with an average value of (309.32) mg L^{-1}. The sulfate and chloride content ranged from (43 to 170) mg L^{-1} with a mean of (84.8) and (9.23 to 139.16) mg L^{-1} with a mean of (30.98) mg L^{-1} respectively. The higher concentrations of bicarbonate 590.52 mg L^{-1} and sulfate 170 mg L^{-1} were found in the soil sampling site (S29-Khdran near bridge and S30-Hizop near bridge) respectively, while the highest concentration of chloride 139.16 mg L^{-1} was founded in soil sample (S7-Wazha) (Table 4.8b). Higher content of HCO_3^- in some soil samples in the downstream part could be related to strong alkaline reaction. The carbonate ions are almost negligible or lesser in amount in majority of soil samples. This is due to precipitation of calcium and magnesium as carbonates.

4.8.9 Soil nutrients

The nitrate concentration in the soil extracts ranged from (4.7 to 21) mg L^{-1} with a mean (8.3) mg L^{-1}. The highest values of NO_3-N were recorded in soil sample (S24-Bosken and S34-Jali up) comparison to the other soils (21 and 19.9) mg L^{-1} respectively. As the pattern of nitrate the nitrite had recorded the highest value in soil sample (S24-Bosken) 0.28 mg L^{-1}, while the NO_2-N ranged from (0.03 to 0.28) mg L^{-1} with a mean (0.14) mg L^{-1}. The ammonium concentration was the highest in soil sample (S29-Khdran near bridge) 3.59 mg L^{-1} and the NH_4-N of all sites ranged from (0.15 to 3.59) mg L^{-1} with an average value of (1.31) mg L^{-1}. The ammonium levels showed different patterns depending on the soil type and the approach of land cultivation. The phosphate levels showed very high peaks in the cultivated areas and the concentrations ranged between (0.4 and 5.4) mg L^{-1} with an average value of (2.46) mg L^{-1}, the highest value was recorded in soil sample (S29-Khdran near bridge) 5.4 mg L^{-1} in comparison to the other values (Fig. 4.8.2 and Table 4.8b). The concentration of soluble nutrients are in the order of NO_3-N > PO_4-P > NH_4-N > NO_2-N in the soils from the study area (Table 4.8b).

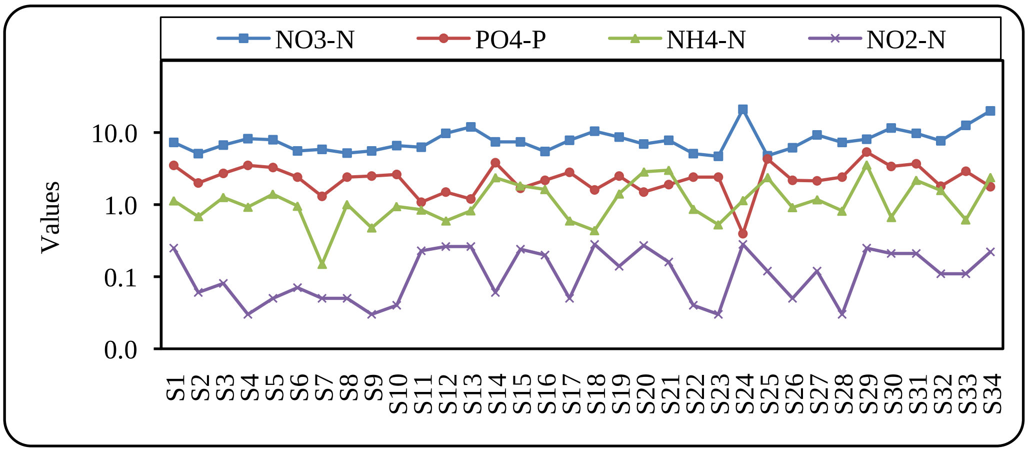

Figure 4.8.2 Soil nutrients variations (mg L^{-1}) in different sampling sites.

Table 4.8b Major cations, anions and nutrients in different sub regions of study area in soils.

Site codes	Concentrations in mg L^{-1}										
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	NO_3-N	PO_4-P	NH_4-N	NO_2-N
S1	87.19	9.24	11.90	8.11	282.14	9.94	57	7.3	3.51	1.14	0.25
S2	99.49	10.94	10.79	5.59	267.94	30.37	81	5.1	2.02	0.69	0.06
S3	92.39	11.16	12.82	8.79	259.86	29.11	80	6.7	2.72	1.27	0.08
S4	101.89	15.99	26.59	6.11	374.56	12.68	85	8.2	3.52	0.93	0.03
S5	155.39	9.96	13.74	7.23	355.42	26.27	98	7.9	3.31	1.41	0.05
S6	64.03	6.72	14.65	7.81	182.50	17.04	69	5.6	2.41	0.96	0.07
S7	169.99	25.32	48.53	5.76	486.34	139.16	91	5.9	1.32	0.15	0.05
S8	65.39	13.00	23.89	5.30	263.04	15.62	59	5.2	2.41	1.01	0.05
S9	87.39	9.94	11.99	2.05	251.08	18.46	75	5.6	2.52	0.48	0.03
S10	138.19	12.68	13.74	6.47	442.38	17.04	85	6.6	2.63	0.95	0.04
S11	43.61	16.92	10.99	1.66	154.70	14.91	69	6.3	1.10	0.85	0.23
S12	123.99	10.32	9.16	5.27	279.38	24.85	97	9.8	1.51	0.60	0.26
S13	117.79	9.60	8.24	2.83	283.04	22.72	55	12.0	1.21	0.83	0.26
S14	182.79	9.12	20.15	9.47	520.22	29.79	111	7.4	3.82	2.39	0.06
S15	89.79	10.90	11.90	5.69	223.76	15.62	102	7.5	1.71	1.84	0.24
S16	82.79	11.04	8.24	3.22	219.60	24.85	69	5.5	2.20	1.64	0.20
S17	152.79	11.76	17.40	4.39	443.60	27.40	91	7.8	2.81	0.60	0.05
S18	150.79	9.48	12.82	5.08	301.34	22.72	156	10.4	1.62	0.44	0.28
S19	99.39	13.92	9.16	3.22	312.08	9.23	64	8.6	2.51	1.42	0.14
S20	73.99	17.76	12.82	3.22	212.28	21.30	82	6.9	1.51	2.87	0.27
S21	56.79	13.92	18.32	2.05	203.74	20.59	43	7.8	1.90	3.03	0.16
S22	79.44	13.66	9.66	3.81	261.38	19.88	55	5.1	2.42	0.87	0.04
S23	93.92	12.96	10.06	4.00	293.06	21.43	69	4.7	2.42	0.53	0.03
S24	159.99	19.32	15.57	9.18	434.32	28.40	88	21.0	0.40	1.15	0.28
S25	89.89	18.96	9.16	3.03	287.80	27.49	64	4.8	4.32	2.40	0.12
S26	78.89	19.08	10.07	3.71	276.32	18.06	79	6.2	2.20	0.92	0.05
S27	73.59	14.88	9.16	4.59	232.54	12.08	64	9.3	2.15	1.18	0.12
S28	97.92	14.99	9.96	3.43	293.16	16.33	69	7.3	2.41	0.82	0.03
S29	158.79	29.04	14.65	24.75	590.52	34.01	63	8.1	5.40	3.59	0.25
S30	213.59	13.20	15.65	9.40	450.02	89.07	170	11.6	3.40	0.67	0.21
S31	156.39	12.80	15.82	19.50	402.86	28.82	141	9.7	3.72	2.20	0.21
S32	79.89	10.92	9.94	1.96	198.96	19.17	73	7.7	1.82	1.59	0.11
S33	90.39	26.76	97.25	19.50	334.28	84.49	120	12.7	2.91	0.62	0.11
S34	112.79	16.68	23.81	6.93	142.74	104.37	108	19.9	1.79	2.40	0.22
Mean	109.54	14.20	17.02	6.56	309.32	30.98	84.8	8.3	2.46	1.31	0.14

4.8.10 Heavy metals in soil

(Table 4.8c) shows the mean levels of the elements obtained in the study sub regions of the study area with statistical analysis.

Table 4.8c Heavy metals in different sub regions of study area in soils.

Site codes	Concentrations in mg kg^{-1}						
	Fe	Cu	Zn	Mn	Pb	Cd	Cr
S1	530.00	7.50	14.25	347.50	0.75	ND	0.75
S2	165.50	2.75	5.00	221.25	0.51	ND	0.25
S3	978.75	5.25	6.50	380.50	0.67	ND	2.75
S4	377.25	4.75	6.00	407.00	1.66	ND	1.50
S5	239.75	3.00	6.25	372.25	0.32	ND	0.25
S6	163.50	4.75	5.00	475.50	0.43	0.75	0.50
S7	1150.50	10.25	10.75	398.75	0.75	ND	1.25
S8	512.00	8.75	11.50	278.00	0.21	ND	0.75
S9	60.75	0.50	3.00	16.25	0.39	0.08	0.50
S10	96.75	2.25	8.50	275.00	0.19	0.25	0.50
S11	101.75	1.50	22.00	361.50	0.27	ND	0.75
S12	209.00	3.75	6.00	277.00	0.39	0.08	1.50
S13	529.50	5.25	9.00	306.00	0.34	0.25	2.75
S14	755.50	6.25	7.75	251.75	1.25	ND	0.75
S15	683.50	7.50	11.00	201.00	0.14	0.25	2.25
S16	348.25	4.75	15.00	186.50	0.51	ND	1.00
S17	451.50	7.50	14.50	383.75	1.00	0.25	0.25
S18	539.50	6.25	7.50	260.50	0.31	ND	1.50
S19	676.50	9.00	15.50	304.50	1.50	0.25	2.00
S20	353.50	4.50	8.50	156.50	0.29	ND	1.25
S21	244.75	3.25	5.00	137.00	0.21	0.19	1.25
S22	553.25	7.50	9.50	273.50	0.18	0.25	1.75
S23	126.75	4.50	6.75	189.50	0.23	0.25	1.00
S24	87.75	3.50	8.75	199.75	0.56	0.20	1.00
S25	166.25	0.75	2.00	129.75	0.41	0.25	0.50
S26	653.50	6.00	19.25	245.75	0.11	ND	2.25
S27	254.00	1.00	4.00	114.00	0.65	0.09	0.75
S28	313.25	6.00	9.25	247.00	0.35	ND	2.00
S29	295.25	3.50	8.75	401.75	0.56	ND	3.25
S30	515.50	6.75	7.75	301.25	0.47	0.25	2.50
S31	517.00	7.00	11.50	466.25	0.42	ND	2.75
S32	1225.50	8.17	10.25	672.50	0.23	ND	6.50
S33	91.00	2.50	4.50	299.00	0.17	0.02	0.50
S34	24.50	2.25	3.75	421.25	0.26	ND	0.75
Mean	411.52	4.96	8.96	292.92	0.49	0.23	1.46

Metal concentration in soil varies significantly depending on the soil type, but also by region (Salmon, 2003). Differences between the soils of the regions were due to parent materials, relief, soil depth, maturity, dumps, municipals waste and agriculture activities. Based on the (Table 4.8c) iron was revealed at all sites within the studied regions with concentrations ranging from (24.50 to 1225.50) mg kg^{-1}, with the mean (411.52) mg kg^{-1}. The highest value of iron was 1225.50 mg kg^{-1} recorded at soil sample (S32-Smaquli up), while the lowest value was 24.50 mg kg^{-1} noted at (S34-Jali up) during study period. Iron exhibited higher concentration values in the soil than those of other metals in this study. High values of Fe in the samples were close to road areas has possibly resulted from the emission of iron from automobiles (Groysman, 2014).

Generally, the values of copper were ranged from (0.50 to 10.25) mg kg^{-1} with mean (4.69) mg kg^{-1}. The highest value of Cu 10.25.25 mg kg^{-1} was recorded at soil sample (S7-Wazha); while the lowest value 0.50 mg kg^{-1} was noted at (S9-Kuna-Masi up) during study period. In natural soils, the average concentration is (2 to 40) mg kg^{-1}. Significant quantities of Cu in the soil are connected in the minerals, therefore, this metal is supplied only by a very slow decay processes. Cu concentration can increase significantly under the effect of anthropogenic activities.

Unpolluted soil contains an average of (15 to 100) mg kg^{-1} of Zn. It occurs in large amounts in the layers of the clay minerals. Because of the extensive use of Zn in industry, the Zn content in soil surrounding the industrial areas can reach even 5000 mg kg^{-1} (Kabata-Pendias, 2010). The mean levels of zinc in the soil within the studied regions were ranged from (2 to 22) mg kg^{-1}. Soil sample (S11-Qashan near bridge) had the highest Zn mean of 22 mg kg^{-1}, while (S25-Chwarqurna) had the lowest mean of 2 mg kg^{-1} with the mean (8.96) mg kg^{-1}. The mean levels of manganese were ranged from (16.25 to 672.50) mg kg^{-1} with mean (292.92) mg kg^{-1}. Soil sample (S32-Smaquli up) recorded the highest mean of 672.5 mg kg^{-1} and (S9-Kuna-Masi up) had the lowest mean of 16.25 mg kg^{-1}. Soil generally contains (200 to 3000) mg kg^{-1} of Mn with an average value of 600 mg kg^{-1} (Okunola *et al.*, 2007). The levels of Mn in soils were relatively low, implying mild contamination of the metal in the soil. Mn exhibited higher levels of contamination in the soil than those of other metals in this study except Fe.

The increasing of lead concentration may be caused by the accumulation of fuel burning residues from the transportation and by the use of some pesticides in gardens or orchards. The mean level of Pb in the soil within the studied regions ranged from (0.11 to 1.66) mg kg^{-1} with mean (0.49) mg kg^{-1}. Soil sample (S4-Joga-Sur near bridge) had the highest Pb mean of 1.66 mg kg^{-1} this could be attributed to the surface runoff during rainy season, while (S26-Sarwchawa) had the lowest mean of 0.11 mg kg^{-1}. After the burning of gasoline in a car engine, lead is emitted into atmosphere and then deposited in soil and throughout the ecological system. Another possible source of lead that should be also noted here is fertilizers application on farmlands. A commercial phosphate fertilizer generally contains varied types of heavy metal elements (Mortvedt, 1996) such as cadmium, arsenic, chromium, lead, mercury, nickel and vanadium. If this fertilizer is applied and the procedure is repeated, the soil in that area can become highly contaminated with lead.

Cadmium was detected at 16 sites within the studied regions with concentrations ranging from (0.02 to 0.75) mg kg^{-1} with mean (0.23) mg kg^{-1}. Soil sample (S6-Kanarwe) had the highest Cd mean of 0.75 mg kg^{-1}, while (S33-Jali low) had the lowest mean of 0.02 mg kg^{-1}. Cd exhibited lower levels of contamination than those of other metals in this study. According to (Mico *et al.*, 2006) the recommended range of Cd in the soil is (0.07 to 1.1) mg kg^{-1} and concentration above 0.5 mg kg^{-1} reflects the influence of human activity. Human activity can contribute to increased Cd levels as a result of urban-industrial activity and/or agricultural practices as reported by (Mico *et al.*, 2006).

The mean levels of chromium in the soil within the studied regions were ranged from (0.25 to 6.5) mg kg^{-1}, with the mean (1.46) mg kg^{-1}. Soil sample (S32-Smaquli up) had the highest mean of 6.5 mg kg^{-1}, while (S2-Mawakan) had the lowest mean of 0.25 mg kg^{-1}. Cr is one of those heavy metals whose concentration is steadily increasing due to industrial growth (Adelekan and Abegunde, 2011). Other sources of Cr permeating the environment are air and water erosion of rocks, liquid fuels, industrial and municipal waste. The concentration of heavy metals are in the order of Fe > Mn > Zn > Cu > Cr > Pb > Cd in the soils from the study area (Table 4.8c).

4.9 Estimation of Erosion

The universal soil loss equation proposed by (Wischmeier and Smith, 1978), was used for the estimation of erosion (ton/hectare/year) for the studied watersheds as shown in (Fig. 4.9).

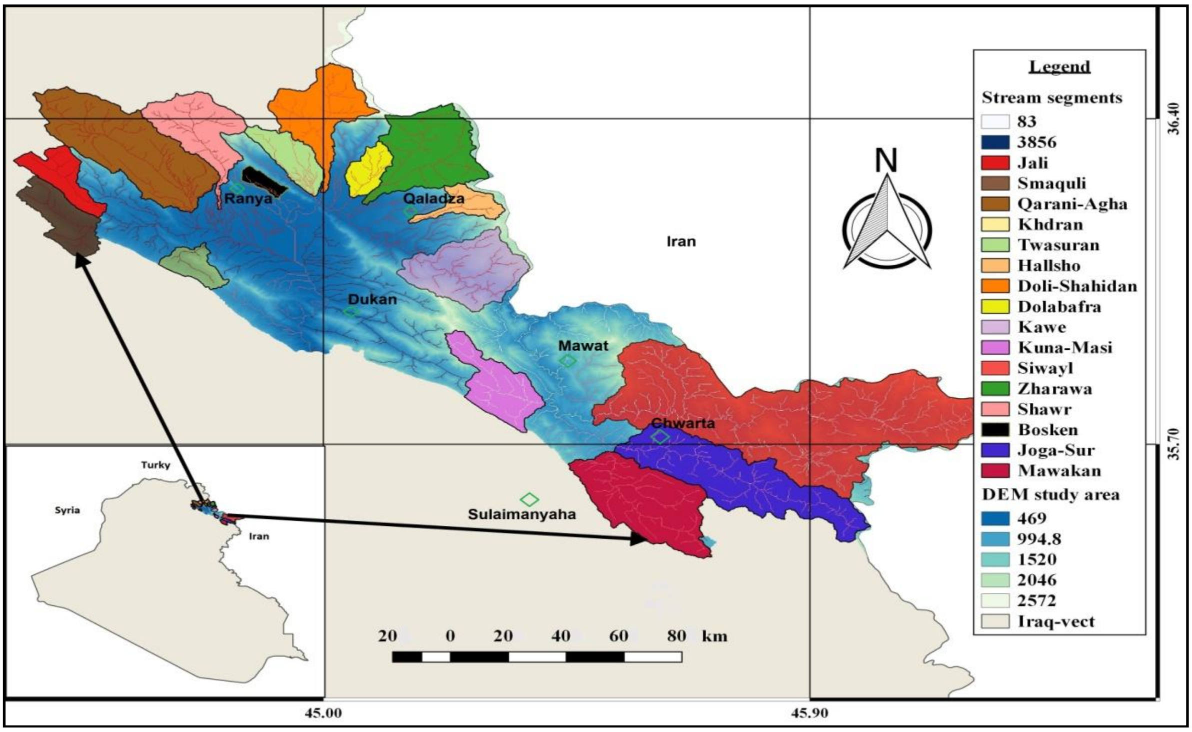

Figure 4.9 Map of the studied watersheds.

(Table 4.9a) represents the calculation of erodibility factor for the studied watershed using the equation suggested by (Wischmeier and Smith, 1958), from the results the highest value was in Twasuran watershed (0.729), the main reason for that is the existence of less vegetation cover and also to high soil content of silt, while the less value of erodibility factor observed in Siwayl watershed (0.290) due to high soil clay content and intense vegetation cover in a whole watershed area. (Table 4.9b) lists the cropping-management factor (C) and conservation practice factor (P) for each watershed. It is apparent that most of the studied watersheds have the low cropping management factor.

Also, (Table 4.9b) exhibits the calculations of the erosion from the calculated and its estimated parameters. From the results of the table, appeared that the highest value of erosion obtained by Zharawa watershed (46.843) ton/hectare/year, that possibly due to the rock formation which contain easily eroded marl, on may be due to the rapidly exchange of the slope from steep to gentle at the wide agriculture plain that extended to the watershed outlet, Consequently, Kuna-Masi watershed took the second highest value of erosion (44.106) ton/hectare/year, this can be concluded to that the watershed has steep slope especially at the upstream and also due to the less vegetation cover in spite of that, geologically the watershed has easy weathered rock formation which mainly contain marl and red bed formation.

As well the value of erosion for Shawr watershed can be considered high, the reason of that is the existence of high steep slope at the north parts of the watershed and changing this steep slope abruptly to the gentle at the wide agricultural land at the middle and south of the watershed, inspite of that, great parts of that agricultural land and its soil was disturbed due to the high activities of urbanization and industrialization on the agricultural land. While in Kawe watershed the relatively high value of erosion mainly was due to the high value of slope steepness factor and to the existence of great area of bare soil especially at the north and west parts of the watershed in addition to that, the rock formation mainly contain easily eroded marl formation. But the relatively high values of erosion for Hallsho watershed was due to the high steep slope of the watershed and the existence of bare area at the south and south west of the watershed. Whereas, the relatively high value of erosion for Doli-Shahidan was due to the existence of easily weathered rocks which contain from both Qulqula and marl formation.

On the other hand the less value of erosion during this study was possessed by Dolabafra watershed (19.976) ton/hectare/year; this is because of the existence the wide agricultural lands of gentle slopes and also to the high values of crop management factor (C). It can be noticed from the mentioned table that the values of erosion for all studied watersheds from high to less value took the following ranking:

Zharawa > Kuna-Masi > Shawr > Kawe > Hallsho > Doli-Shahidan > Siwayl > Qarani-Aqha > Twasuran > Mawakan > Khdran > Jali > Joga-Sur > Bosken > Smaquli > Dolabafra

(Seyhan, 1976) was stated that gully erosion was one-fifth (1/5) of the total sediment occurred, while channel erosion was about 10% of sheet and rill erosion. Thus;

$$E = (A + G + C) \qquad (4.1)$$

Where, (E) is gross erosion, (A) is sheet and rill erosion resulted from USLE, (G) is gully erosion and (C) is channel erosion.

On the other hand (Barzinji, 2003) proposed multiplying the annual soil loss by a factor of 1.25 to obtain the gross erosion for a watershed close to the watersheds under study. Accordingly the value of computed sheet and rill erosion for the studied watersheds was multiplied by a factor of 1.25 to obtain gross erosion, (Table 4.9b).

Table 4.9a Calculation of soil erodibility factor for the studied watersheds.

