**Ministry of Higher Education**
**and Scientific Research**
**University of Baghdad**
**College of Science**
**Department of Geology**

# Hydrogeochemistry of the Sawa Lake, Southern Iraq

**A thesis**
**Submitted to the College of Science -University of Baghdad in Partial Fulfillment of the Requirements for the Degree of Master of Science in Geology**
**(Geochemistry)**

**By**

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

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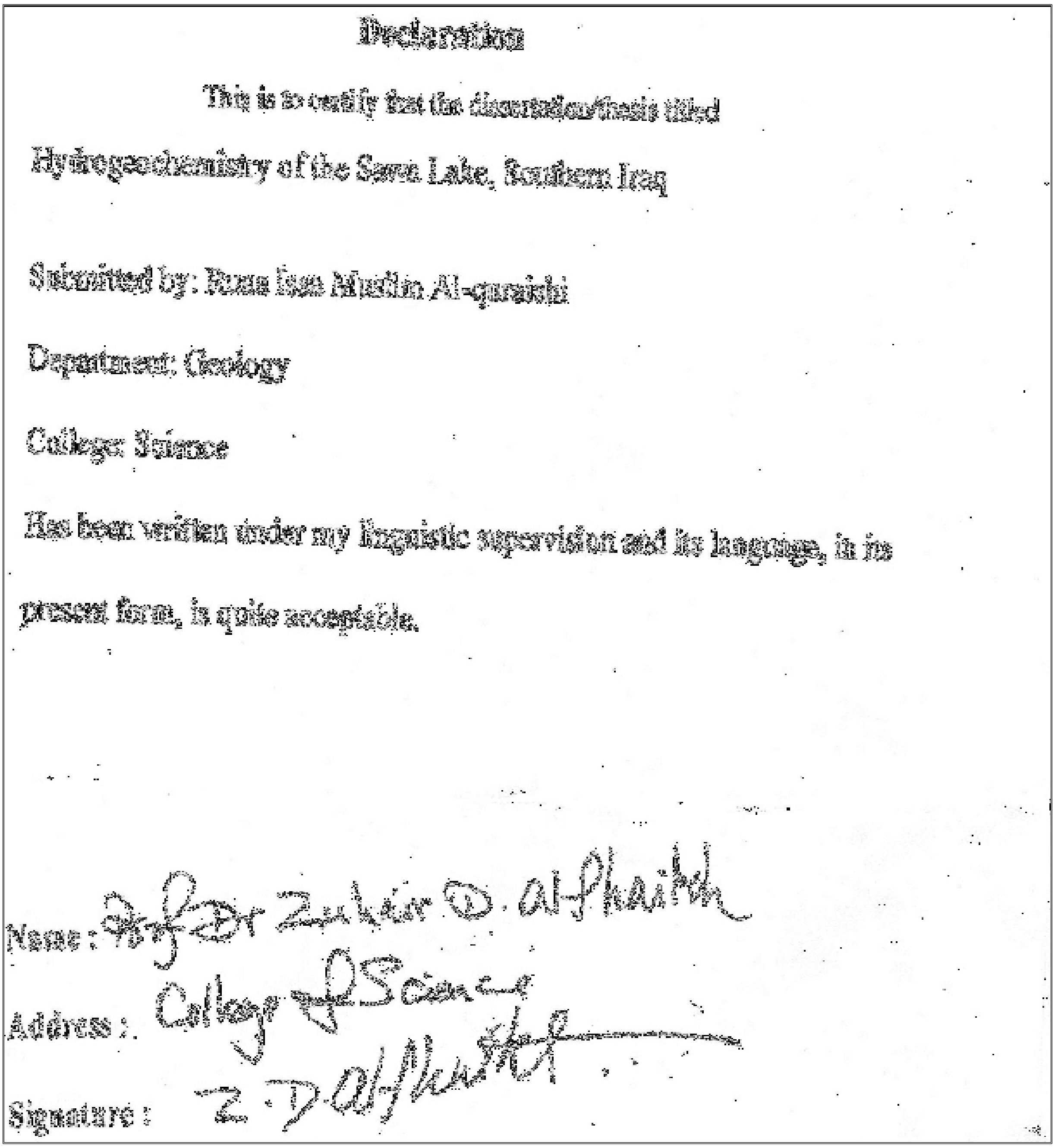

# Declaration

This is to certify that the dissertation/thesis titled

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Has been written under my linguistic supervision and its language, in its present form, is quite acceptable.

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# DEDICATION

*I would like to dedicate this work to:*
*Supervisor Dr. Salih Muhammad Awadh*
*Father…… Mother*
*My brothers (Hussian, Ali, Saif)*
*My Sister(Rana)*
*My husband (Jawad) …..Daughter (Fatima)*
*All those who love me*
*With my love and respect*

*Ruaa*

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*Ruaa Issa Muslim Al-quraishi*

## Abstract

Hydrochemistry of the Sawa Lake water and geochemistry of its sediments are studied. Twenty three water samples were collected from the lake during both dry (7/10/2011) and wet periods (22/3/2012), as well as three groundwater samples that are collected from wells adjacent to the lake in the wet period. Nineteen samples are collected from the lake sediments during the dry period of the year 2011.

Water samples are analyzed for physico-chemical parameters which included turbidity, color, taste, odor, total suspended solid (TSS), hydrogen number (pH), total dissolved solid (TDS), electrical conductivity (EC), and temperature (T), major cations ($K^+$, $Na^+$, $Mg^{2+}$, $Ca^{2+}$), major anions ($Cl^-$, $SO_4^=$, $HCO_3^-$, $CO_3^=$), minor anions ($PO_4^{3-}$ and $NO_3^-$), trace elements (Pb, Cd, Ni, Fe, Mn, Co, As, Cu, B and Sr), radiation measurements ($^{226}Ra$, $^{137}Cs$, $^{40}K$, $^{228}Ac$, $^{232}Th$, $^{238}U$, and $^{214}Bi$). Biological analyses such as dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), and some bacterial tests also are achieved. The results of the Physico-chemical parameters analysis are compared with international standards and classifications to assess the water quality for different purposes.

Hydrochemically, Sawa Lake water is classified as brackish to saline of alkaline water, while ground water taken from wells was slightly-brackish water. The chemistry of Sawa Lake differs from the groundwater of wells is characterized as Mg-chloride whilst, wells water are Mg-sulfate. Genetically, the source of the lake water is deep ground water of marine origin ascending upwards through cracks and joints to be mixed with shallower water of aquifers underneath the Lake, especially the Euphrates, Dammam and Umm Er Radhuma aquifers. It reaches the surface filling the depression with water forming the lake body. Trace elements concentration in the lake water (Zn, Pb, Cu, Cd, Ni, Co, As, Mn, Fe, Sr and B) is higher than their concentration in sea water, where B and Sr are characterized by very high concentrations.

The radiation level in the sediment and water are within the acceptable limit. But in sediment, radiation seems to be higher than its level in water. Two radioactive decay series are detected; these are $^{232}Th$ decay series and $^{238}U$ decay series as well as $^{40}K$, while the $^{235}U$ decay series and $^{137}Cs$ were not detected. The radioactive isotope concentrations were recorded in higher level in sediments rather than that in the water

Assessment of lake water for drinking (human and animal), irrigation, industrial and building purposes showed that the water quality is unacceptable for these purposes. Sawa Lake is classified as bad water quality according to Water Quality Index (WQI). Sawa Lake is characterized by limit of mechanical sediments, while, chemical precipitation is active. Generally, mechanical sediment is characterized by being fine particles settled from the atmosphere.

Nineteen sediment samples were collected and studied in term of mineralogy and geochemistry. Sawa Lake sediment is mainly composed of gypsum (87%) as dominant mineral, clay minerals (5.5%), quartz (4.5%) and halite (3%). The lake is surrounded by a gypseous wall. Gypsum plays major role in the process of building this wall by the equilibrium between evaporation and precipitation. The length of gypsum barrier surrounding the lake is 12.5 km with 3-6 m high. The Dissolution processes of the gypsum wall form caves, and collapses of part of this wall contributing to increase the surface area. Many patterns of gypsum are identified. The dominant oxides in the lake sediments are CaO (31%), $SO_3$ (34%) and LOI (18%) which reflect the abundance of gypsum. Other oxides, $SiO_2$ (8.0%), $Al_2O_3$ (1.5%), MgO (3.0%) and $Fe_2O_3$ (0.6%), $Na_2O$ (1.5%) and Cl (2.0%) reflect quartz, clay minerals and halite. Heavy metals (23 ppm Pb), (41ppm Ni), (19 ppm Co) in the Sawa Lake sediments are concentrated within the salts sediments with tendency to be more than the concentration of average of global soil, except Fe recorded a decrease in concentration.

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# Chapter One

## Introduction

# 1- Introduction

## 1-1 Preface

Sawa Lake is a strange lake in Iraq characterized by the highest salinity value among the Iraqi inland waters. It is a mixo-mesohaline water body of no inflow and outflow. The lake is an elongated closed basin with no tributary of surface water available to it. This lake may be fed by groundwaters of the Euphrates and Dammam aquifers through system of joints, cracks and fissures. Its water level fluctuates during dry and wet seasons. Its water do not dry up because of the equilibrium state between water feed up and evaporation (Jamil, 1977).

The water chemistry, which is unique among Iraqi lakes, suggests that, it is probably of relatively recent karstic origin and not a relic of a mid-Holocene origin. It formed over limestone rock. The water in this lake is extremely salty due to heavy evaporation in the searing heat of Mesopotamia, even more than the water in the Arabian Gulf.

## 1-2 Importance of the study

Hundreds square kilometer area around Sawa Lake has an approximate population of 1161882 (0.011619 persons per square meter). Sawa Lake is a resource of surface water even it is brine, but still need to be studied periodically to understand how it change with time. What is the role of chemical reaction that changes the chemistry of water.

The type of water must be well known in order to classify the lake water for multi-purposes uses, and follow the optimum conditions in water consumption.

## 1-3 Aims of the study

This study aims to:

1- Determine the origin of Sawa Lake and comparing the results with previous studies to monitor the water chemistry changes.
2- Study the probable chemical and biological pollution in the lake.
3- Assess and classify the lake water to indicate suitability for the different purposes.
4- Study the mineralogical composition of the lake sediments as well as its geochemistry.

## 1-4 General description and Location

There is no surface water source feeding the Sawa Lake. The source may be groundwater. It is a land locked lake with maximum length of 4.74 km and maximum width of 1.77 km isolated by gypsum barrier with total path of 12.5 km surrounding the lake. Sawa Lake lies between longitudes (44° 59 29.01 and 4°5 01 46.61) and Latitudes (31 17 43.10 and 31 19 49.79). Sawa Lake locates about 23 km to the west of Al-Samawa city, in Al- Muthanna province. It is accessible by road that goes parallel to AL-Atshan River a branch of the Euphrates River.

The Lake is free of mechanical sediments. Generally, there is no mechanical deposition except that fine dust particles derived mainly from the atmosphere (Hassan,2007)

The lake has an elongated shape with NW-SE trend (Figure 1-1). The study area is part of a gypsiferous plain, and it is characterized by a flat land, as part of the southern part of the Western Desert. The topographic gradient of this area increases generally from the northeast to southwest with average elevation 2.7m per Kilometer (Al–Shemari, 2006). This area is also characterized by several important phenomena such a Sabkha and sand dune**.**

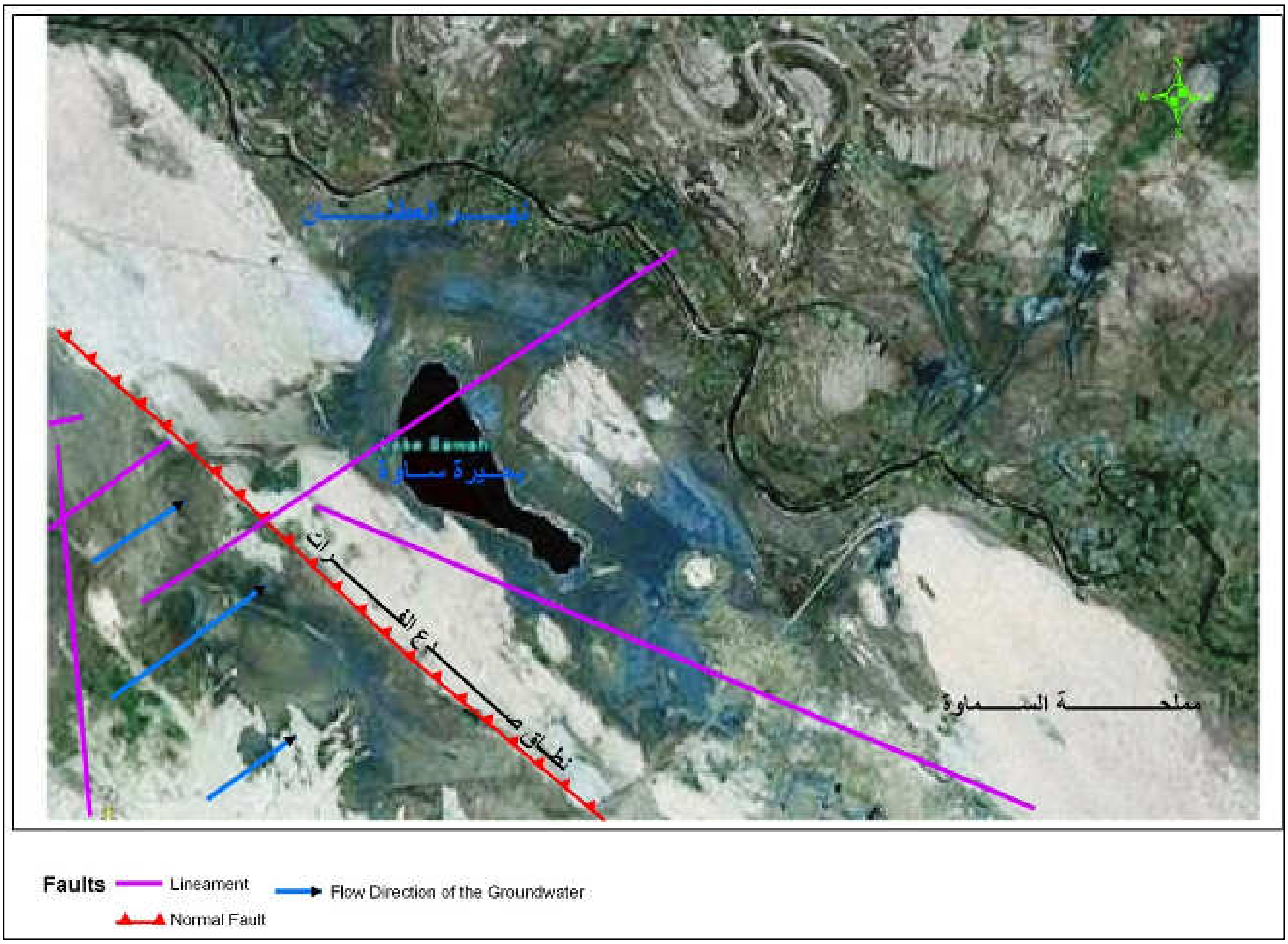

Figure1-1: Arial photo of the Sawa Lake with direction for the moving of groundwater and faults in the study area (modified by Buday and Jassim, 1987 in Al-Basrawi, 2012)

## 1-5 Previous studies

The most part of the previous studies that carried out on the region have dealt with the hydrogeological aspects because the region is rich with groundwater. The most important studies include:

- Al-Rawi and Al-Hadithi (1968) investigated Sawa Lake in term of geology and the salt in Samawa. The study directed to the existence of saline springs of water providing salt to the lake.
- Al-Rawi (1975) studied hydrogeology of Samawa Salt deposit, point out that the lake is fed by ground waters of the Euphrates and Dammam aquifers and its water chemistry, which is unique among Iraqi lakes.
- Jamil (1977) studied geological and hydrochemical aspects of Sawa Lake. He concluded that the Sawa Lake is marine water mixed and diluted with meteoric water and of cation-chloride water type. The system of joints, cracks and fissures from the Euphrates aquifer is feeding the lake.
- Al- Naqash (1977) studied Hydrochemical and geomorphological properties of Sawa Lake. The study showed that the sediments around the lake are gypsum salt deposits.The origin of the lake due to the structural activity in the area.
- Al-Ani (1983) studied the hydrochemistry of the spring extending from Hit to Al-Samawa and he found, it characterizes by hard brine water of marine origin.
- Al-Rawi and Al-Sam (1983 ) divided the southern part of the Western Desert into three blocks (1, 2, 3) including the Salman basin and they described the stratigraphy and geology, as well as, a water balance and studied all the hydrochemical variables between recharge and discharge site in the area of the basin.
- Samaan (1985) studied the geochemistry and mineralogy of the Samawa saltern and concluded that the mineralogy of the crystalline precipitated salts is madeup mainly of halite with secondary minerals in minor amounts of K and Mg chlorides and sulphates. Salts deposits was found from hydrochemical ratio interpretations that this water is marine of deep origin mixed with shallow circulating meteoric waters.
- Al-Badri et al., (1985) study area around salt deposits in Al-Samawa and estimated the future salty reserve.
- Abdel Aal and Al Hiti (1988) studied the hydrogeology and estimated the quality and quantity of major groundwater aquifers in Al- Samawa playa.
- Bahgat., (1993) conclude that secondary gypsum formed as a result of the rise of deep water with a high content of sulfates and calcium. A result of the high temperature and extreme evaporation, deposited layers of gypsum crust. Sawa Lake have edges of the high thickness (5m).
- Al-Muqdadi (2003) studied hydrogeology of area located between Al-Samawa city and Shnifia area, the study area influenced by three sets of major faults. The ground water occurred in carbonates rocks of the

Umm- ErRadhuma, Dammam and Euphrates formations; he determined the flow direction of groundwater and water chemistry. He concluded that the Sawa Lake is chloride water quality (marine origin). The low water level of the lake is as salt of the reduction of dilution factor with the existence rate of evaporation in addition to the wide surface area of the lake. Poor rains and the increase in the number of drilled water wells irregularly in the area in recent years have caused the low level of the lake.

- Al-Shemari (2006) was carried out a study of evaluation of hydrogeological and hydrochemical conditions of the Rehab area, south and south-west Samawa city. This study showed that the aquifer of the carbonate rocks is of confined type influenced by many faults of different directions, specially the Euphrates fault zone. The water quality of these aquifers is unsuitable for industrial and building uses due to very high hardness.
- Hassan (2007) studied the physio-chemical characteristic of Sawa Lake water and concluded that the water of this lake are similar to the Euphrates river rather than the well nearby it or sea waters. Its water is mixing with fresh water. Sawa Lake is over saturated with calcite, dolomite, aragonite, gypsum and anhydrite minerals.