Watershed	No. of sample	Clay (%)	Silt (%)	VFS (%)	(Silt+VFS) (%)	M	O.M (%)	S.C.	P.C.	K
Mawakan	1.Ashi Qazi	18.584	32.862	11.047	43.909	3574.888	1.695	4	3	0.407
	2.Mawakan	30.769	46.357	7.748	54.105	3745.750	1.548	4	4	0.462
Joga-Sur	1.Joga Sur up	21.076	48.891	11.543	60.433	4769.651	2.007	4	3	0.518
	2.Joga Sur near bridge	5.781	56.540	11.240	67.779	6386.143	1.001	3	6	0.706
Siwayl	1.Kanarwe	59.555	29.785	1.070	30.856	1247.958	0.754	4	6	0.290
	2.Wazha	5.005	50.717	6.921	57.638	5475.296	1.726	4	3	0.606
Kuna-Masi	1.Kuna Masi near bridge	50.520	38.248	2.442	40.690	2013.363	1.698	4	6	0.352
	2.Kuna Masi up	51.021	43.884	1.415	45.299	2218.694	1.104	4	6	0.382
Kawe	Kawe	14.200	62.224	5.198	67.421	5784.722	1.545	4	6	0.649
Hallsho	1.Halsho near allawa village	11.026	57.923	4.180	62.103	5525.510	1.791	4	3	0.608
	2.Halsho near bridge	4.440	55.475	10.789	66.264	6332.181	1.882	4	3	0.690
Zharawa	1.Zharawa up	23.578	61.892	3.819	65.710	5021.725	1.578	4	3	0.564
	2.Zharawa near grideg	23.040	54.048	9.112	63.160	4860.779	1.368	4	3	0.556
Dolabafra	1.Dolabafra up	12.982	74.305	3.283	77.588	6751.537	1.634	3	3	0.709
	2.Dolabafra near bridge	10.881	73.698	4.198	77.896	6941.984	2.210	3	3	0.692
Doli-Shahidan	1.Qadrawa village	40.889	55.361	1.006	56.368	3331.972	0.959	4	6	0.502
	2.Dollishahidan near bridge	44.939	40.134	1.463	41.597	2290.347	0.602	4	6	0.399
Twasuran	Twasuran near bridge	15.038	79.247	2.409	81.655	6937.632	1.648	3	3	0.729
Bosken	Bosken	54.893	38.342	1.499	39.840	1797.098	2.210	4	6	0.324
Chwarqurna	Chwarqurna	20.279	47.114	14.365	61.479	4901.158	1.679	4	3	0.546
Qarani-Agha near bridge	Qarani Agha near bridge	22.247	48.881	11.020	59.900	4657.432	1.722	4	3	0.519
Khdran	1.Khdran up	49.986	41.384	1.358	42.741	2137.651	2.620	4	5	0.314
	2.Khdran near bridge	7.834	43.304	12.871	56.175	5177.484	2.290	4	3	0.547
Smaquli	1.Smaquli near bridge	17.724	78.101	1.889	79.990	6581.225	2.980	4	3	0.649
	2.Smaquli up	23.769	55.418	5.595	61.012	4651.059	1.844	4	3	0.513
Jali	1.Jali low	14.536	65.219	9.608	74.826	6394.990	2.390	4	3	0.667
	2.Jali up	3.427	28.261	6.408	34.669	3348.116	0.788	4	2	0.377

Where, $M= (\text{Silt}+\text{VFS})\ (100-\text{Clay})$

Table 4.9b Estimation of erosion for the studied watersheds using USLE.

Watersheds	R Metric uint	K Metric uint	L	S	C	P	Erosion ton/hectare/year	Gross erosion ton/hectare/year
Mawakan	33.907	0.4345	3.384	4.712	0.172	0.746	30.142	37.678
Joga-Sur	33.907	0.612	2.586	6.146	0.085	0.846	23.716	29.645
Siwayl	33.907	0.448	3.327	5.675	0.143	0.914	37.486	46.857
Kuna-Masi	38.365	0.367	3.174	9.925	0.113	0.88	44.106	55.133
Kawe	30.178	0.649	2.421	11.35	0.084	0.907	41.003	51.254
Hallsho	30.178	0.649	3.526	12.395	0.063	0.745	40.176	50.220
Zharawa	30.178	0.56	3.447	10.978	0.112	0.654	46.843	58.554
Dolabafra	30.178	0.7005	3.258	2.389	0.201	0.604	19.976	24.970
Doli-Shahidan	32.082	0.4505	3.849	12.158	0.069	0.84	39.200	49.000
Twasuran	32.082	0.729	4.213	7.444	0.057	0.772	32.276	40.344
Bosken	32.082	0.324	3.939	4.79	0.18	0.605	21.358	26.697
Shawr	30.124	0.546	4.182	11.751	0.073	0.733	43.250	54.063
Qarani-Agha	31.247	0.519	4.042	6.03	0.112	0.767	33.955	42.443
Khdran	31.247	0.4305	3.518	3.302	0.199	0.814	25.312	31.640
Smaquli	31.247	0.581	3.413	4.264	0.095	0.822	20.631	25.789
Jali	31.247	0.522	3.531	4.49	0.106	0.885	24.259	30.323

On the basis of gross erosion, most of the watersheds are placed in the moderate erosion hazard class (15-50) ton/hectare/year. The possible explanation is due to its high gradient (Barzinji, 2003).

4.10 Sediment Yield Estimation

4.10.1 Sediment yield prediction equation

Using Bali's equation (Bali *et al.*, 1972) for estimating the sediment yield in 16 studied watersheds, as shown in (Table 4.10a). (Table 4.10a) reveals that the highest value of sediment yield using Bali method gives by Doli-Shahidan watershed (17.196) ton/hectare/year, and the less value was appeared at Dolabafra watershed (6.449) ton/hectare/year, while the sediment yield values for the remained watersheds lies between these two values. The main reason behind the high value of sediment yield in Doli-Shahidan watershed returned mainly to the high steep slope at the upper parts of the watershed and abruptly changing this slope to the gentle near the outlet, while at Dolabafra watershed the slope is gentle at most parts of the watershed, for that reason the sediment yield took the least value among all of the studied watersheds.

4.10.2 Sediment yield by factorial score model (FSM)

From (Table 4.10b) appeared that the highest value of sediment yield by using the FSM model was observed at Bosken watershed (7.037) ton/hectare/year, this is because of that shape of this watershed is rather approximate to semi-circular, that leads to rapid occurrence of peak runoff produced by rainfall storms. On the other hand the small area of the watershed, less vegetation cover and less elevation difference between the most parts of watershed area and its outlet point are another factors. At the same table it was appeared that the less value of sediment yield produced by Siwayl watershed (0.803) ton/hectare/year, this is due to its large area and dense vegetation cover, besides to its lithology, which mainly consists from slowly eroded rocks of walash and qulqula formation. While the value of sediment yield for the remains studied watersheds lies between these two extrems.

Table 4.10a Sediment yield calculation for the studied watersheds.

Watershed	Area (mi^2)	X1	X2	X3	X4	Log (100+Y)	Y (acre.ft/mi^2.year)	Y (acre.ft/year)	Y (ton/year)	Y (ton/hectare/year)
Mawakan	122.911	0.475	23.5	1.762	24.676	2.008	1.840	226.136	278944.780	8.755
Joga-Sur	148.135	0.475	27.32	6.446	13.428	2.007	1.570	232.557	286865.320	7.471
Siwayl	373.621	0.475	26.12	2.938	32.280	2.009	2.122	792.696	977811.241	10.097
Kuna-Masi	54.262	0.468	35.64	2.309	50.770	2.014	3.267	177.259	218653.503	15.546
Kawe	139.232	0.317	38.35	1.466	14.200	2.011	2.640	367.526	453352.139	12.562
Hallsho	45.927	0.317	40.23	3.209	7.733	2.011	2.457	112.831	139179.450	11.691
Zharrawa	102.328	0.317	37.66	2.055	23.309	2.012	2.912	298.003	367594.499	13.859
Dolabafra	27.023	0.317	15.76	1.909	6.432	2.005	1.150	31.073	38329.842	6.449
Doli-Shahidan	82.780	0.317	39.81	2.921	42.914	2.015	3.614	299.134	368989.116	17.196
Twasuran	57.347	0.323	30.41	0.394	7.038	2.009	1.980	113.573	140095.521	10.832
Bosken	12.201	0.323	23.72	1.158	54.893	2.013	3.135	38.247	47178.741	14.918
Shawr	73.969	0.323	39.08	1.470	31.094	2.014	3.230	238.937	294735.361	15.372
Qarani-Agha	131.177	0.323	27.03	0.330	22.247	2.010	2.351	308.397	380415.745	11.188
Khdran	24.394	0.313	19.12	2.224	28.910	2.009	2.075	50.609	62427.233	9.873
Smaquli	13.996	0.313	22.19	1.652	20.747	2.009	2.040	28.546	35212.051	9.706
Jali	34.718	0.313	22.86	1.808	8.981	2.007	1.650	57.274	70649.321	7.851

Table 4.10b Time of water concentration and FSM scores of each factor for the studied watersheds.

Watersheds	Area (km^2)	Elevation	Basin shape	Lithology	Vegetation cover	Gullies	FSM	Sediment yield ton/hectare/year	Time of concentration (hr)
Mawakan	325.01	1	2	3	3	3	54	4.334	2.857
Joga-Sur	418.18	1	1	2	3	3	18	1.196	4.952
Siwayl	1220.51	1	1	3	3	3	27	0.803	7.798
Kuna-Masi	163.45	1	2	3	3	2	36	4.083	1.582
Kawe	248.39	1	3	3	3	2	54	4.742	3.222
Hallsho	62.76	1	1	3	3	2	18	4.520	0.615
Zharawa	271.62	1	2	2	2	3	24	2.270	2.017
Dolabafra	62.72	1	3	2	2	2	24	5.454	0.995
Doli-Shahidan	217.32	1	2	2	3	2	24	2.633	1.403
Twasuran	148.53	1	2	3	2	3	36	2.407	1.010
Bosken	26.2	1	2	2	1	1	4	7.037	0.324
Shawr	191.58	1	2	3	2	3	36	2.232	1.128
Qarani-Agha	339.75	1	2	2	2	2	16	1.319	2.131
Khdran	61.72	1	2	1	1	1	2	3.792	0.811
Smaquli	36.25	1	2	2	2	2	16	6.660	0.532
Jali	95.59	1	2	2	2	1	8	3.077	1.054

Table 4.10c Estimation of sediment delivery ratio from gross erosion and estimated sediment yield.

Watershed	Sediment yield using Balie method ton/hectare/year	Sediment yield using FSM method ton/hectare/year	Sum	Average Sediment yield (Balie + FSM) method ton/hectare/year	Gross	Sediment delivery ratio (SDR)
Mawakan	8.755	4.334	13.089	6.545	37.345	0.175
Joga-Sur	7.471	1.196	8.667	4.333	29.491	0.147
Siwayl	10.097	0.803	10.899	5.450	46.277	0.118
Kuna-Masi	15.546	4.083	19.628	9.814	55.864	0.176
Kawe	12.562	4.742	17.304	8.652	50.707	0.171
Hallsho	11.691	4.986	16.678	8.339	49.429	0.169
Zharrawa	13.859	2.270	16.129	8.064	57.736	0.140
Dolabafra	6.449	5.454	11.903	5.951	24.673	0.241
Doli-Shahidan	17.196	2.633	19.829	9.915	48.785	0.203
Twasuran	10.832	4.272	15.104	7.552	40.568	0.186
Bosken	14.918	7.037	21.955	10.978	26.707	0.411
Shawr	15.372	2.232	17.604	8.802	53.524	0.164
Qarani-Agha	11.188	1.319	12.507	6.253	42.119	0.148
Khdran	9.873	3.792	13.665	6.833	31.422	0.217
Smaquli	9.706	6.660	16.366	8.183	25.681	0.319
Jali	7.851	3.077	10.928	5.464	30.265	0.181

4.11 Sediment Delivery Ratio

The sediment yields for each of the studied watersheds were estimated via using sediment yield predictive equation by (Bali *et al.*, 1972) and also by using FSM. The sediment delivery ratio is defined as the ratio between the sediment yield and the gross erosion in a watershed and expressed as the percent (Chow, 1964). To obtain the sediment delivery ratio, the following equation was used,

$$SDR = Y / E \qquad (4.2)$$

Where, SDR = sediment delivery ratio (<1.0), Y = sediment yield, and
E = gross erosion, it includes sheet, rill and channel (gullies, valley trenches and stream bank) erosions.

(Fig. 4.11a) displays plot of sediment delivery ratio (obtained from sediment yield predicted equation by (Bali *et al.*, 1972) versus watershed area for all studied watersheds. A power function model was proposed to relate sediment delivery ratio to a watershed area as follows,

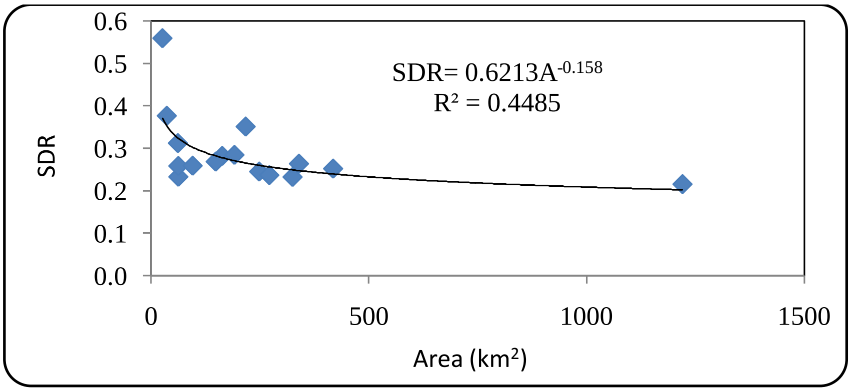

Figure 4.11a Sediment delivery ratio versus watershed area for all studied watersheds.

And the relationship between sediment delivery ratio (found out by employing FSM model) and watershed area represented by (Fig. 4.11b),

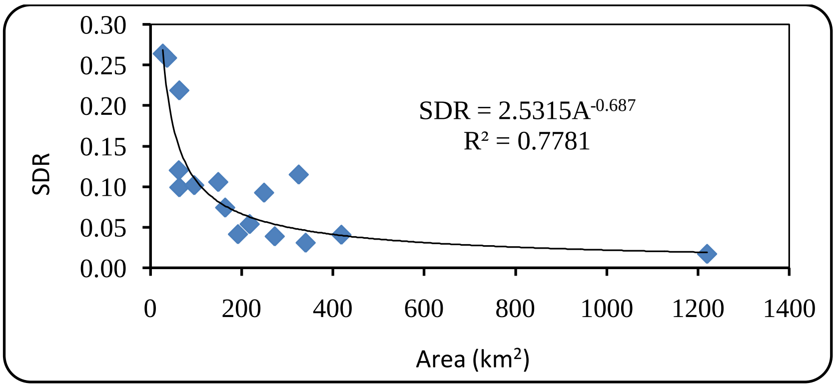

Figure 4.11b Sediment delivery ratio versus watershed area for all studied watersheds.

But most of the values of SDR obtained by using FSM model were very less and they are not much acceptable. Therefore its preferable, summing and then averaging the values of sediment yield produced from both sediment yield predictive equation and from FSM model, to obtain the final sediment yield, (Table 4.10c). As well the sediment delivery ratio values resulted from the averaged sediment of both studied models were more acceptable, and the final SDR when plotted against watershed area a power function model was obtained, as it was shown in (Fig 4.11c).

The proposed model accounted for 75% of variation in sediment delivery ratio.

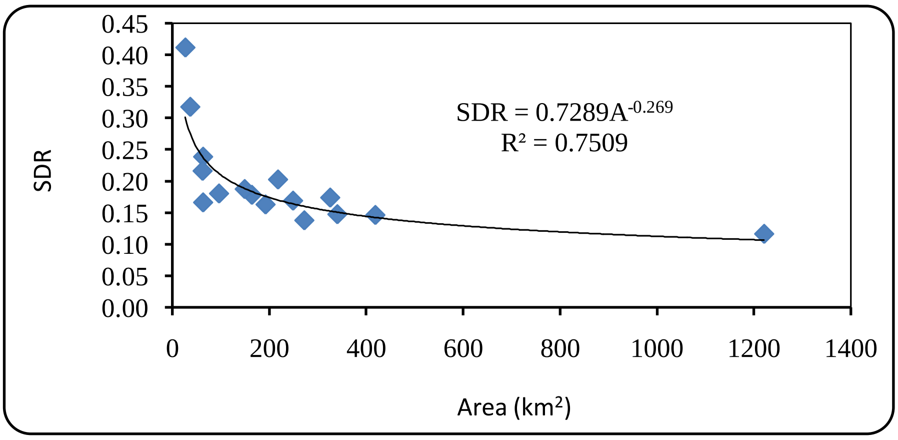

Figure 4.11c Sediment delivery ratio versus watershed area for all studied watersheds.

It is worthy to mention that when the data of Hallsho watershed omits, the accuracy of the model raises to approximately 0.85, (Fig. 4.11d).

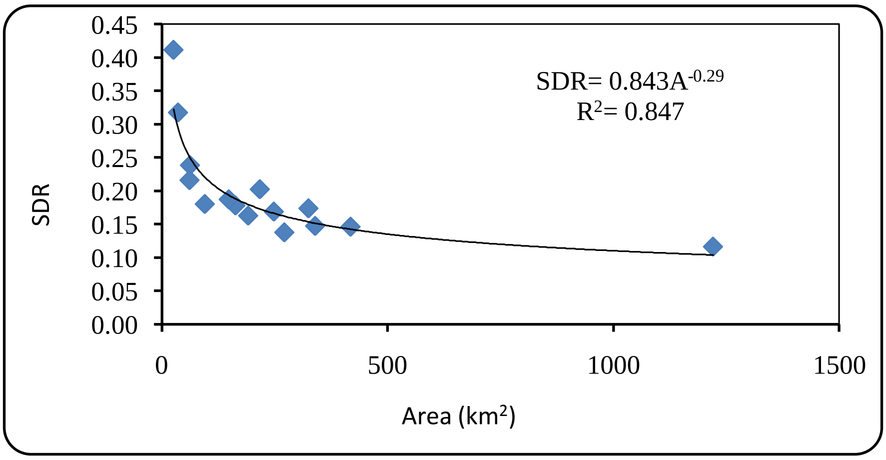

Figure 4.11d Sediment delivery ratio versus watershed area for the studied watersheds, after omitting Hallsho watershed.

It seems from (Table 4.10c) that the highest value of sediment delivery ratio was at Bosken watershed (0.411), and the less value of SDR observed at Siwayl watershed (0.118), while the rest studied watershed lies between these two extremes. The high value of SDR in Bosken watershed is due to the small area of the watershed and its semi-circular shape which leads to make rapid runoff and less value of time of concentration, (Table 4.10b), and also another point is the less vegetation cover in Bosken watershed, and the explanation is opposite of that for Siwayl watershed.

According to (Santos *et al.*, 2011) which cited by (Julio *et al.*, 2017) bands of vegetation act as barriers to sediment transport, favoring infiltration into the soil as a result of the increase in organic matter and the reduction in soil density that increase hydraulic conductivity. The vegetation also works to dissipate runoff energy, resulting in greater opportunity time for the processes of infiltration and sediment deposition (Santos *et al.*, 2011). Runoff and sediment connectivity along the slopes and in the watershed decrease as the plant cover increases (Fryirs *et al.*, 2007). Hassa (2001) demonstrated that circular shaped watersheds or watersheds with steep slope yield low value for time of concentration. The reverse may be true for elongated watershed with gentle slopes.

Finally the average estimated gross erosion value was 40.625 ton/hectare/year for all studied watersheds, the average amount of 7.571 ton/hectare/year was estimated sediment yielded, and about 17.23% was estimated to be the sediment delivery ratio.

5. CONCLUSIONS

The following main conclusions can be drawn as follows:

All studied physicochemical and hydrological parameters at all sites and months were within the standards when compared with the IQS and international WHO standards, suggesting that these parameters were derived from the natural processes without much effect of anthropogenic activities. On the other hand turbidity, NH_4-N, BOD_5, TSS, color and alkalinity out of the range of standards, this indicates that the rivers are locally contaminated especially water sample sites (W7-Kawe, W9-Sndollan, W12-Doli-Shahidan and W14-Bosken) compare to other sites approximately in February, March and April with these parameters which were possibly derived from the impact of anthropogenic activities in besides to natural processes.

In all studied sites, cations were dominated by Ca^{+2} followed by Na^{+}, Mg^{+2} and K^{+} in a downward sequence, while anions were dominated by HCO_3^{-} and followed by SO_4^{2-} and Cl^{-} and the highest concentrations of cations and anions were recorded in August, November, February and March. The concentrations of heavy metals in water samples are higher than the IQS and international WHO standards for Pb, Cd, Cr and for Fe in some sites, this indicates that the rivers are nearby polluted particularly sites (W2-Mawakan, W5-Kuna-Masi, W6-Qashan, W12-Doli-Shahidan, W13-Darbany-Ranya and W14-Bosken) with these metals deeply in February and November which were possibly derived from the impact of anthropogenic activates compare to other sites. While the metal concentrations for Cu, Zn and Mn within the permissible limits for drinking, signifying that these metals were derived from the natural processes.

Depending on the observed values of *HPI*, *HEI*, and *Cd* used for assessing water quality clearly appeared that all water sampling sites during of the studied period under the third class of pollution (high degree), signifying that rivers are highly polluted mainly site (W14-Bosken) for all studied months due to the impact of anthropogenic activities. The normal self-purification capacity of the studied rivers were found to be greater than unity which implies that, re-aeration is greater than de-oxygenation during all studied period except in April reversely and less than unity as a result of (high DO reduction) in April compare to other months. Based on all considered parameters and indices for irrigation water quality the rivers were compared with the international standards. The salinity of collected water samples fall in the class ‘low to high’, SAR in ‘excellent’, SSP in ‘good to excellent’ and RSC in ‘suitable’ for irrigation water quality.

The physicochemical characteristics of the soils from different land uses were showed that the pH values observed in the study area were within the ranges of neutral to alkaline soil reactions and the highest EC_e and TDS values were recorded under the grazing land (S7-Wazha), whereas the lowest values under the cultivated land (S11-Qashan near brideg). The soil bulk density was under the crop land has recorded lowest value as soil sample (Khdran up-S28); while the highest value on the grazing land was recorded as soil sample (S34-Jali up). SOM and SHC were at the lowest values at soil sample (S21-Doli-Shahidan near bridge), while the SOM at the highest value in soil sample (S31-Smaquli near bridge) and the highest SHC was recorded at soil sample (S34-Jali up). According to the soil texture analysis, the soils of study area composes from sand, silt and clay with various ratios and the soil texture classes are ranged from clay to sandy loam.

In all studied soils, soluble cations like in river waters were dominated by Ca^{+2} followed by Na^+, Mg^{+2} and K^+ in a downward sequence, while anions were dominated by HCO_3^- and followed by SO_4^{2-} and Cl^- and the concentration of soluble nutrients are in the order NO_3-N > PO_4-P > NH_4-N > NO_2-N but the concentration of cations, anions and nutrients in soils are more than concentrations in rivers water. The concentrations of seven soluble metals in soils were conquered by Fe followed by Mn, Cd, Cu, Cr, Pb and Zn. The concentrations of Pb, Cd and Cr in soils lower than concentrations in rivers water whereas the concentrations of Cu, Zn, Mn and Fe in soils higher than concentrations in rivers water.

Among the studied watersheds the highest value of estimated soil erosion was in Zharawa watershed and followed by Kuna-Masi > Shawr > Kawe > Hallsho > Doli-Shahidan > Siwayl > Qarani-Aqha > Twasuran > Mawakan > Khdran > Jali > Joga-Sur > Bosken > Smaquli > Dolabafra. Sediment yield by using Bali method gave the highest value at Doli-Shahidan watershed and the lowest value at Dolabafra watershed, but sediment yield by using the FSM method gave the highest value at Bosken watershed, while the lowest value appeared in Siwayl watershed. In addition, the highest value of sediment delivery ratio was at Bosken watershed, and the lowest value of SDR observed at Siwayl watershed.

6. RECOMMENDATIONS

In the light of the results obtained from the studied area, the following recommendations should be taking into account:

1. Installing gauging stations on the studied rivers for monitoring the discharge fluctuations of water.
2. Installing metrological stations inside the studied watersheds.
3. More studies of sediment yield should be done in detail and for each of the studied watersheds.
4. Detailed studies on river management and its riparian zones are necessary.
5. Prevention or at least reducing the numbers of the established sand washers on the main streams where affected on both quantity and quality of the river water.
6. We recommend avoiding disposal wastes of Khidran subdistrict far from directly disposal into Dukan Lake; as well we have the same recommendation for Qaladza, Zharawa, Sangasar, Ranya and Qarani-Agha subdistricts.

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Appendix 1

Table 4.1.1 Monthly variation of water temperature (^oC) during the period of study.

Site codes	Sites name	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	29.2	16.6	7.8	12.2	17.9	21.3	17.5
W2	Mawakan	18.3	15.4	13.7	14.6	18.3	20.7	16.8
W3	Shakha-Sur	24.0	15.2	10.8	12.2	19.8	22.2	17.4
W4	Siwayl	29.1	12.7	7.7	11.1	17.8	20.4	16.5
W5	Kuna-Masi	21.6	11.6	13.7	12.3	19.1	21.2	16.6
W6	Qashan	31.1	11.8	8.6	11.6	18.5	22.2	17.3
W7	Kawe	27.6	14.1	8.9	11.2	14.4	17.2	15.6
W8	Hallsho	No	16.5	12.3	10.2	13.3	16.2	13.7
W9	Sndollan	29.2	15.5	9.6	10.8	14.7	17.5	16.2
W10	Zharawa	No	17.3	13.0	10.4	15.3	18.0	14.8
W11	Dolabafra	26.8	No	16.1	17.5	18.7	21.0	20.0
W12	Doli-Shahidan	25.4	16.2	14.7	13.2	14.5	17.0	16.8
W13	Darbany-Ranya	31.4	18.9	10.3	12.5	17.8	24.4	19.2
W14	Bosken	29.1	16.6	17.4	19.0	23.6	23.5	21.5
W15	Dukan-Lake	29.9	19.1	10.2	13.3	17.9	24.1	19.1
W16	Qarani-Agha	27.1	13.6	11.9	18.3	22.7	28.9	20.4
W17	Khdran	19.2	13.5	11.9	17.5	21.2	24.8	18.0
W18	Hizop	23.7	11.0	9.4	16.8	23.4	29.3	18.9
W19	Smaquli	27.0	21.1	13.6	21.1	24.2	28.0	22.5
W20	Jali	22.2	15.2	9.6	16.7	22.5	25.2	18.6
W21	Qashqoli	12.7	15.0	8.8	9.5	10.2	11.3	11.3
Mean		25.5	15.3	11.4	13.9	18.4	21.6	17.7
IQS (2009) guideline value							None set	
WHO (2018) guideline value							None set	
Number of countries and territories setting a regulatory/guideline value							18 (out of 104)	
Maximum value set							35 ^oC	
Minimum value set							15 ^oC	
Median value							25 ^oC	

Table 4.1.2 Monthly variation of water turbidity (NTU) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	6.0	15.5	61.3	15.9	15.6	38.3	25.4
W2	Mawakan	1.0	< 0.01	26.1	92.7	20.2	7.6	24.6
W3	Shakha-Sur	6.9	4.0	32.5	24.7	19.1	26.1	18.9
W4	Siwayl	4.4	0.4	3.9	10.3	6.4	2.0	4.6
W5	Kuna-Masi	1.3	0.9	2.9	2.8	21.7	5.5	5.8
W6	Qashan	10.4	3.3	10.1	26.4	20.3	16.8	14.6
W7	Kawe	2.8	20.1	24.2	96.6	34.0	49.8	37.9
W8	Hallsho	No	6.5	19.9	12.6	25.6	22.1	17.3
W9	Sndollan	19.5	37.2	18.8	111.0	46.5	49.9	47.2
W10	Zharawa	No	10.1	2.6	33.5	30.2	13.6	18.0
W11	Dolabafra	4.5	No	5.7	13.2	7.7	13.9	9.0
W12	Doli-Shahidan	196.0	659.0	4.4	18.7	101.0	31.7	168.5
W13	Darbany-Ranya	1.8	9.9	19.3	50.1	4.1	11.0	16.0
W14	Bosken	48.1	86.4	61.4	45.0	49.4	42.4	55.5
W15	Dukan-Lake	1.9	3.4	5.8	24.6	1.3	7.1	7.3
W16	Qarani-Agha	61.2	31.6	12.9	44.3	19.9	20.6	31.8
W17	Khdran	3.4	2.0	8.7	29.5	3.7	11.3	9.8
W18	Hizop	5.9	5.9	56.0	156.0	289.0	7.6	86.7
W19	Smaquli	5.3	11.0	49.6	133.0	10.2	3.3	35.4
W20	Jali	7.2	8.1	47.8	149.0	242.0	13.6	77.9
W21	Qashqoli	< 0.01	2.1	3.0	2.1	46.9	1.2	9.2
Mean		20.4	45.9	22.7	52.0	48.3	18.8	34.7
IQS (2009) guideline value							None set	
WHO (2018) guideline value							None set	
Number of countries and territories setting a regulatory/guideline value							85 (out of 104)	
Maximum value set							25 NTU	
Minimum value set							0.3 NTU	
Median value							5 NTU	

Table 4.1.3 Monthly variation of water color (Hazen unit) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	1.6	5.0	32.5	47.0	45.1	16.0	24.5
W2	Mawakan	0.5	6.8	15.5	71.2	47.3	11.3	25.4
W3	Shakha-Sur	1.7	3.4	18.4	59.6	49.3	14.7	24.5
W4	Siwayl	0.9	9.0	9.2	56.2	54.2	11.2	23.5
W5	Kuna-Masi	0.2	4.2	13.1	46.4	45.1	14.7	20.6
W6	Qashan	0.7	6.3	15.1	56.1	48.2	12.5	23.2
W7	Kawe	8.1	7.5	26.9	62.2	58.2	12.7	29.3
W8	Hallsho	No	6.0	22.6	48.2	48.1	10.6	27.1
W9	Sndollan	8.1	6.4	32.5	61.2	62.0	15.3	30.9
W10	Zharawa	No	9.1	54.5	55.1	45.1	13.2	35.4
W11	Dolabafra	8.7	No	22.5	48.1	43.1	15.1	27.5
W12	Doli-Shahidan	21.1	5.3	9.8	42.2	46.2	10.8	22.6
W13	Darbany-Ranya	8.2	6.0	19.1	64.7	52.2	11.7	27.0
W14	Bosken	93.2	36.1	65.2	74.2	55.2	18.0	57.0
W15	Dukan-Lake	6.3	6.0	10.6	53.3	54.0	10.9	23.5
W16	Qarani-Agha	13.8	7.7	12.4	53.2	48.2	20.3	25.9
W17	Khdran	6.8	5.2	10.6	47.6	46.3	13.2	21.6
W18	Hizop	11.2	7.2	9.5	57.1	44.0	13.6	23.8
W19	Smaquli	0.5	4.0	19.6	71.2	43.0	9.7	24.7
W20	Jali	2.8	6.3	14.4	78.3	44.2	11.1	26.2
W21	Qashqoli	8.8	7.3	7.6	42.4	48.2	10.7	20.8
Mean		10.7	7.7	21.0	56.9	48.9	13.2	26.4
IQS (2009) guideline value							None set	
WHO (2011) guideline value							15 Hazen unit	
WHO (2018) guideline value							None set	
Number of countries and territories setting a regulatory/guideline value							80 (out of 104)	
Number of countries and territories setting a regulatory/guideline value greater than WHO Guideline recommendation of 15 Hazen unit							20	
Number of countries and territories setting a regulatory/guideline value at the WHO Guideline recommendation of 15 Hazen unit							44	
Number of countries and territories setting a regulatory/guideline value less than WHO Guideline recommendation of 15 Hazen unit							16	
Maximum value set							50 Hazen unit	
Minimum value set							0.5 Hazen unit	
Median value							15 Hazen unit	

Table 4.1.4 Monthly variation of water pH during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	8.14	8.02	8.30	8.33	8.27	8.11	8.20
W2	Mawakan	7.69	7.62	7.96	8.06	8.02	7.64	7.83
W3	Shakha-Sur	7.82	7.78	8.24	8.33	8.43	8.10	8.12
W4	Siwayl	8.43	8.35	8.33	8.32	8.46	8.39	8.38
W5	Kuna-Masi	8.02	8.13	8.24	8.12	8.17	8.15	8.14
W6	Qashan	8.29	8.32	8.39	8.30	8.38	8.34	8.34
W7	Kawe	8.42	8.41	8.38	8.33	8.36	8.20	8.35
W8	Hallsho	No	8.10	8.35	8.38	8.48	8.33	8.33
W9	Sndollan	8.41	8.16	8.44	8.28	8.34	8.19	8.30
W10	Zharawa	No	8.35	8.70	8.31	8.46	8.33	8.43
W11	Dolabafra	7.78	No	8.17	8.12	8.45	8.25	8.15
W12	Doli-Shahidan	7.91	8.22	8.45	8.20	8.27	8.27	8.22
W13	Darbany-Ranya	8.42	7.84	7.89	8.14	8.06	8.45	8.13
W14	Bosken	7.79	7.73	7.84	7.82	7.98	7.91	7.85
W15	Dukan-Lake	8.39	8.34	8.47	8.14	8.23	8.53	8.35
W16	Qarani-Agha	8.44	8.33	8.46	8.43	8.34	8.33	8.39
W17	Khdran	8.29	8.33	8.41	8.34	8.47	8.47	8.39
W18	Hizop	8.35	8.36	8.38	8.31	8.36	8.39	8.36
W19	Smaquli	7.90	8.02	7.83	8.01	7.88	7.95	7.93
W20	Jali	7.66	8.04	8.29	8.25	8.26	8.06	8.09
W21	Qashqoli	7.61	7.45	7.95	8.10	7.99	7.80	7.82
Mean		8.09	8.10	8.26	8.22	8.27	8.20	8.19
pH maximum								
IQS (2009) guideline value							None set	
WHO (2018) guideline value							None set	
Number of countries and territories setting a regulatory/guideline value							103 (out of 104)	
Maximum value set							9.7	
Minimum value set							8	
Median value							8.5	
pH minimum								
IQS (2009) guideline value							None set	
WHO (2018) guideline value							None set	
Number of countries and territories setting a regulatory/guideline value							102 (out of 104)	
Maximum value set							7	
Minimum value set							5	
Median value							6.5	

Table 4.1.5 Monthly variation of water EC_t (µS cm^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	325	361	393	375	375	357	364
W2	Mawakan	722	702	589	534	549	550	608
W3	Shakha-Sur	459	441	416	396	375	383	412
W4	Siwayl	331	347	339	342	353	332	341
W5	Kuna-Masi	509	480	428	442	416	433	451
W6	Qashan	347	367	369	359	358	341	357
W7	Kawe	318	392	375	356	305	299	341
W8	Hallsho	No	452	367	342	327	406	379
W9	Sndollan	349	386	386	356	307	305	348
W10	Zharawa	No	295	319	320	288	286	302
W11	Dolabafra	342	No	361	366	340	314	345
W12	Doli-Shahidan	358	322	341	344	281	299	324
W13	Darbany-Ranya	249	324	388	355	324	221	310
W14	Bosken	866	932	801	618	641	606	744
W15	Dukan-Lake	274	269	311	354	315	218	290
W16	Qarani-Agha	469	513	483	443	423	406	456
W17	Khdran	383	401	525	528	502	466	468
W18	Hizop	976	757	665	670	604	773	741
W19	Smaquli	619	591	708	664	612	588	630
W20	Jali	947	727	664	645	600	710	716
W21	Qashqoli	263	339	298	317	315	313	308
Mean		479	470	454	435	410	410	443
IQS (2009) guideline value							None set	
WHO (2018) guideline value							None set	
Number of countries and territories setting a regulatory/guideline value							51 (out of 104)	
Maximum value set							2700 µS cm^{-1}	
Minimum value set							170 µS cm^{-1}	
Median value							2500 µS cm^{-1}	

Table 4.1.6a Monthly variation of water salinity (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	191.57	277.48	376.28	320.40	280.08	246.76	282.10
W2	Mawakan	531.16	554.86	485.15	430.62	405.82	385.44	465.51
W3	Shakha-Sur	298.46	350.54	367.94	338.34	268.08	259.83	313.87
W4	Siwayl	194.78	292.92	325.66	300.08	263.87	234.15	268.58
W5	Kuna-Masi	349.54	416.26	352.53	376.79	301.91	299.85	349.48
W6	Qashan	197.32	316.62	345.98	311.33	263.49	231.33	277.68
W7	Kawe	192.74	320.12	348.72	311.91	247.12	226.76	274.56
W8	Hallsho	No	348.29	312.86	307.31	271.85	315.19	311.10
W9	Sndollan	205.72	304.60	352.52	314.87	246.98	229.56	275.71
W10	Zharawa	No	223.16	267.24	286.52	228.37	212.88	243.63
W11	Dolabafra	211.00	No	281.18	275.47	249.15	218.44	247.05
W12	Doli-Shahidan	227.29	249.98	274.33	286.87	226.96	227.53	248.83
W13	Darbany-Ranya	140.88	236.19	349.39	301.05	242.20	143.13	235.47
W14	Bosken	507.69	716.97	604.40	458.80	422.14	400.27	518.38
W15	Dukan-Lake	159.05	195.23	279.45	294.30	235.27	142.03	217.56
W16	Qarani-Agha	286.50	423.53	415.77	327.47	283.99	240.87	329.69
W17	Khdran	273.18	331.83	451.92	397.40	347.62	299.43	350.23
W18	Hizop	641.51	666.16	610.31	512.42	399.71	455.14	547.54
W19	Smaquli	378.73	410.39	584.52	471.71	397.95	354.87	433.03
W20	Jali	638.20	577.88	606.42	494.53	404.35	452.58	528.99
W21	Qashqoli	221.68	270.55	277.31	290.12	283.25	273.44	269.39
Mean		307.74	374.18	393.80	352.78	298.58	278.55	334.27
IQS (2009) guideline value							1000 mg L^{-1}	
WHO (2018) guideline value							None set	
WHO (2011) guideline value							1000 mg L^{-1}	

Table 4.1.6b Monthly variation of water EC $_{25^{o}C}$ (µs cm^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	299.33	433.56	587.93	500.63	437.63	385.56	440.77
W2	Mawakan	829.94	866.97	758.04	672.84	634.10	602.25	727.36
W3	Shakha-Sur	466.34	547.72	574.91	528.65	418.88	405.98	490.41
W4	Siwayl	304.35	457.69	508.84	468.88	412.30	365.86	419.65
W5	Kuna-Masi	546.16	650.40	550.83	588.74	471.74	468.51	546.06
W6	Qashan	308.31	494.72	540.59	486.45	411.70	361.46	433.87
W7	Kawe	301.15	500.19	544.88	487.36	386.13	354.32	429.01
W8	Hallsho	No	544.21	488.84	480.17	424.77	492.48	486.09
W9	Sndollan	321.43	475.94	550.82	491.99	385.90	358.68	430.79
W10	Zharawa	No	348.69	417.57	447.68	356.83	332.62	80.68
W11	Dolabafra	329.69	No	439.34	430.42	389.30	341.32	386.09
W12	Doli-Shahidan	355.14	390.59	428.64	448.23	354.62	355.51	388.79
W13	Darbany-Ranya	220.12	369.04	545.92	470.39	378.43	223.64	367.92
W14	Bosken	793.26	1120.26	944.38	716.88	659.59	625.42	809.97
W15	Dukan-Lake	248.52	305.05	436.64	459.85	367.61	221.92	339.93
W16	Qarani-Agha	447.66	661.77	649.64	511.67	443.73	376.36	515.14
W17	Khdran	426.85	518.49	706.13	620.93	543.16	467.86	547.24
W18	Hizop	1002.35	1040.88	953.61	800.65	624.54	711.16	855.53
W19	Smaquli	591.76	641.24	913.32	737.04	621.79	554.48	676.61
W20	Jali	997.19	902.93	947.53	772.71	631.80	707.16	826.55
W21	Qashqoli	346.37	422.73	433.29	453.31	442.58	427.25	420.92
Mean		480.84	584.65	615.32	551.21	466.53	435.23	522.31
IQS (2009) guideline value							2000 µs cm^{-1}	
WHO (2018) guideline value							None set	
WHO (2011) guideline value							1500 µs cm^{-1}	

Table 4.1.7 Monthly variation of water DO (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	5.85	7.68	9.46	8.95	8.48	4.85	7.55
W2	Mawakan	4.36	4.95	7.30	8.22	7.99	4.83	6.28
W3	Shakha-Sur	4.81	6.54	8.84	8.89	8.12	5.19	7.07
W4	Siwayl	6.65	7.27	9.28	8.50	8.50	5.12	7.55
W5	Kuna-Masi	7.12	7.37	8.41	8.57	8.25	5.39	7.52
W6	Qashan	6.40	7.77	9.30	8.42	8.35	5.42	7.61
W7	Kawe	6.85	8.20	10.25	9.25	9.20	5.30	8.18
W8	Hallsho	No	6.08	9.03	9.39	9.45	6.00	8.02
W9	Sndollan	6.65	7.57	10.35	9.22	8.87	5.24	7.98
W10	Zharawa	No	7.21	9.50	8.25	9.00	6.14	6.68
W11	Dolabafra	6.95	No	8.30	8.20	8.30	6.06	7.56
W12	Doli-Shahidan	7.04	6.65	9.10	9.40	9.25	6.40	7.97
W13	Darbany-Ranya	6.87	6.42	7.17	8.65	8.84	7.30	7.54
W14	Bosken	5.19	5.40	6.37	6.60	6.71	4.30	5.76
W15	Dukan-Lake	7.82	6.93	10.30	8.83	8.75	7.36	8.33
W16	Qarani-Agha	6.93	5.45	9.75	8.40	7.60	6.63	7.46
W17	Khdran	8.20	8.64	10.30	7.54	7.85	7.00	8.26
W18	Hizop	6.98	8.73	9.66	8.06	7.50	6.00	7.82
W19	Smaquli	6.51	5.35	7.20	6.27	6.94	4.50	6.13
W20	Jali	6.67	6.17	9.06	7.87	7.65	5.50	7.15
W21	Qashqoli	5.29	5.06	8.47	8.28	8.87	5.30	6.88
Mean		5.86	6.45	8.92	8.37	8.31	5.71	7.27
IQS (2009) guideline value							None set	
WHO (2018) guideline value							None set	
Number of countries and territories setting a regulatory/guideline value							4 (out of 104)	
Maximum value set							8 mg L^{-1}	
Minimum value set							4 mg L^{-1}	
Median value							6 mg L^{-1}	

Table 4.1.8 Monthly variation of water BOD_5 ($mg\ L^{-1}$) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	2.43	2.41	2.60	3.66	5.60	3.25	3.33
W2	Mawakan	3.42	1.05	2.92	4.78	5.27	1.93	3.23
W3	Shakha-Sur	2.81	1.66	2.36	3.90	2.42	1.69	2.47
W4	Siwayl	2.73	1.14	2.58	4.63	3.99	1.62	2.78
W5	Kuna-Masi	3.01	1.44	2.92	2.40	4.73	1.89	2.73
W6	Qashan	2.44	1.47	2.16	4.28	6.53	2.82	3.28
W7	Kawe	4.13	2.49	5.73	8.00	6.36	2.55	4.88
W8	Hallsho	No	0.68	8.37	5.21	6.67	3.22	4.83
W9	Sndollan	3.93	2.41	4.64	7.92	7.82	3.14	4.98
W10	Zharawa	No	1.80	2.18	1.31	5.66	3.07	2.80
W11	Dolabafra	4.19	No	1.48	5.05	5.78	5.31	4.36
W12	Doli-Shahidan	6.89	5.73	4.72	7.90	7.07	5.95	6.38
W13	Darbany-Ranya	2.51	3.05	0.13	5.43	3.19	3.16	2.91
W14	Bosken	61.50	78.30	60.00	69.30	50.10	41.10	60.05
W15	Dukan-Lake	6.75	0.59	6.01	5.56	2.43	3.70	4.17
W16	Qarani-Agha	3.53	1.29	8.97	4.35	4.90	4.11	4.53
W17	Khdran	1.91	2.98	6.09	2.63	7.22	4.18	4.17
W18	Hizop	3.64	2.63	1.82	3.16	5.84	4.35	3.57
W19	Smaquli	3.56	2.39	6.23	3.05	3.82	1.34	3.40
W20	Jali	2.74	1.42	5.28	2.23	4.97	4.25	3.48
W21	Qashqoli	0.72	1.80	2.91	3.64	7.39	1.58	3.01
Mean		6.47	5.84	6.67	7.54	7.51	4.96	6.50
IQS (2009) guideline value							None set	
WHO (2018) guideline value							None set	
WHO (2011) guideline value							< 3 $mg\ L^{-1}$	

Table 4.1.9 Monthly variation of water TS (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	210	233	329	250	251	242	253
W2	Mawakan	464	501	440	480	362	355	434
W3	Shakha-Sur	295	284	329	291	241	255	283
W4	Siwayl	215	225	218	232	252	216	226
W5	Kuna-Masi	328	308	277	272	266	282	289
W6	Qashan	229	236	266	273	250	233	248
W7	Kawe	205	266	291	341	642	278	337
W8	Hallsho	No	296	298	232	361	294	296
W9	Sndollan	225	296	275	426	652	270	357
W10	Zharawa	No	189	218	267	242	200	223
W11	Dolabafra	220	No	250	270	240	202	236
W12	Doli-Shahidan	468	1449	247	230	298	224	486
W13	Darbany-Ranya	162	211	277	285	225	146	218
W14	Bosken	558	640	557	409	416	411	499
W15	Dukan-Lake	177	179	222	273	220	145	203
W16	Qarani-Agha	357	369	336	357	289	261	328
W17	Khdran	249	260	339	379	338	304	312
W18	Hizop	628	485	481	648	394	498	522
W19	Smaquli	399	380	548	592	397	380	449
W20	Jali	608	468	456	554	396	456	490
W21	Qashqoli	193	220	197	206	213	201	205
Mean		326	357	326	346	331	279	330
IQS (2009) guideline value							None set	
WHO (2018) guideline value							None set	
WHO (2011) guideline value							1000 mg L^{-1}	