## 1-6 Tectonic and structural setting

Tectonically, the studied area is located within the eastern boundary of the south part of the Western Desert (Al -Kadhimi et al., 1996). It is represented by small part from the borderline between the stable shelf (Salman sub zone) and the unstable shelf (Samawa -Nasisrya sub zone). The rise of the Western Desert Block was formed by faults systems called Abu–Jir Faults. This fault is a large influence on the hydrological setting of the studied area, as well as many faults in different directions. One can observe the effect of Abu –Jir Faults through the line of springs and flowing wells distributed along the NW – SE direction. There are three types of the faults (Al - Mubarak and Amin, 1983) as a result of influence the structural and tectonic setting in whole area (Figure 1- 2). The first is NE trend .These faults are the oldest, and belong to the Late Cambrian age. It is only effecting in the deeper sediments.

a. The second type is trending NE - SW, and have an age of Late Cambrian - Mesozoic, they are normal faults.
b. The third type is trending NW - SE, and has Mesozoic - Tertiary age. This type is normal faults as well

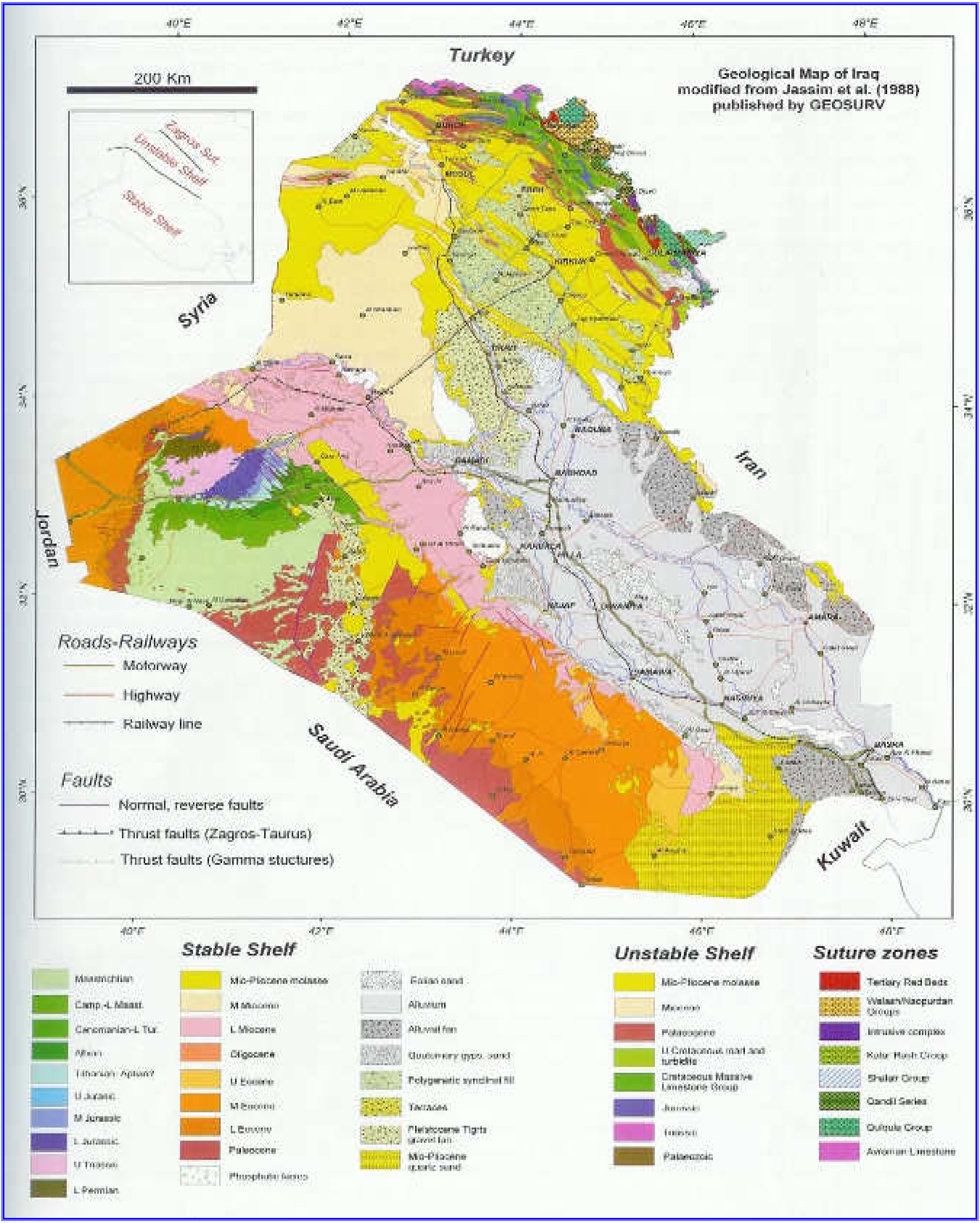

Figure 1-2: Geological map of Iraq (After Jassim and Goff, 2006).

## 1-7 Geology and hydrology of the study area

Al-Rawi and Al- Hadithi (1968) that the springs in Samawa salt deposits that are the main source of salt deposits. The source of Samawa springs are the water of the Euphrates aquifer, the marine water origin mixed and diluted with water of Dammam aquifer of meteoric water in percolation and rose through the joints, crakes and fissures., The relative high concentration of $CaSO_4$ in water is a result of the weathering of anhydrite rocks of the Rus Formation by the water of Dammam Formation. The source of the Sawa Lake water is the springs percolating from Euphrates and Dammam aquifers.

The area is covered by recent alluvial and dune sediments that vary in thickness from1 to 10 m. It is underlain by recent salts deposit (Figure1-3). Geology plays a role and is considered as an essential factor in determination of the quality of water. According to the reports (GEOSURV) (1983), the formation in the study area from oldest to youngest can be described as follows:

### 1-7-1 Tertiary sequence

### 1-7-1-1 Rus Formation (Jil) (E. Eocene)

This formation consists of anhydrite alternating with marl, shale and limestone, in its middle parts, and dolomitize limestone below, and soft, chalky limestone above them. The environment of deposition is Lagoonal (Buday, 1980). The formation does not appear in studied area, but it appears in the lithological section of the deeper wells. The Rus Formation is well defined in a very restricted area in Iraq in the southern Salman and Mesopotamian zones. Outcrops along the Saudi-Iraqi border suggested the use of the Name Jil Formation for the Rus equivalent at outcrop where the anhydrite has been dissolved. The Rus Formation corresponds to beds previously assigned to the Dammam formation (Owen and Nasr in 1958); the Rus (Jil) formation can be divided into two members: The Lower member (equivalent of Wagsa) is 20 m thick and consists of flaky yellowish marl with thin beds of nummulitic limestone. The Upper member (equivalent to the Sharaf, Shbicha and lower Huweiimi units) is 62 m thick. Its best exposures are near Shbicha town. It comprises recrystallized limestone, partly silicified (Jassim and Goff, 2006).

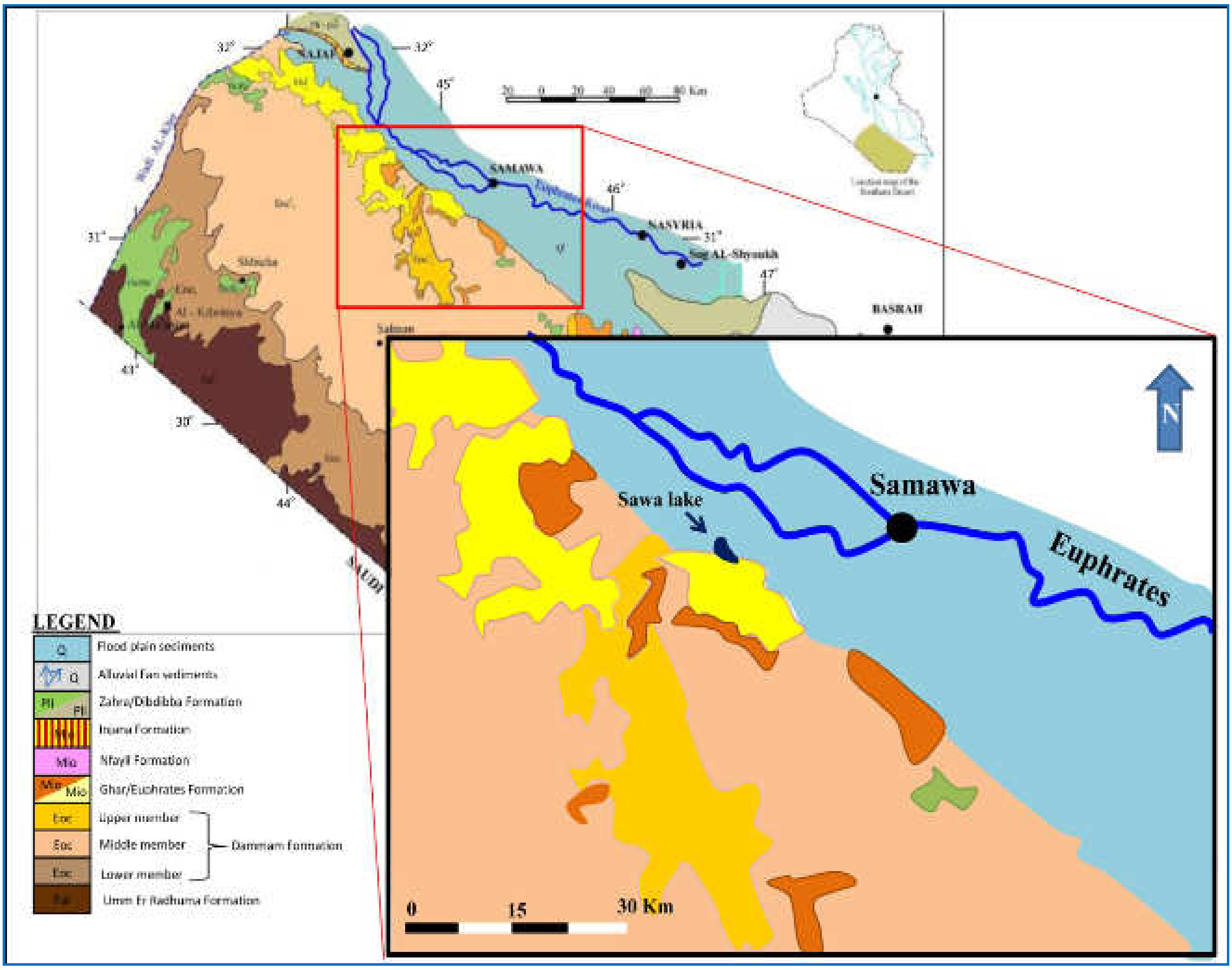

Figure 1-3: Geological map of the study area and the surrounding areas (After Sissakian, 2000)

### 1-7-1-2 Dammam Formation (E- L. Eocene)

The formation consists of variable carbonate rocks mainly limestone, dolomitic limestone, chert nodules, with chalky and marly limestone. It is characterized by the presence of cavities and karstified canals in addition to fractures, fissures and joints. The environment of formation is shallow neritic. However, during the regional geological survey (Al-Mubarak and Amin, 1983). subdivided this formation in the southern desert into three units, as follows

**A.** The upper unit consists of chalky to marley limestone. The age of this unit is L-M. Eocene.

**B.** The middle unit consists of dolometic limestone with horizons of chert.

**C.** The lower unit called the Jil Formation, whose age is E. Eocene (Alatia, 2006), it consist of highly jointed and fractured, recrystallized, nummulitic limestone with yellowish white marl to marley limestone.

The formation thickness ranges from 100–150 m according to reports of State Company of Geological Survey and Mining (GEOSURV, 1983).

**D.** Subsurface type section in Iraq is M. Eocene (Bellen et al, 1959). Al- Hashimi in 1973 suggested that the age of formation is Middle Eocene; Jassim et al.,( 1984) confirmed that Dammam Formation is also part of Late Eocene age in southwest of Iraq.

The hydrogeological investigations in the Southern Desert (GEOSURV, 1983) shared that Dammam Formation contains huge amounts of groundwater. This aquifer is a part of a complex hydrogeological unit within different formations, on a regional scale, with hydraulic connection between them. Dammam Formation is considered as the main regional groundwater aquifer within the Southern Desert, due to its wide extension and content of huge amounts of groundwater according to pumping tests provided by the hydrogeological data base of wells discharge from this formation reflect hydrogeological parameters as: transmissivity coefficient ranges from 3.1 – 4752 $m^3$/day, permeability coefficient ranges from 0.1- 100 m/day, well discharge ranges from 26 – 6542 $m^3$/day and static water level ranges from 170 m below ground surface to artesian flow. Total dissolved solids(TDS) range from 350 – 8530 mg/l, with predominant sulphatic water type and presence of chloride and bicarbonate water types also (Al-Jibury and Al-Basrawi, 2009).

The source of the sulphate is attributed to the presence of evaporites within the rocks of the formation and/ or other formations, or gypsiferous soils, which are dissolved by rain water and percolate through permeable strata or through fractures, fissures, joints and cavities within the cap rocks to the groundwater aquifers (Al-Jiburi and Al-Basrawi, 2000; Al-Dabbaj and Al-Khashab, 2000 and; Al-Wa'aily et al., 2002). In the discharge area, huge groundwater issues form large springs, locally forming lakes (Sawa Lake and Samawa Salt Lake). The remaining groundwater is confined below the relatively impermeable layers of the Mesopotamian (Krasny, 1982 in Jassim and Goff, 2006).

### 1-7-1-3 Euphrates Formation (E. Miocene)

Generally, the formation consists mainly of limestone with textures ranging from oolitic to chalky, which locally contain corals and shell coguinas (Jassim and Goff, 2006). However, in the studied area consists mainly of limestone with impermeable clay and marl and hard, massive, cavernous, chalky limestone (Al-Mubarak and Amin, 1983; Al-Rawi et al., 1983). It has thickness reaching 30-50 m.

The groundwater Aquifer in Ghar – Euphrates formations present within these two formations, especially at the northeastern parts of the Southern Desert, which represent a discharge area as these formations are exposed. The results of pumping tests of many wells provided by the Hydrogeological Data Base of wells discharge from this aquifer reflect hydrgeological parameters as: transmissivity coefficient ranges from 21- 246 $m^3$/day, permeability coefficient ranges from 1.3 – 14 m/day, well discharge ranges from 99 – 881 $m^3$/day and static water level ranges from 2.4 – 16.6 m, below ground surface. Total dissolved solids range from 1966 – 64853 mg/l, with predominance of chloride water type. This aquifer is not considered as a main and important one, due to its bad water quality in most cases and its limited extension (Al-Jibury and Al-Basrawi, 2009).

### 1-7-2 Quaternary Sediments

These sediments consist of gypecrete, sabkha, salt sheet, and slope deposits. The aeolian deposit is represented by the sand dunes and sand sheets. These sediments cover a number of formations. The thickness of the sediments according to the information obtained from the lithological sections of wells ranging from 120 m (Al-Mubarak and Amin, 1983). These sediments are limit and a few thicknesses as well as there are found depended on the topography of vary parts on this area and covered the old formations especially on the adjacency areas with the Euphrates basin (Jawad et al., 1994).

The aquifer within Quaternary sediments is mainly concentrated at the southeastern part of the Southern Desert., Quaternary sediments cover this part with a considerable thickness that makes these sediments suitable to contain water and represent the uppermost main aquifer in the area. These sediments are mainly composed of sand, pebbles, silt and mud or clay in addition to salt, gypcrete is also well known within surface sediments of Al-Batin alluvial fan (Krasny, 1982 in Jassim and Goff, 2006).

Generally, Quaternary sediments are characterized by their inhomogeneous nature vertically and laterally, especially, within the upper parts of these sediments due to the presence of different layers of silt and clay at a depth that may reach to 20 and 25 m (Krasny, 1982 in Jassim and Goff, 2006).

The thickness of these sediments and their lithological nature are suitable to contain and store water especially, in valleys, this may happen seasonally or annually depending on wet seasons (Al-Jibury and Al-Basrawi, 2009).

#### 1-7-2-1Gypcrete Deposits (Pleistocene – Holocene)

This sediment represents the old deposits in the Quaternary period, and consist of secondary gypsum that is formed as a result of raising deep water which is containing high $CaSO_4$, Deposited beds were formed from crust Gypcrete (Al-Naqash, 1977) this deposits found as a shape around the Sawa Lake forming its high edges which is about 5 m high.

### 1-7-2-2 Depression Filling Deposits

The depression fill deposits are generally fine clastic, where calcareous silty clay or loam is more dominate. The thickness of these deposits depends mostly on the size and depth of the depression. There are many small sized and shallow depressions scattered in the study area, beside the main depressions which have large extension such as Al-Salman, Al-Sa`ah and Al-Shbicha. The main depressions are usually deeper and have wide catchment areas, and hence the thickness of the depression fill reaches few meters (Al-Mubarak and Amin, 1983).

### 1-7-2-3 Sabkha and Salt Sheet Deposits Sabkha

It is found in the area of high flow of ground waters. In this case, the soil becomes wet; when the raise water through summer months formed salts deposits cover the surface of the earth as a crust which is different in its thickness. It is found near the saltcellar on the salt factory, its distance is about 10 $km^2$ which contain halite deposits with thickens of 10 m in the middle parts.

### 1-7-2-4 Slope Deposits (Pleistocene-Holocene)

The slope deposits are developed along the foot of ridges and cliffs, surrounding the main depressions in the study area. They consist of mixture of fine clastic and rock fragments. The rock fragments decrease in size and amount down the slopes (Al-Mubarak and Amin, 1983).

### 1-7-2-5 Aeolian deposits (Recent)

There are sand dunes and sand sheets. They are represented by a zone extending toward NW-SE with the same dominant direction of wind, it is commonly sandy deposits which is transported from a nearby area because its compositions of calcic materials (Al-Ani 1983).

## 1-8 Climate elements

Desert conditions prevail in the studied area, because it lies in the hot arid zone with low rain. The present climate is characterized by a short, dry cool winter and a very hot dry long summer.

The study area lies within the southern part of the Western Desert with arid climate. It's called desert because the mean annual rainfall is 100_150 mm. Although it is considered as a desert, but considerable parts are covered by fertile soil in which different kinds of wild flowers and other kind of vegetation grow during rainy seasons. Many weather meteorological stations are available in the concerned area.

Climatic data (temperature, rainfall, relative humidity, evaporation, wind direction and speed) from meteorological Samawa Station are obtained for period 1990 - 2011(Table 1-1).

Climate has a direct influence on water quality of Sawa Lake. The Iraqi climate characterized by hot dry summers and cold rainy winters. Nearly 90% of the annual rainfall occurs between November and April, most of it in the winter months from December till March. The remaining six months (From May to October), particularly the hottest ones are June, July, and August. The average temperatures in Iraq range from higher than 48 ºC in July and August to below freezing in January.

The day is hot, whereas the night is relatively cool. Generally, the climate of Mesopotamia is semi-arid with maximum temperature up to 53 ºC in July-August and minimum Temperature of -7 ºC in January (jassim and Goff, 2006).

Table 1-1: Mean monthly values of climatic elements of Samawa area (1990-2011).

| **Climate elements** | **Months** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **JAN** | **FEB** | **MAR** | **APR** | **MAY** | **JUN** | **JUL** | **AUG** | **SEP** | **OCT** | **NOV** | **DEC** |
| Max.of Tem.($^o$C) | 17 | 20.4 | 25.8 | 31.4 | 38.8 | 43.2 | 44.5 | 44.2 | 41.2 | 35 | 26 | 19.4 |
| Min. of Tem. ($^o$C) | 5.8 | 7.7 | 11.8 | 17.6 | 23.3 | 26.3 | 27.6 | 27.3 | 23.5 | 19 | 12.2 | 7.4 |
| Rainfall (mm) | 26.6 | 16.2 | 17.0 | 11.5 | 2.8 | 0.0 | 0.0 | 0.0 | 0.3 | 5.9 | 12.3 | 15.7 |
| Relative humidity (%) | 65.16 | 57.2 | 46.7 | 39 | 28 | 23.5 | 22.9 | 24.2 | 28 | 37 | 51.5 | 61.5 |
| Evaporation | 89.2 | 120 | 209 | 270 | 381 | 467 | 506 | 483 | 369 | 261 | 143 | 94.9 |
| Wind speed m/sec | 2.5 | 3.0 | 3.3 | 3.7 | 3.7 | 4.1 | 4.0 | 3.4 | 3.1 | 2.6 | 2.3 | 2.4 |

### 1-8-1 Temperature

It is a controlling factor that determines evaporation. The increasing of temperature during day heats materials on surface; eventually leading to dispersing of the pollutants upward, whereas the decrease of temperature in the night causes concentration of the pollutant materials on surface via the descending air column downward (Musa, 2000).

Temperature is one of the most important and common variable used to describe the state of the atmosphere; it is a usual component of weather reports and forecast (Moran and Morgan, 1994).

Temperature is the most important factor which causes physical erosion. It is an assistant factor in the fragmentation of the components of the earth surface. This is because of the summer high temperature accompanied with a drought periods (Al-Bayati and Mousa, 1989).It can be seen from Table 1-1 that the highest temperature was in July 44.5 °C, while lowest temperature was in the January17 °C (Figure1-4).