Table 4.1.10 Monthly variation of water TDS (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	207	217	249	237	236	180	221
W2	Mawakan	457	470	371	361	354	349	394
W3	Shakha-Sur	288	268	264	260	239	221	257
W4	Siwayl	205	210	184	221	242	199	210
W5	Kuna-Masi	318	283	235	266	259	255	269
W6	Qashan	215	234	215	231	239	190	221
W7	Kawe	199	247	192	258	205	156	210
W8	Hallsho	No	283	188	223	126	222	208
W9	Sndollan	204	253	197	227	202	148	205
W10	Zharawa	No	184	167	245	194	155	189
W11	Dolabafra	207	No	182	224	153	193	192
W12	Doli-Shahidan	247	221	168	215	183	163	200
W13	Darbany-Ranya	156	200	212	243	218	126	193
W14	Bosken	531	563	416	338	382	322	425
W15	Dukan-Lake	170	172	170	228	192	126	176
W16	Qarani-Agha	319	359	294	307	269	240	298
W17	Khdran	241	249	239	324	308	272	272
W18	Hizop	611	483	322	433	375	470	449
W19	Smaquli	381	372	419	498	390	362	404
W20	Jali	530	467	330	410	365	434	423
W21	Qashqoli	192	217	144	195	184	183	186
Mean		299	298	246	283	253	236	269
IQS (2009) guideline value							None set	
WHO (2018) guideline value							None set	
Number of countries and territories setting a regulatory/guideline value							66 (out of 104)	
Maximum value set							2500 mg L^{-1}	
Minimum value set							200 mg L^{-1}	
Median value							1000 mg L^{-1}	

Table 4.1.11 Monthly variation of water TSS (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	3	16	80	13	15	62	32
W2	Mawakan	7	31	69	119	8	6	40
W3	Shakha-Sur	7	16	65	31	2	34	26
W4	Siwayl	10	15	34	11	10	17	16
W5	Kuna-Masi	10	25	42	6	7	27	20
W6	Qashan	14	2	51	42	11	43	27
W7	Kawe	6	19	99	83	437	122	128
W8	Hallsho	No	13	110	9	235	72	88
W9	Sndollan	21	43	78	199	450	122	152
W10	Zharawa	No	5	51	22	48	45	34
W11	Dolabafra	13	No	68	46	87	9	45
W12	Doli-Shahidan	221	1228	79	15	115	61	287
W13	Darbany-Ranya	6	11	65	42	7	20	25
W14	Bosken	27	77	141	71	34	89	73
W15	Dukan-Lake	7	7	52	45	28	19	26
W16	Qarani-Agha	38	10	42	50	20	21	30
W17	Khdran	8	11	100	55	30	32	39
W18	Hizop	17	2	159	215	19	28	73
W19	Smaquli	18	8	129	94	7	18	46
W20	Jali	78	1	126	144	31	22	67
W21	Qashqoli	1	3	53	11	29	18	19
Mean		27	77	81	63	78	42	61
IQS (2009) guideline value							None set	
WHO (2018) guideline value							None set	
WHO (2011) guideline value							25 to 40 mg L^{-1}	

Table 4.1.12 Monthly variation of water NO_3-N (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	2.3	1.1	4.4	4.8	4.2	3.1	3.3
W2	Mawakan	1.5	1.1	5.1	6.1	5.4	4.3	3.9
W3	Shakha-Sur	1.9	2.4	6.9	5.8	4.6	3.1	4.1
W4	Siwayl	3.1	1.9	5.4	6.7	6.6	4.1	4.6
W5	Kuna-Masi	2.1	1.1	4.7	5.3	4.7	2.9	3.5
W6	Qashan	2.1	1.7	7.9	6.2	5.8	3.9	4.6
W7	Kawe	2.4	3.3	3.6	5.6	5.2	3.4	3.9
W8	Hallsho	No	1.9	4.4	5.7	6.3	5.1	4.7
W9	Sndollan	2.8	2.5	5.3	5.6	5.8	3.7	4.3
W10	Zharawa	No	1.5	5.6	5.1	5.2	4.6	4.4
W11	Dolabafra	2.1	No	5.7	6.3	5.8	4.9	5.0
W12	Doli-Shahidan	2.9	1.3	5.1	5.2	5.1	3.3	3.8
W13	Darbany-Ranya	2.6	1.1	5.6	5.2	5.7	4.4	4.1
W14	Bosken	2.6	1.9	4.7	6.1	6.3	5.1	4.5
W15	Dukan-Lake	2.0	1.2	4.6	5.2	4.8	3.3	3.5
W16	Qarani-Agha	3.4	2.2	4.7	5.6	4.4	3.7	4.0
W17	Khdran	2.9	2.2	6.5	6.2	6.0	3.1	4.5
W18	Hizop	3.1	5.1	5.7	5.3	5.2	4.1	4.8
W19	Smaquli	1.4	3.2	7.6	5.1	4.3	3.2	4.1
W20	Jali	1.9	3.1	5.1	5.8	5.4	4.3	4.3
W21	Qashqoli	2.1	1.2	4.3	4.1	4.2	3.3	3.2
Mean		2.4	2.1	5.4	5.6	5.3	3.9	4.1
IQS (2009) guideline value							50 mg L^{-1} as NO_3-N	
WHO (2018) guideline value							50 mg L^{-1} as NO_3-N	
Number of countries and territories setting a regulatory/guideline value							104 (out of 104)	
Number of countries and territories setting a regulatory/guideline value greater than WHO Guideline							2	
Number of countries and territories setting the WHO Guideline							69	
Number of countries and territories setting a regulatory/guideline value less than WHO Guideline							33	
Maximum value set							75 mg L^{-1} as NO_3-N	
Minimum value set							40 mg L^{-1} as NO_3-N	
Median value							50 mg L^{-1} as NO_3-N	

Table 4.1.13 Monthly variation of water NO_2-N (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	0.01	0.02	0.03	0.02	0.02	0.03	0.02
W2	Mawakan	0.03	0.03	0.03	0.04	0.04	0.07	0.04
W3	Shakha-Sur	0.01	0.02	0.03	0.03	0.02	0.03	0.02
W4	Siwayl	0.01	0.01	0.02	0.04	0.02	0.02	0.02
W5	Kuna-Masi	0.01	0.01	0.02	0.03	0.03	0.02	0.02
W6	Qashan	0.01	0.01	0.03	0.03	0.02	0.02	0.02
W7	Kawe	0.01	0.03	0.03	0.04	0.04	0.03	0.03
W8	Hallsho	No	0.01	0.04	0.03	0.02	0.02	0.02
W9	Sndollan	0.02	0.02	0.04	0.06	0.04	0.04	0.04
W10	Zharawa	No	0.02	0.02	0.03	0.02	0.02	0.02
W11	Dolabafra	0.02	No	0.02	0.03	0.02	0.02	0.02
W12	Doli-Shahidan	0.02	0.05	0.02	0.03	0.02	0.02	0.03
W13	Darbany-Ranya	0.02	0.03	0.03	0.05	0.04	0.03	0.03
W14	Bosken	0.04	0.11	0.21	0.19	0.16	0.22	0.16
W15	Dukan-Lake	0.02	0.03	0.02	0.04	0.04	0.03	0.03
W16	Qarani-Agha	0.02	0.03	0.04	0.05	0.04	0.05	0.04
W17	Khdran	0.05	0.01	0.03	0.03	0.03	0.12	0.05
W18	Hizop	0.01	0.01	0.02	0.04	0.02	0.03	0.02
W19	Smaquli	0.01	0.01	0.03	0.06	0.05	0.02	0.03
W20	Jali	0.01	0.01	0.02	0.07	0.02	0.02	0.03
W21	Qashqoli	0.08	0.01	0.02	0.03	0.03	0.03	0.03
Mean		0.02	0.02	0.04	0.05	0.04	0.04	0.03

IQS (2009) guideline value	3 mg L^{-1} as NO_2-N
WHO (2018) guideline value	3 mg L^{-1} as NO_2-N
Number of countries and territories setting a regulatory/guideline value	96 (out of 104)
Number of countries and territories setting a regulatory/guideline value greater than WHO Guideline	2
Number of countries and territories setting the WHO Guideline	39
Number of countries and territories setting a regulatory/guideline value less than WHO Guideline	55
Maximum value set	3.3 mg L^{-1} as NO_2-N
Minimum value set	0.003 mg L^{-1} as NO_2-N
Median value	0.5 mg L^{-1} as NO_2-N

Table 4.1.14 variation of water NH_4-N (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	0.50	0.40	0.15	0.40	0.43	0.44	0.39
W2	Mawakan	0.95	0.62	0.71	0.49	0.49	0.55	0.64
W3	Shakha-Sur	0.89	1.12	0.62	0.44	0.42	0.46	0.66
W4	Siwayl	0.92	1.60	0.27	0.40	0.38	0.51	0.68
W5	Kuna-Masi	0.93	1.07	0.27	0.40	0.40	2.84	0.99
W6	Qashan	0.20	0.03	0.26	0.48	0.39	1.30	0.44
W7	Kawe	0.85	1.20	0.45	0.47	0.44	1.66	0.85
W8	Hallsho	No	0.30	0.84	0.40	0.39	0.55	0.50
W9	Sndollan	1.00	0.10	0.39	0.49	0.76	2.72	0.91
W10	Zharawa	No	0.10	0.43	0.39	0.48	0.63	0.41
W11	Dolabafra	0.30	No	0.91	0.41	0.40	0.48	0.50
W12	Doli-Shahidan	1.03	0.92	0.81	0.53	0.41	0.65	0.73
W13	Darbany-Ranya	0.82	0.91	0.67	0.62	0.39	0.44	0.64
W14	Bosken	3.90	5.10	2.32	3.00	3.08	3.12	3.42
W15	Dukan-Lake	0.93	1.04	0.73	0.42	0.82	0.29	0.71
W16	Qarani-Agha	1.00	0.06	0.61	0.51	0.42	0.44	0.51
W17	Khdran	0.99	1.00	0.62	0.41	0.46	0.57	0.68
W18	Hizop	0.40	0.10	0.41	0.42	0.41	0.32	0.34
W19	Smaquli	0.60	0.20	0.65	0.65	0.39	0.38	0.48
W20	Jali	0.52	0.60	0.72	0.75	0.43	0.28	0.55
W21	Qashqoli	0.70	0.04	0.50	0.48	0.57	0.39	0.45
Mean		0.83	0.79	0.64	0.60	0.59	0.91	0.72

IQS (2009) guideline value	None set
WHO (2011) guideline value	1.5 mg L^{-1} as NH_4-N
WHO (2018) guideline value	None set
Number of countries and territories setting a regulatory/guideline value	81 (out of 104)
Maximum value set	3 mg L^{-1} as NH_4-N
Minimum value set	0.05 mg L^{-1} as NH_4-N
Median value	0.2 mg L^{-1} as NH_4-N

Table 4.1.15 Monthly variation of water PO_4-P (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	0.07	0.12	0.11	0.08	0.12	0.03	0.09
W2	Mawakan	0.06	0.08	0.09	0.11	0.10	0.01	0.08
W3	Shakha-Sur	0.05	0.12	0.09	0.08	0.10	0.06	0.08
W4	Siwayl	0.04	0.05	0.09	0.10	0.11	0.03	0.07
W5	Kuna-Masi	0.04	0.02	0.09	0.09	0.05	0.05	0.06
W6	Qashan	0.06	0.04	0.08	0.08	0.08	0.03	0.06
W7	Kawe	0.05	0.04	0.06	0.13	0.08	0.06	0.07
W8	Hallsho	No	0.05	0.09	0.10	0.08	0.03	0.07
W9	Sndollan	0.09	0.06	0.05	0.09	0.09	0.06	0.07
W10	Zharawa	No	0.03	0.09	0.08	0.07	0.06	0.07
W11	Dolabafra	0.09	No	0.03	0.10	0.07	0.06	0.07
W12	Doli-Shahidan	0.12	0.08	0.04	0.11	0.04	0.06	0.08
W13	Darbany-Ranya	0.04	0.04	0.05	0.12	0.07	0.03	0.06
W14	Bosken	0.80	1.00	1.16	1.04	0.71	0.50	0.87
W15	Dukan-Lake	0.03	0.06	0.08	0.11	0.09	0.11	0.08
W16	Qarani-Agha	0.06	0.04	0.07	0.08	0.04	0.05	0.06
W17	Khdran	0.03	0.04	0.09	0.07	0.06	0.21	0.08
W18	Hizop	0.05	0.06	0.07	0.08	0.07	0.05	0.06
W19	Smaquli	0.06	0.05	0.08	0.18	0.05	0.03	0.08
W20	Jali	0.03	0.04	0.06	0.15	0.05	0.03	0.06
W21	Qashqoli	0.04	0.04	0.07	0.08	0.07	0.25	0.09
Mean		0.10	0.10	0.13	0.15	0.10	0.09	0.11
IQS (2009) guideline value							None set	
WHO (2018) guideline value							None set	

Table 4.1.16 Monthly variation of water Ca^{+2} (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	45.79	49.27	63.38	66.84	49.12	49.04	53.91
W2	Mawakan	92.81	97.68	90.68	84.94	66.14	75.98	84.71
W3	Shakha-Sur	55.88	55.69	65.45	72.82	57.56	54.42	60.30
W4	Siwayl	44.08	48.18	51.94	53.68	46.28	43.88	48.01
W5	Kuna-Masi	51.85	68.24	68.68	78.85	59.96	61.04	64.77
W6	Qashan	42.05	46.97	57.49	58.92	46.14	46.05	49.60
W7	Kawe	24.54	45.89	53.98	62.22	45.36	48.89	46.81
W8	Hallsho	No	58.08	40.29	60.65	52.06	53.89	52.99
W9	Sndollan	48.06	39.94	49.62	59.08	46.04	46.87	48.27
W10	Zharawa	No	44.97	49.14	53.42	49.48	48.76	49.15
W11	Dolabafra	61.97	No	73.04	60.81	56.28	53.86	61.19
W12	Doli-Shahidan	40.65	43.48	52.76	56.12	50.07	47.97	48.51
W13	Darbany-Ranya	40.89	42.98	54.94	55.86	44.16	28.04	44.48
W14	Bosken	96.28	67.98	75.92	81.94	79.98	85.78	81.31
W15	Dukan-Lake	36.26	34.98	44.14	57.54	46.85	31.76	41.92
W16	Qarani-Agha	60.03	60.89	61.84	60.14	53.24	55.34	58.58
W17	Khdran	52.87	40.51	63.94	54.96	56.14	55.58	54.00
W18	Hizop	64.05	62.41	62.92	58.89	47.12	52.32	57.95
W19	Smaquli	80.59	70.12	69.86	62.94	58.92	67.98	68.40
W20	Jali	86.97	66.98	61.91	57.94	48.72	63.92	64.41
W21	Qashqoli	53.27	48.79	39.16	41.94	47.06	47.14	46.23
Mean		56.78	54.70	59.58	61.93	52.70	53.26	56.49
IQS (2009) guideline value							150 mg L^{-1}	
WHO (2018) guideline value							None specified	
Number of countries and territories setting a regulatory/guideline value							31 (out of 104)	
Maximum value set							500 mg L^{-1}	
Minimum value set							30 mg L^{-1}	
Median value							150 mg L^{-1}	

Table 4.1.17 Monthly variation of water Mg^{+2} (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	14.40	19.29	11.97	10.92	17.28	16.32	15.03
W2	Mawakan	13.94	18.27	14.98	12.56	20.04	24.36	17.36
W3	Shakha-Sur	17.80	20.92	17.48	9.76	12.46	15.95	15.73
W4	Siwayl	19.20	18.72	15.88	14.54	20.52	18.96	17.97
W5	Kuna-Masi	24.87	23.16	18.72	11.89	14.98	18.84	18.74
W6	Qashan	24.01	17.96	18.12	15.78	21.12	16.76	18.96
W7	Kawe	26.40	25.68	14.86	10.61	15.84	9.98	17.23
W8	Hallsho	No	25.18	25.23	9.92	16.04	17.79	18.83
W9	Sndollan	16.47	27.92	16.63	15.84	15.72	11.69	17.38
W10	Zharawa	No	14.86	17.08	9.96	9.96	8.16	12.00
W11	Dolabafra	8.87	No	10.11	9.76	10.92	10.96	10.12
W12	Doli-Shahidan	26.40	20.76	14.93	13.25	10.02	12.88	16.37
W13	Darbany-Ranya	7.29	14.11	14.86	16.92	17.12	16.08	14.40
W14	Bosken	26.40	45.98	41.78	23.88	16.86	23.36	29.71
W15	Dukan-Lake	12.02	16.92	17.04	11.76	10.96	10.24	13.16
W16	Qarani-Agha	25.04	30.94	27.76	24.94	27.16	22.02	26.31
W17	Khdran	26.40	32.28	31.78	34.94	34.56	29.86	31.64
W18	Hizop	52.80	45.24	34.98	37.86	40.92	54.12	44.32
W19	Smaquli	24.27	38.88	34.72	33.97	38.78	33.96	34.10
W20	Jali	22.80	39.88	38.52	37.79	39.96	36.84	35.97
W21	Qashqoli	15.98	16.98	26.12	19.86	13.94	15.24	18.02
Mean		21.33	25.70	22.07	18.41	20.25	20.21	21.33
IQS (2009) guideline value							150 mg L^{-1}	
WHO (2018) guideline value							None specified	
Number of countries and territories setting a regulatory/guideline value							34 (out of 104)	
Maximum value set							1000 mg L^{-1}	
Minimum value set							10 mg L^{-1}	
Median value							100 mg L^{-1}	

Table 4.1.18 Monthly variation of water TH (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	173.55	202.36	207.45	211.77	193.71	189.56	196.40
W2	Mawakan	289.02	318.98	287.98	263.69	247.55	289.88	282.85
W3	Shakha-Sur	212.72	225.09	235.30	221.92	194.94	201.46	215.24
W4	Siwayl	189.03	197.29	194.99	193.82	199.96	187.54	193.77
W5	Kuna-Masi	231.76	265.63	248.46	245.73	211.30	229.88	238.79
W6	Qashan	203.76	191.14	218.06	212.00	202.07	183.91	201.82
W7	Kawe	169.89	220.22	195.88	198.96	178.40	163.10	187.74
W8	Hallsho	No	248.58	204.38	192.20	195.95	207.71	209.76
W9	Sndollan	187.73	214.58	192.28	212.65	179.60	165.09	191.99
W10	Zharawa	No	173.39	192.94	174.32	164.49	155.28	172.08
W11	Dolabafra	191.18	No	223.91	191.95	185.41	179.53	194.40
W12	Doli-Shahidan	210.10	193.95	193.12	194.60	166.21	172.73	188.45
W13	Darbany-Ranya	132.06	165.34	198.28	209.05	180.67	136.16	170.26
W14	Bosken	348.95	358.88	361.42	302.79	269.01	310.23	325.21
W15	Dukan-Lake	139.97	156.94	180.29	192.01	162.04	121.41	158.78
W16	Qarani-Agha	252.87	279.30	268.58	252.74	244.65	228.74	254.48
W17	Khdran	240.60	233.95	290.37	280.96	282.34	261.60	264.97
W18	Hizop	377.14	341.94	300.99	302.78	286.00	353.29	327.02
W19	Smaquli	301.02	335.01	317.24	296.88	306.64	309.42	311.04
W20	Jali	310.90	331.29	313.04	300.13	286.04	311.14	308.76
W21	Qashqoli	198.72	191.65	205.23	186.40	174.83	180.37	189.53
Mean		229.52	242.28	239.53	230.35	214.85	216.10	228.77
IQS (2009) guideline value							500 mg L^{-1} as $CaCO_3$	
WHO (2011) guideline value							500 mg L^{-1} as $CaCO_3$	
WHO (2018) guideline value							None set	
Number of countries and territories setting a regulatory/guideline value							57 (out of 104)	
Maximum value set							1000 mg L^{-1}	
Minimum value set							100 mg L^{-1}	
Median value							500 mg L^{-1}	

Table 4.1.19 Monthly variation of water Na^+ (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	11.27	7.97	11.86	5.49	5.67	7.93	8.37
W2	Mawakan	36.30	29.88	22.96	16.96	19.43	25.36	25.15
W3	Shakha-Sur	17.18	13.95	10.83	7.58	7.66	9.97	11.20
W4	Siwayl	15.20	9.96	9.16	7.97	6.81	9.79	9.82
W5	Kuna-Masi	11.29	4.98	6.66	2.89	3.89	6.82	6.09
W6	Qashan	12.75	11.96	10.21	7.88	6.53	7.98	9.55
W7	Kawe	10.78	12.95	8.33	6.54	5.16	6.62	8.40
W8	Hallsho	No	8.96	5.08	3.58	4.32	5.68	5.52
W9	Sndollan	12.35	12.95	8.93	4.88	5.27	9.83	9.04
W10	Zharawa	No	7.97	5.03	3.39	4.82	5.87	5.42
W11	Dolabafra	7.86	No	3.03	3.49	3.62	4.98	4.60
W12	Doli-Shahidan	10.78	7.97	5.43	4.49	3.85	5.87	6.40
W13	Darbany-Ranya	8.82	8.96	8.93	5.78	4.36	6.43	7.21
W14	Bosken	41.75	67.94	32.89	28.95	25.83	28.81	37.70
W15	Dukan-Lake	8.82	7.97	8.13	6.08	6.17	7.57	7.46
W16	Qarani-Agha	9.38	7.97	5.24	3.18	4.86	7.02	6.28
W17	Khdran	7.94	6.97	10.93	9.27	8.97	8.93	8.84
W18	Hizop	93.25	44.82	27.89	31.96	35.26	51.12	47.38
W19	Smaquli	15.69	12.95	35.86	22.89	20.68	13.99	20.34
W20	Jali	63.93	39.84	25.82	27.82	30.22	43.72	38.56
W21	Qashqoli	9.80	9.96	9.08	8.68	7.04	7.96	8.75
Mean		21.32	16.84	12.97	10.46	10.50	13.44	14.26
IQS (2009) guideline value							200 mg L^{-1}	
WHO (2018) guideline value							None specified	
Number of countries and territories setting a regulatory/guideline value							81 (out of 104)	
Maximum value set							400 mg L^{-1}	
Minimum value set							100 mg L^{-1}	
Median value							200 mg L^{-1}	

Table 4.1.20 Monthly variation of water K^+ (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	1.64	1.37	1.39	0.90	0.91	1.19	1.23
W2	Mawakan	2.89	2.35	2.08	1.99	1.78	2.18	2.21
W3	Shakha-Sur	1.99	1.86	1.58	1.10	0.99	1.39	1.49
W4	Siwayl	1.45	0.88	0.89	0.83	0.89	0.79	0.96
W5	Kuna-Masi	1.93	1.18	1.39	1.20	1.29	2.18	1.53
W6	Qashan	1.35	1.18	0.99	0.91	0.89	1.09	1.07
W7	Kawe	2.60	2.65	1.58	1.71	1.49	1.58	1.94
W8	Hallsho	No	1.37	2.08	1.10	1.09	1.19	1.37
W9	Sndollan	2.80	2.45	1.68	1.50	1.68	1.58	1.95
W10	Zharawa	No	2.06	1.39	1.09	1.19	1.09	1.36
W11	Dolabafra	1.79	No	0.79	0.72	0.69	0.89	0.98
W12	Doli-Shahidan	1.54	1.47	0.99	0.71	0.74	0.89	1.06
W13	Darbany-Ranya	2.12	1.86	1.49	1.43	1.29	1.68	1.65
W14	Bosken	7.71	9.51	8.91	5.49	4.85	3.47	6.66
W15	Dukan-Lake	2.31	1.86	1.98	1.40	1.49	1.88	1.82
W16	Qarani-Agha	1.75	1.57	1.09	1.10	0.99	1.98	1.41
W17	Khdran	0.96	0.78	1.68	1.50	1.29	1.88	1.35
W18	Hizop	4.53	4.12	3.07	3.19	2.87	4.95	3.79
W19	Smaquli	3.18	2.65	4.16	4.99	3.57	2.87	3.57
W20	Jali	6.94	4.02	2.87	2.69	2.67	3.17	3.73
W21	Qashqoli	1.87	1.76	2.08	1.90	1.88	1.98	1.91
Mean		2.70	2.35	2.10	1.78	1.64	1.90	2.08
IQS (2009) guideline value					None set			
WHO (2011) guideline value					12 mg L^{-1}			
WHO (2018) guideline value					None specified			
Number of countries and territories setting a regulatory/guideline value					12 (out of 104)			
Maximum value set					50 mg L^{-1}			
Minimum value set					1.5 mg L^{-1}			
Median value					10 mg L^{-1}			

Table 4.1.21 Monthly variation of water Cl^- (mg L^{-1}) during the period of study.

Sites code	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	11.36	18.62	12.07	7.39	6.75	9.23	10.90
W2	Mawakan	24.02	15.62	16.37	13.16	8.89	16.88	15.82
W3	Shakha-Sur	15.81	18.17	11.36	7.10	5.12	8.09	10.94
W4	Siwayl	15.62	18.46	14.56	12.98	7.10	13.04	13.63
W5	Kuna-Masi	10.15	11.01	16.69	6.04	5.13	7.62	9.44
W6	Qashan	16.69	26.98	14.19	13.27	8.02	6.75	14.32
W7	Kawe	9.23	32.31	5.68	9.72	8.08	9.05	12.35
W8	Hallsho	No	23.79	1.87	4.84	5.26	9.94	9.14
W9	Sndollan	11.01	33.53	8.17	11.14	6.06	8.24	13.03
W10	Zharawa	No	22.17	4.97	8.41	3.84	6.06	9.09
W11	Dolabafra	7.46	No	3.99	4.64	2.89	6.09	5.01
W12	Doli-Shahidan	8.52	23.08	4.62	4.39	3.98	6.46	8.51
W13	Darbany-Ranya	7.46	26.13	6.75	9.78	10.05	8.17	11.39
W14	Bosken	51.96	81.75	37.19	31.18	26.09	24.24	42.07
W15	Dukan-Lake	25.56	15.98	5.73	6.03	4.99	9.81	11.35
W16	Qarani-Agha	6.98	14.16	3.20	10.07	9.89	9.78	9.01
W17	Khdran	18.82	16.69	10.65	12.07	12.27	13.27	13.96
W18	Hizop	116.09	80.59	31.53	24.13	34.44	83.03	61.64
W19	Smaquli	13.85	11.36	20.16	16.11	11.72	12.18	14.23
W20	Jali	101.00	70.29	32.26	33.14	28.05	46.09	51.81
W21	Qashqoli	20.15	32.12	14.56	10.08	5.33	9.85	15.35
Mean		25.88	29.64	13.17	12.17	10.19	15.42	17.75
IQS (2009) guideline value							250 mg L^{-1}	
WHO (2011) guideline value							250 mg L^{-1}	
WHO (2018) guideline value							None set	
Number of countries and territories setting a regulatory / guideline value							100 (out of 104)	
Number of countries and territories setting a regulatory / guideline value greater than WHO Guideline recommendation of 250 mg L^{-1}							15	
Number of countries and territories setting a regulatory / guideline value at the WHO Guideline recommendation of 250 mg L^{-1}							77	
Number of countries and territories setting a regulatory / guideline value less than WHO Guideline recommendation of 250 mg L^{-1}							8	
Maximum value set							1200 mg L^{-1}	
Minimum value set							20 mg L^{-1}	
Median value							250 mg L^{-1}	

Table 4.1.22 Monthly variation of water SO_4^{-2} (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	22	30	34	20	23	28	26
W2	Mawakan	73	71	84	58	50	83	70
W3	Shakha-Sur	46	37	37	26	24	47	36
W4	Siwayl	24	27	31	25	21	26	26
W5	Kuna-Masi	22	18	28	25	23	37	26
W6	Qashan	25	34	33	26	25	27	28
W7	Kawe	38	33	29	29	26	24	30
W8	Hallsho	No	38	31	26	29	27	30
W9	Sndollan	27	36	32	26	25	23	28
W10	Zharawa	No	25	26	21	23	25	24
W11	Dolabafra	33	No	24	21	23	27	26
W12	Doli-Shahidan	26	30	28	22	25	27	26
W13	Darbany-Ranya	26	27	37	25	22	24	27
W14	Bosken	51	80	67	56	60	52	61
W15	Dukan-Lake	25	27	34	26	23	20	26
W16	Qarani-Agha	68	78	67	49	53	64	63
W17	Khdran	35	19	52	53	54	52	44
W18	Hizop	99	67	95	111	97	95	94
W19	Smaquli	62	57	125	115	117	108	97
W20	Jali	63	58	87	87	86	83	77
W21	Qashqoli	25	26	34	31	37	46	33
Mean		42	41	48	42	41	45	43
IQS (2009) guideline value							250 mg L^{-1}	
WHO (2011) guideline value							250 mg L^{-1}	
WHO (2018) guideline value							None set	
Number of countries and territories setting a regulatory/guideline value							97 (out of 104)	
Maximum value set							800 mg L^{-1}	
Minimum value set							50 mg L^{-1}	
Median value							250 mg L^{-1}	

Table 4.1.23 Monthly variation of water Alkalinity (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	219.36	221.24	239.13	231.68	215.94	207.16	222.42
W2	Mawakan	365.02	388.33	300.21	271.01	258.64	301.05	314.04
W3	Shakha-Sur	252.33	258.62	256.81	253.29	226.31	214.31	243.61
W4	Siwayl	224.18	196.42	202.62	205.33	221.92	203.29	208.96
W5	Kuna-Masi	295.32	301.17	261.69	276.41	244.33	251.13	271.68
W6	Qashan	215.03	192.08	221.87	228.39	220.17	203.18	213.45
W7	Kawe	179.65	208.84	215.21	209.60	184.22	175.78	195.55
W8	Hallsho	No	228.75	219.04	204.11	195.81	218.43	213.23
W9	Sndollan	190.93	219.02	219.36	217.53	194.42	189.12	205.06
W10	Zharawa	No	171.12	197.03	191.09	180.49	169.95	181.94
W11	Dolabafra	221.17	No	216.92	215.07	200.69	190.32	208.83
W12	Doli-Shahidan	237.60	191.03	208.99	212.65	163.48	181.18	199.16
W13	Darbany-Ranya	154.69	161.73	217.17	227.34	190.32	132.37	180.60
W14	Bosken	437.20	441.15	423.26	360.01	282.43	354.07	383.02
W15	Dukan-Lake	128.41	158.43	185.44	201.07	185.01	129.06	164.57
W16	Qarani-Agha	206.42	263.01	251.98	245.59	232.46	202.52	233.66
W17	Khdran	263.99	246.44	311.07	298.16	285.31	271.89	279.48
W18	Hizop	390.71	306.22	292.22	308.04	270.84	311.76	313.30
W19	Smaquli	348.31	350.75	321.15	292.10	294.51	275.36	313.70
W20	Jali	371.55	360.18	311.15	301.01	270.23	324.62	323.12
W21	Qashqoli	228.51	187.14	184.22	205.09	182.76	171.41	193.19
Mean		259.49	252.58	250.31	245.46	223.82	222.76	242.40
IQS (2009) guideline value							125 mg l^{-1}	
WHO (2011) guideline value							200 mg l^{-1}	

Appendix 2

Table 4.2.1 Monthly variation of Fe in water (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	0.231	0.241	0.271	0.262	0.268	0.250	0.254
W2	Mawakan	0.227	0.213	0.279	0.265	0.268	0.239	0.249
W3	Shakha-Sur	0.243	0.226	0.266	0.259	0.244	0.247	0.248
W4	Siwayl	0.218	0.215	0.225	0.222	0.218	0.211	0.218
W5	Kuna-Masi	0.231	0.221	0.249	0.251	0.242	0.234	0.238
W6	Qashan	0.226	0.219	0.240	0.235	0.088	0.228	0.206
W7	Kawe	0.232	0.246	0.297	0.295	0.295	0.247	0.269
W8	Hallsho	No	0.181	0.213	0.206	0.194	0.175	0.194
W9	Sndollan	0.318	0.305	0.294	0.272	0.279	0.281	0.292
W10	Zharawa	No	0.314	0.326	0.302	0.309	0.292	0.309
W11	Dolabafra	0.214	No	0.259	0.263	0.253	0.219	0.242
W12	Doli-Shahidan	0.269	0.262	0.339	0.347	0.329	0.300	0.308
W13	Darbany-Ranya	0.243	0.251	0.332	0.319	0.313	0.261	0.287
W14	Bosken	0.389	0.382	0.336	0.303	0.292	0.326	0.338
W15	Dukan-Lake	0.196	0.212	0.182	0.208	0.213	0.204	0.203
W16	Qarani-Agha	0.308	0.301	0.335	0.253	0.264	0.313	0.296
W17	Khdran	0.211	0.203	0.236	0.226	0.225	0.190	0.215
W18	Hizop	0.273	0.224	0.337	0.321	0.296	0.286	0.290
W19	Smaquli	0.234	0.228	0.283	0.270	0.257	0.241	0.252
W20	Jali	0.259	0.242	0.306	0.302	0.279	0.260	0.275
W21	Qashqoli	0.195	0.187	0.270	0.294	0.268	0.198	0.235
Mean		0.248	0.244	0.280	0.270	0.257	0.248	0.258
IQS (2009) guideline value							0.3 mg L^{-1}	
WHO (2018) guideline value							None set	
Number of countries and territories setting a regulatory/guideline value							99 (out of 104)	
Maximum value set							2 mg L^{-1}	
Minimum value set							0.2 mg L^{-1}	
Median value (permissible value)							0.3 mg L^{-1}	
Desirible value							None set	

Table 4.2.2 Monthly variation of Cu in water (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	0.009	0.008	0.013	0.011	0.010	0.009	0.010
W2	Mawakan	0.004	0.007	0.013	0.011	0.011	0.009	0.009
W3	Shakha-Sur	0.005	0.008	0.014	0.012	0.011	0.010	0.010
W4	Siwayl	0.009	0.008	0.015	0.013	0.012	0.010	0.011
W5	Kuna-Masi	0.003	0.007	0.009	0.009	0.008	0.008	0.007
W6	Qashan	0.002	0.008	0.012	0.011	0.011	0.009	0.009
W7	Kawe	0.007	0.011	0.014	0.012	0.010	0.008	0.010
W8	Hallsho	No	0.008	0.012	0.011	0.009	0.008	0.010
W9	Sndollan	0.007	0.009	0.013	0.011	0.009	0.006	0.009
W10	Zharawa	No	0.009	0.013	0.012	0.012	0.010	0.011
W11	Dolabafra	0.007	No	0.013	0.011	0.010	0.008	0.010
W12	Doli-Shahidan	0.005	0.011	0.014	0.012	0.010	0.007	0.010
W13	Darbany-Ranya	0.010	0.010	0.015	0.013	0.012	0.007	0.011
W14	Bosken	0.007	0.008	0.016	0.014	0.012	0.008	0.011
W15	Dukan-Lake	0.009	0.010	0.013	0.012	0.011	0.008	0.011
W16	Qarani-Agha	0.006	0.009	0.014	0.012	0.011	0.009	0.010
W17	Khdran	0.009	0.008	0.014	0.012	0.010	0.008	0.010
W18	Hizop	0.006	0.010	0.013	0.013	0.012	0.010	0.011
W19	Smaquli	0.006	0.009	0.014	0.012	0.011	0.009	0.010
W20	Jali	0.005	0.007	0.014	0.014	0.013	0.010	0.011
W21	Qashqoli	0.009	0.010	0.014	0.013	0.012	0.009	0.011
Mean		0.007	0.009	0.013	0.012	0.011	0.009	0.010
IQS (2009) guideline value							1 mg L^{-1}	
WHO (2018) guideline value							2 mg L^{-1}	
Number of countries and territories setting a regulatory/guideline value							104 (out of 104)	
Number of countries and territories setting a regulatory / guideline value greater than WHO Guideline							2	
Number of countries and territories setting the WHO Guideline							51	
Number of countries and territories setting a regulatory / guideline value less than WHO Guideline							51	
Maximum value set							3 mg L^{-1}	
Minimum value set							0.05 mg L^{-1}	
Median value (permissible value)							1.5 mg L^{-1}	
Desirible value							2 mg L^{-1}	

Table 4.2.3 Monthly variation of Zn in water (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	0.143	0.148	0.125	0.127	0.131	0.134	0.135
W2	Mawakan	0.179	0.182	0.162	0.163	0.167	0.169	0.170
W3	Shakha-Sur	0.148	0.157	0.132	0.137	0.139	0.141	0.142
W4	Siwayl	0.155	0.156	0.136	0.138	0.139	0.144	0.145
W5	Kuna-Masi	0.134	0.144	0.112	0.117	0.120	0.123	0.125
W6	Qashan	0.146	0.146	0.131	0.135	0.136	0.138	0.139
W7	Kawe	0.164	0.161	0.148	0.152	0.156	0.157	0.156
W8	Hallsho	No	0.126	0.117	0.119	0.122	0.125	0.122
W9	Sndollan	0.173	0.171	0.154	0.157	0.159	0.162	0.163
W10	Zharawa	No	0.137	0.126	0.129	0.132	0.135	0.132
W11	Dolabafra	0.150	No	0.131	0.134	0.137	0.139	0.138
W12	Doli-Shahidan	0.161	0.157	0.143	0.147	0.149	0.152	0.152
W13	Darbany-Ranya	0.154	0.154	0.139	0.142	0.144	0.146	0.147
W14	Bosken	0.223	0.220	0.207	0.209	0.211	0.213	0.214
W15	Dukan-Lake	0.156	0.152	0.139	0.141	0.143	0.146	0.146
W16	Qarani-Agha	0.150	0.150	0.136	0.141	0.143	0.144	0.144
W17	Khdran	0.165	0.163	0.151	0.153	0.158	0.157	0.158
W18	Hizop	0.171	0.174	0.155	0.158	0.161	0.164	0.164
W19	Smaquli	0.169	0.172	0.145	0.149	0.153	0.159	0.158
W20	Jali	0.196	0.200	0.174	0.178	0.181	0.185	0.186
W21	Qashqoli	0.151	0.148	0.134	0.137	0.140	0.141	0.142
Mean		0.163	0.161	0.143	0.146	0.149	0.151	0.152
IQS (2009) guideline value							3 mg L^{-1}	
WHO (2018) guideline value							None set	
Number of countries and territories setting a regulatory/guideline value							74 (out of 104)	
Maximum value set							15 mg L^{-1}	
Minimum value set							1 mg L^{-1}	
Median value (permissible value)							5 mg L^{-1}	
Desirible value							5 mg L^{-1}	

Table 4.2.4 Monthly variation of Mn in water (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	0.002	0.002	0.001	0.001	0.001	0.001	0.001
W2	Mawakan	0.004	0.002	0.002	0.002	0.002	0.002	0.002
W3	Shakha-Sur	0.002	0.002	0.001	0.001	0.001	0.001	0.001
W4	Siwayl	0.003	0.002	0.003	0.002	0.002	0.002	0.002
W5	Kuna-Masi	0.001	0.002	0.002	0.002	0.002	0.001	0.002
W6	Qashan	0.003	0.002	0.002	0.002	0.002	0.002	0.002
W7	Kawe	0.003	0.002	0.003	0.002	0.003	0.002	0.003
W8	Hallsho	No	0.001	0.002	0.001	0.001	0.001	0.001
W9	Sndollan	0.004	0.002	0.003	0.002	0.001	0.001	0.002
W10	Zharawa	No	0.001	0.002	0.001	0.001	0.001	0.001
W11	Dolabafra	0.001	No	0.002	0.001	0.001	0.001	0.001
W12	Doli-Shahidan	0.003	0.002	0.005	0.002	0.002	0.002	0.003
W13	Darbany-Ranya	0.006	0.004	0.006	0.006	0.005	0.002	0.005
W14	Bosken	0.067	0.052	0.033	0.023	0.021	0.018	0.036
W15	Dukan-Lake	0.004	0.002	0.004	0.002	0.003	0.003	0.003
W16	Qarani-Agha	0.004	0.003	0.005	0.003	0.003	0.003	0.004
W17	Khdran	0.005	0.004	0.002	0.002	0.001	0.001	0.003
W18	Hizop	0.005	0.004	0.003	0.002	0.002	0.002	0.003
W19	Smaquli	0.002	0.002	0.003	0.002	0.002	0.002	0.002
W20	Jali	0.006	0.003	0.002	0.002	0.001	0.001	0.003
W21	Qashqoli	0.007	0.016	0.005	0.006	0.007	0.006	0.008
Mean		0.007	0.006	0.004	0.003	0.003	0.003	0.004

IQS (2009) guideline value	0.1 mg L^{-1}
WHO (2018) guideline value	No value established in the fourth edition, previously 0.4 mg L^{-1}
Number of countries and territories setting a regulatory/guideline value	103 (out of 104)
Number of countries and territories setting a regulatory / guideline value greater than the previous WHO Guideline	19
Number of countries and territories setting the previous WHO Guideline	11
Number of countries and territories setting a regulatory / guideline value less than the previous WHO Guideline	73
Maximum value set	0.5 mg L^{-1}
Minimum value set	0.05 mg L^{-1}
Median value (permissible value)	0.1 mg L^{-1}
Desirible value	0.4 mg L^{-1}

Table 4.2.5 Monthly variation of Pb in water (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	0.031	0.064	0.062	0.054	0.026	0.019	0.043
W2	Mawakan	0.078	0.084	0.072	0.051	0.041	0.044	0.062
W3	Shakha-Sur	0.072	0.068	0.057	0.042	0.036	0.028	0.051
W4	Siwayl	0.043	0.077	0.055	0.051	0.047	0.055	0.055
W5	Kuna-Masi	0.076	0.079	0.072	0.061	0.058	0.087	0.072
W6	Qashan	0.052	0.069	0.062	0.056	0.062	0.070	0.062
W7	Kawe	0.021	0.071	0.054	0.051	0.041	0.052	0.048
W8	Hallsho	No	0.064	0.048	0.026	0.020	0.023	0.036
W9	Sndollan	0.052	0.091	0.079	0.037	0.034	0.042	0.056
W10	Zharawa	No	0.074	0.070	0.042	0.036	0.043	0.053
W11	Dolabafra	0.037	No	0.070	0.040	0.038	0.043	0.046
W12	Doli-Shahidan	0.084	0.075	0.038	0.026	0.022	0.030	0.046
W13	Darbany-Ranya	0.033	0.067	0.056	0.042	0.038	0.046	0.047
W14	Bosken	0.055	0.050	0.077	0.027	0.023	0.032	0.044
W15	Dukan-Lake	0.031	0.045	0.058	0.051	0.045	0.043	0.046
W16	Qarani-Agha	0.049	0.080	0.041	0.038	0.047	0.048	0.051
W17	Khdran	0.043	0.055	0.079	0.043	0.036	0.046	0.050
W18	Hizop	0.006	0.051	0.065	0.044	0.032	0.038	0.039
W19	Smaquli	0.053	0.059	0.062	0.045	0.041	0.053	0.052
W20	Jali	0.050	0.061	0.061	0.052	0.045	0.050	0.053
W21	Qashqoli	0.031	0.044	0.065	0.046	0.041	0.050	0.046
Mean		0.047	0.066	0.062	0.044	0.039	0.045	0.051

IQS (2009) guideline value	0.01 mg L^{-1}
WHO (2018) guideline value	0.01 mg L^{-1}
Number of countries and territories setting a regulatory / guideline value	104 (out of 104)
Number of countries and territories setting a regulatory / guideline value greater than WHO Guideline	19
Number of countries and territories setting the WHO Guideline	84
Number of countries and territories setting a regulatory / guideline value less than WHO Guideline	1
Maximum value set	0.1 mg L^{-1}
Minimum value set	0.005 mg L^{-1}
Median value (permissible value)	0.01 mg L^{-1}
Desirible value	0.01 mg L^{-1}

Table 4.2.6 Monthly variation of Cd in water (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	0.112	0.117	0.099	0.103	0.107	0.096	0.106
W2	Mawakan	0.116	0.121	0.094	0.097	0.109	0.087	0.104
W3	Shakha-Sur	0.110	0.117	0.091	0.095	0.103	0.085	0.100
W4	Siwayl	0.109	0.116	0.093	0.097	0.105	0.087	0.101
W5	Kuna-Masi	0.102	0.109	0.086	0.091	0.093	0.083	0.094
W6	Qashan	0.113	0.115	0.101	0.105	0.108	0.097	0.107
W7	Kawe	0.114	0.119	0.101	0.107	0.109	0.094	0.107
W8	Hallsho	No	0.109	0.095	0.098	0.103	0.091	0.099
W9	Sndollan	0.117	0.124	0.110	0.113	0.115	0.106	0.114
W10	Zharawa	No	0.121	0.109	0.116	0.118	0.107	0.114
W11	Dolabafra	0.091	No	0.078	0.083	0.086	0.074	0.082
W12	Doli-Shahidan	0.131	0.137	0.121	0.124	0.127	0.118	0.126
W13	Darbany-Ranya	0.118	0.123	0.109	0.111	0.112	0.109	0.114
W14	Bosken	0.148	0.153	0.142	0.144	0.146	0.138	0.145
W15	Dukan-Lake	0.119	0.125	0.105	0.111	0.113	0.101	0.112
W16	Qarani-Agha	0.126	0.132	0.113	0.116	0.119	0.111	0.120
W17	Khdran	0.105	0.111	0.094	0.096	0.099	0.091	0.099
W18	Hizop	0.103	0.108	0.082	0.087	0.094	0.079	0.092
W19	Smaquli	0.106	0.111	0.096	0.098	0.101	0.093	0.101
W20	Jali	0.111	0.116	0.097	0.099	0.105	0.093	0.104
W21	Qashqoli	0.126	0.129	0.115	0.119	0.121	0.112	0.120
Mean		0.115	0.121	0.101	0.105	0.109	0.098	0.108

IQS (2009) guideline value	0.003 mg L^{-1}
WHO (2018) guideline value	0.003 mg L^{-1}
Number of countries and territories setting a regulatory / guideline value	101 (out of 104)
Number of countries and territories setting a regulatory / guideline value greater than WHO Guideline	59
Number of countries and territories setting the WHO Guideline	38
Number of countries and territories setting a regulatory / guideline value less than WHO Guideline	4
Maximum value set	0.05 mg L^{-1}
Minimum value set	0.001 mg L^{-1}
Median value (permissible value)	0.005 mg L^{-1}
Desirible value	0.003 mg L^{-1}

Table 4.2.7 Monthly variation of Cr in water (mg L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	0.506	0.474	0.464	0.468	0.473	0.481	0.478
W2	Mawakan	0.646	0.584	0.568	0.575	0.584	0.606	0.594
W3	Shakha-Sur	0.618	0.521	0.508	0.518	0.535	0.577	0.546
W4	Siwayl	0.598	0.461	0.436	0.452	0.464	0.486	0.483
W5	Kuna-Masi	0.574	0.397	0.358	0.373	0.398	0.448	0.425
W6	Qashan	0.523	0.406	0.397	0.407	0.413	0.427	0.429
W7	Kawe	0.639	0.685	0.498	0.503	0.516	0.523	0.561
W8	Hallsho	No	0.498	0.487	0.496	0.501	0.511	0.499
W9	Sndollan	0.483	0.444	0.432	0.446	0.451	0.458	0.452
W10	Zharawa	No	0.421	0.414	0.419	0.423	0.437	0.423
W11	Dolabafra	0.478	No	0.432	0.437	0.446	0.454	0.449
W12	Doli-Shahidan	0.606	0.553	0.534	0.542	0.557	0.573	0.561
W13	Darbany-Ranya	0.728	0.653	0.632	0.622	0.611	0.634	0.647
W14	Bosken	0.790	0.693	0.688	0.683	0.692	0.704	0.708
W15	Dukan-Lake	0.655	0.211	0.489	0.511	0.525	0.589	0.497
W16	Qarani-Agha	0.600	0.687	0.367	0.404	0.442	0.518	0.503
W17	Khdran	0.587	0.509	0.493	0.502	0.511	0.531	0.522
W18	Hizop	0.595	0.477	0.441	0.466	0.487	0.515	0.497
W19	Smaquli	0.602	0.493	0.476	0.484	0.503	0.522	0.513
W20	Jali	0.614	0.685	0.484	0.488	0.492	0.544	0.551
W21	Qashqoli	0.636	0.683	0.545	0.551	0.559	0.614	0.598
Mean		0.604	0.527	0.483	0.493	0.504	0.531	0.524

IQS (2009) guideline value	0.05 mg L^{-1}
WHO (2018) guideline value	0.05 mg L^{-1}
Number of countries and territories setting a regulatory / guideline value	99 (out of 104)
Number of countries and territories setting a regulatory / guideline value greater than WHO Guideline	3
Number of countries and territories setting the WHO Guideline	94
Number of countries and territories setting a regulatory / guideline value less than WHO Guideline	1
Maximum value set	0. 5 mg L^{-1}
Minimum value set	0.04 mg L^{-1}
Median value (permissible value)	0.05 mg L^{-1}
Desirible value	0.05 mg L^{-1}

Appendix 3

Table 4.6.1 Modeling parameters for the month of August 2016.