### 1-8-2 Rainfall

In June, July and August precipitation stop. The global of mean annual precipitation (rain plus melted snow) exhibits great spatial variability. Some of this variability can be attributed to topography and the distribution of land and sea, but the planetary-scale circulation is also important (Moran, and Morgan, 1994).

The Precipitations played a direct role in geomorphological processes, where it is role is clear in the process of fragmentation of the materials forming of the earth's surface, at the collision of rain drops, on the ground surface or as a result of dissolution after the rain drops hitting the ground in rills take water from the areas of weakness represents in cracks and joints a course and then the process of erosion and the transfer of rock fragments resulting from the weathering process and consequently the deposition. The maximum value of mean monthly rainfall is limited in the cold months (October 5.9 mm to May 17.0 mm). Rainless in summer (June 0.0 mm to September 0.3 mm) (Figure 1-5). Rainfall intensity is the opposite of temperature degrees (Table 1-1) (Meteorological Organization Al-Samawa Station).

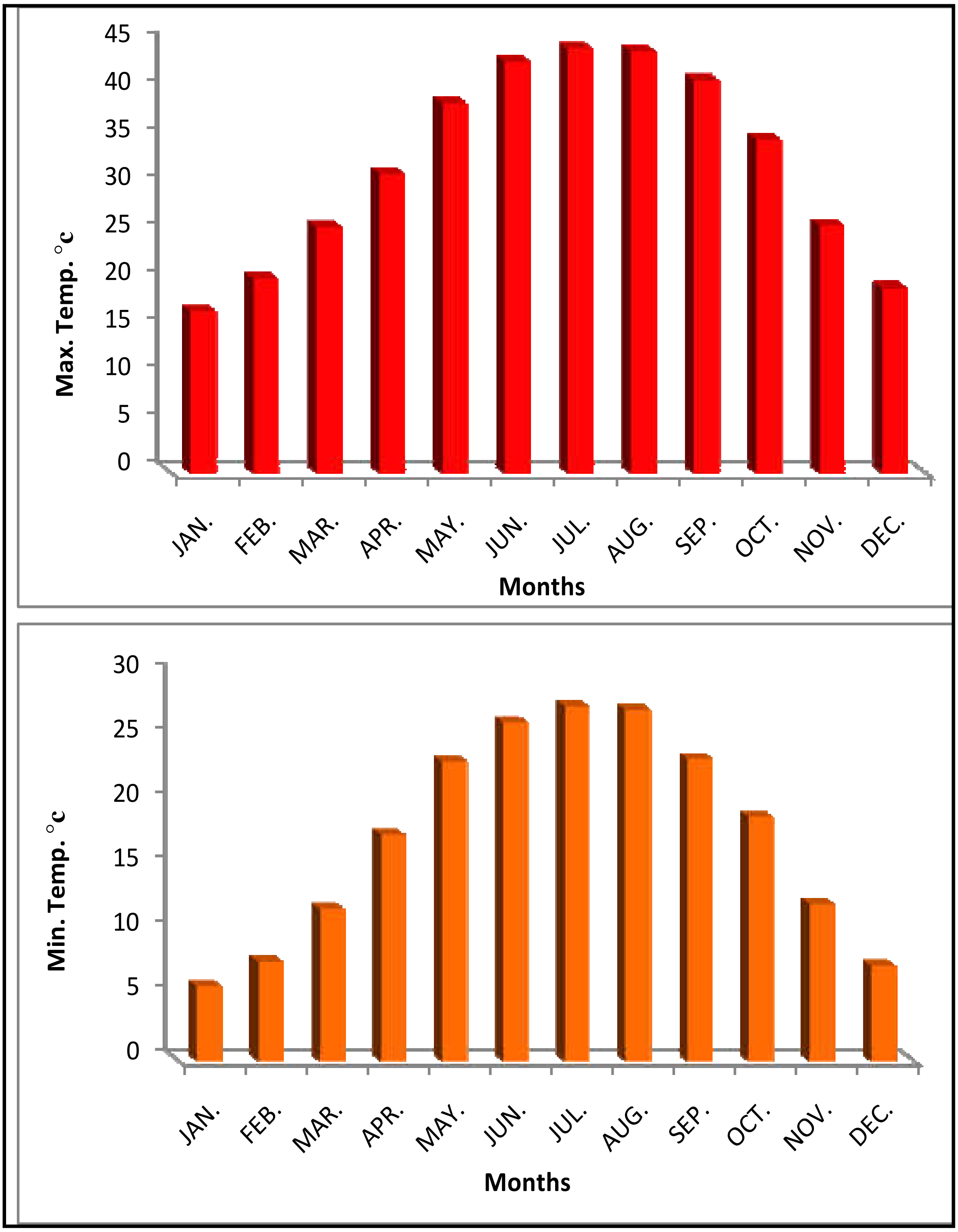

Figure1-4: Mean monthly of maximum and minimum temperatures for the period 1990-2011.

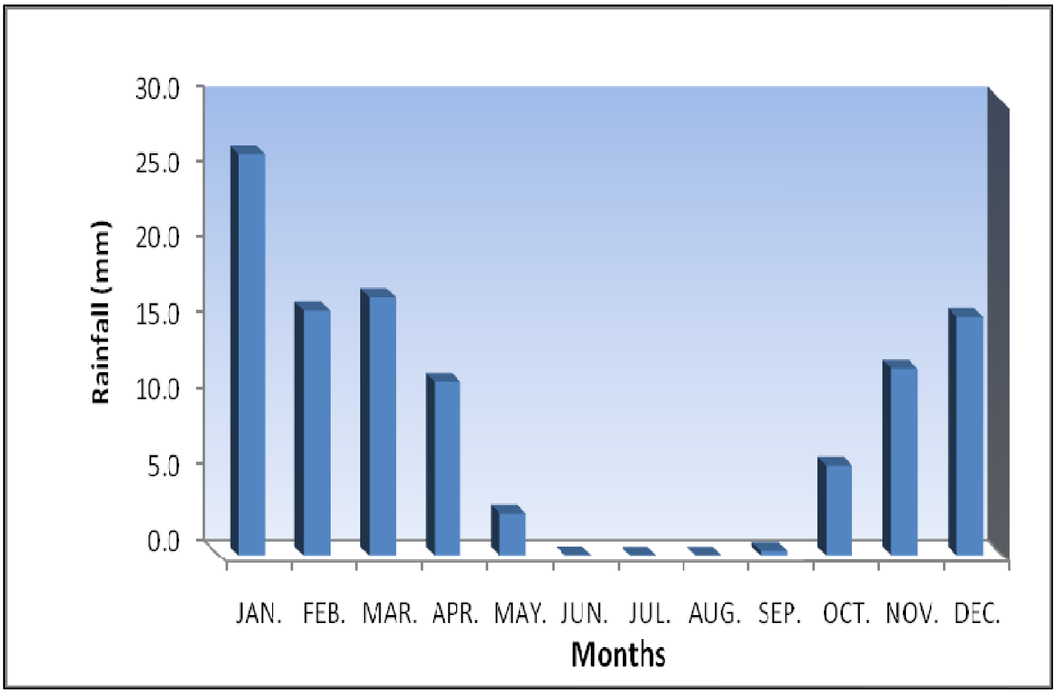

Figure 1-5: Mean monthly of rain fall for the period 1990-2011.

### 1-8-3 Relative humidity

The relative humidity is the ratio between the actual (real) water vapor pressures to saturated water vapor pressure. The relative humidity depends on air temperature and rain. It decreases in summer due to increasing temperature and little rain fall, but it increases in winter due to decreasing the temperature and increasing rain fall. So the relation between relative humidity and temperature is negative, while the relation between relative humidity and rain fall is positive (Al-Maliki, 2005).

It depends on temperature and rainfall; it decreases during summer but increases during winter. In the case of high humidity, the water vapor will react with gases like $NO_2$ and $SO_2$ that may form acidic rain (Farag and Ahmed, 2009). The highest rate of relative humidity was in January 65.16% in the period of 1990-2012 and the lowest in July 22.9% (Figure1-6).

### 1-8-4 Evaporation

The evaporation is considered as one of the affective climate elements, which affects erosion process. Intensity of evaporation varies depending on some factors such as sun shine, temperature and wind speed which are important factors affecting the increase in evaporation (Soliman, 1998) Indirectly through its relation with temperature increase and soil roughing, which causes decomposition of rock material and then easy to eroded by wind action. There is a direct relation between the evaporation factor and temperature and indirect relationship with precipitation. It affects both water quality and quantity; it depends on sunny radiation, wind speed and temperature (Farag and Ahmed, 2009). The highest values of evaporation occur during July 506 and August 483, with the lowest values occurring in December 94.9, January 89.2 and February 120 (Table 1-1) (Figure1-7). Evaporation has negative influence on environment. It forms salts in the sediments which eventually make the lake water bad.

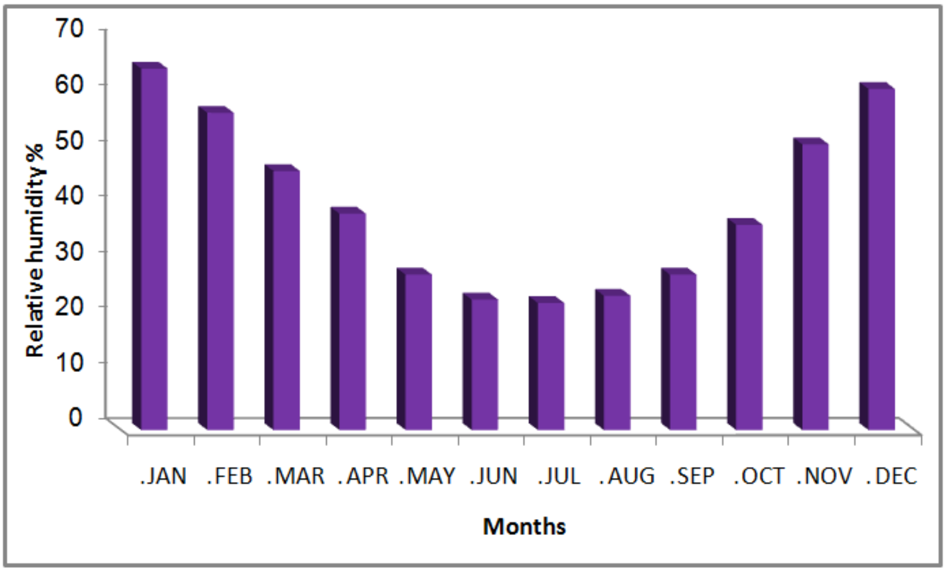

Figure1-6: Mean monthly of relative humidity for the period 1990-2011.

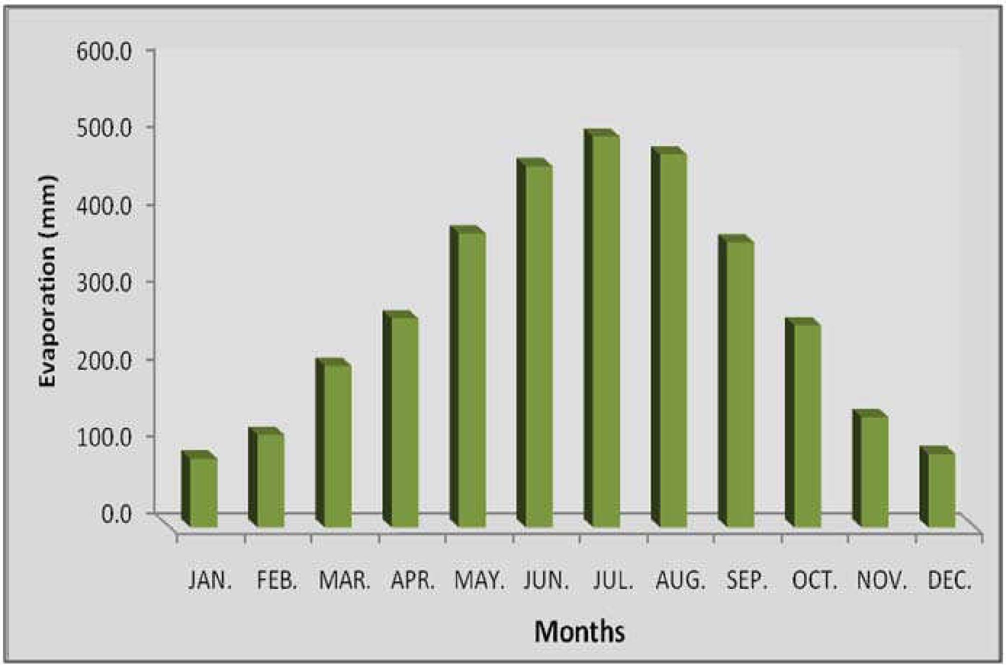

Figure 1-7: Mean monthly of evaporation for the period 1990-2011.

## 1-8-5 Wind direction and speed

Wind direction and speed could play an important role in the pollutants distribution in the atmosphere. Pollutants concentration decrease and disperse widely with increasing wind action, then the solid suspended particles are deposited whenever the wind speed becomes low (Awadh, 2009).

The Winds, when air moves, it picks up loose material and transports it to other places. Air differs from other erosional forces because it usually cannot pick up heavy sediments. Winds are one of the most important erosion elements that have permanent effect on the geomorphological landforms in the arid and semi-arid areas (Al-Naqash and Hambarsom, 1985). Winds are capable of picking up and carrying dust particles from fields high into the atmosphere and depositing them thousands of kilometers away.

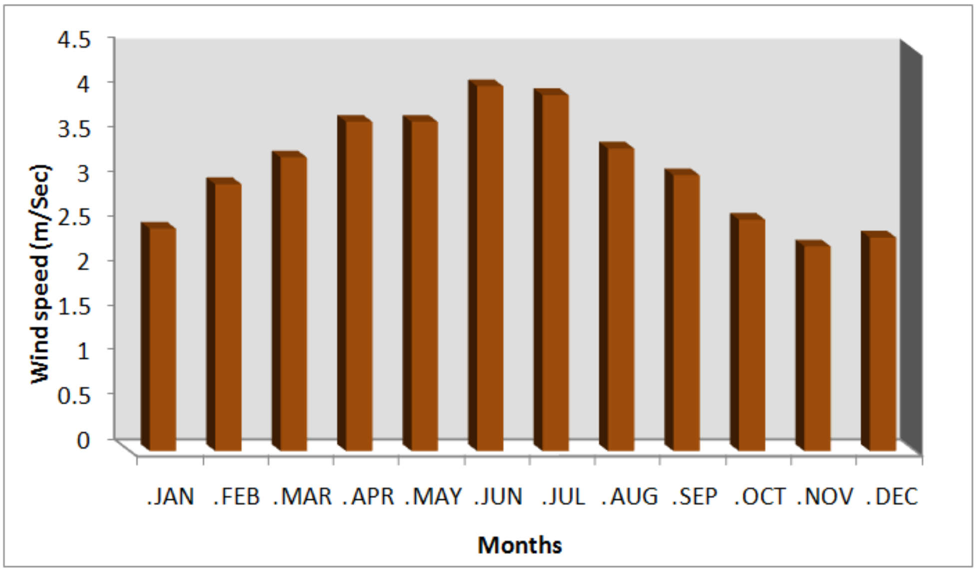

Figure 1-8: Mean wind speed for the period 1990-2011.

The wind direction in the study area most of the days of the year is NW, where this wind is dry as well as lacks of soil moisture. Therefore, winds have two main roles: the erosion and transportation and deposition.

Wind direction in the study area is primarily from the NW and W (Table1-2). Some wind reversals occur chiefly during winter causing reversal of slip-face below the crests of dunes, but apparently having little regional effect on sediment transport in study area (Abdul-Ameer, 2012). Mean monthly wind speed reaches a maximum 4.1 m/sec during June and minimum 2.3 m/sec during November in the period of 1990-2011(Table 1-1) (Figure1-8).

Table 1-2: Monthly Wind direction in the study area from 1990 to 2011
Samawa Station

| **Station of Samawa** | **Element prevailing wind** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Jan.** | **Feb.** | **Mar.** | **Apr.** | **May** | **Jun.** | **Jul.** | **Aug.** | **Sep.** | **Oct.** | **Nov.** | **Dec.** |
| **1990** | W/NW | NW/E | NW/W | NW | NW | NW | NW/W | NW | NW | NW/W | W/N | NW/W |
| **1991** | | | | | | NW | NW | NW | NW | NW | NW | W |
| **1992** | NW/W | W | NW/W | NW | NW | NW | NW | W/NW | NW | NW | NW | NW |
| **1993** | W | NW | NW/E | NW/E | W/NW | NW | NW | NW | NW | NE/NW | NW | NW |
| **1994** | W | NW | NW | NW | NW | NW | NW | NW | NW | NW | NW | NW |
| **1995** | NW | NW | NW | NW | NW | NW | NW | NW | NW | NW | NW | NW |
| **1996** | NW/W | NW/W | NW | NW | NW | NW | NW | NW | NW | NW | NW | E |
| **1997** | NW | NW | NW | NW | NW | NW | NW | NW | NW | NW | NW | W/NW |
| **1998** | NW | NW | NW | S/NW | NW | NW | NW | NW | NW | NW | NW | NW |
| **1999** | NW | W/NW | NW | NW | | NW | NW | NW | NW | NW | NW | NW |
| **2000** | NW | NW | NW | NW | NW | NW | NW | NW | NW | NW | NW/W | NW |
| **2001** | NW | NW=W | NW | NW | NW | NW | NW | NW | NW | NW | NW | NW |
| **2002** | NW | NW | NW | NW | NW | NW | NW | NW | NW | NW | W | |
| **2003** | | | | | | | | | | | | |
| **2004** | | | | | | | | | | | | |
| **2005** | | | | | | | | | NW | NW | NW | NW |
| **2006** | NW | NW/E | NW | NW | NW | NW | NW | NW | NW | E | NW | W |
| **2007** | W | NW | NW | NW | NW | NW | NW | NW | NE | NW | NW | NW |
| **2008** | SW | NW | NW | NW | NW | NW | NW | NW | N | S/N | N | N/NW |
| **2009** | S | S | S/N | N | N | N | N | N | N | N | N | S |
| **2010** | S | S | S/N | S | N/S | N | NW | NW | NW | NW | NW | NW |
| **2011** | S | NW | NW | S | NW | NW | NW | NW | Nw | NW | NW | NW |

# Chapter Two

## Materials and Methods

## 2-Materials and methods

### 2-1 Preface

To perform the aims of this study, field and laboratory works are carried out. Analyses of physical, chemical and biological properties are completed inside Iraq. This chapter describes methods and techniques used in this study. Sampling was processed on water during dry (7/10/2011) and wet periods (22/3/2012) as well as three samples that are collected from wells adjacent to the lake in the wet period only which are used for comparison. Nineteen samples are collected from the lake sediments during the dry period of the year 2011.

### 2-2 Field work

The field work comprises reconnaissance trips to determine the effective sampling sites. Consequently, 20 sites were chosen for sampling the Sawa Lake in addition to 3 wells close to the lake (Figure 2-1). Samples of water and sediments were collected from the Sawa Lake. Field work has been accomplished through two field trips. Water samples from the Sawa Lake were collected in clean and washed polyethylene bottles of 2L capacity. Bottles then were filled to expel air and closed tightly. The presence of air with the sample may affect the value of pH and stability of carbonate and bicarbonate when stored for indefinite time. Triplicate samples were collected from each site. The first was used for hydrochemical analyses, the second for radioactive analysis and the third for biological analyses. Samples for biological tests were collected and stored in specific dark sterilized bottles of 1L size. A Total of 19 sediment samples were collected and stored in plastic bags.

Latitudes and Longitudes coordination for each sampling site are accurately determined by using the Global Positioning System GPS (Table 2-1).