Site names	Temp. ^{o}C	Velocity km hr^{-1}	Time days $^{-1}$	BOD$_5$ mg L^{-1}	DO initial	DO Deficit	Lo	K1	K2	F
Joga-Sur	29.2	3.13	0	2.43	5.85	1.81	2.94	0	0	0
Mawakan	18.3	2.77	0.0228	3.42	4.36	5.05	5.22	8.037	30.792	3.831
Shakha-Sur	24.0	4.14	0.0402	2.81	4.81	3.61	3.75	3.121	13.877	4.446
Siwayl	29.1	1.50	0.3033	2.73	6.65	1.02	3.31	0.274	0.035	0.127
Kuna-Masi	21.6	0.79	0.0242	3.01	7.12	1.69	4.24	6.137	9.448	1.539
Qashan	31.1	3.27	0.4748	2.44	6.4	1.01	2.86	0.146	0.012	0.084
Kawe	27.6	5.40	0.7103	4.13	6.85	1.03	5.13	0.133	0.019	0.139
Hallsho	0.0	0.00	0.0000	0.00	0.00	0.00	0.00	0.000	0.000	0.000
Sndollan	29.2	4.79	0.9875	3.93	6.65	1.01	4.75	0.083	0.005	0.055
Zharawa	0.0	0.00	0.0000	0.00	0.00	0.00	0.00	0.000	0.000	0.000
Dolabafra	26.8	0.36	0.5787	4.19	6.95	1.04	5.29	0.174	0.033	0.189
Doli-Shahidan	25.4	4.50	0.0229	6.89	7.04	1.16	8.93	4.931	2.840	0.576
Bosken	29.1	1.15	0.1154	61.50	5.19	2.48	74.46	0.720	3.425	4.760
Qarani-Agha	27.1	4.79	0.0465	3.53	6.93	1.02	4.43	2.119	0.202	0.095
Khdran	19.2	3.13	0.0601	1.91	8.2	1.04	2.85	2.888	0.301	0.104
Jali	22.2	0.73	0.2748	2.74	6.67	2.04	3.80	0.519	1.127	2.174
Smaquli	27.0	0.90	0.1769	3.56	6.51	1.46	4.47	0.561	0.923	1.644
Hizop	23.7	0.40	1.1216	3.64	6.98	1.49	4.89	0.114	0.153	1.342

Table 4.6.2 Modeling parameters for the month of November 2016.

Site names	Temp. ^{o}C	Velocity km hr^{-1}	Time days $^{-1}$	BOD$_5$ mg L^{-1}	DO initial	DO Deficit	Lo	K1	K2	F
Joga-Sur	16.6	4.54	0	2.41	7.68	2.07	3.85	0	0	0
Mawakan	15.4	2.04	0.0310	1.05	4.95	5.05	1.73	7.017	22.712	3.237
Shakha-Sur	15.2	3.15	0.0528	1.66	6.54	3.50	2.75	4.164	10.319	2.478
Siwayl	12.7	4.20	0.1082	1.14	7.27	3.34	2.03	2.320	4.843	2.087
Kuna-Masi	11.6	1.26	0.0152	1.44	7.37	3.51	2.65	17.441	35.847	2.055
Qashan	11.8	4.18	0.3721	1.47	7.77	3.06	2.69	0.706	1.305	1.849
Kawe	14.1	5.62	0.6830	2.49	8.2	2.09	4.26	0.342	0.468	1.370
Hallsho	16.5	1.44	0.3125	0.68	6.08	3.69	1.09	0.654	1.815	2.777
Sndollan	15.5	5.04	0.9382	2.41	7.57	2.41	3.96	0.230	0.407	1.768
Zharawa	17.3	2.57	0.0639	1.8	7.21	2.40	2.82	3.052	5.952	1.950
Dolabafra	0.0	0.00	0.0000	0.00	0.00	0.00	0.00	0.000	0.000	0.000
Doli-Shahidan	16.2	7.99	0.0129	5.73	6.65	3.18	9.25	16.136	39.047	2.420
Bosken	16.6	0.29	0.4615	78.3	5.4	4.35	124.98	0.440	1.384	3.144
Qarani-Agha	13.6	2.41	0.0922	1.29	5.45	4.95	2.24	2.597	7.531	2.900
Khdran	13.5	3.13	0.0601	2.98	8.64	1.78	5.19	4.005	4.184	1.045
Jali	15.2	1.37	0.1468	1.42	6.17	3.88	2.36	1.497	4.008	2.677
Smaquli	21.1	5.31	0.0300	2.39	5.35	3.55	3.40	5.125	18.358	3.582
Hizop	11.0	2.06	0.2161	2.63	8.73	2.30	4.93	1.265	1.674	1.324

Table 4.6.3 Modeling parameters for the month of February 2017.

Site names	Temp. ^{o}C	Velocity km hr^{-1}	Time days $^{-1}$	BOD$_5$ mg L^{-1}	DO initial	DO Deficit	Lo	K1	K2	F
Joga-Sur	7.8	11.34	0	2.6	9.46	2.44	5.40	0	0	0
Mawakan	13.7	4.32	0.0147	2.92	7.3	3.08	5.05	16.255	33.307	2.049
Shakha-Sur	10.8	3.96	0.0420	2.36	8.84	2.24	4.45	6.572	8.351	1.271
Siwayl	7.7	5.15	0.0882	2.58	9.28	2.65	5.37	3.611	4.800	1.329
Kuna-Masi	13.7	5.83	0.0033	2.92	8.41	1.97	5.05	72.510	89.524	1.235
Qashan	8.6	4.39	0.3538	2.16	9.3	2.37	4.37	0.865	1.060	1.226
Kawe	8.9	5.94	0.6458	5.73	10.25	1.34	11.48	0.467	0.196	0.420
Hallsho	12.3	15.08	0.0298	8.37	9.03	1.68	15.10	8.587	7.534	0.877
Sndollan	9.6	5.36	0.8815	4.64	10.35	1.05	9.09	0.331	0.023	0.069
Zharawa	13.0	11.12	0.0148	2.18	9.5	1.04	3.85	16.748	1.164	0.069
Dolabafra	16.1	10.91	0.0191	1.48	8.3	1.55	2.39	10.941	10.024	0.916
Doli-Shahidan	14.7	4.90	0.0210	4.72	9.1	1.05	7.94	10.745	1.086	0.101
Bosken	17.4	6.52	0.0204	60	6.37	3.22	93.75	9.501	24.890	2.620
Qarani-Agha	11.9	3.42	0.0651	8.97	9.75	1.05	16.37	4.018	0.354	0.088
Khdran	11.9	6.23	0.0302	6.09	10.3	2.77	11.12	8.644	14.646	1.695
Jali	9.6	4.21	0.0477	5.28	9.06	2.34	10.35	6.127	7.729	1.261
Smaquli	13.6	4.75	0.0335	6.23	7.2	3.20	10.82	7.152	15.088	2.110
Hizop	9.4	5.27	0.0843	1.82	9.66	1.79	3.59	3.499	3.003	0.858

Table 4.6.4 Modeling parameters for the month of March 2017.

Site names	Temp. ^{o}C	Velocity km hr^{-1}	Time days $^{-1}$	BOD$_5$ mg L^{-1}	DO initial	DO Deficit	Lo	K1	K2	F
Joga-Sur	12.2	15.01	0	3.66	8.95	1.78	6.62	0	0	0
Mawakan	14.6	8.14	0.0078	4.78	8.22	1.96	8.06	29.175	37.424	1.283
Shakha-Sur	12.2	5.87	0.0283	3.9	8.89	1.84	7.06	9.088	9.360	1.030
Siwayl	11.1	10.89	0.0417	4.62	8.5	2.50	8.64	6.520	9.561	1.466
Kuna-Masi	12.3	6.91	0.0028	2.4	8.57	2.14	4.33	92.383	118.947	1.288
Qashan	11.6	5.54	0.2803	4.28	8.42	2.46	7.88	0.947	1.394	1.473
Kawe	11.2	6.41	0.5986	8	9.25	1.73	14.92	0.452	0.397	0.879
Hallsho	10.2	28.08	0.0160	5.21	9.39	1.85	10.02	17.720	16.634	0.939
Sndollan	10.8	5.76	0.8209	7.92	9.22	1.86	14.95	0.336	0.329	0.978
Zharawa	10.4	16.34	0.0100	1.31	8.25	2.93	2.50	28.003	46.508	1.661
Dolabafra	17.5	16.38	0.0127	5.05	8.2	1.37	7.87	15.148	10.734	0.709
Doli-Shahidan	13.2	8.50	0.0121	7.9	9.4	1.09	13.88	20.194	3.202	0.159
Bosken	19.0	9.11	0.0146	69.3	6.6	2.68	103.90	12.052	29.339	2.434
Qarani-Agha	18.3	6.01	0.0370	4.35	8.4	1.01	6.64	4.961	0.149	0.030
Khdran	17.5	7.92	0.0238	2.63	7.54	2.03	4.10	8.102	12.929	1.596
Jali	16.7	2.33	0.0861	2.23	7.87	1.86	3.55	2.345	3.132	1.335
Smaquli	21.1	7.23	0.0220	3.05	6.27	2.63	4.34	6.973	19.063	2.734
Hizop	16.8	10.94	0.0406	3.16	8.06	1.65	5.02	4.946	5.357	1.083

Table 4.6.5 Modeling parameters for the month of April 2017.

Site names	Temp. °C	Velocity km hr^{-1}	Time days $^{-1}$	BOD$_5$ mg L^{-1}	DO initial	DO Deficit	Lo	K1	K2	F
Joga-Sur	17.9	14.62	0	5.60	8.48	1.01	8.64	0	0	0
Mawakan	18.3	4.82	0.0131	5.27	7.99	1.42	8.04	13.986	11.676	0.835
Shakha-Sur	19.8	3.97	0.0418	2.42	8.12	1.01	3.56	3.998	0.122	0.030
Siwayl	17.8	8.14	0.0558	3.99	8.5	1.01	6.17	3.390	0.077	0.023
Kuna-Masi	19.0	6.91	0.0028	4.73	8.25	1.03	7.09	63.425	4.643	0.073
Qashan	18.5	4.90	0.3174	6.53	8.35	1.02	9.92	0.572	0.033	0.058
Kawe	14.2	6.55	0.5854	6.36	9.2	1.07	10.85	0.396	0.047	0.119
Hallsho	13.3	24.37	0.0185	6.67	9.45	1.02	11.68	13.180	0.487	0.037
Sndollan	14.7	5.98	0.7912	7.82	8.87	1.28	13.15	0.285	0.137	0.481
Zharawa	15.3	19.08	0.0086	5.66	9	1.02	9.36	25.402	1.167	0.046
Dolabafra	18.7	17.46	0.0119	5.78	8.5	1.04	8.73	15.016	1.299	0.087
Doli-Shahidan	14.2	5.08	0.0203	7.07	9.25	1.02	12.06	11.445	0.324	0.028
Bosken	23.6	2.52	0.0527	50.10	6.71	1.77	67.44	2.447	4.710	1.925
Qarani-Agha	22.7	3.76	0.0591	4.90	7.6	1.03	6.73	2.327	0.206	0.089
Khdran	21.2	6.40	0.0294	7.22	7.85	1.03	10.26	5.189	0.467	0.090
Jali	22.4	2.52	0.0797	4.97	7.65	1.03	6.87	1.764	0.147	0.084
Smaquli	24.2	3.77	0.0422	3.82	6.94	1.45	5.08	2.928	3.802	1.299
Hizop	23.4	1.91	0.2328	5.84	7.5	1.01	7.90	0.563	0.026	0.046

Table 4.6.6 Modeling parameters for the month of May 2017.

Site names	Temp. °C	Velocity km hr^{-1}	Time days $^{-1}$	BOD$_5$ mg L^{-1}	DO initial	DO Deficit	Lo	K1	K2	F
Joga-Sur	21.3	11.05	0	3.25	4.85	4.01	4.61	0	0	0
Mawakan	20.7	3.28	0.0193	1.93	4.83	4.14	2.78	8.159	31.912	3.911
Shakha-Sur	22.2	3.60	0.0462	1.69	5.19	3.52	2.35	3.087	11.838	3.835
Siwayl	20.4	5.94	0.0765	1.62	5.12	3.90	2.35	2.104	7.736	3.677
Kuna-Masi	21.2	9.94	0.0019	1.89	5.39	3.49	2.69	79.101	281.572	3.560
Qashan	22.2	4.68	0.3320	2.82	5.42	3.29	3.92	0.429	1.558	3.629
Kawe	17.2	6.08	0.6305	2.55	5.3	4.33	4.01	0.311	1.009	3.245
Hallsho	16.2	18.17	0.0248	3.22	6	3.83	5.20	8.390	23.560	2.808
Sndollan	17.5	5.51	0.8584	3.14	5.24	4.33	4.89	0.224	0.741	3.303
Zharawa	18.0	14.44	0.0114	3.07	6.14	3.33	4.72	16.443	45.952	2.795
Dolabafra	21.0	17.35	0.0120	5.31	6.06	2.86	7.58	12.880	37.973	2.948
Doli-Shahidan	17.0	2.75	0.0374	5.95	6.4	3.27	9.40	5.310	13.766	2.593
Bosken	23.5	2.93	0.0454	41.1	4.3	4.20	55.44	2.863	13.719	4.792
Qarani-Agha	28.9	8.88	0.0251	4.11	6.63	1.07	4.99	3.373	1.193	0.354
Khdran	24.8	4.51	0.0418	4.18	7	1.29	5.49	2.826	2.670	0.945
Jali	25.2	3.54	0.0567	4.25	5.5	2.73	5.53	2.020	7.700	3.812
Smaquli	28.0	1.26	0.1263	1.34	4.5	3.32	1.65	0.723	4.130	5.712
Hizop	29.3	0.85	0.5228	4.35	6	1.65	5.25	0.156	0.415	2.657

Appendix 4

Table 4.7.1 Monthly variation of SAR (meq L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	0.37	0.25	0.36	0.16	0.18	0.25	0.26
W2	Mawakan	0.93	0.73	0.59	0.45	0.53	0.65	0.65
W3	Shakha-Sur	0.52	0.40	0.31	0.23	0.24	0.3	0.33
W4	Siwayl	0.48	0.31	0.29	0.25	0.21	0.31	0.31
W5	Kuna-Masi	0.32	0.13	0.19	0.08	0.12	0.20	0.17
W6	Qashan	0.39	0.37	0.30	0.24	0.20	0.25	0.29
W7	Kawe	0.36	0.38	0.26	0.20	0.17	0.23	0.27
W8	Hallsho	No	0.24	0.16	0.11	0.13	0.17	0.16
W9	Sndollan	0.40	0.38	0.28	0.15	0.17	0.34	0.29
W10	Zharawa	No	0.26	0.16	0.11	0.16	0.2	0.18
W11	Dolabafra	0.25	No	0.09	0.11	0.11	0.16	0.14
W12	Doli-Shahidan	0.32	0.25	0.17	0.14	0.13	0.19	0.20
W13	Darbany-Ranya	0.33	0.30	0.28	0.17	0.14	0.24	0.24
W14	Bosken	0.97	1.55	0.75	0.72	0.68	0.71	0.90
W15	Dukan-Lake	0.33	0.28	0.26	0.19	0.21	0.30	0.26
W16	Qarani-Agha	0.26	0.21	0.14	0.09	0.13	0.20	0.17
W17	Khdran	0.22	0.20	0.28	0.24	0.23	0.24	0.24
W18	Hizop	2.09	1.05	0.70	0.80	0.90	1.18	1.12
W19	Smaquli	0.39	0.31	0.87	0.58	0.51	0.34	0.50
W20	Jali	1.57	0.95	0.64	0.70	0.77	1.07	0.95
W21	Qashqoli	0.30	0.31	0.27	0.28	0.23	0.26	0.28
Mean		0.57	0.44	0.35	0.29	0.29	0.37	0.39
Al-Maliki (2013)		S1 (0-10)		Excellent				
		S2 (10-18)		Good				
		S3 (18-26)		Doubtful				
		S4 (>26)		Unsuitable				

Table 4.7.2 Monthly variation of SSP (%)during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	13.18	8.80	11.63	5.69	6.52	8.95	9.13
W2	Mawakan	22.15	17.51	15.39	12.86	15.14	16.61	16.61
W3	Shakha-Sur	15.85	12.61	9.75	7.55	8.34	10.37	10.75
W4	Siwayl	15.40	10.3	9.79	8.62	7.35	10.59	10.34
W5	Kuna-Masi	10.36	4.39	6.25	3.04	4.51	7.14	5.95
W6	Qashan	12.51	12.49	9.66	8.10	7.02	9.22	9.83
W7	Kawe	13.79	12.63	9.25	7.75	6.84	9.24	9.92
W8	Hallsho	No	7.81	6.25	4.64	5.20	6.24	6.03
W9	Sndollan	14.04	12.60	10.07	5.56	7.08	12.53	10.31
W10	Zharawa	No	10.26	6.17	4.91	6.75	8.36	7.29
W11	Dolabafra	9.19	No	3.25	4.20	4.44	6.30	5.48
W12	Doli-Shahidan	10.74	8.93	6.26	5.04	5.34	7.43	7.29
W13	Darbany-Ranya	14.17	11.62	9.65	6.36	5.72	10.75	9.71
W14	Bosken	22.37	30.72	18.63	18.8	18.84	17.73	21.18
W15	Dukan-Lake	13.83	11.07	10.02	7.42	8.58	13.39	10.72
W16	Qarani-Agha	8.20	6.51	4.52	3.24	4.59	7.19	5.71
W17	Khdran	7.08	6.36	8.11	7.24	6.91	7.67	7.23
W18	Hizop	35.48	22.97	17.52	19.45	21.88	24.9	23.70
W19	Smaquli	11.2	8.54	20.67	15.97	13.81	9.87	13.34
W20	Jali	32.12	21.64	16.2	17.61	19.3	24.06	21.82
W21	Qashqoli	10.55	11.02	9.77	10.45	9.17	9.97	10.16
Mean		15.38	12.44	10.42	8.79	9.21	11.36	11.26
Todd and Mays (2005		<20		Excellent				
		20 - 40		Good				
		40 - 60		Permissible				
		60 - 80		Doubtful				
		>80		Unsuitable				

Table 4.7.3 Monthly variation of RSC (meq L^{-1}) during the period of study.