Many parameters are measured locally in the field; these measurements included the hydrogen number (pH), temperature (T), electrical conductivity (EC) and total dissolved solid (TDS). Total dissolved solid (TDS) values were out of the range of device due to the high salinity. The used device TDS-EC-pH and T meter produced by HANNA instrument, type H19811, made in Portugal. This instrument is calibrated by buffer solutions which are a standard solution for pH and TDS to attain suitable reading.

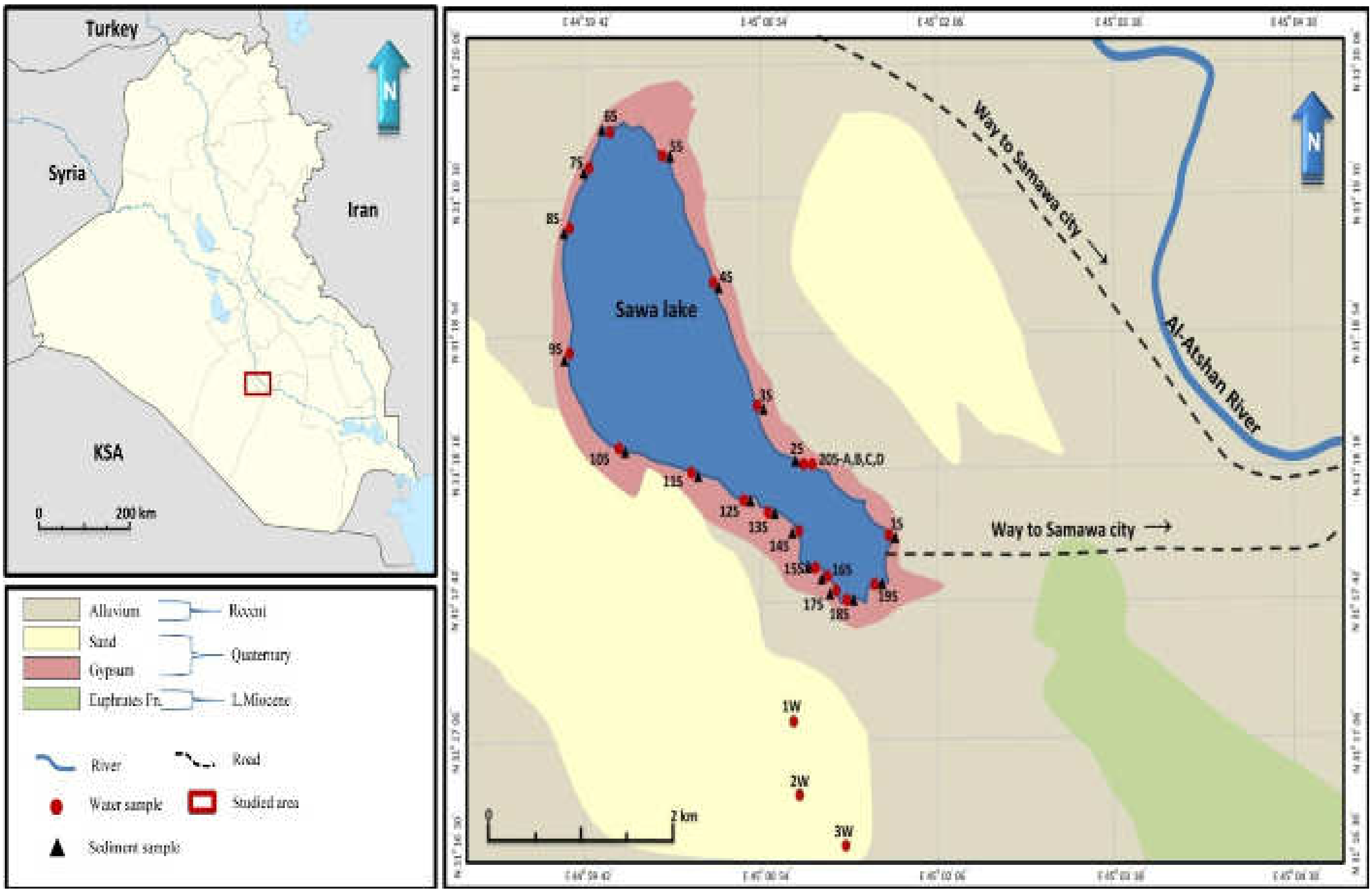

Figure 2-1: Location map shows the study area and sampling sits (modified Jamil, 1977).

### 2-2-1 Lake Water Sampling

Twenty surface water samples at depth (0-25 cm) were collected from Sawa Lake during dry and wet periods. Three samples were collected vertically from same site of the lake at depth (25-100 cm) using 2L bottle. Ground water from three wells at depth range from 35-40 m from Dammam aquifer was also sampled during the wet period (Figure 2-2). $H_2S$ gas is precipitated directly in the field by a chemical method; then $H_2S$ gas dissolved in water was chemically precipitated directly in the field

A detail procedure that has been followed is: 4 mls of 20% of $(CH_3COO)_2$ Zn and 1 ml of 1NNaOH were transferred into volumetric flask of 100 ml (Al-Baity, 1980).Then flask was filled by sample water and closed well.

In this case, $H_2S$ became as white precipitate (Figure 2-3) in form of ZnS according to the equation shown below:

$$(CH_3COO)_2Zn + 2NaOH + H_2S = ZnS + 2CH_3COONa + 2H_2O$$

Sulfur concentration is computed using the molecular weights of Zn, S and. Then it is determined in the laboratory.

Table 2-1: Location of the water and sediment samples collected from Sawa Lake. S=Sawa; t=sediment, w= well

| Sample No. | | | Coordination | | |
|---|---|---|---|---|---|
| **Water** | **Sediments** | **Depth** | **Longitude** | **Latitude** | **Elevation (m)** |
| **1S** | **1S-t** | Surface | N 31 18 0.5 | E 45 01 44.5 | 13 |
| **2S** | **2S-t** | Surface | N 31 18 19.7 | E 45 01 11.0 | 14 |
| **3S** | **3S-t** | Surface | N 31 18 36.5 | E 45 00 50.7 | 13.5 |
| **4S** | **4S-t** | Surface | N 31 19 08.3 | E 45 00 34.0 | 13 |
| **5S** | **5S-t** | Surface | N 31 19 42.5 | E 45 00 14.0 | 11 |
| **6S** | **6S-t** | Surface | N 31 19 48.3 | E 44 59 53.5 | 11 |
| **7S** | **7S-t** | Surface | N 31 19 39.0 | E 44 59 44.8 | 11 |
| **8S** | **8S-t** | Surface | N 31 19 23.0 | E 44 59 36.4 | 11 |
| **9S** | **9S-t** | Surface | N 31 18 50.1 | E 44 59 36.5 | 12 |
| **10S** | **10S-t** | Surface | N 31 18 24.3 | E 44 59 56.1 | 11 |
| **11S** | **11S-t** | Surface | N 31 18 18.1 | E 45 00 25.2 | 11 |
| **12S** | **12S-t** | Surface | N 31 18 10.3 | E 45 00 46 | 13 |
| **13S** | **13S-t** | Surface | N 31 18 07.1 | E 45 00 56.4 | 13 |
| **14S** | **14S-t** | Surface | N 31 18 02.3 | E 45 01 8.3 | 13 |
| **15S** | **15S-t** | Surface | N 31 17 52.2 | E 45 01 14.7 | 13 |
| **16S** | **16S-t** | Surface | N 31 17 50.0 | E 45 01 19.7 | 14 |
| **17S** | **17S-t** | Surface | N 31 17 46.6 | E 45 01 22.7 | 14 |
| **18S** | **18S-t** | Surface | N 31 17 43.6 | E 45 01 27.9 | 14 |
| **19S** | **19S-t** | Surface | N 31 17 48.0 | E 45 01 38.7 | 14 |
| **20S-A** | **---** | 0-25 cm | N 31 17 19.7 | E 45 01 13.9 | 14 |
| **20S-B** | **---** | 25-50 cm | N 31 17 19.7 | E 45 01 13.9 | 13 |
| **20S-C** | **---** | 50-75 cm | N31 17 19.7 | E 45 01 13.9 | 13 |
| **20S-D** | **----** | 75-100 cm | N31 18 19.7 | E 45 01 13.9 | 13 |
| **1W** | **----** | --- | N31 17 16.1 | E 45 01 5.0 | 13 |
| **2W** | **----** | --- | N31 16 57.4 | E 45 01 7.6 | 14 |
| **3W** | **----** | ---- | N31 16 43.6 | E 45 01 7.6 | 13 |

Figure 2-2: Groundwater collection from well (1W).

Figure 2-3: Fogy color solution at left due to $H_2S$ gas fixation on-site in the field; sample on the right untreated chemically.

### 2-2-2 Lake sediments sampling

For the duration of the dry period, Samples were collected from fine sediments under water, and other samples were collected from salt mass precipitated on the lake shore (Figure 2-4).

Coordinates of latitudes, longitude and DGPS for each sampling site of sediments are accurately determined by using the Global Positioning System (GPS) as shown in Table (2-1).

### 2-2-3 Sediment features

The sediments of Sawa Lake are characterized by salt sediments of chemical precipitate rather than mechanical precipitate. Gypsum appears to be dominant and the major mineral forming the lake bottom wall.

Many features of gypsum were distinguished. Aggregated grain gypsum of pure white color ranges from 0.3 mm to 2cm was the distinguish feature of sediment covered the southern lake shore (Figure 2-5). Cauliflower shape of gypsum is the dominant feature. Gypsum varies from friable to moderately hard.

Figure 2-4: Part of salt shore of Sawa Lake.

Figure 2-5: Aggregated grain of white to gray color gypsum from the southern shore of the Sawa Lake.

The Sawa Lake appears to have possibility to build self-wall from gypsum, up to 6 meters. Wall is a curvy barrier roughness. It exposed to landslides in most of its parts because of dissolving the lower parts of the wall, and this causes the expansion of the surface area of the lake. Foam salt also has been existed in the side of the wind face (Figure 2-6).

Figure 2-6: White salt foam floats on the shore line of the Sawa Lake.

### 2-2-4 Organisms in the aquatic environment

The environment of the lake is characterized by high salty water, unturbid near the shore. The aquatic environment of the lake includes some aquatic plants and algae that can be seen under the water's surface due to unturbid and transparently of water. Also, lake contains strange soft small fish *(Aphanius* Genus) up to 10 cm long. Fish very quickly lose their eyes after death for unknown reasons (Figure 2-7). However, the reasons for the loss of their eyes may be attributed to the loss of immunity after death and then, eyes cannot resist the high salinity, or they may be eaten by living fish. From the point of view of biologists, these fish express a unique organism in Iraq and belong to marine origin (Personal communication).

Chemical weathering erodes the formations hosting the lake such as the Euphrates Formation. Consequently, Gastropoda is found within the west and south shores of the lake (Figure 2-8).

Figure 2-7: Soft fish in the Sawa Lake.

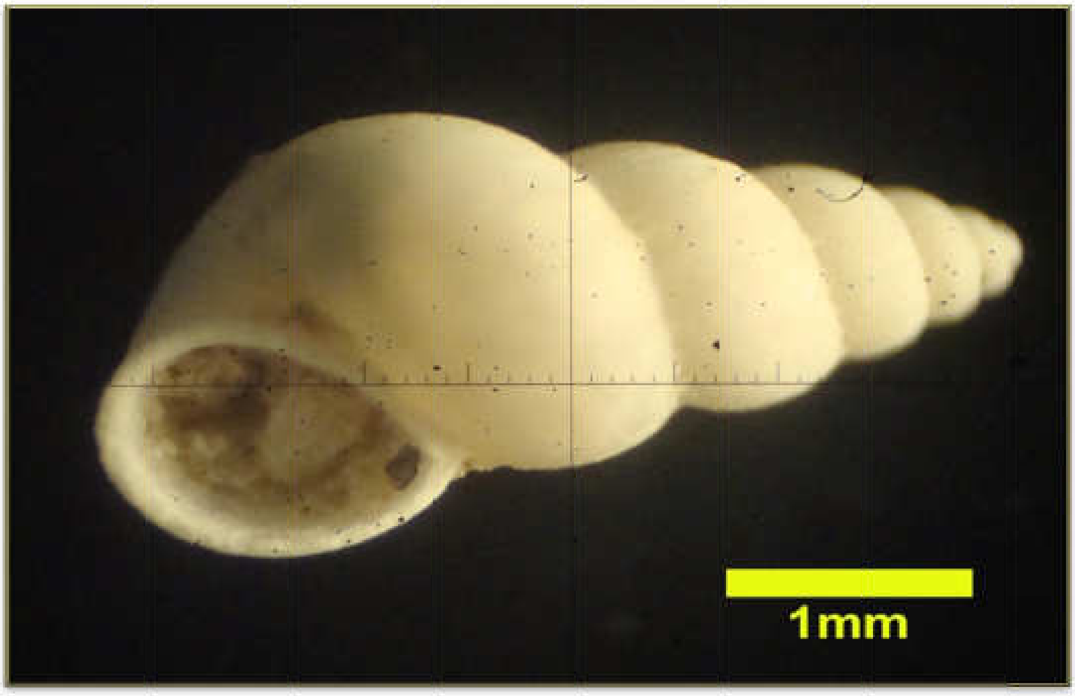

Figure 2-8: Photomicrograph under microscope of fossils collected from sediment of the Sawa Lake

## 2-3 Laboratory work

After completing the field work, immediately all samples (water and sediments) were subjected to the laboratory work. Samples were prepared for the purpose of chemical and biological and radiological analyses.

### 2-3-1 Analyses of water samples

The water samples from Sawa Lake and wells are analyzed by many methods. The analytical methods and the name of laboratories are listed in Table 2-2. Water samples are analyzed for:

**1-** Cations ($K^+$, $Na^+$, $Mg^{2+}$, $Ca^{2+}$).
**2-** Anions ($Cl^-$, $SO_4^{=}$, $HCO_3^-$, $CO_3$, $PO_4^{3-}$, $NO_3^-$ ).
**3-** Trace elements (Zn, Pb, Cd, Ni, Fe, Mn, Co, As, Cu, B and Sr)
**4-** Total dissolved solid (TDS), Electrical Conductivity (EC), pH and temperature.
**5-** Radioactivity measurements are achieved on both water samples and sediments. One litter of water samples are sent to the laboratories of Environment Ministry for the purpose of radioactivity measurement.
**6-** Bacterial testes on water were achieved as well as the biological oxygen demand (BOD), chemical oxygen demand (COD) and dissolved oxygen (DO).
**7-** Total suspended solid (TSS): filtration is used for determination the TSS. The solid particles on filter paper called residuals then the filtrate water are sent to the laboratories for chemical analyses.
**8-** $H_2S$ determination (Figure 2-9).
**9-** Organic compounds were determined by using FTIR technique.

Table 2-2: Methods of analysis and name of laboratories achieved.

| Parameters | Methods of analysis | Name of laboratory |
|---|---|---|
| **$Na^+$, $K^+$** | **Elico-Flame Photometer (APHA,1998) (Harris, 1995)** | **Service Laboratory of Chemistry Department at College of Science, University of Baghdad** |
| **$Ca^{+2}$, $Mg^{+2}$** | **Titration with EDTA (Ethylene DiamineTetra Acidic Acid) ASTM, 1989** | |
| **$SO_4^{=}$, $PO_4^{-3}$, $NO_3^-$** | **UV-visble spectrophotometer( kenkel, 2003)** | |
| **$Cl^-$** | **Titration with $AgNO_3$** | |
| **$CO_3^{=}$, $HCO_3^-$** | **Titration with HCl and Bromocrysolgreen + methyl red indicator** | |
| **B, As, Sr** | **Atomic-absorption spectrometer** | **Ministry of Industry and Minerals, IBN SINA State Company** |
| **Pb, Cu, Fe, Ni, Mn, Zn, Co** | **Atomic-absorption spectrometer** | **Service Laboratory of Chemistry Department at College of Science, University of Baghdad** |
| **Temperature** | **Field thermometer ± 0.1C° accuracy** | |
| **pH** | **pH-meter<br>TDS-EC-Ph meter (in field)** | |
| **TDS (mg/l)** | **Vaporization, in 105 C°(hot_plate)( in the Lab.)(Boyd,2000)<br>TDS-EC-pH meter (in the field)** | |
| **EC µs/c** | **Electrical Conductivity<br>TDS-EC-pH meter (in the field and the Lab.)** | |
| **Organic compounds** | **FTIR Prestige-21,Shimadzu 1601 pc, Japan** | **Ministry of Industry and Minerals, IBN SINA State Company** |
| **TSS (mg/l)** | **Filtration** | **Geochemical Laboratory of geology Department at College of Science, University of Baghdad** |
| **DO, BOD, COD** | **Dissolved oxygen meter, H19146<br>Standard Methods APHA (1996)** | **Laboratory of Water Treatment's Technology at the Ministry of Science and Technology** |
| **Radiation Measurement** | **Gamma Spectrometer System** | **Ministry of Environment, Radiation Protection Center** |

### 2-3-1-1 Determining $H_2S$ gas

Fixing of $H_2S$ in 19 water sample was done directly in the field by chemical method which converts gas to precipitated material. Then, $H_2S$ gas was determined in geochemistry laboratory in geology department at College of Science, University of Baghdad by filtration method (precipitation) and weight it (Figure 2-9).

Figure 2-9: Filtration of the water samples and $H_2S$ determination.

### 2-3-1-2 Dissolved Oxygen (DO)

Dissolved oxygen probe is used for determining the dissolved oxygen. It measures DO directly and converse into digital reading expressed by mg/l which equal ppm. Dissolved oxygen (DO) is measured in the Laboratory of Water Treatment's Technology at the Ministry of Science and Technology.

### 2-3-1-3 Biological oxygen demand (BOD)

During the collection water sample for BOD analyses, specific bottles are used. Each sample is collected in two bottles, one is transparent and the second is opaque incubator in complete darkness at 20 °C for 5 days. (Figure 2-10). Two mls of $MnSO_4$ as well as Azide $Na_3N$ were added to the transparent bottle (Figure 2-10). The BOD test takes 5 days to be completed and is performed using a dissolved oxygen test kit. The BOD level is determined by comparing the DO level of a water sample taken immediately with the DO level of water sample that has been incubated in a dark location for 5 days.

The difference between the two DO levels represents the amount of oxygen required for the decomposition of any organic material in the sample and is a good examination of the BOD level (Figure 2-10).

Figure 2-10: Water sample no. 6S for BOD measurement; Right bottle contains water sample with 2 mls of $MnSO_4$ as well as Azide $Na_3N$, whilst bottle on the left contain just the sample water.

### 2-3-1-4 Chemical oxygen demand (COD)

The measurement method of chemical oxygen demand according to the Standard Methods APHA (1996) for the Examination of Water is applied here.

### 2-3-1-5 Bacterial tests

Eleven water samples are collected in sterilized of 1L bottles. The total count test (also standard plate count and colony count) yields the aggregate number of microorganisms in a water sample. The water to be tested is first mixed with liquefied Yeast-Extract Agar and then poured into Petri dishes or gas positive tube to solidify according to the type isolation (Benson, 2001 and Tortora et al., 2004). A set of plates of bacteria are incubated for one day at 37C°. The total count test is most often used to assess the sanitation of a water distribution system or the suitability of a large water supply for food and beverage preparation. Free living algae and prozoa, bacteria colony were isolated and identified, then count by unit per ml.

Bacterial tests were measured in the Laboratory of Water Treatment's Technology at the Ministry of Science and Technology.

### 2-3-2 Analyses of sediments

The Sawa Lake sediments are collected from the lake shore. All sediment samples are dried under sun light. Thereafter, by agate mortar they are grounded quietly in the Geochemistry Laboratory at Geology Department, College of Science in order to identify the mineralogical composition. Thin section were prepared and identified at workshop of the Department of Geology (Figure 2-11). The major laboratory works can be summarized below:

**1-** XRD technique: Nine bulk sediments sample are preparein the laboratories of the Iraqi Geological Survey.

**2-** Chemical analyses: One gram of sample is sent to the laboratories center of the Iraqi Geological Survey for determining the major oxides ($SiO_2$, $Al_2O_3$, CaO, MgO, $Fe_2O_3$, $Na_2O$, $K_2O$, $SO_3$, Cl and LOI as well as heavy metals (Pb, Ni and Co).

**3-** Radiological analyses: One kilogram of sample was sent to the laboratories of the Ministry of Environment to determine the radiation level.

**4-** FTIR technique was used to detect any minerogic compound present. 0.02 gram of each sediment samples was sent to the Ministry of Industry, IBN SINA Company.

Figure 2-11: Slides preparation at the workshop in the Department of Geology.

### 2-3-2-1 Chemical analyses

Lake sediment samples are dried at 53ºC then analyzed for $SiO_2$, $Al_2O_3$, CaO, MgO, $Fe_2O_3$, $Na_2O$, $K_2O$, $SO_3$, Cl and LOI as well as heavy metals (Pb, Ni and Co).Table 2-3 list the method that has been for analyses each element.

Table 2-3: Methods of chemical analyses and laboratories that used for analyzing the sediments samples.

| **Major oxides and heavy metals** | **Methods** | **Name of laboratory** |
|---|---|---|
| $SiO_2$, L.O.I, $H_2O$ | Gravimetric | Laboratory of the Iraqi Geological Survey |
| CaO, MgO | Titration | |
| $Na_2O$, $K_2O$, $Fe_2O_3$, $Al_2O_3$, $Cl^-$, Pb, Ni, Co | Atomic absorption spectrophotometry (A.A.S) | |
| $SO_3$ | Sedimentation | |

### 2-3-2-2 Mineralogical identification

Both of XRD technique, polarized microscope and FTIR technique were used for identifying minerals. Nine Sediment samples were investigated by XRD technique. The conditions of analysis are listed in Table 2-4. Fourty five thin sections were prepared from samples and subjected to the microscope identification. Fourier Transform Infrared spectrophotometer (FTIR) was done in the Ministry of Industry and Minerals, IBN SINA State Company. Three sediment samples (7S-$t_1$, 7S-$t_2$ and 19S-t) in addition to two water samples (7S and 19S) were subjected to analyze by FTIR. Run is done in the range (4000-400) $cm^{-}1$ spectra-recorded as potassium bromide disc. The basic principle of the FTIR technique is that infrared radiation stimulates molecular vibrations and, as a consequence of the quantum mechanical behavior, this radiation is absorbed at specific wave numbers. For water samples, special cell was used for FTIR analysis. Infrared spectra are obtained using shimadzu (FT-IR)-Prestige-21.

Table 2-4: Analyses conditions of XRD.

| **X-ray** | **Slit** | **Measure** |
|---|---|---|
| Traget : Cu<br>Wave : 1.54060<br>Voltage : 40 KV<br>Current : 30 mA | Divergence slit =1.00000 deg<br>Scatter= 1.00000 deg<br>Receiving= 0.30000 (mm) | axis = Theta-2Theta<br>Scan mode= Continuous Scan<br>Scan range = 3.000 - 49.981<br>Sampling pitch = 0.0987 deg<br>speed = 10.0000 (deg/min |

### 2-3-3 Radiation measurements of water and sediments

Radiation measurements were done on ten samples in the Ministry of Environment (see Appendix-2), Radiation Protection Center. Radioactivity in 1 Kg of five sediment samples (2S-t, 6S-t, 9S-t, 13S-t, 19S-t) as well as in 1L of five water samples (2S, 6S, 9S, 13S, 19S-A) are analyzed. Physical modeling was carried out on the models by removing impurities and drying of wet samples using standard methods modeling.

The system efficiency using Gamma Spectrometer System based on high purity germanium detector with effecter 30% and resolution 2Kev at the energy line 1.33Mev energy-to peer Co-60.

## 2-4 Office work

1. General review of the literatures, previous studies and collecting geological information of the studied area are made.
2. Climatic data of the studied area from the Iraqi Meteorological Organization, Samawa Stations for the period from 1990 to 2011 is collected.
3. The geological and location map of the studied area are prepared.
4. Using computer software program for treating data and illustrating the figures. These programs are Rock ware 2008 and AquaSalchem-2012.
5. Water quality Index (WQI) program is applied in this study
6. Interpreting data

## 2-5 Accuracy

### 2-5-1 Accuracy of water samples

The analytical accuracy for all water samples is computed according to Hem, (1985) by the equation below:

$$U\% = \frac{\mathbf{rSumofcations - rSumofanions}}{\mathbf{rSumofcations + rSumofanions}} * \mathbf{100}$$

**C= 1- U**

Where:

**U** is the uncertainty (reaction error)

**C** is the certainty or Accuracy

When U ≤ 5, the result could be accepted, but if 5< U ≤ 10 the result will accepted with risk (Hem, 1989). Accuracy of water analyses appear to be within acceptable value (Table 2-5)

Table 2-5: Results of analytical accuracy of water samples

| SampleNo. | Accuracy (U) | | | |
|---|---|---|---|---|
| | Dry period | Decision | Wet period | Decision |
| 1S | 4 | Accepted | 4 | Accepted |
| 2S | 4 | Accepted | 4 | Accepted |
| 3S | 3 | Accepted | 5 | Accepted |
| 4S | 3 | Accepted | 4 | Accepted |
| 5S | 2 | Accepted | 4 | Accepted |
| 6S | 5 | Accepted | 1 | Accepted |
| 7S | 2 | Accepted | 3 | Accepted |
| 8S | 2 | Accepted | 2 | Accepted |
| 9S | 1 | Accepted | 1 | Accepted |
| 10S | 2 | Accepted | 1 | Accepted |
| 11S | 2 | Accepted | 1 | Accepted |
| 12S | 1 | Accepted | 2 | Accepted |
| 13S | 4 | Accepted | 4 | Accepted |
| 14S | 3 | Accepted | 3 | Accepted |
| 15S | 2 | Accepted | 2 | Accepted |
| 16S | 2 | Accepted | 2 | Accepted |
| 17S | 1 | Accepted | 1 | Accepted |
| 18S | 3 | Accepted | 2 | Accepted |
| 19S | 2 | Accepted | 1 | Accepted |
| 20S-A | 4 | Accepted | 3 | Accepted |
| 20S-B | 2 | Accepted | 1 | Accepted |
| 20S-C | 1 | Accepted | 2 | Accepted |
| 20S-D | 3 | Accepted | 2 | Accepted |
| 1W | not sample | ---- | 4 | Accepted |
| 2W | not sample | ---- | 3 | Accepted |
| 3W | not sample | ---- | 5 | Accepted |

## 2-5-2 Precision of sediments analysis

Precision is used in describing the agreement of a set of results among themselves. Precision is usually expressed as the deviation of a set of results from the arithmetic mean (Table 2- 6).

Standard deviation used for finding precision. The following equation shows the relative standard deviation (R.S.D) from the confidence level 63%, in this case, the precision will be acceptable to 5-15% (Stanton, 1966).

$$R.S.D\ \% = (\sigma/x)\ 100$$

The relative standard deviation (R.S.D) at confidence level of 95% could be obtained

$$R.S.D\ \% = (2\sigma/x)\ 100$$

In this case, the precision will be accepted of 25% extent (Maxwell, 1968). To be ensure that our analyses are acceptable, the sample number12S-t was chosen for analyzing three times, precision appear to be acceptable with risk (Table 2-6).

Table 2- 6: Precision results of sample number 12S-t.

| **Elements** | **Number Of Analyses** | | | **X ± σ** | **(σ /X)100** | **(2 σ /X)100** |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | | | |
| $SiO_2$ | 15.9 | 14.6 | 14.8 | 15.1±0.57 | 15.67 | 7.57 |
| $Al_2O_3$ | 3.43 | 3.38 | 4.3 | 3.7±0.42 | 4.12 | 22.81 |
| CaO | 31.6 | 32.48 | 32.2 | 32.0±0.36 | 32.46 | 2.28 |
| MgO | 3.2 | 3.03 | 3.2 | 3.14±0.08 | 3.22 | 5.09 |
| $Na_20$ | 0.46 | 0.59 | 0.68 | 0.57±0.09 | 0.66 | 31.32 |
| $K_2O$ | 0.14 | 0.12 | 0.12 | 0.12±0.009 | 0.136 | 14.88 |
| $SO_3$ | 25.51 | 26.1 | 25.84 | 25.817±0.24 | 26.05 | 1.87 |
| Cl | 0.72 | 0.66 | 0.71 | 0.69±0.02 | 0.72 | 7.53 |
| pb | 23 | 29 | 26 | 26±2.44 | 28.44 | 18.84 |
| Ni | 42 | 39 | 41 | 40.6±1.24 | 41.91 | 6.13 |
| Co | 22 | 16 | 17 | 18.33±2.62 | 20.95 | 28.63 |

**σ**= Standard deviation, **X**= average

# Chapter Three

## Hydrochemistry

# 3- Hydrochemistry

## 3-1 preface

A number of factors influence water chemistry. Rock weathering, atmospheric precipitation, evaporation and crystallization control the chemistry of surface water. The influence of geology on chemical water quality is widely recognized (Gibbs, 1970 and Langmuir, 1997). The influence of soils on water quality is very complex and can be ascribed to the processes controlling the exchange of chemicals between the soil and water (Hesterberg, 1998; APHA, 1975 and Cotruvo, 1988).

The hydrochemical study is concentrated on studying the physical, chemical and biological parameters. Physical parameters include turbidity, color, taste, temperature, electrical conductivity (EC), Total dissolved solid (TDS) and total suspended solid (TSS).

This chapter deals with 23 water sample collected from Sawa Lake during the two periods (dry and wet) in addition to three samples collected during wet period from wells that lies near the lake. All these samples were analyzed for major cations ($K^+$, $Na^+$, $Ca^{2+}$, and $Mg^{2+}$), and major anions ($CO_3^{=}$, $HCO_3^-$, $SO_4^{=}$, and $Cl^-$), minor anions ($PO_4^{3-}$ and $NO_3^-$), $H_2S$, in addition to the trace elements (Pb, Cd, Zn, As, Ni, Co, Cu, Mn, Fe, B and Sr), Radiation measurements ($^{226}Ra$, $^{137}Cs$, $^{40}K$, $^{228}Ac$, $^{232}Th$, $^{238}U$, and $^{214}Bi$), Biological tests that included dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD) and some bacteriological tests. All these parameters are investigated in the Sawa Lake water during two periods; the first represents the dry period (Octobers- 2011), whereas the second one, was the wet period (March- 2012). Here it is worthy to mention that the dissolved oxygen (DO), biological oxygen demand (BOD) and chemical oxygen demand (COD) are measured just during the wet period, whereas bacteriological tests are measured only during dry period.

## 3-2 Physical parameters

### 3-2-1 Temperature (T °C)

Temperature of the water samples was determined in situ during the sampling processes. The minimum, maximum and mean values of water temperature for both of dry and wet periods are shown in Table 3-1. Generally, the average temperature values for water samples in the study area vary between 29°C and 20°C for the dry and wet periods respectively.

Table 3-1: Physical parameter results of Sawa Lake during dry and wet periods compared with Iraqi Standards, 2009.

| Sample no. | Dry period | | | | | Wet period | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **TDS ppm** | **EC µs/cm** | **TSS ppm** | **pH** | **T ºC** | **TDS ppm** | **EC µs/cm** | **TSS ppm** | **pH** | **T ºC** |
| **1S** | 21646 | 36798 | 13 | 9.3 | 30 | 23147 | 39350 | 11 | 8.46 | 19 |
| **2S** | 21092 | 36067 | 17 | 9.6 | 28 | 22210 | 37979 | 8 | 8.43 | 22 |
| **3S** | 21918 | 37699 | 12 | 9.0 | 27 | 22152 | 38101 | 19 | 8.48 | 15 |
| **4S** | 22013 | 37202 | 13 | 9.0 | 29 | 21206 | 35838 | 15 | 8.35 | 22 |
| **5S** | 21613 | 36309 | 11 | 9.0 | 30 | 21569 | 36236 | 11 | 8.37 | 18 |
| **6S** | 22258 | 37171 | 12 | 8.5 | 30 | 22660 | 37842 | 14 | 8.42 | 17 |
| **7S** | 20838 | 35425 | 14 | 8.4 | 28 | 20763 | 35297 | 17 | 8.41 | 22 |
| **8S** | 22340 | 38201 | 10 | 8.4 | 28 | 21687 | 37085 | 10 | 8.5 | 17 |
| **9S** | 21649 | 37020 | 19 | 8.3 | 27 | 21809 | 37511 | 16 | 8.38 | 21 |
| **10S** | 21145 | 36369 | 11 | 8.3 | 29 | 23094 | 39029 | 18 | 8.35 | 19 |
| **11S** | 21047 | 35569 | 24 | 8.1 | 28 | 22549 | 37882 | 21 | 8.46 | 20 |
| **12S** | 20959 | 35631 | 14 | 8.4 | 26 | 21776 | 36366 | 12 | 8.39 | 19 |
| **13S** | 20958 | 35838 | 15 | 8.2 | 29 | 23200 | 39440 | 10 | 8.43 | 21 |
| **14S** | 21466 | 36921 | 13 | 8.3 | 28 | 22705 | 38825 | 9 | 8.45 | 22.5 |
| **15S** | 21415 | 36191 | 18 | 8.4 | 30 | 22804 | 39223 | 15 | 8.44 | 22 |
| **16S** | 21053 | 35369 | 20 | 8.3 | 30 | 21710 | 36690 | 13 | 8.48 | 20 |
| **17S** | 22578 | 37705 | 15 | 8.3 | 29 | 23021 | 38675 | 16 | 8.39 | 23 |
| **18S** | 22870 | 38879 | 18 | 8.3 | 28 | 23275 | 38869 | 10 | 8.51 | 22 |
| **19S** | 20882 | 35708 | 14 | 8.3 | 29 | 22156 | 37665 | 9 | 8.45 | 24.5 |
| **20S-A** | 21100 | 36292 | 17 | 8.3 | 29 | 22810 | 39005 | 22 | 8.36 | 16 |
| **20S-B** | 22103 | 37354 | 10 | 8.3 | 29 | 22656 | 38968 | 111 | 8.35 | 23 |
| **20S-C** | 20994 | 35060 | 17 | 8.3 | 30 | 22988 | 38849 | 14 | 8.41 | 20 |
| **20S-D** | 22182 | 37044 | 15 | 8.4 | 29 | 22523 | 38064 | 12 | 8.36 | 18 |
| **Range** | -20838 22870 | 35060-38879 | 10-24 | 8.1-9.6 | 26-30 | 20763-23275 | 35297-39440 | 8-22 | 8.3-8.5 | 15-24.5 |
| **Mean** | 21570 | 36601 | 15 | 8.5 | 29 | 22368 | 36427 | 14 | 8.4 | 20 |
| **1W** | ND | ND | ND | ND | ND | 6812 | 11581 | 5 | 8.3 | ND |
| **2W** | ND | ND | ND | ND | ND | 8498 | 14362 | 8 | 8.2 | ND |
| **3W** | ND | ND | ND | ND | ND | 7387 | 12702 | 7 | 8.1 | ND |
| **Range** | ND | ND | ND | ND | ND | 6812-8498 | 11580-14362 | 5-8 | 8.1-8.3 | ND |
| **Mean** | ND | ND | ND | ND | ND | 7566 | 12883 | 7 | 8 | ND |
| ***I.S** | 1000 | 1530 | ---- | 6.5-8.5 | ---- | 1000 | 1530 | ---- | 6.5-8.5 | ---- |

*I.S= Iraqi standard, 2009, ND= Not determined

### 3-2-2 Total Suspended Solids (TSS), color, taste and odor

Turbidity is a measure of the cloudiness of water. It may be caused by TSS. Total Suspended Solids (TSS) represents the amount of filterable solids in a water sample which can be removed from the raw water by physical or mechanical means, such as precipitation or filtration (Bartram and Ballance, 1996). The difference between TSS and TDS is that the latter one is the salts that pass through a filter.

In the study area, total suspended solids (TSS) ranges from 10 to 24 ppm with mean of 15 mg/l during dry period, whereas it ranges from 8 to 22 mg/l with mean 14 mg/l during the wet period. TSS in the well water appears to be lower than that of the lake where it ranges from 5 ppm to 8 ppm with mean of 7 ppm (Table 3-1).

The low concentration of TSS in the Sawa Lake during dry and wet periods is attributed to the low energy and low biogenic activity near the bottom. Some time, it was seen, there are local spots of turbidity. This turbidity is restricted around fish population that swims near bottom in the shallow areas.

Many reasons cause color variation such as iron and manganese oxides, decay organisms, planktons, industrial wastes (Pierce et, al., 1998). Color is measured for water samples that are devoid of turbidity, because turbidity gives color value more than actual value. Color appears to be less than 5CU (color unit) during both periods of dry and wet periods, which is expressed as normal and within the acceptable limit according to the Iraqi Standard no. 417, 2010. The acceptable limit of the standard guide line is 10 CU. Odor and taste probably come from variety of sources such as humic compounds, algae and fishes, and dissolved gases in water (Pierce et, al., 1998).These physical properties are considered important and necessary parameters to be examined. Taste of the Sawa Lake water appears to be impermissible, because this lake holds numerous salts compounds that make it very salty. In term of odor, one can detect a light odor of the smell similar to rotten eggs due to the emission of $H_2S$ as well as the exhale fish that possible to detect.

### 3-2-3 Hydrogen number (pH)

It is defined as the negative common logarithm of the concentration of hydrogen ions $[H^+]$ in moles/liter as: $pH = -\log10 [H^+]$. It is numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. Its scale commonly in use ranges from0 to 14 (Langmuir, 1997); and expresses a very important control factor for chemical reactions of solid-water-gas systems. Temperature and aqueous plants can affect the pH value, because they lead to deplete the $CO_2$ from aqueous solution (Harned and Mayer, 1985).

In the present study, pH is measured directly in the field and indicates that the water of Sawa Lake tends toward alkalinity. During the dry period, pH ranges from 8.1 to 9.5 with mean of 8.5; whereas it is recorded from8.3to 8.5 with mean of 8.4 during the wet period (Table 3-1).

Most natural fresh water has a pH close to 7.0 (neutral), and marine waters close to 8.2 (Silliman et al., 2005). The pH is affected by several factors including, temperature, the presence of calcium carbonate and plants. As the process of photosynthesis will reduce the amount of carbon dioxide which caused an increase in the pH value in the water of the study area.

### 3-2-4 Total dissolved solid (TDS)

Total dissolved solids refer to anything present in water other than the pure water molecule ($H_2O$) and suspended solids. Basically, the total dissolved solid is the sum of the cations and anions in the water. This means that the total dissolved solid (TDS) is a total of solids remaining after a water sample evaporates to dryness (Drever, 1997).

TDS is measured by the ppm or mg/l units (Boyd, 2000). The concentration of dissolved ions within natural water depended on the type of soil and rocks that are in contact with it and the period of tangency process (Hem, 1991). A simple laboratory method for determining the concentration of dissolved solids is to filter the water, evaporate the filtrate and weight the residue.

TDS under dry period conditions range between 20838 ppm to 22870 ppm with mean values 21570 ppm, and it ranges between 20763 ppm to 23275 ppm with mean values 22368 ppm in the wet period. Wells near the lake were characterized by the range from 6812 ppm to 8498 ppm with the average of 7566 ppm in the wet period (Figure 3-1).The salinity of wells is clearly less than of that of the lake.

When TDS levels exceed 1000 mg/l, it is generally considered unfit for human consumption. From Table 3-2, based on TDS, the water of Sawa Lake during the two periods can be classified as brackish according to Altoviski, 1962 and Todd, 2007, but it appears saline water according to Drever, 1997. The groundwater collected from wells adjacent the lake are slightly-brackish water.