Site codes	Site names	Months						Mean
		August	November	February	March	April	May	
W1	Joga-Sur	0.106	-0.444	-0.246	-0.454	-0.356	-0.416	-0.302
W2	Mawakan	0.182	-0.040	-0.861	-0.851	-0.737	-0.894	-0.534
W3	Shakha-Sur	-0.141	-0.288	-0.519	-0.302	-0.206	-0.537	-0.332
W4	Siwayl	-0.129	-0.749	-0.599	-0.530	-0.386	-0.442	-0.473
W5	Kuna-Masi	0.176	-0.405	-0.704	-0.402	-0.240	-0.505	-0.347
W6	Qashan	-0.578	-0.696	-0.747	-0.517	-0.458	-0.368	-0.561
W7	Kawe	-0.482	-1.011	-0.409	-0.559	-0.568	-0.395	-0.571
W8	Hallsho	No	-1.252	-0.526	-0.513	-0.730	-0.596	-0.723
W9	Sndollan	-0.646	-0.733	-0.270	-0.708	-0.425	-0.217	-0.500
W10	Zharawa	No	-0.681	-0.650	-0.368	-0.345	-0.332	-0.475
W11	Dolabafra	-0.212	No	-0.938	-0.328	-0.434	-0.487	-0.480
W12	Doli-Shahidan	-0.338	-0.772	-0.456	-0.424	-0.658	-0.501	-0.525
W13	Darbany-Ranya	-0.116	-0.673	-0.425	-0.476	-0.515	-0.572	-0.463
W14	Bosken	0.154	0.001	-0.339	-0.185	-0.774	-0.431	-0.262
W15	Dukan-Lake	-0.710	-0.561	-0.587	-0.561	-0.223	-0.325	-0.495
W16	Qarani-Agha	-1.704	-1.311	-1.275	-1.059	-1.115	-1.282	-1.291
W17	Khdran	-0.516	-0.675	-0.746	-0.772	-1.010	-0.810	-0.755
W18	Hizop	-1.197	-1.870	-1.270	-1.050	-1.326	-2.015	-1.455
W19	Smaquli	-0.342	-0.996	-1.121	-1.189	-1.349	-1.715	-1.119
W20	Jali	-0.157	-0.767	-1.205	-1.112	-1.336	-0.944	-0.920
W21	Qashqoli	-0.249	-0.787	-1.115	-0.389	-0.518	-0.817	-0.646
Mean		-0.363	-0.736	-0.715	-0.607	-0.653	-0.695	-0.628
After Richards (1954		<1.25		Suitable				
		1.25-2.5		Marginal suitable				
		>2.5		Unsuitable				

الخلاصة

اجريت هذه الدراسة في أحواض تغذية بحيرة دوكان وذلك للبحث عن تأثيرات العمليات الطبيعية وألانشطة البشرية على الصفات الفيزوكيمياوية والنوعية لمياه الانهر و الجداول المغذية لبحيرة دوكان. أختيرت أحدى وعشرون موقا لجمع المياه موزعة على الانهر الرئيسي لقلعةجوالان-الزاب الصغير، هيزوب، من داخل بحيرة دوكان، من خارج منفذ سددوكان وعلى الأفرع النهرية الأخرى لسهل رانية واللاتي تغذي بحيرة دوكان و أخذ أربعة وثلاثون نموذجا للتربة ضمن منطقة الدراسة.

جمعت نماذج المياه خلال الأشهر (آب، تشرين الثاني، شباط، آذار، نيسان، آيار) و بالأعتماد على تذبذب التصاريف في المواقع المدروسة خلال فترة من (أب 2016) الى (آيار 2017). تم تحليل النماذج مختبريا. اجريت التحاليل لنماذج المياه من حيث درجة الحرارة، العكارة، درجة التفاعل، التوصيل الكهربائي، الأوكسجين الذائب، المتطلبات الكيموحيوية للأوكسجين، مجموع الدقائق الصلبة، مجموع الدقائق الصلبة المذابة، مجموع الأجسام الصلبة المعلقة، والمغذيات (نيترات، نيتريت، الأمونيوم، والفسفور)، اللون، مجموع الأيونات الموجبة و السالبة و المعادن الثقيلة.

اضافة الى تقيم نوعية مياه الأنهارو الجداول بأستخدام بعض الدلائل و الموديلات مثل (دليل التلوث الفلزي و منحنى انخفاض الأوكسجين الذائب). نتائج التحاليل قرنت مع مقايس منظمة الصحة العالمية (WHO) و كذلك المعايير النوعية العراقية (IQS) لمياه الشرب كما وقرنت مع بعض المعايير الدولية لمياه الري.

اظهرت من نتائج التحاليل بأن درجة حرارة المياه تتراوح من (7.7 الى 31.4)درجة سليسية. وأن أقل قيمة لها كانت في شهرشباط فيما سجلت أعلى قيمة لها في شهر آب. أن قيم العكارة تراوحت بين (اقل من 0.01 الى 659) NTU، وأن أقل قيمة لها وجدت في موقع نموذج المياه رقم (W21) لمنطقة قشقولي خارج منفذ السد و كذلك في موقع نموذج المياه رقم (W2) في حوض ماوكان و ذلك خلال شهرين آب و تشرين الثاني على التوالي. فيما اظهرت أعلى قيمة لها في موقع نموذج المياه رقم (W12) في حوض دولي شهيدان وخلال شهرتشرين الثاني. قيمة درجة التفاعل لنماذج المياه تراوحت من (7.45 الى 8.7). وان اقل قيمة لها كانت في موقع رقم (W21) قشقولي خلال شهر تشرين الثاني و أعلى قيمة لها كانت في موقع نموذج رقم (W10) ژاراوه وخلال شهر شباط. أن قيمة

التوصيل الكهربائي تراوحت بين (218 الى 976) مايكروموز سم$^{-1}$ في درجة حرارة الحقل. وأن أقل قيمة لها كانت في موقع نموذج رقم (W15) وداخل سددوكان وذلك خلال شهر مايس و أن أعلى قيمة لها لوحظت في موقع نموذج رقم (W18) في هيزوب وخلال شهر أب، بينما قيمة التوصيل الكهربائي في درجة حرارة المختبر تراوحت بين (220.12 الى 1120.26) مايكروموز سم$^{-1}$. وأن أقل قيمة للتوصيل الكهربائي المختبرى لوحظت في موقع نموذج (W13) في دربند رانية وخلال شهر أب في حين أن أعلى قيمة لها سجلت خلال شهر تشرين الثاني ولموقع نموذج (W14) في بوسكين. أن أقل قيمة وأعلى قيمة لملوحة المياه كانت عند نموذج (W13) في دربندرانية و نموذج (W14) بوسكين على التوالي خلال شهرين آب و تشرين الثاني على التوالي، حين تراوحت بين (140.88 الى 716.97) ملغم لتر$^{-1}$.

أن قيم الأوكسجين الذائب و المتطلبات اوكسجين الحيوية و مجموع الأجسام الصلبة و مجموع الأجسام الذائبة و مجموع الدقائق المعلقة تراوحت بين (4.30 الى 10.35)، (0.13 الى 78.3)، (145 الى 1449)، (126 الى 611) و (1 الى 1228) على التوالي. أن أقل قيمة الأوكسجين الذائب كانت خلال شهر مايس وعند نموذج المياه (W14) في حوض بوسكين، بينما أعلى قيمة له سجلت في شهر شباط وعند موقع نموذج المياه (W9) في حوض صندولان. أن أقل قيمة لمتطلبات الأوكسجين سجلت خلال شهر شباط وعند موقع نموذج المياه (W13) في دربندرانية و فيما كانت أعلى قيمة لها سجلت عند موقع نموذج المياه (W14) في حوض بوسكين وعلى طول فترة اخذ النماذج. أن أقل قيمة لجمبع الدقائق الصلبة كانت خلال شهر مايس و سجلت عند موقع نموذج المياه رقم (W15) لبحيرة دوكان و أن أعلى قيمة لها كانت عند موقع نموذج المياه رقم (W12) في حوض دولى شهيدان و لشهر تشرين الثاني. كما وأظهرت النتائج بأن أقل قيمة لمجموع الدقائق الصلبة ذائبة وحدث عند موقع نموذج المياه (W8) في حوض هلشو وخلال شهر نيسان و أيضا عند موقع نموذج المياه رقم (W13) في دربندرانية و كذلك عند موقع نموذج المياه رقم (W15) داخل بحيرة دوكان وخلال شهر مايس للموقعين الأخيرين، لكن أعلى قيمة كانت عند موقع (W18) في هيزوب وخلال شهر آب، من جهة أخرى أن أقل قيمة لمجموع الأجسام الصلبة المعلقة وجدت عند المواقع (W20) في حوض جلي و (W21) قشقولي و خلال شهرين آب و تشرين الثاني، في حين أن أعلى قيمة لها لوحظت في شهر تشرين الثاني وفي موقع نموذج المياه (W12) في حوض دولى شهيدان.

مستوى العناصر الغذائية الموجودة في المياه من العالي الى الواطىء تراوحت بين (1.1 الى 7.9)، (0.03 الى 5.10)، (0.01 الى 1.16)، (0.01 الى 0.22) ملغم لتر$^{-1}$ للعناصر نيترات، الأمونيوم، الفسفور و نيتريت على التوالي. وأن أقل قيمة لتركيز نيترات لوحظت في شهر تشرين الثاني و في عدد من المواقع، فيما وجدت أعلى قيمة لها عند موقع نموذج (W6) في قشان و في شهر شباط. أن أقل وأعلى قيمة لتركيز الأمونيوم لوحظت في نموذج (W6) لموقع قشان و (W14) لموقع بوسكين على التوالي وخلال شهر تشرين الثاني. من بين المواقع أن أقل تركيز فسفور لوحظت في نموذج (W2) في حوض ماوكان وخلال شهر مايس، فيما أن أعلى قيمة لها وجدت عند موقع نموذج (W14) في بوسكين وخلال شهر شباط و بينما تركيز نيتريت وجدت في أقل قيمة لها في جميع المواقع المأخوذة منها نماذج المياه، حيث أن أعلى قيمة لها كانت عند موقع (W14) في موقع بوسكين وخلال شهر مايس، فيما يخص قيم التصاريف واللون لنماذج المياه المأخوذة تراوحت قيم التصاريف للمياه من (0.01 الى 321) م^{3} ثا$^{-1}$ و للألوان من (0.2 الى 93.2) هزن. حيث سجلت أقل تصريف مياه في موقع نموذج (W18) لموقع هيزوب خلال شهر آب، وأعلى قيمة لها كانت عند موقع (W15) لبحيرة دوكان وذلك خلال شهر آذار. أن أقل و أعلى قيمة للون المياه سجلت عند موقع نموذج (W5) كونه ماسي و موقع (W14) بوسكين على التوالي و خلال شهر آب.

الأيونات السائدة في الانهرو الجداول المدروسة خلال هذه الدراسة أخذة نمط $HCO_3^{-} > SO_4^{2-} > Ca^{2+} > Cl^{-} > Na^{+} > Mg^{2+} > K^{+}$ و مجموع العسرة الكلية تراوحت بين (121.41 الى 377.41) ملغم لتر$^{-1}$. وأقل كمية لعسرة الكلية لها سجلت خلال شهر مايس وفي موقع نموذج (W15) في بحيرة دوكان. بينما أكبر كمية لها كانت عند موقع نموذج (W18) في موقع هيزوب وفي شهر آب. وأن تركيز العناصر الثقيلة في نماذج المياه المأخوذة من القيم الأعلى الى الأقل كانت Cr من (0.211 الى 0.790) ملغم لتر$^{-1}$، Fe من (0.088 الى 0.389) ملغم لتر$^{-1}$، Zn من (0.112 الى 0.223) ملغم لتر$^{-1}$، Cd من (0.074 الى 0.153) ملغم لتر$^{-1}$، Pb من (0.006 الى 0.091) ملغم لتر$^{-1}$، Mn من (0.001 الى 0.067) ملغم لتر$^{-1}$ و Cu من (0.002 الى 0.016) ملغم لتر$^{-1}$. حيث وجدت بأن تراكيز العناصر الثقيلة في نماذج المياه من الأنهار أخذت أعلى تركيز لها عند موقع النموذج (W14) في بوسكين وكانت أكبر من بين بقية المواقع.

لقد أظهرت وبوضوح أن أكبر حمل للملوثات الفيزيوكيميائية والعناصر الثقيلة أتت من موقع النموذج المائي (W2) ماوكان، (W9) صندولان، (W12) دولى شهيدان، (W14) بوسكين، (W17) خدران، (W18) هيزوب،

(W19) سماقولي و (W20) جلي بسبب الانشطة الأنسان مثل الأنشطة الزراعية و التي تمارس في مواقع مختلفة على طول الانهر و قذف الزبالة قرب أو داخل الانهرو رمى المخلفات المنزلية ورشح الملوثات من أماكن جمع النفايات، بالأضافة الى العمليات الطبيعية مثل تجوية الصخور و التعرية المائية للتربة. معدل أمكانية التنقية الزاتية لمواقع المياه المدروسة كان أكبر من واحد، حيث كان (1.173) في آب، (2.037) في تشرين الثاني، (1.011) في شباط، (1.171) في آذار و (3.032) في مايس و التي كانت أكبر منها لشهر نيسان (0.297). والسبب لوجود هذه القيم ماعدا قيم شهر نيسان يمكن أن يكون نتيجة قلة أنخفاض لأوكسجين الذائب، لكن في شهر نيسان يبدو أن يكون التلوث أكثر حدوثا مما يؤي الى أنخفاض شديد لأوكسجين الذائب وبالتحديد عند موقع نموذج الماء (W14) في بوسكين وكذلك (W12) في دولي شهيدان وذلك بسبب أنشطة الأنسان.

في جميع المواقع المدروسة، أن معايير نوعية مياه الري من القيم العالية الى المنخفضة كانت (220.12 الى 1120.26) مايكروموز سم $^{-1}$ للملوحة، ومن (3.04 الى 35.48)٪ لنسبة الصوديوم الذائب، ومن (0.08 الى 2.09) مليمكافيء لتر $^{-1}$ لنسبة الصوديوم المدمص و (-2.015 الى 0.182) مليمكافيء لتر $^{-1}$ لكاربونات الصوديوم المتبقية. وبالأعتماد على المعاير المحسوبة لنوعية مياه الري فأن مياه الأنهر و الجداول المدروسة كانت ملائمة للري مقارنة بالمعايير الدولية لنوعية المياه. أن EC للنماذج المجمعة وقعت ضمن المستوى الواطىء الى العالي، أن SAR كانت ممتاز، SSP كان بين جيد الى ممتاز و RSC كان مناسب حسب نوعية مياه الري.

أظهرت من نتائج التحليل لنماذج التربة بأن قيمة درجة تفاعل التربة تراوحة من (7.29 الى 8.09). أن أقل قيمة درجة تفاعل له وجد في حقل زراعي وفي نمذج تربة رقم (S22)، فيما سجل أعلى قيمة له عند نموذج تربة رقم (S13). ان قيم كل من التوصيل الكهربائي، مجموع الدقائق الصلبة المذابة، الكثافة الظاهرية، المادة العضوية و التوصيل الهدروليكى لنماذج التربة تراوحت من (309.56 الى 1305.97) مايكروموز سم $^{-1}$، (198.56 الى 835.82) ملغم لتر $^{-1}$، (1.33 الى 1.52) غم سم $^{-3}$، (0.06 الى 2.98)٪ و (2.52E-06 الى 6.12E-04) سم ثا $^{-1}$ على التوالي. أن التوصيل الكهربائي و مجموع الدقائق الصلبة المذابة أخذت نفس النمط في جميع مواقع حيث أن أقل قيمة لها كانتا في موقع نموذج تربة رقم (S11) و بينما أعلى قيمة لها كانتا عند نموذج تربة رقم (S7)، أقل قيمة للكثافة الظاهرية كانت في حقل زراعي وفي نموذج تربة رقم (S28) و أعلى قيمة لها ظهرت في حقل مراعي الطبيعية وفي نموذج تربة رقم (S34)، وأقل قيمة للمادة العضوية في التربة

وجدت في حقل محاصيل وفي تنوذج (S21)، بينما أعلى قيمة لها سجلت في مراعي طبيعي وفي نموذج (S31). أن أقل قيمة لتوصيل الهيدروليكى ظهرت في نموذج تربة رقم (S21)، وأعلى قيمة له كانت في نموذج تربة رقم (S34).

أظهرت نتائج التحليل الميكانيكى لنماذج التربة بأن صنف النسجة التربة كانت طينية، طينية مزيجية، غرينية طينية مزيجية، مزيجية، غرينية، غرينية مزيجية و رملية مزيجية لمنطقة الدراسة. أن ترتيب الأيونات السائدة في نماذج التربة المأخوذة من منطقة الدراسة كانت $HCO_3^- > Ca^{2+} > SO_4^{2-} > Cl^- > Na^+ > Mg^{2+} > K^+$، بينما قيم مستوى العناصر من الأعلى الى الأقل كانت (0.28 الى 21)، (0.4 الى 5.4)، (0.15 الى 3.59) و (0.03 الى 0.28) لكل من النترات، الفسفور، الأمونيوم و النتريت وعلى التوالي. حيث أن أعلى قيمة لنترات و النتريت سجلت في نموذج تربة (S24). بينما تراكيز كل من الأمونيوم و الفسفور كانت في أعلى قيم لها عند نموذج تربة رقم (S29).

أن تراكيز العناصر الثقيلة في التربة من الأكثر الى الأقل Fe (24.50 الى 1225.50) ملغم كغم$^{-1}$، Mn (16.25 الى 672.50) ملغم كغم$^{-1}$، Zn (2 الى 22) ملغم كغم$^{-1}$، Cu (0.5 الى 10.25) ملغم كغم$^{-1}$، Cr (0.25 الى 6.50) ملغم كغم$^{-1}$، Pb (0.11 الى 1.66) ملغم كغم$^{-1}$ و Cd (0.02 الى 0.75) ملغم كغم$^{-1}$. حيث أن أقل قيمة للحديد لوحظت في نموذج (S34)، وأعلى قيمة له سجلت في نموذج (S32). وبالنسبة لمنغنيز فأن أقل قيمة له كانت في نموذج (S9) و أعلى قيمة له كانت في (S32). أن نموذج (S25) أعطت أقل قيمة لتركيز الخارصين لكن نموذج (S11) أعطت أعلى قيمة له. وأن أقل قيمة لتركيز النحاس كانت في نموذج (S9)، لكن أعلى قيمة له كانت في نموذج (S7). وان أقل قيمة لكروم كانت في نموذج (S2)، أما أعلى قيمة له كانت في نموذج (S32). و ان النموذج رقم (S26) اعطت اقل قيمة لرصاص بينما أعلى قيمة له كانت في (S4)، وبالنسبة لتركيز كادميوم فأن أعلى قيمة له كانت في نموذج (S33) وأقل قيمة له كانت في (S6).

قيم تعرية التربة (طن/هكتار/سنة) لكل الأحواض المدروسة من القيم العالية الى الواطئة كانت، ژاراوه > كونەماسی > شاور > كه وی > هەلشو > دولی شەهیدان > سیویل > قەرەنی ئاغا > توه سوران > ماوەكان > خدران > جەلی > جو گه سور > بوسكين > سماقولی > دولەبەفره. حيث أن أعلى قيمة للتعرية كانت (46.843 طن/هكتار/سنة) في حوض ژاراوه وأقل قيمة لها كانت في دوله به فره (19.976 طن/هكتار/سنة).

وأظهرت النتائج بأن كل من الأحواض زاراوه، كونه ماسى و شاور اعطت قيم علية للتعرية من بين بقية الأحواض المدروسة. من جهة أخرى أن أعلى قيم لنتائج الرسوبات المتنبؤي بأستخدام طريقة Bali, 1972 لوحظت في حوض دولى شهيدان حيث كانت (17.196 طن/هكتار/سنة) و فيما كانت أقل قيمة لها لوحظت في حوض دوله به فره والتي كانت (6.449 طن/هكتار/سنة)، لكن بستخدام طريقة FSM فأن أعلى قيمة لنتائج الرسوبيات أظهرت عند حوض بوسكين وكانت (7.037 طن/هكتار/سنة)، فيما كانت أقل قيمة لها وجدت في حوض سيويل وكانت (0.803 طن/هكتار/سنة). كما ولوحظت من نتائج الدراسة هذه بأن أعلى قيمة لكمية الرسوبيات الواصلة (SDR) كانت (0.411) و عند الحوض النهري بوسكين وأن أقل قيمة لها كانت (0.118) حيث لوحظت في حوض سيويل.

حكومة أقليم كوردستان

وزارةالتعليم العالى و البحث العلمي

جامعة السليمانية

كلية هندسة العلوم الزراعية

تأثيرالعمليات الطبيعية وانشطة الأنسان على نوعية مياه منطقة تغذية خزان دوكان/ اقليم كوردستان العراق

رسالة

مقدمة الى مجلس كلية هندسة العلوم الزراعية/جامعة السليمانية كجزء من متطلبات نيل شهادة دكتوراه فلسفة في العلوم الزراعية

نوعية المياه

من قبل

على باوه شێخ احمد بابه

بكالوريوس في العلوم الزراعية/ علوم التربة/ جامعة السليمانية(2004)

ماجستير في العلوم الزراعية/ كيمياء المياه/ جامعة الصلاح الدين(2010)

بإشراف

د. خالد طيب محمد البرزنجي

الأستاذ المساعد

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کورتە

ئەم توێژینەوەیە لەئاوزێڵەکانی سەربەبەنداوی دوکان بەمەبەستی لێکۆڵینەوە لەکاریگەری کردارە سروشتیەکان و چالاکی کاری مرۆڤ لەسەر سیفەتە فیزیۆکیمیاییەکان و جۆرێتی ئاوی ڕووباروجۆگەکانی ئاودەر بە بەنداوی دوکان ئەنجام درا. بیست ویەك شوێن دیاری کرا بەدرێژایی ڕوباری سەرەکی (قەلاچوالان-زێی بچوك)، ڕوباری هیزۆپ، ناوبەنداوی دوکان، دەرەوەی دەرچەی بەنداوەکە، هەروەها لەسەرلقەڕووبارەکانی ترلەدەشتی ڕانیە کە ئاودەدات بەدەریاچەی دوکان وە وەرگرتنی سی و چوار نموونەی خاك لەسەرانسەری ناوچەی توێژینەوەکە.

نموونەکانی ئاو کۆکرانەوە لەماوەی مانگەکانی (ئاب، تشرینی دووەم، شوبات، مارت، نیسان و مایس)، بە پشت بەستن بەگۆڕانکاری لەبڕی ڕێکردی ئاوی ڕووبارەکان لەناوچەکانی توێژینەوەکە لەماوەی نێوان (مانگی ئابی 2016 تاکو مانگی مایسی 2017). دواتر نموونەکانی ئاو شیکاری تاقیگەییان بۆئەنجام درا. شیکاری ئەنجام درا بۆنموونە وەرگیراوەکانی ئاو لەڕووی پلەی گەرمی، لێڵێتی، خەستی ئایۆنی هایدرۆجین، گەیاندنی کارەبایی، ئۆکسجینی تواوە، پێویستی ئۆکسجینی بایۆکیمیاوی، کۆی تەنۆلکەڕەقەکان، کۆی تەنۆلکە تواوەکان، کۆی تەنۆلکە هەڵواسراوەکان و توخمە خۆراکیەکانی وەك (نیترات، نتریت، ئەمۆنیۆم و فسفۆڕ). هەروەها دیاری کردنی ڕەنگی ئاو و کۆی ئایۆنە موجەب و سالبەکان و توخمە قورسەکان. جگەلەوەش جۆرێتی ئاوی ڕووباروجۆگەکان هەڵسەنگاندنی بۆئەنجام درا بەبەکارهێنانی هەندێ ڕێبەرو مۆدێلی وە ك (ڕێبەری پیس بوونی کانزایی و چەماوەی شۆڕبونەوەی ئۆکسجینی تواوە). ئەنجامی شیکاری تاقیگەیی نموونەکان بەراووردکرا بە پێوەری ڕێکخراوی تەندرووستی جیهانی (WHO) وە پێوەرەکانی جۆرێتی عێراقی (IQS) بۆئاوی خواردنەوە. هەروەها بەراوردکرا لەگەڵ پێوەرە نێودەوڵەتیەکان بۆئاوی ئاودێری.