Table 3-2: Classification of water salinity according to the TDS (ppm).

| **Altoviski (1962)** | **Drever (1997)** | **Todd (2007)** | **Water class** |
|---|---|---|---|
| 0-1000 | < 1000 | 10-1000 | Fresh water |
| 1000-3000 | 1000-2000 | ----- | Slightly water |
| 3000-10000 | 2000-20000 | 1000-10000 | Slightly-Brackish water |
| 10000-100000 | ----- | 10000-100000 | Brackish water |
| ----- | 20000-35000 | ----- | Saline water |
| >100000 | >35000 | >100000 | Brine water |

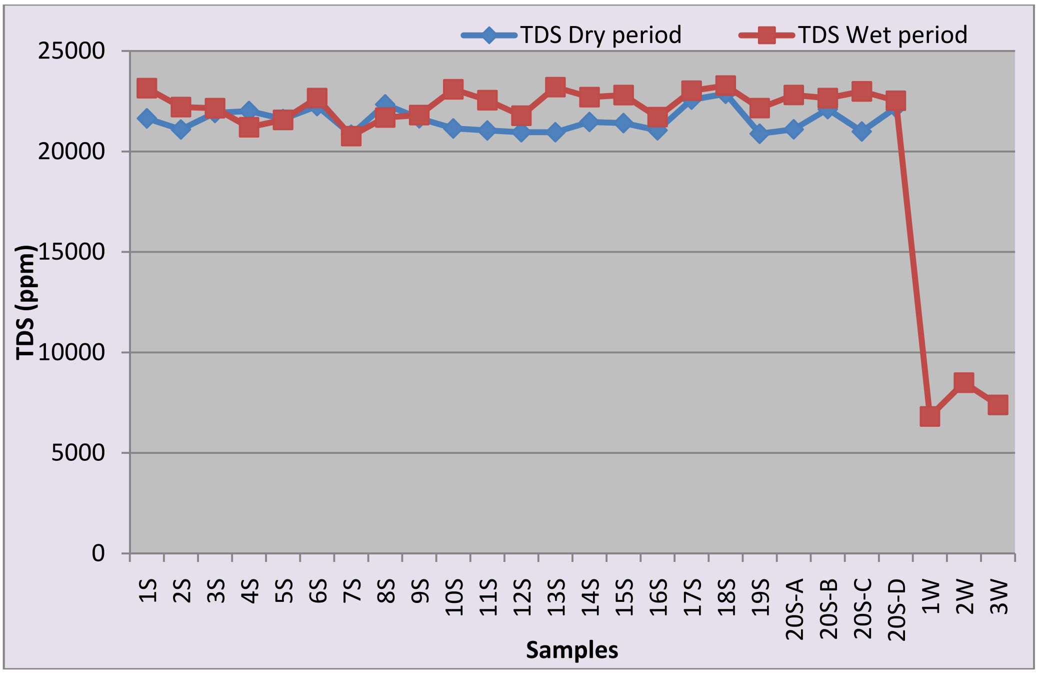

Figure 3-1: Total dissolved solid (TDS) of the Sawa Lake and wells.

### 3-2-5 Electrical conductivity (EC)

In hydrochemical studies, electrical conductivity is the ability of 1cm³ of water to pass electrical current at 25 ºC (Michaud, 1991). It is generally used as a measure of the purity of water or the concentration of ionized chemicals in water. However, it responds to all ionic content and cannot distinguish particular conductive materials in the presence of others.

In the Sawa Lake, EC during the dry period appears to range between 35060-38879 µs/cm, with 36601µs/cm in average. However it decreases and ranges from 35297 to 39440 µs/cm with 36247µs/cm in average during the wet period.

The relationship of electrical conductivity and TDS is not standardized and to be meaningful, should be specified whenever TDS units are used.

Relationship between EC and TDS tend to be linear at both periods (dry and wet respectively) (Figure 3-2).

TDS = EC * F

F = factor, ranges between 0.55 – 0.75, and the high values belong to high sulfate content in water.

TDS (mg/l) = EC (µs/cm) * 0.69 (Albu et.al., 1997).

TDS (mg/l) = EC * 0.56µs/cm (Todd, 1980 and Detay, 1997).

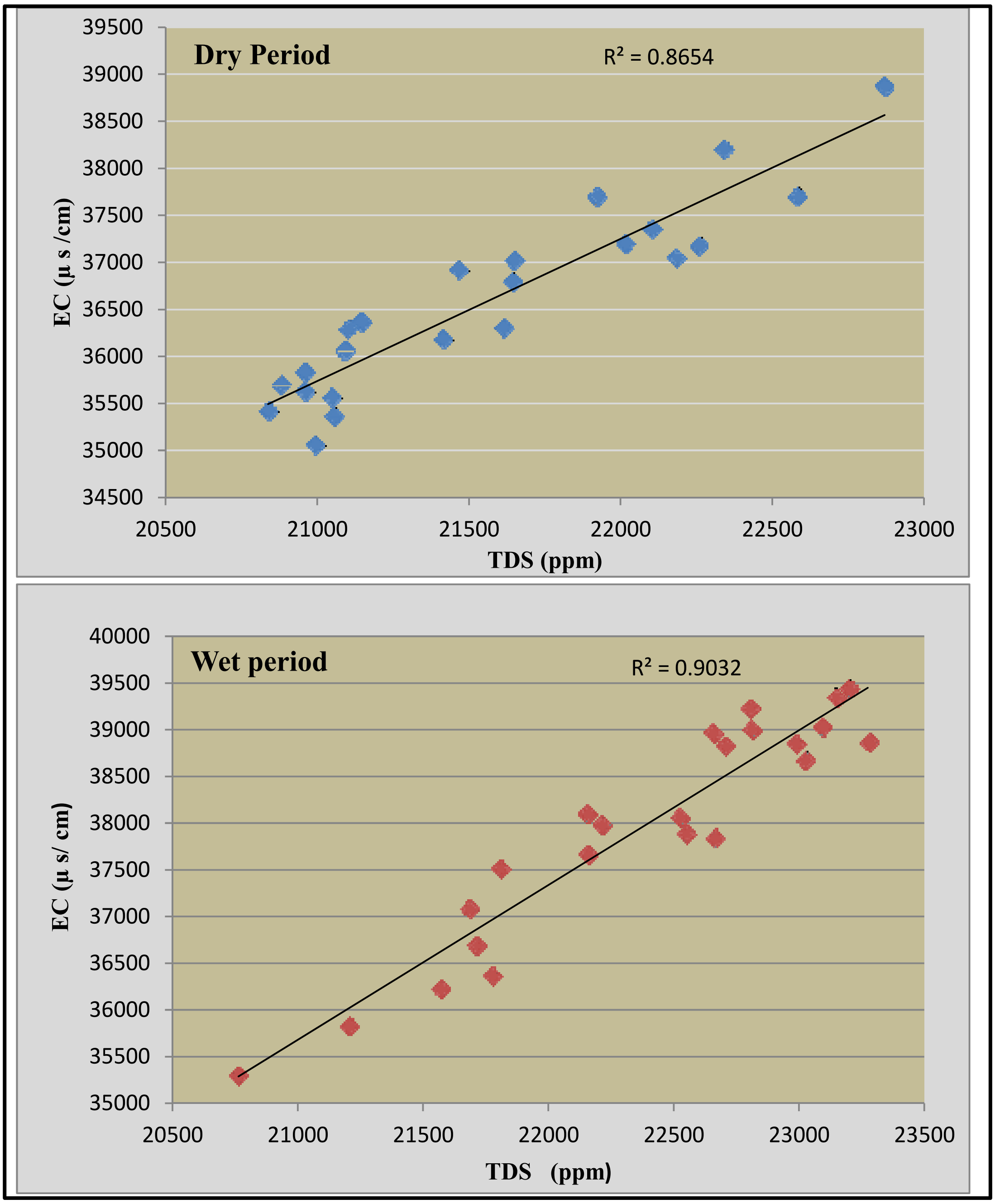

Figure 3-2: Relationship between TDS and EC in dry and wet periods.

EC is very important to know the quantity of dissolved salts in water, through which we can assess the water quality, and are also a good evidence to determine the degree of mineralization of water (Detay, 1997). In term of water mineralization, the Sawa Lake and groundwater collected from wells are excessively mineralized water (Table 3-3).

Table 3-3: Water classification based on electrical conductivity (Detay, 1997)

| EC(µc/cm) | Mineralization |
|---|---|
| <1000 | Very weakly mineralized water |
| 1000-2000 | Weakly mineralized water |
| 2000-4000 | Slightly mineralized water |
| 4000-6000 | Moderately mineralized water |
| 6000-10000 | Highly mineralized water |
| >10000 | Excessively mineralized water |

## 3-3 Chemical parameters

The chemistry of water is detected mainly by ion concentrations. Accordingly, all samples were analyzed for major cations ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$), major anions ($SO_4^{=}$, $Cl^{-}$ and $HCO_3^{-}$), minor anions ($NO_3^{-}$ and $PO_4^{3-}$) and $H_2S$.These chemical components provide good understanding of the chemistry of Sawa Lake. These components are discussed below during the dry and wet periods.

### 3-3-1 Cations

### 3-3-1-1 Calcium ion

This ion is one of the earth alkali metals which are the most abundant in nature. Generally, it is produced from chemical weathering of minerals containing plagioclase, pyroxene, amphibole, calcite, aragonite, dolomite, and fluorite**.** Calcium is dissolved from almost all soils and rocks, especially from limestone, dolomite and gypsiferous sediments (Weight and Sonderegger, 2001). One of the main reasons for the abundance of calcium in water is its natural occurrence in the earth's crust. Calcium contributes to the hardness of water and it is the fifth most common element found in most natural waters (Hem, 1985).

Rivers in lime areas may have calcium concentrations as high as 100 ppm (Enache et al., 2009).The average concentration of $Ca^{2+}$ 410 ppm in the sea water (Kladi et al., 1999).

In this study, during dry period, Ca ranges from 610 to 751 ppm with 657 ppm in mean (Table 3-4), but during wet period, it ranges from 625 to 995 ppm with 789 ppm in mean (Table 3-5). Calcium concentration of the wells water was 512 to 650 ppm with the mean 562 ppm at the same period**.** Calcium concentration of Sawa Lake is very high. In comparison with previous works, the historical change of water chemistry has almost changed where Ca was 1060 ppm 35 years ago according to Jamil (1977).This may be attributed to the mechanism of gypsum precipitation. Calcium content in Sawa Lake is higher than that of sea water.

### 3-3-1-2 Magnesium ion

Magnesium is one of the most common elements in the earth’s crust. It is present in all natural waters. It is an important contributor to water hardness. The sources of magnesium in natural water are dolomites and mafic minerals (amphibole) in rocks. The major minerals in Iraq that supply Mg to the water is dolomite. It has many different purposes and it also ends up in the environment from fertilizer application and from cattle feed (Greenwood et. al., 2002b).Such these uses cause an add on $Mg^{2+}$ at to the water.

In this study, during dry period, $Mg^{2+}$ranges from 2744 to 3623 ppm with 3121ppm in mean (Table 3-4), while during wet period, it ranges from 2592 to 3810 ppm with 3327ppm in mean (Table 3-5). $Mg^{2+}$ concentration of the water wells nearby the lake record from 943 to 1260 ppm with the average of 1130 ppm at the wet period.

Magnesium in Sawa Lake appears to be a dominant cation (Figure 3- 3) at dry and wet periods respectively. It compared with result of Jamil (1977) (1028 ppm). $Mg^{+2}$ appears to be extremely increased where 1028 ppm was before 35 years ago. Magnesium content in Sawa Lake water is higher than that of sea water (Table 3-4 and 3-5).

Table 3-4: Chemical component (ppm) of Sawa Lake during the dry period compared with Iraqi Standards, 2009.

| **Sample N0.** | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | $Cl^{-}$ | $SO_4^{=}$ | $HCO_3^{-}$ | $CO_3^{=}$ | $PO_4^{3}$ | $NO_3^{-}$ | $H_2S$ | **TH** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **ppm** | | | | | | | | | | | |
| 1S | 667 | 2854 | 1870 | 265 | 8852 | 7024 | 38 | 3 | 0 | 13 | 190 | 13369 |
| 2S | 684 | 2744 | 1862 | 283 | 8603 | 6792 | 34 | 4 | 14 | 12 | 220 | 12960 |
| 3S | 726 | 3520 | 1871 | 263 | 8607 | 6824 | 27 | 4 | 3 | 13 | 160 | 16247 |
| 4S | 674 | 3623 | 1872 | 213 | 8751 | 6778 | 28 | 3 | 0 | 11 | 190 | 16539 |
| 5S | 724 | 2991 | 1843 | 278 | 8910 | 6743 | 32 | 3 | 20 | 9 | 250 | 14073 |
| 6S | 706 | 3420 | 1861 | 328 | 8514 | 7344 | 17 | 4 | 0 | 4 | 190 | 15787 |
| 7S | 659 | 2816 | 1875 | 253 | 8826 | 6304 | 30 | 3 | 3 | 9 | 260 | 13193 |
| 8S | 703 | 3536 | 1890 | 279 | 8761 | 7066 | 34 | 2 | 0 | 9 | 150 | 16255 |
| 9S | 751 | 3328 | 1857 | 248 | 8756 | 6592 | 34 | 2 | 11 | 10 | 230 | 15522 |
| 10S | 684 | 3287 | 1867 | 220 | 8515 | 6468 | 26 | 5 | 0 | 13 | 170 | 15187 |
| 11S | 695 | 3301 | 1850 | 265 | 8250 | 6579 | 31 | 2 | 0 | 14 | 290 | 15272 |
| 12S | 724 | 2847 | 1868 | 210 | 8543 | 6652 | 34 | 3 | 6 | 12 | 103 | 13488 |
| 13S | 632 | 2788 | 1841 | 211 | 8514 | 6864 | 31 | 4 | 0 | 13 | 170 | 13011 |
| 14S | 652 | 2945 | 1865 | 273 | 9153 | 6452 | 29 | 7 | 19 | 11 | 220 | 13704 |
| 15S | 647 | 2956 | 1878 | 213 | 8714 | 6872 | 23 | 5 | 35 | 12 | 160 | 13737 |
| 16S | 638 | 2845 | 1896 | 260 | 8519 | 6765 | 30 | 4 | 24 | 12 | 260 | 13259 |
| 17S | 654 | 3288 | 1902 | 235 | 9620 | 6752 | 25 | 7 | 23 | 12 | 190 | 15116 |
| 18S | 640 | 3214 | 1824 | 202 | 9052 | 7814 | 21 | 7 | 24 | 12 | 220 | 14777 |
| 19S | 650 | 3284 | 1874 | 219 | 8422 | 6304 | 32 | 4 | 19 | 14 | 220 | 15089 |
| 20S-A | 610 | 2808 | 1845 | 208 | 8621 | 6876 | 34 | 5 | 18 | 15 | ND | 13038 |
| 20S-B | 639 | 3108 | 1869 | 215 | 9180 | 6952 | 32 | 10 | 23 | 15 | ND | 14340 |
| 20S-C | 651 | 3261 | 1894 | 272 | 8517 | 6272 | 24 | 7 | 24 | 12 | ND | 14997 |
| 20S-D | 725 | 3024 | 1887 | 220 | 9052 | 7088 | 76 | 7 | 29 | 14 | ND | 14211 |
| Range | 610-751 | 2744-3623 | 1824-1902 | 202-328 | 8250-9620 | 6272-7814 | 17-76 | 2-10 | 0-35 | 4-15 | 103-290 | 12960-16539 |
| Mean | 657 | 3121 | 1868 | 245 | 8750 | 6790 | 31 | 5 | 13 | 12 | 202 | 14485 |
| *I.S | 150 | 100 | 200 | ---- | 350 | 400 | ---- | ---- | 0.4 | 50 | ---- | 500 |
| **Sea water | 400 | 1350 | 10500 | 380 | 19000 | 2600 | 142 | ---- | ---- | ---- | ---- | ---- |

** Edmund (2009); *I.S= Iraqi standard, 2009; ND= Not determined

Table 3-5: Chemical component of Sawa Lake during the wet period compared with Iraqi standards, 2009.

| Sample no. | $Ca^{+2}$ | $Mg^{+2}$ | $Na^{+}$ | $K^{+}$ | $SO_4^{=}$ | $Cl^{-}$ | $HCO_3^{-}$ | $CO_3^{=}$ | $PO_4^{=}$ | $NO^{3-}$ | $H_2S$ | TH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ppm | | | | | | | | | | | |
| 1S | 743 | 3084 | 1923 | 293 | 6952 | 9904 | 129 | 45 | 21 | 53 | 137 | 14502 |
| 2S | 625 | 3024 | 1894 | 284 | 6592 | 9431 | 207 | 36 | 5 | 112 | 168 | 13961 |
| 3S | 688 | 2856 | 1889 | 275 | 6536 | 9573 | 214 | 2 | 8 | 111 | 193 | 13430 |
| 4S | 896 | 2592 | 1893 | 260 | 6219 | 8862 | 299 | 48 | 25 | 112 | 137 | 12867 |
| 5S | 995 | 2592 | 1882 | 222 | 6234 | 9189 | 286 | 48 | 25 | 96 | 237 | 13115 |
| 6S | 978 | 3421 | 1871 | 287 | 6299 | 9230 | 381 | 48 | 23 | 122 | 198 | 16471 |
| 7S | 895 | 2598 | 1898 | 268 | 6184 | 8545 | 205 | 54 | 14 | 102 | 268 | 12889 |
| 8S | 816 | 3336 | 1894 | 258 | 6498 | 8585 | 159 | 30 | 8 | 103 | 198 | 15718 |
| 9S | 883 | 3228 | 1876 | 273 | 6496 | 8629 | 272 | 48 | 17 | 87 | 263 | 15442 |
| 10S | 864 | 3300 | 1812 | 215 | 6816 | 9608 | 309 | 63 | 16 | 91 | 237 | 15690 |
| 11S | 725 | 3264 | 1891 | 212 | 6392 | 9585 | 313 | 48 | 17 | 102 | 203 | 15195 |
| 12S | 726 | 3408 | 1895 | 262 | 6752 | 8363 | 211 | 54 | 8 | 97 | 168 | 15788 |
| 13S | 924 | 3780 | 1882 | 212 | 6800 | 9140 | 256 | 68 | 38 | 100 | 168 | 17808 |
| 14S | 843 | 3696 | 1803 | 214 | 6064 | 9650 | 253 | 81 | 15 | 86 | 228 | 17261 |
| 15S | 698 | 3624 | 1898 | 212 | 6872 | 9007 | 321 | 66 | 13 | 93 | 188 | 16603 |
| 16S | 750 | 3380 | 1883 | 242 | 6280 | 8650 | 364 | 51 | 13 | 97 | 172 | 15733 |
| 17S | 625 | 3696 | 1897 | 246 | 6298 | 9818 | 253 | 87 | 15 | 86 | 107 | 16716 |
| 18S | 857 | 3672 | 1905 | 235 | 6848 | 9236 | 340 | 72 | 15 | 95 | 128 | 17198 |
| 19S | 786 | 3614 | 1862 | 213 | 6376 | 8783 | 371 | 54 | 11 | 86 | 237 | 16782 |
| 20S-A | 685 | 3810 | 1897 | 248 | 6176 | 9540 | 303 | 60 | 5 | 86 | ND | 17333 |
| 20S-B | 689 | 3588 | 1893 | 278 | 6436 | 9219 | 391 | 54 | 22 | 86 | ND | 16433 |
| 20S-C | 724 | 3760 | 1836 | 214 | 6588 | 9418 | 291 | 54 | 7 | 96 | ND | 17226 |
| 20S-D | 728 | 3208 | 1892 | 214 | 6250 | 9618 | 409 | 99 | 9 | 96 | ND | 14973 |
| Range | -625<br>995 | -2592<br>3810 | -1803<br>1923 | -212<br>293 | -6064<br>6952 | 8363-<br>9904 | 129-409 | 2-99 | 5-38 | 53-872 | -107<br>268 | -12867<br>17808 |
| Mean | 789 | 3327 | 1881 | 215 | 6476 | 9199 | 284 | 55 | 15 | 95 | 191 | 15614 |
| 1W | 525 | 943 | 438 | 20 | 3314 | 1109 | 342 | 6 | 8 | 77 | ND | 5179 |
| 2W | 650 | 1260 | 401 | 19 | 3295 | 2223 | 403 | 5 | 8 | 204 | ND | 6791 |
| 3W | 512 | 1187 | 408 | 18 | 3165 | 1709 | 226 | 3 | 17 | 212 | ND | 6147 |
| Range | 512-<br>650 | 943-<br>1260 | 408-<br>438 | 18-20 | 3165-<br>3314 | 1109-<br>2223 | 226-403 | 3-6 | 8-17 | 77-212 | ND | 5179-<br>6791 |
| Mean | 526 | 1130 | 302 | 19 | 3258 | 1680 | 323 | 5 | 302 | 164 | ND | 6039 |
| *I.S | 150 | 100 | 200 | ---- | 400 | 350 | ---- | ---- | 0.4 | 50 | ---- | 500 |
| **Sea water | 400 | 1350 | 10500 | 380 | 2600 | 19000 | 142 | ---- | ---- | ---- | ---- | ---- |

** Edmund (2009); *I.S= Iraqi standard, 2009; ND= Not determined

### 3-3-1- 3 Sodium ion

The characteristic cation in sea water is the sodium ion ($Na^{+}$). Sodium ion is one of the most reactive metals present in nature. Alkali feldspar is the main source of this element, and is also found in evaporation minerals such as halite and rock salt. The rain water is believed to be enriched in sodium ions, as resultant particles from the evaporation of seawater (Lengmuir, 1997). Sodium adsorbed on fine sediment in case of high evaporation. Na concentrations are more than 100 000 mg/l in brine which are in contact with salt bed (Hanil and Bell, 1986).

During dry period, $Na^+$ ranges from 1824 to 1902 ppm with 1868 ppm in mean (Table 3-4).The highest concentration of sodium in the water lake because of the high salinity and evaporation in study area.

During wet period, $Na^+$ ranges from 1803 to1923 ppm with 1881 ppm in mean (Table 3-5). The concentration in the water wells close to the lake was from 308 to 438 with the mean of 302 ppm at the wet period. Sodium occupies the second order after $Mg^{2+}$. The distribution patterns for the dry and wet periods are presented in Figure 3-3. Sodium values in comparison with result of Jamil (1977) (3220 ppm), it decreased from 3220 to 1881 ppm. Sodium content in the lake is lower than $Na^+$ content in sea water (Table 3-4 and 3-5).

### 3-3-1-4 Potassium ion

Although the abundance of potassium in the earth's crust is about the same as that of sodium, potassium is commonly less than one tenth the concentration of sodium in natural water. Like sodium, potassium is high soluble, therefore it is not easily removed from water except by ion exchange (Hamil and Bell, 1986). Potassium in water comes from many sources. It originates from weathering of many minerals like orthoclase, mica and feldspathoid. Also it commonly exists within structure of clay minerals like illite or occurs adsorbed on surface of fine grain clay minerals. Sylvite (KCl) is the main mineral of potassium which often formed as evaporated mineral (Hem, 1991).

In the present study, during dry period, potassium ranges from 202 to 328 ppm with 245 ppm in mean (Table 3-4).During wet period, it ranges from 212 to 293 ppm with 215 ppm in mean (Table 3-5). Figure 3-3 displays the distribution patterns of cations during dry and wet periods respectively. Potassium concentration of the water wells nearby Sawa Lake at the wet period was ranges from 18 to 20 ppm with19 ppm mean. Potassium concentration of Sawa Lake is high and it increases double, compared with result of Jamil (1977) which was 122 ppm. Potassium content in Sawa Lake is lower than that in Sea water (Table 3-4 and 3-5).

All cations ($K^+$, $Na^+$ and $Ca^{2+}$) display a smooth pattern along Sawa Lake, except $Mg^{2+}$ which displays a zigzag pattern. This reflects the $Mg^{2+}$heterogenity. The behavior of $Mg^{2+}$ is due to the dynamic of dissolution and precipitation of dolomite (Figure 3-3).

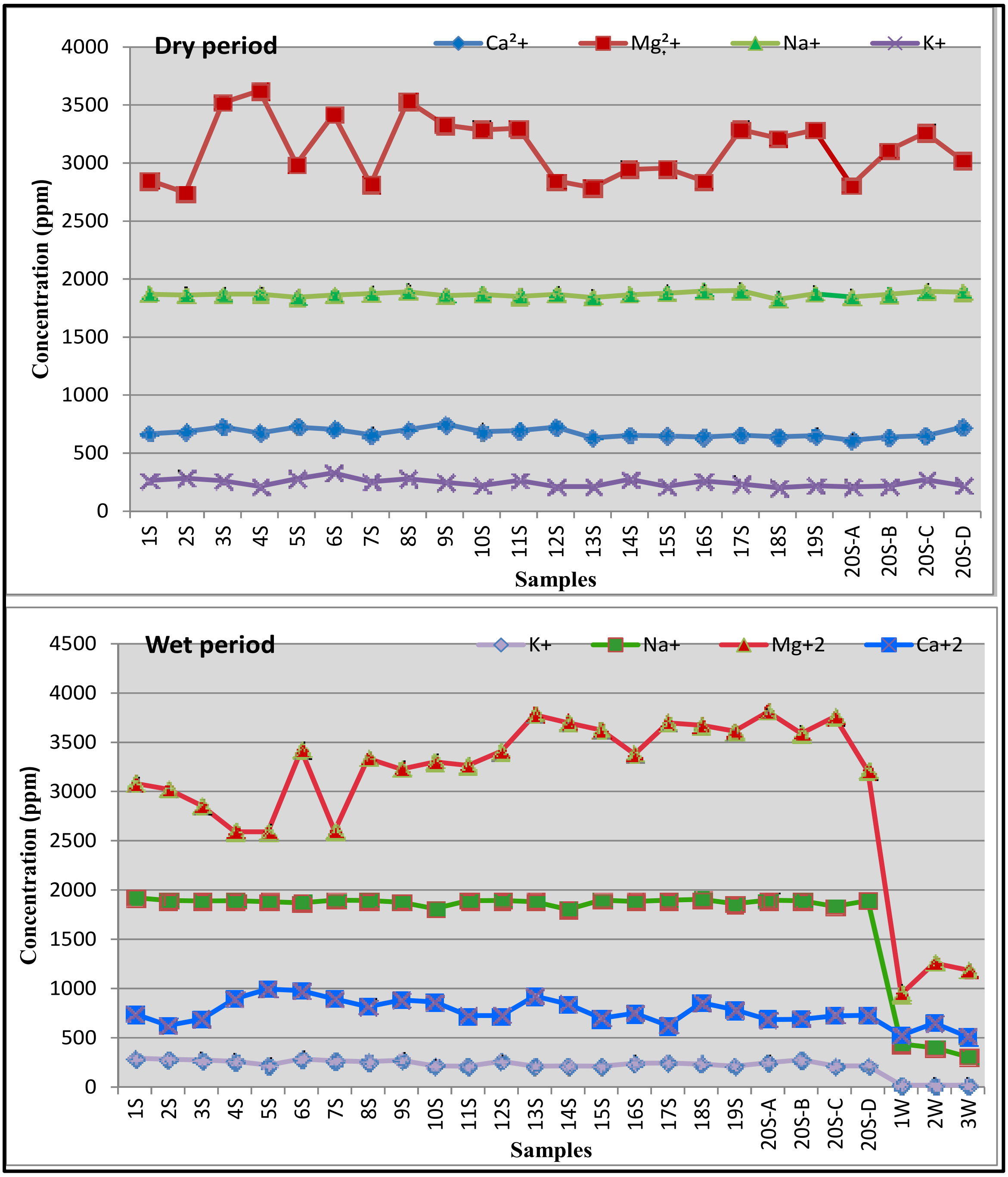

Figure 3- 3: Cations distribution pattern of the Sawa Lake and wells water during the dry and wet periods.

### 3-3-1 -5 Total hardness (TH)

This factor is computed as measurement of the Ca and Mg ions in the water as mg/l or ppm, and it is usually expressed as the equivalent of $CaCO_3$ (Faure, 1998). It can be calculated by using the following formula:

$TH=2.5\ Ca+4.1\ Mg$

Total Hardness is an essential factor for studying water quality. Most important sources are the existence of limestone, dolomite, gypsum, and anhydrite in the formation beneath the lake.

During dry period, the total hardness ranges from 12960 ppm to 16539 ppm with 14485 ppm in mean (Table 3-4). This refers to very hard water. During wet period, the total hardness ranges from 12867 ppm to17808 ppm with 15614 ppm in mean (Table 3-5), as well as, the total hardness concentration of three water wells in this area at the same period ranges from 5179 ppm to 6791 ppm with 6039 ppm as average. The result of total hardness shows that the water of the lake are very hard (Todd, 1980) (Table 3-6).

Table 3-6: Different water classes according to their total hardness (After Todd, 1980).

| Total hardness mg/l | Water class |
|---|---|
| 0-75 | Soft |
| 75-150 | Moderate hard |
| 150-300 | Hard |
| Over 300 | Very hard |

### 3-3-2 Major Anions

Chloride, sulfate, bicarbonate and carbonate are analyzed; their results are presented as follows:

#### 3-3-2-1 Chloride

The Chloride content in the groundwater is due to the presence of soluble chlorides from rocks, saline, intrusions, connate and juvenile waters, and/or contamination by industrial effluence or domestic sewages. Chloride is a minor constituent in the earth's crust. Halite is one of the principal minerals sources. Its presence in large amounts may be due to natural processes such as the indication of pollution from sea water intrusion, industrial or domestic waste. Potable water should not exceed 250 ppm of chloride (WHO, 2004).

Air masses containing NaCl particles may move to inlands and drop out salt by mechanism other than by washing out in rainfall (Hem, 1991). $Cl^-$ added during water treatment for drinking purposes (WHO, 1996), and sewage and industrial effluents (WHO, 2004)

In this study, during dry period, it ranges from 8250 to 9620 ppm with 8750 ppm in mean (Table 3-4).During wet period, it ranges from 8363 to 9904 ppm with 9199 ppm in mrean(Table 3-5). Its concentration in water wells during the wet period was ranged from 1109 to 2223 ppm with mean

1680 ppm. Chloride in Sawa Lake is predominant among anions at two periods (Figure 3-4). Chloride was highly increased since 35 years ago, where it was 5148 ppm according the result of Jamil (1977). Chloride content in Sawa Lake is lower than the seawater (Table 3-4).

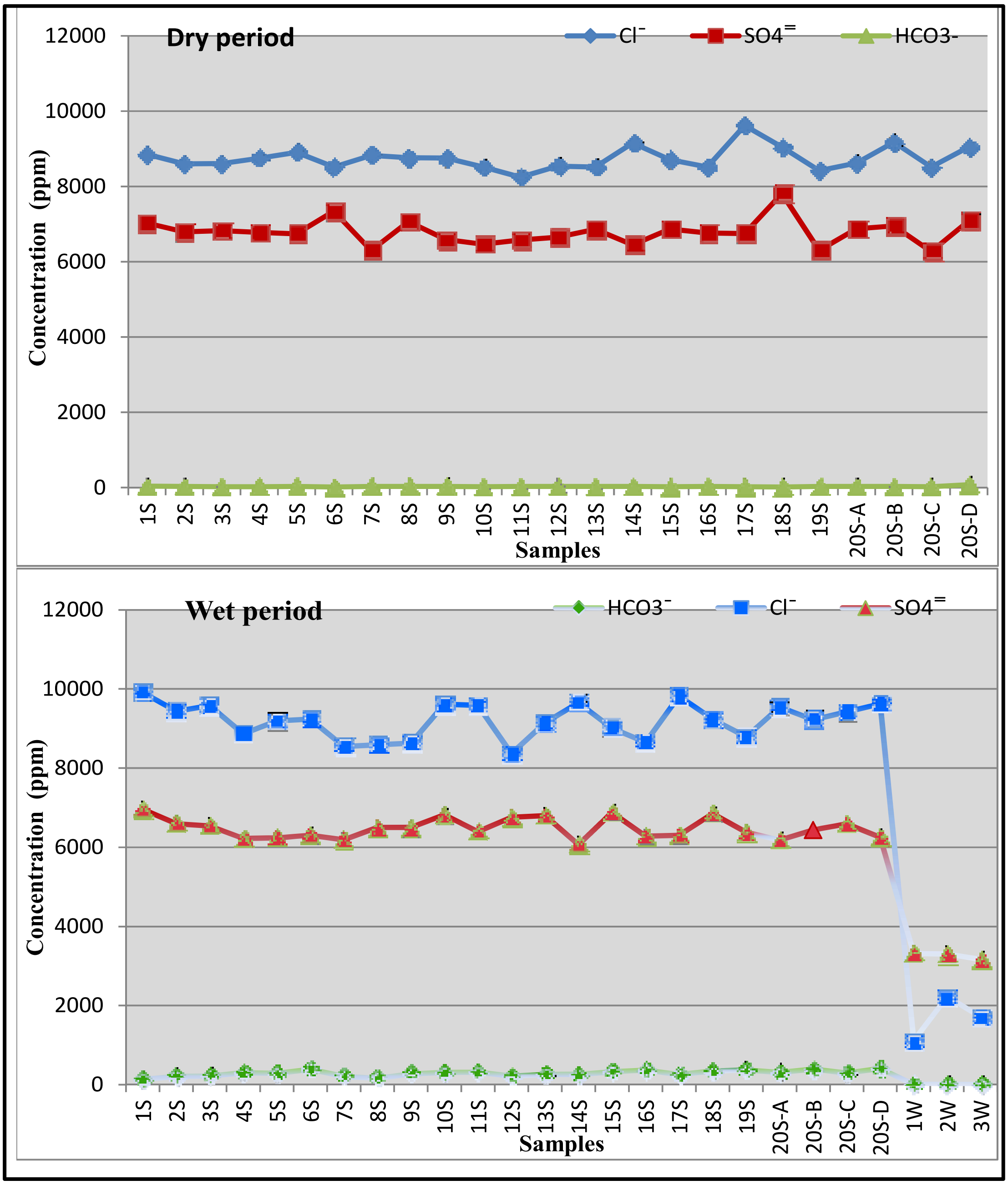

Figure 3-4: Anions distribution pattern of the Sawa Lake and wells water during dry and wet periods; S=Sawa Lake, W= wells

### 3-3-2-2 Sulfate

Sulphate occurs in water as the inorganic sulphate salts. It is not anxious substance, although high sulphate in water may have a laxative effect (Obiefuna and Sheriff, 2011). Sulfate in groundwater interacts with Ca to form sulfate salt (NASD, 2001).

The mean concentration of sulfate in the Sawa Lake in dry period is measured as 6790 ppm and ranging from 6272 to 7814 ppm (Table 3-4). During the wet period, sulfate ranges from 6064 to 6952 ppm with 6476 ppm in mean (Table 3-5). Sulfate concentration of Sawa Lake is dominating as major anions after chloride. It shows a very high value and close and slightly increases in comparison with result of Jamil (1977) which was 6432 ppm. The most extensive important sources of sulfate are evaporites (gypsum and anhydrite) found in the study area within the Rus Formation. Sulfate concentration in the water wells ranges from 3165 to 3314 ppm with 3258 ppm in average. Sulphate content in Sawa Lake is higher than its concentration in sea water.

Ions (Na, Mg, Ca, Cl, and $HCO_3$) in the wet period appear to be higher than the dry period, whilst the ions (K, and $SO_4$) in wet period tend to be lower than of dry period. This reflects the dissolution of limestone and dolomite from Euphrates, Dammam, and Umm Er Radhuma Formations which feed the lake during the wet period. Sulfate was less than during wet period due to the relative dissolution of gypsum and anhydrite originated mainly from Rus Formation. (Figure 3-5).

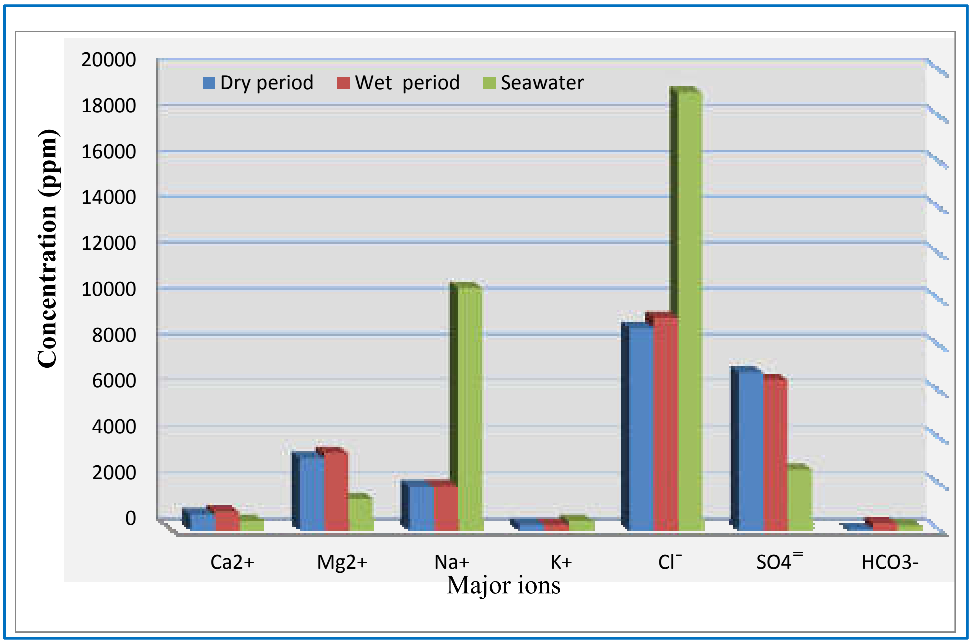

Figure 3-5: Bar shape for the major ions of Sawa Lake and sea water during the dry and wet periods

### 3-3-2-3 Bicarbonate

Carbonate ($CO_3$) is found in some waters at high pH (>8.0), while total alkalinity is a measure of carbonates, bicarbonates and hydroxyl dissolved in rivers and groundwater, (Hassan, 2007) At normal pH levels alkalinity is primarily in the form of bicarbonate. The source of bicarbonate ions in groundwater is from the dissolution of carbonate rocks and from carbonate species present when the pH of the water is usually between 5 and 7 (Taylor, 1958).

In this study, during dry period, bicarbonate ranges from 17 to 76 ppm with 31 ppm in mean (Table 3-4), whereas during wet period, it ranges from 129 to 409 ppm with a mean 248 ppm (Table 3-5). There is high variation in carbonate concentration between the dry and wet periods. Bicarbonate concentration in Sawa Lake during dry period is low, but, it appears concordant with the result of Jamil (1977) that was 120 ppm**.** Bicarbonate concentration in the water wells at the wet period ranges between 226 – 403 ppm with average 323 ppm.

### 3-3-3 Minor anions

Nitrate and phosphate are analyzed:-

### 3-3-3-1 Phosphate ion

The apatite mineral groups are the main source that contains Phosphorus in the earth crust forming a ratio of 0.12%. Sediments contain a quantity of phosphate more than its presence in surface water and groundwater (Boyd, 2000). Phosphates are rocks having chemical compounds that contain phosphorus. As water runs over and through rocks, it carries off small amounts of elements such as calcium, and phosphates.

During dry period, it ranges from nil to 35 ppm with 13 ppm in mean (Table 3-4), whilst during wet period, it ranges between 5-38 ppm with of 15ppm (Table 3-5). Phosphate concentration in the water wells shows a range of 8 to 17 ppm with mean 11ppm.