لەئەنجامی شیکاریەکانەوە دەرکەوت کەپلەی گەرمی ئاوەکان لەنێوان (7.7 بۆ 31.4) پلەی سیلیسی دایە، کەکەمترین بڕی پلەی گەرمی لەمانگی شوبات وە زۆرترین پلەی گەرمی لەمانگی ئاب دا دەرکەوت. لێڵێتی نموونەکانی ئاو لەنێوان (کەمترلە 0.01 بۆ 659) NTU دابوو بەجۆرێك کەکەمترین بەهای لێڵێتی لەشوێنی نموونەی ژمارە (W21) دابوو لەناوچەی قەشقوڵی لەدەرەوەی دەرچەی بەنداوەکە وە هەروەها لەنموونەی (W2)

لەئاوزێڵی ماوەکان لەمانگی ئاب و تشرینی دووەم بەدوای یەکدا، لەکاتێکدا کەگەورەترین بەهای لێڵێتی لەنموونەی ئاوی (W12) دا دەرکەوت لەئاوزێڵی دۆڵی شەهیدان لەمانگی تشرینی دووەم دا. بەهای خەستی ئایونی هادروجین لەنێوان (7.45 بۆ 8.70) دابوو کەکەمترین بەهای لەنموونەی (W21) ناوچەی قەشقوڵی دا دەرکەوت وە بۆ مانگی تشرینی دووەم، لەکاتێکدا کەزۆرترین بەهاکەی لەنموونەی (W10) دا دەرکەوت لە ئاوزێڵی ژاراوە لەمانگی شوبات دا. بەهای گەیاندنی کارەبایی نموونە ئاویەکان لەنێوان (218 بۆ 976) میکروموز سم $^{-1}$ دابوو لەپلەی گەرمی کێڵگەدا. بەجۆرێك کەکەمترین بەهاکەی لەنموونەی (W15) دا دەرکەوت لەناو دەریاچەکە لەمانگی مایس دا وە زۆرترین بەهاکەیشی لەنموونەی (W18) دا تێبینی کرا لەناوچەی هیزوپ لەمانگی ئاب دا، ئەمەلەکاتێکدا بەهای کارەبا گەیاندنی ئاوەکان لەپلەی گەرمی تاقیگەدا لەنێوان (220.12 بۆ 1120.26) میکروموز سم $^{-1}$ بوو. کەکەمترین بەهای لەنموونەی (W13) لەدەربەندی ڕانیە دەرکەوت لەمانگی ئاب دا وە لەکاتێکدا کەزۆرترین بەهاکەی لەنموونەی (W14) لەئاوزێڵی بۆسکێن دا بینرا لەمانگی تشرینی دووەم دا. کەمترین و زۆرترین بەهای خوێ ی ئاو لە نموونەی (W13) لەدەربەندی ڕانیە و لە نموونەی (W14) لە بۆسکێن دادەرکەوت وە لەهەردوومانگی ئاب و تشرینی دووەم دا بەدوای یەکدا. بەجۆرێك کەنرخەکەی لەنێوان (140.88 بۆ 716.97) ملغم لتر $^{-1}$ دابوو.

بەهای ئوکسجینی تواوە، پێویستی□ئۆکسجین، کۆی تەنۆلکە ڕەقەکان، تەنۆلکە تواوەکان و تەنۆلکە هەڵواسراوەکان لەنێوان (30□4 بۆ 35□10)، (13□0 بۆ 3□78)، (145 بۆ 1449)، (126 بو 611) و (1 بۆ 1228) ملغم لتر $^{-1}$ دابوو بەدوای یەکدا. کەمترین بەهای ئوکسجین تواوە لەمانگی مایس دابوو لەنموونەی ئاوی (W14) لەئاوزێڵی بۆسکین، لەکاتێکدا کەبەرزترین بەهاکەی لەمانگی شوبات دا لەنموونەی ئاوی (W9) لەناوچەی سندۆڵان. وەکەمترین بەهای پێویستی□ئۆکسجین لەمانگی شوبات دا تۆمارکرا لە نموونەی ئاوی (W13) لەدەربەندی ڕانیە وە بەرزترین بەهای پێویستی□ئۆکسجین لەنموونەی ئاوی (W14) دادەرکەوت لەهەمووکاتەکانی وەرگرتنی نموونەکاندا. کەمترین بەهای کۆی تەنۆلکە ڕەقەکان لە نموونەی ئاوی (W15) دادەرکەوت لە ناودەریاچەکەدا لە مانگی مایس دا وە لەکاتێکدا کەزۆرترین بەهاکەی لەنموونەی ئاوی (W12) دادەرکەوت لەمانگی تشرینی دووەم لەئاوزێڵی دۆڵی شەهیدان. هەروەها لەئەنجامەکانەوە دەرکەوتوە کە کەمترین

بەهای تەنۆلکە تواوەکان لە نموونەی ئاوی (W8) دا بەدی کرا لەئاوزێڵی هەڵشۆ لەمانگی نیسان دا وە هەروەها هەمان کەمترین بەهاکەی لەنموونەی (W13) و (W15) دا دەرکەوت لەدەربەندی ڕانیە و ئاوی ناودەریاچەکەدا بەدوای یەکدا لەماوەی مانگی مایس دا، بەڵام بەرزترین بەهای تەنۆلکە تواوەکان لە نموونەی ئاوی (W18) دادەرکەوت لەناوچەی هیزوپ لە مانگی ئاب دا وە لەلایەکی ترەوە کەمترین بەهای تەنۆلکە هەڵواسراوەکان لەنموونەکانی ئاوی (W20) لەئاوزێڵی جەلی و (W21) لەناوچەی قەشقوڵی بۆهەردوو مانگی ئاب و تشرینی دووەم، وەبەرزترین بەهای تەنۆلکە هەڵواسراوەکان لەنموونەی ئاوی (W12) دا بینرا لە مانگی تشرینی دووەم لەئاوزێڵی دۆڵی شەهیدان.

بەهای ئاستی توخمە خۆراکیەکان لەئاودا لەبەرزترین بەهاکەی بۆ نزمترین لەنێوان (1.1 بۆ 7.9)، (0.03 بۆ 5.10)، (0.01 بۆ 1.16) و (0.01 بۆ 0.22) ملغم لتر$^{-1}$ بۆتوخمەکانی نیترات، ئەمۆنیوم، فسفۆڕ و نیتریت بەدوای یەکدا. لەکاتێکدا کەکەمترین بەهای پەیتی نیترات لەمانگی تشرینی دووەم دابەدی کرا لەزۆرێك لەشوێنەکانی توێژینەوەکەدا وە زۆرترین بەهاکەی لەنموونەی ئاوی (W6) لە ڕووباری قەشان لەمانگی شوبات دا بەدی کرا. هەروەها کەمترین و زۆرترین پەیتی ئەمۆنیوم لەهەریەك لەنموونەکانی (W6 و W14) دابەدی کرا لەمانگی تشرینی دووەم لەهەریەك لەڕووباری قەشان و ئاوزێڵی بۆسکێن بەدوای یەکدا. لەنێوان هەموو شوێنەکاندا کەمترین پەیتی فسفۆڕ لەنموونەی ئاوی (W2) لە ئاوزێڵی ماوەکان بەدی کرا وە لەماوەی مانگی مایس دا، بەڵام زۆرترین بەهاکەی لەنموونەی (W14) دا بینرا بۆئاوزێڵی بۆسکێن لە مانگی شوبات دا وە کەمترین پەیتی نیتریت لەنموونەی ئاوی هەموو شوێنەکاندا بەدی کرا وە زۆرترین پەیتیەکەی لەنموونەی ئاوی (W14) دا دەرکەوت لەئاوزێڵی بۆسکێن وەلە مانگی مایس دا.

سەبارەت بەبەهای ڕێکردنی ڕوبارەکان و ڕەنگی ئاوی نموونە وەرگیراوەکان، دەرکەوت کەبەهای ڕێکردنی ئاوەکان لەنێوان (0.01 بۆ321)م^{3} چرکە$^{-1}$ دایە. وەکەمترین بەهای ڕێکردنی ئاو لەشوێنی نموونەی ئاوی (W18) لە هیزۆپ دا دەرکەوت لەمانگی ئاب دا، بەڵام زۆرترین بەهای ڕێکردنی ئاو لەشوێنی نموونەی ئاوی (W15) دادەرکەوت لەکاتی چونە ناوەوەی ڕوبارەکان بۆدەریاچەکە وەلەمانگی ئازاردا. وەلەڕوی ڕەنگی ئاوی

نموونەکانەوە کەلەنیوان (0.2 بۆ 93.2) یەکەی هەزن بوون، دەرکەوت کەکەمترین و زۆرترین بەهای ڕەنگی ئاوەکان لەنموونەی ئاوی (W5) لەکونەماسی و (W14) لە بۆسکێن دا تۆمارکران بەدوای یەکدا لەمانگی ئاب دا.

ئایۆنەزاڵەکانی ناو ئاوی ڕووباروجۆگەکان لەم لێکۆلینەوەیەدا ئەم ڕیزبەندیەی وەرگرت $HCO_3^- > SO_4^{2-} > Cl^- > Na^+ > Mg^{2+} > K^+$ وە ناسازی گشتی ئاوەکان لەنێوان (121.41 بۆ 377.14) ملغم لتر $^{-1}$ دا بوو.

کەمترین بەهاکەی لەنموونەی ئاوی (W15) دادەرکەوت لەمانگی مایس لە ناودەریاچەکەدا، لەکاتێکدا کەزۆرترین بەهاکەی لەنموونەی ئاوی (W18) دادەرکەوت لەناوچەی هیزۆپ لە مانگی ئاب دا. لەلایەکی ترەوە پەیتی کانزا قورسەکان لەنموونەی وەرگیراوەکانی ئاودا لەبەهای زۆرەوە بۆکەم بەم جۆرەبوو Cr (0.211 بۆ 0.790)، Fe (0.088 بۆ 0.389)، Zn (0.112 بۆ 0.223)، Cd (0.074 بۆ 0.153)، Pb (0.006 بۆ 0.090)، Mn (0.001 بۆ 0.067) و Cu (0.002 بۆ 0.016) ملغم لتر $^{-1}$، بەجۆرێك کەزۆرترین بەهای پەیتی کانزا قورسەکان لەنموونەی ئاوی (W14) ی بۆسکێن دادەرکەوت کەزۆرترین بەهای هەبوو لەچاوسەرجەم شوێنەکانی تردا.

لەئەنجامەکانی توێژینەوەکەوە دەرکەوت کەزۆرترین باری ئاوی ڕوبارەکان لەمادەپیسکەرەکانی وەك مادەی فیزیوکیمیاوی و کانزاقورسەکان لەشوێنی نموونەی ئاوی (W2) ی ماوەکان، (W17) ی خدران، (W18) ی هیزۆپ، (W19) ی سماقولی و (W20) ی جەلی یەوە هاتوون، ئەمەش بەهۆی زۆری چالاکی مرۆڤ و کشتوکاڵ کردنەوە کەبە درێژای دەوروبەری ڕوبارەکان ئەنجام ئەدرێت، فڕێدانی خۆڵ و خاشاك و پاشماوە خزمەتگوزاریەکان لەنزیك یان بۆناو ڕوبارەکان. جگەلەوەش کرداره سروشتیەکانی وەك بەکەش بوونی بەردەکان و ڕامالینی خاك بە ئاوی باران هەموو هۆکارن بۆپیس بوونی ئاوەکانی ناوچەکە.

لەم توێژینەوەیەدا بۆمان دەرکەوت کەتێکڕای توانستی خۆپاککردنەوەی ئاو لەناوچەی توێژینەوەکەدا گەورەترە لەیەك بەجۆرێك کە (1.173) بوو بۆ مانگی ئاب، (2.037) لە مانگی تشرینی دووەم، (1.011) لە مانگی شوبات، (1.171) لەمانگی ئازار و (3.032) لەمانگی مایس دا، لەکاتێکدا کەمترین بەهاکەی کە (0.297) بوو لە مانگی نیسان دا دەرکەوت. وەهۆکاری بوونی ئەم نرخانە جگە لەمانگی نیسان ئەتوانرێت لێکبدرێتەوە بۆ کەمی دابەزینی ئوکسجینی تواوە بەلاّم لەمانگی نیسان دا دیارەکە پیسبوون زیاتر ڕووئەدات کەئەمەش ئەبێتە

هۆی دابەزینێکی زۆری ئۆکسجینی تواوە وە بەتایبەتی لەشوینی وەرگرتنی نموونەی ئاوی (W14) ی بۆسکێن و (W12) ی دۆلی شەهیدان کە لەودووشوێنەدا چالاکی مرۆڤ زیاترە. لەسەرجەم شوێنەکانی توێژینەوەکەدا پێوەرەکانی جۆرێتی ئاوی ئاودێری لە بەهای زۆرەوە بۆکەم بەم شێوەیە بوو، بە پێ ی بوونی خوێ (سوێرێتی) (220.12 بۆ 1120.26) مایکروموز سم $^{-1}$، بەپێ ی ڕێژەی صۆدیۆمی تواوە (3.04 بۆ 35.48)٪، بەپێ ی ڕێژەی صۆدیۆمی پێوەلکاو (0.08 بۆ 2.09) ملیمکافئ لتر $^{-1}$ وە بەپێ ی کاربۆناتی صۆدیۆمی ماوە (2.015- بۆ 0.182) ملیمکافئ لتر $^{-1}$. وەپالێشت بەپێوەرە ئەژمارکراوەکان بۆجۆریەتی ئاوی ئاودێری دەرکەوت کەئاوی ڕووبار و جۆگەکانی سەربەتوێژینەوەکە گونجاون بۆ ئاودێری بەراورد بەپێوەرە نێودەولەتیەکانی جۆرێتی ئاو.

بەهای EC بۆ نموونە کۆکراوەکان لەنێوان (نزم بۆ بەرز) بوون، SAR ی نموونەکانی ئاو (نایاب) بوو، SSP لەنێوان (باش بۆ نایاب) بوو وە RSC (گونجاوو) بوو بەپێ ی جۆرێتی ئاوی ئاودێری.

ئەنجامی شیکاری نموونەکانی خاك دەریان خست کەبەهای (pH) ی خاك لەنێوان (7.29 بۆ 8.09) دابوو. کەمترین بەهای pH لە کێلگەی کشتوکاڵی بوو لە نموونەی (S22)، وە زۆرترین بەهاکەی لەنموونەی (S31) داتۆمارکرا. بەهای هەریەکە لە EC_e، TDS، چڕی ڕوکەشی، مادەی ئورگانی و ئاوگەیاندنی نموونەکانی خاك لە نێوان (309.56 بۆ 1309.97) مایکروموز سم $^{-1}$، (198.56 بۆ 835.82) ملغم لتر $^{-1}$، (1.33 بۆ 1.52) غم سم $^{-3}$، (0.06 بۆ 2.98)٪ و (2.52E-06 بۆ 6.12E-04) سم چرکە $^{-1}$ دابوو بەدوای یەکدا. EC_e و TDS ی نموونەکانی خاك هەمان شێوازیان هەبوو لەهەموو نموونەکاندا، بە جۆرێك کەکەمترین بەهاکەیان لەنموومەی خاك ژمارە (S11) دا دەرکەوت وە بەرزترین بەهاکەیان لەنموونەی (S7) دابوو، کەمترین بەهای چڕی ڕووکەشی خاك لە کێلگەی کشتوکاڵی دا بەدی کرا لەنموونەی (S28) وە بەرزترین بەهاکەی لەخاکی لەوەڕگادا دەرکەوت لەنموونەی (S34)، کەمترین بەهای مادەی ئورگانی لە خاك دا SOM لەکێلگە ی کشتوکاڵی دابوو لەنموونەی (S21) دا، وەبەرزترین بەهاکەیشی لەخاکی لەوەڕگای سروشتی دادەرکەوت لەنموونەی خاکی (S31) دا. هەروەها بەهای ئاوگەیاندنی خاك کەمترین بەهاکەی لە نموونەی (S21) دا، و زۆرترین بەهاکەیشی لەنموونەی خاکی ژمارە (S34) دا دەرکەوت.

شیکاری میکانیکی نموونەکانی خاك دەریخست کەجۆری شانەی خاك بۆ نموونە وەرگیراوەکانی خاك بەم جۆرەبوو، (خاك، خاکی تێکەڵ، قومی خاکی تێکەڵ، تێکەڵەیی، قومی تێکەڵەیی وە لمی تێکەڵەیی) بۆ سەرجەم ناوچەکانی توێژینەوەکە. ڕیزبەندی ئایونە زاڵەکان لەنموونەکانی خاك دا بۆناوچەی توێژینەوەکە بەم ڕیزبەندیەبوو، $HCO_3^- > Ca^{2+} > SO_4^{2-} > Cl^- > Na^+ > Mg^{2+} > K^+$، لەکاتێکدا کەبەهای ئاستی توخمەکان لەزۆرەوە بۆکەم بریتی بوولە، (0.28 بۆ 21)، (0.4 بۆ 5.4)، (0.15 بۆ 3.59) و (0.03 بۆ 0.28) بۆ هەریەکە لەتوخمەکانی نیترات، فسفۆر، ئەمونیوم و نتریت بەدوای یەکدا. بەجۆرێك کەزۆرترین بەهای نیترات و نتریت لەنموونەی خاکی (S24) دا تۆمارکرا. لەکاتێکدا کەپەیتی هەریەك لە ئەمونیوم و فسفۆر بەرزترین بەهاکەیان لەنموونەی خاکی ژمارە (S29) دابوو.

پەیتی کانزا دەگمەنەکان لەخاکدا لەزۆرەوە بۆکەم بەم جۆرە بوو، Fe (24.50 بۆ 1225.50) ملغم کغم$^{-1}$، Mn (16.25 بۆ 672.50) ملغم کغم$^{-1}$، Zn (2 بۆ 22) ملغم کغم$^{-1}$، Cu (00.5 بۆ 10.25) ملغم کغم$^{-1}$، Cr (0.25 بۆ 6.50) ملغم کغم$^{-1}$، Pb (0.11 بۆ 1.66) ملغم کغم$^{-1}$ و Cd (0.02 بۆ 0.75) ملغم کغم$^{-1}$. بەجۆرێك کەکەمترین بەهای Fe لە نموونەی خاکی (S34) دا دەرکەوت، و بەرزترین بەهاکەیشی لەنموونەی خاکی (S32) دا بەدی کرا. سەبارەت بە Mn کەمترین بەهاکەی لەنموونەی خاکی (S9) دابوو وە زۆرترین بەهاکەی لە (S32) دابوو. نموونەی خاکی (S25) کەمترین بەهای Zn ی تێدابوو، بەڵام نموونەی خاکی (S11) زۆرترین بەهای Zn ی تێدابوو. لەکاتێکدا کەکەمترین بەهای Cu لەنموونەی (S9) دابوو، وەبەرزترین بەهاکەشی لەنموونەی (S7) دابوو. جگەلەوەش کەمترین بەهای Cr لە نموونەی (S2) دادەرکەوت وەبەرزترین بەهاکەی لەنموونەی (S32) دادەرکەوت. هەروەها نموونەی ژمارە (S26) کەمترین بەهای Pb ی دیاری کرد، لەکاتێکدا کە نموونەی (S4) زۆرترین بەهاکەی تێدابوو. هەرچی پەیتی Cd ئەوا زۆرترین بەهاکەی لەنموونەی (S33) دا و ە کەمترینیشی لە (S6) دا تۆمارکرا.

بەهای ڕاماڵینی خاك بە (تەن/هیکتار/ساڵ) بۆ ئاوزێڵەکانی ناوتوێژینەوەکە لەزۆرەوە بۆکەم ئەم ڕیزبەندی یەی وەرگرت، ژاراوە > کونەماسی > شاور > کەویە >هەڵشۆ > دۆڵی شەهیدان > سیوەیل > قەرەنیاغا > تومەسوران > ماوەکان > خدران > جەلی > جۆگەسور > بۆسکێن > سماقولی > دۆڵەبەفرە. بەجۆرێك کەبەرزترین بەهای

ڕامالێن له ئاوزێلی ژاراوەدا بەدی کرا کە بڕەکەی (46.843) تەن/هیکتار/ساڵ بوو وە کەمترین بەهای ڕامالێنیش له ئاوزێلی دۆڵەبەفرە تومارکرا کەبڕکەی (19.976) تەن/هیکتار/ساڵ بوو. هەروەها ئەنجامەکان دەریان خست کە هەریەکە لەئاوزێڵەکانی ژاراوە و کونەماسی و شاور زۆرترین بەهای ڕامالێنیان هەبوو لەنێوان سەرجەم ئاوزێڵە کانی تری توێژینەوەکەدا. لەلایەکی ترەوە بەرزترین بەهای پێشبینیکراوی مادە نیشتووەکان بەبەکارهێنانی ڕێگای (Bali, 1972) له ئاوزێڵی دۆڵی شەهیدان دا بەدی کررا کەبڕەکەی (17.196) تەن/هیکتار/ساڵ بوو لەکاتێکدا کەکەمترین بەهاکەی لەئاوزێڵی دۆڵەبەفرە دا بەدی کرا کە (6.449) تەن/هیکتار/ساڵ بووە، بەلاّم بەبەکارهێنانی ڕێگای FSM دەرکەوت کە ئاوزێڵی بۆسکێن زۆرترین بەهای بەرهەمی مادە نیشتووەکان هەبوو کەبڕەکەی (7.037) تەن/هێکتار/ساڵ بوو، بەلاّم کەمترین بەهاکەی لەئاوزێڵی سیوەیل دا بەدی کرا کەبەهاکەی (0.803) تەن/هیکتار/ساڵ بوو. هەروەها لەئەنجامەکانی توێژینەوەکەوە دەرکەوت کە زۆرترین بڕی نیشتووە گەیشتوەکان SDR (0.411) بوو له ئاوزێڵی بۆسکێن، و کەمترین بەهاکەی کە (0.118) بوو له ئاوزێڵی سیوەیل.

حکومەتی هەرێمی کوردستان

وە زارەتی خوێندنی باڵاو توێژینەوەی زانستی

زانکۆی سلێمانی

کۆلێجی زانستە ئەندازیارییە کشتوکاڵیەکان

کاریگەری کردارە سروشتیەکان و چالاکی مرۆڤ لەسەرجۆرێتی ئاوی ناوچەی ئاوپێدەری بەنداوی دوکان/ هەرێمی کوردستان عێراق

نامەیەکە

پێشکەشە بە ئەنجومەنی کۆلێژی زانستە ئەندازیارییە کشتوکاڵیەکان/ زانکۆی سلێمانی وەك بەشێك لە پێداویستیەکانی بەدەستهێنانی بڕوانامەی دکتۆرای فەلسەفە لەزانستە کشتوکاڵیەکان

جۆرێتی ئاو

لە لایەن

علی باوەشێخ أحمد بابە

بەکالۆریۆس لەزانستە کشتوکاڵیەکاندا/ زانستی خاك/ زانکۆی سلێمانی (2004)

ماستەر لەزانستە کشتوکاڵیەکاندا/ کیمیای ئاو/ زانکۆی صەلاحەدین (2010)

بەسەرپەرشتی

د. خالد طیب محمد بەرزنجی

پرۆفیسۆری یاریدەدەر

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