Organic phosphates are a plant nutrient and are taken in by plants with water and incorporated in to organic phosphate compounds. The organophosphate is important for plants; it means that the presence of organism obtain their essential phosphorus from phosphates in water and plant material. Small fishes are seen in Sawa Lake, this actually consumed part of phosphate causing $PO_4^{3-}$ depletion. However, $PO_4^{3-}$ appears high. The main sources of phosphate pollution are run-off from land, sewage effluence, detergents and effects of aquatic life (Hutak, 2000).

### 3-3-3-2 Nitrate ( $NO_3^-$)

Nitrate originates from many sources such as agricultural activities especially fertilizers, animal wastes, plant remains, industrial and sewage disposal (Hem, 1985). Most of the Nitrogen in groundwater is derived from the biosphere. Nitrate ion is derived from the oxidation of decaying organic material, particularly that with high protein content (Kelly, 1997). Rodvang and Simpking (2001) explained that the concentration of nitrates in an area that do not contain plants is higher than that of the area covered by plants this is due to the use of nitrate by the plants.

In the present study, during dry period, it ranges from 4 to 15 ppm with 12 ppm in mean (Table 3-4). During wet period, Nitrate ranges from 53 to 872 ppm with 95 ppm in mean (Table 3-5). Nitrate concentration in water wells at the wet period was ranged from 77 to 212 ppm, with mean 164 ppm.

### 3-3-3-3 $H_2S$

This gas arises from sulfate reduction by bacterial action. Significant concentrations of $H_2S$ gas in all springs along the Abu-Jir Fault Zone. $H_2S$ gas was found to be 600 ppm as average for the 12 springs dissolved in the spring waters along the Abu-Jir fault Zone (Awadh et al., 2013).

During dry period, $H_2S$ value ranges from 103 to 268 ppm with 191 ppm as average (Table 3-4). During wet period, $H_2S$ gas ranges from103 ppm to 290 ppm with 202 ppm in mean (Table 3-5).

### 3-3-4 Trace elements

The Sawa Lake water was analyzed for trace elements (Zn, Pb, Cu, Cd, Ni, Co, As, Mn, Fe, Sr and B). Each element is described below:

### 3-3-4-1 Zinc (Zn)

Concentration of free zinc ion usually is low because the controlling minerals have low solubility within the pH range of most natural waters (Boyd, 2000).The most important sources are sphalerite and smithsonite (Rose et al., 1981). The zinc precipitates when pH value is in between 7-9 from of zinc sulfide (ZnS), when the sulfur deposits were found (Drever, 1997). Zinc is available in the earth crust in ratio of 75 ppm, in granite rocks 52ppm, sandstone 30 ppm, limestone 20 ppm and shale 120 ppm. The metallic element is present abundantly in natural resources, soil, sediments, etc, and also discharges from municipal and industrial waste water treatment plant (CGWB and CPCB, 2000). Zinc is very essential requirement for healthy body and growth of human and plants, and potentially most dangerous for the biosphere (Romic and Romic, 2003). The concentration of Zn in surface waters is between 10-250 ppb and in groundwater 8.9 ppb (Crompton, 1997).

In this study, during dry period, Zn ranges from 0.02 to 0.2 ppm with 0.09 ppm in mean (Table 3-7), but during wet period, it ranges from 0.02 to 0.16 ppm with 0.08 ppm in mean. Zinc concentration in the well water ranges from 0.02 ppm to 0.03 ppm with the mean 0.026 ppm (Table 3-8). Zn content is in Sawa Lake is higher than its content in sea water (0.01ppm).

Table 3-7: Trace elements concentration in the Sawa Lake during the dry period compared with Iraqi standards, 2009.

| Sample NO. | Zn | pb | Cu | Cd | Ni | Co | As | Fe | Mn | Sr | B |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ppm | | | | | | | | | | |
| **1s** | 0.10 | 0.37 | 0.09 | 0.04 | 0.42 | 0.18 | 0.79 | 1.43 | 0.87 | 39.5 | 137 |
| **2S** | 0.06 | 1.46 | 0.09 | 0.15 | 0.39 | BDL | 0.85 | 0.76 | 0.15 | 40.7 | 104 |
| **3S** | 0.08 | 0.67 | 0.06 | 0.10 | 0.57 | BDL | 0.81 | 0.66 | 0.13 | 40.3 | 150 |
| **4S** | 0.06 | 0.71 | 0.12 | 0.09 | 0.10 | BDL | 0.81 | 0.61 | 0.14 | 39.3 | 154 |
| **5S** | 0.03 | 0.83 | 0.06 | 0.12 | 0.36 | BDL | 0.79 | 0.50 | 0.1 | 41. 9 | 150 |
| **6S** | 0.2 | 2.78 | 0.6 | 0.36 | 0.28 | BDL | 0.79 | 0.80 | 0.28 | 40.7 | 150 |
| **7S\2** | 0.11 | BDL | 0.08 | 0.12 | 0.6 | BDL | 0.80 | 0.69 | 0.1 | 40.7 | 162 |
| **8S** | 0.13 | 0.42 | 0.09 | 0.09 | 0.66 | BDL | 0.85 | 0.38 | 0.1 | 40.7 | 192 |
| **9S** | 0.13 | 1.67 | 0.09 | 0.09 | 0.48 | BDL | 0.86 | 0.38 | 0.14 | 42.3 | 200 |
| **10S** | 0.13 | 2.82 | 0.04 | 0.12 | 0.34 | 0.15 | 0.81 | 0.2 | 0.06 | 39.1 | 158 |
| **11S** | 0.12 | 0.57 | 0.04 | 0.11 | 0.28 | BDL | 0.82 | 0.41 | 0.11 | 38.3 | 183 |
| **12S** | 0.09 | 1.20 | 0.1 | 0.10 | 0.13 | 0.01 | 0.82 | 0.79 | 0.07 | 39.1 | 92 |
| **13S** | 0.02 | 1.51 | 0.09 | 0.10 | BDL | 0.13 | 0.81 | 0.7 | 0.14 | 42.7 | 200 |
| **14S** | 0.11 | 1.35 | 0.1 | 0.12 | 0.15 | 0.16 | 0.83 | 0.42 | 0.09 | 39.1 | 154 |
| **15S** | 0.05 | 1.85 | 0.11 | 0.05 | 0.48 | 0.23 | 0.8 | 0.02 | 0.07 | 42.7 | 108 |
| **16S** | 0.14 | 0.41 | 0.06 | 0.08 | 0.3 | 0.31 | 0.83 | 0.23 | 0.13 | 40.7 | 150 |
| **17S** | 0.09 | 2.26 | 0.07 | 0.08 | 0.12 | 0.17 | 0.82 | 1.2 | 0.10 | 40.7 | 179 |
| **18S** | 0.10 | 0.2 | 0.08 | 0.04 | 0.27 | 0.01 | 0.87 | 0.62 | 0.1 | 39.9 | 121 |
| **19S** | 0.12 | 3.11 | 0.05 | 0.11 | 0.16 | 0.01 | 0.84 | 0.51 | 0.1 | 41. 9 | 342 |
| **20S-A** | 0.08 | BDL | 0.06 | 0.08 | 0.26 | 0.33 | 0.79 | 0.82 | 0.06 | 39.1 | 225 |
| **20S-B** | 0.02 | 1.01 | 0.11 | 0.08 | 0.50 | 0.07 | 0.83 | 0.66 | 0.04 | 40.7 | 196 |
| **20S-C** | 0.09 | 1.58 | 0.11 | 0.18 | 0.11 | 0.05 | 0.83 | 0.51 | 0.06 | 39.9 | 175 |
| **20S- D** | 0.11 | BDL | 0.08 | 0.09 | 0.04 | 0.08 | 0.82 | 1.11 | 0.04 | 39.5 | 167 |
| **Range** | 0.02-0.2 | BDL - 3.11 | 0.04-0.6 | 0.04-0.36 | BDL-0.66 | BDL-0.33 | 0.79-0.87 | 0.02-1.43 | 0.04-0.87 | 38.3-43 | 92-342 |
| **Mean** | 0.09 | 1.16 | 0.12 | 0.10 | 0.30 | 0.09 | 0.82 | 0.62 | 0.13 | 37 | 167 |
| *I.S | 3 | 0.01 | 1 | 0.003 | 0.02 | 0.05 | 0.01 | 0.3 | 0.1 | ---- | 5.0 |
| ****Seawater** | 0.01 | 0.00003 | 0.003 | 0.00011 | 0.0054 | 0.00027 | 0.003 | 0.01 | 0.002 | 8 | 4.4*** |

** Edmund (2009); ***Turekian (1968); *I.S= Iraqi Standard, 2009;
BDL= below detection limit(detection limit= 0.001)

Table 3-8: Trace elements concentration in the Sawa Lake and ground water during the wet period compared with Iraqi standards, 2009.

| Sample no. | Zn | pb | Cu | Cd | Ni | Co | Fe | Mn |
|---|---|---|---|---|---|---|---|---|
| | ppm | | | | | | | |
| 1S | 0.16 | 3.05 | 0.1 | 0.19 | 0.83 | 0.67 | 0.62 | 0.24 |
| 2S | 0.09 | 0.33 | 0.07 | 0.17 | 0.9 | 0.34 | 0.33 | 0.1 |
| 3S | 0.06 | 2.25 | 0.11 | 0.13 | 1.03 | 0.45 | 0.59 | 0.13 |
| 4S | 0.14 | 1.49 | 0.08 | 0.1 | 0.7 | 0.5 | 0.35 | 0.04 |
| 5S | 0.07 | 1.83 | 0.12 | 0.08 | 0.69 | 0.21 | 0.56 | 0.02 |
| 6S | 0.07 | 1.86 | 0.12 | 0.12 | 0.68 | 0.22 | 0.29 | 0.01 |
| 7S | 0.14 | 2.38 | 0.09 | 0.14 | 0.58 | 0.54 | 0.44 | 0.07 |
| 8S | 0.07 | 1.66 | 0.03 | 0.15 | 0.62 | 0.2 | 0.51 | BDL |
| 9S | 0.07 | 0.53 | 0.06 | 0.14 | 0.84 | 0.14 | 0.4 | 0.12 |
| 10S | 0.14 | 2.7 | 0.12 | 0.12 | 0.72 | 0.39 | 0.6 | 0.03 |
| 11S | 0.08 | 1.36 | 0.15 | 0.13 | 0.59 | 0.38 | 0.55 | 0.12 |
| 12S | 0.07 | 1.83 | 0.01 | 0.15 | 0.67 | 0.48 | 0.63 | 0.07 |
| 13S | 0.09 | 0.00 | BDL | 0.11 | 0.5 | 0.18 | 0.44 | BDL |
| 14S | 0.08 | 0.46 | 0.08 | 0.12 | 1.16 | 0.16 | 0.4 | BDL |
| 15S | 0.08 | 2.05 | 0.09 | 0.12 | 0.9 | 0.42 | 0.51 | 0.02 |
| 16S | 0.08 | 0.02 | 0.06 | 0.13 | 0.59 | 0.27 | 0.64 | BDL |
| 17S | 0.06 | BDL | 0.06 | 0.14 | 0.53 | 0.37 | 0.63 | 0.05 |
| 18S | 0.06 | 0.31 | 0.04 | 0.15 | 0.6 | 0.39 | 0.49 | 0.11 |
| 19S | 0.07 | 3.5 | 0.09 | 0.16 | 0.61 | 0.38 | 0.15 | 0.07 |
| 20S-A | 0.04 | 2.04 | 0.1 | 0.16 | 0.59 | 0.26 | 0.55 | 0.09 |
| 20S-B | 0.08 | 0.21 | 0.09 | 0.15 | 0.86 | 0.24 | 0.39 | 0.12 |
| 20S-C | 0.02 | 2.7 | 0.06 | 0.16 | 0.67 | 0.33 | 0.48 | 0.03 |
| 20S-D | 0.03 | BDL | 0.08 | 0.19 | 0.8 | 0.23 | 0.44 | 0.09 |
| Range | 0.02-0.16 | 0.00-3.5 | BDL-0.1 | 0.08-0.19 | 0.5-1.16 | 0.14-0.67 | 0.15-0.64 | BDL-0.24 |
| **Mean** | 0.08 | 1.2 | 0.06 | 0.12 | 0.72 | 0.33 | 0.44 | 0.06 |
| 1W | 0.03 | BDL | BDL | 0.06 | 0.29 | 0.16 | 0.11 | 0.02 |
| 2W | 0.03 | BDL | BDL | 0.04 | 0.04 | 0.009 | BDL | 0.03 |
| 3W | 0.02 | BDL | BDL | 0.03 | 0.34 | 0.07 | 0.39 | BDL |
| Range | 0.02-0.03 | BDL | BDL | 0.03-0.06 | 0.04-0.34 | 0.009-0.16 | BDL-0.39 | BDL-0.03 |
| **Mean** | 0.026 | BDL | BDL | 0.04 | 0.22 | 0.08 | 0.2 | 0.01 |
| *I.S | 3 | 0.01 | 1 | 0.003 | 0.02 | 0.05 | 0.3 | 0.1 |
| ****Seawater** | 0.01 | 0.00003 | 0.003 | 0.00011 | 0.0054 | 0.00027 | 0.01 | 0.002 |

** Edmund (2009); *I.S= Iraqi standards, 2009; BDL= below detection limit (detection limit= 0.001)

## 3-3-4-2 Lead (Pb)

Naturally lead originates from its minerals such as galena (PbS), anglesite ($PbSO_4$) and cerussite ($PbCO_3$) (Rose et al., 1981). The added fertilizers to the agricultural soil also supply a considerable amount of Pb to the soil that eventually drains to the water. Iraqi fertilizers contain Pb as TSP

(52 ppm), MAP (42 ppm), (NP 38ppm), and NPK (38 ppm) (Al-Qaraghuli, 2005).

The major man made source of lead in the environment is emissions from the combustion of leaded gasoline. Lead (in the form of tetraethyl lead {$Pb(CH_2CH_3)_4$} is added to gasoline to allow engines to run at higher compression.

During dry period, lead ranges from below detection limit to 3 ppm with 1.1 ppm in average (Table 3-7), but during wet period, it ranges from below detection limit to 3.5 ppm with 1.2 ppm in average (Table 3-8). Agricultural land around the lake and the use of fertilizers, possibly dust storms that may carry some thing as well as environmental pollution antenna. The high concentration of Pb in the Sawa Lake water gives a proof of high level lead contamination in the area. Pb content is higher than its concentration in sea water (0.00003 ppm).

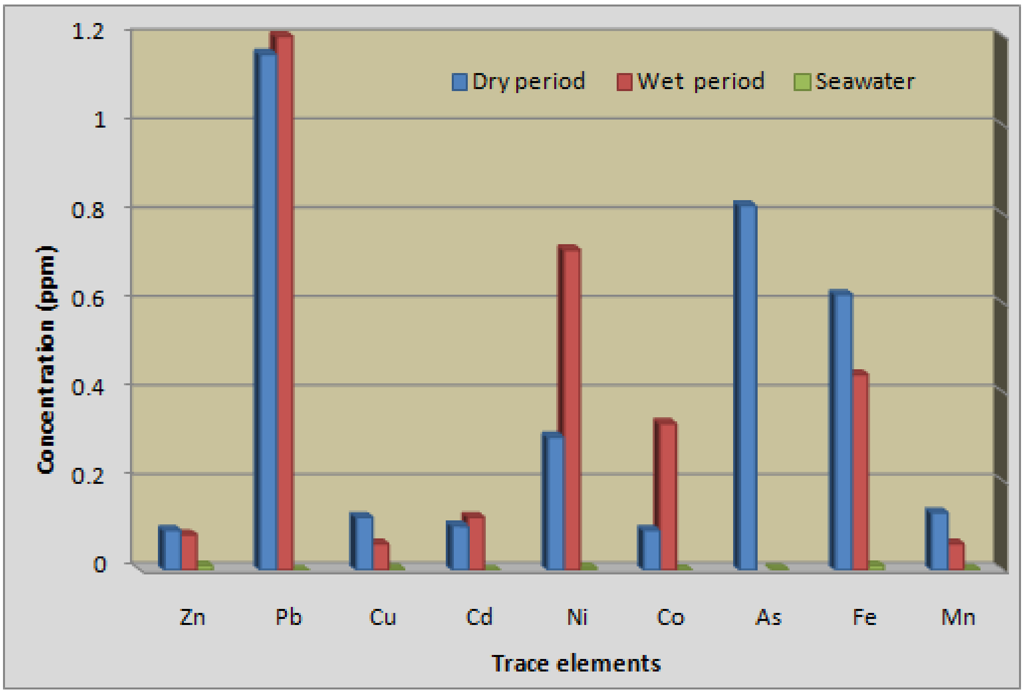

Figure 3-6: Concentrations of trace elements for the dry, wet periods and sea water

### 3-3-4-3 Copper (Cu)

The dominant copper minerals are both oxide and sulfides such as chalcocite, chalcopyrite and cuprite. Also it occurs as sulfate like azurite and malachite. Copper distributes in the earth crust heterogeneously with average content of about 50 ppm, may be existed as native element (Rankama and Sahama, 1950). In acidic oxidized environment, Cu has high mobility (Hem, 1985).

The added fertilizers to the agricultural soil also supplies a considerable amount of Cu; Iraqi fertilizers contain Cu as TSP (32 ppm), MAP (32ppm), NP (17 ppm), and NPK (14 ppm) (Al-Qaraqhuli, 2005).

During dry period, Copper ranges from 0.04 to 0.6 with 0.12 ppm in mean (Table 3-7), but in wet period was decreased; it ranges from below detection limit to 0.1 ppm with 0.06 ppm in mean. The concentration of Cu in the well water close to the Sawa Lake was below detection limit (Table 3-8). Cu content in Sawa Lake is higher than that in sea water (0.003 ppm).

### 3-3-4-4 Cadmium (Cd)

In the nature, cadmium originate from weather Cd-minerals like cadmoselite, clays also can liberates Cd because they contain about of 19 ppm adsorbed Cd (Rankama and Sahama, 1950). Cd is soluble in oxidizing acidic environments, but in reducing environments. It forms complexes with organic matter or present in the sphalerite and Cu ores as CdS (Hem, 1991).

Cadmium is released to the environment in waste water and diffuse pollution is caused by contamination from fertilizers and local air pollution (WHO, 2006). It occurs naturally in close association with zinc. Consequently, whenever zinc is released into the environmental (such as from the corrosion of galvanized objects) a small amounts of cadmium is released as well. Small amounts of cadmium are present in phosphate fertilizers, so some cadmium is released into the environment whenever these fertilizers are used. Small amounts of cadmium are present in tobacco, and for a habitual smoker this can represent the major source of cadmium intake. Cadmium sulphide (CdS) is yellow and is used as a pigment (cadmium yellow). Cadmium tends to become concentrated in sewage sludge and in areas where cadmium levels are high this sludge cannot be used as a fertilizer. Most cadmium in the environment is in the form of dissolved $Cd^{2+}$or insoluble cadium (II) compounds. Cadmium ions are readily precipitated from natural waters containing carbonate ions as:

$$Cd^{2+}_{(aq)} + CO_3^{2+}{}_{(aq)} \rightarrow CdCO_{3(s)}$$

On the other hand, Cd will pass into solution if cadmium carbonate comes into contact with acidic solutions (such as soft water) as:

$$CdCO_{3(s)} + 2H^{+}_{(aq)} \rightarrow Cd^{2+}_{(aq)} + CO_{2(aq)} + H_2O$$

Excessive amount more than 10 ppm in drinking and irrigation waters will be toxic (Prasad, 2008). The added fertilizers to the agricultural soil also supplies a considerable amount of Cd. Iraqi fertilizers contain Cd as TSP (21 ppm), MAP (27ppm), NP (11 ppm), and NPK (8 ppm) (Al-Qaraqhuli,2005).

During dry period, Cd ranges from 0.04 to 0.36 ppm with 0.10 ppm in average (Table 3-7), but during the wet period was increased and it ranges from 0.08 ppm to 0.19 ppm with 0.12 ppm in average (Table 3-8). The concentration of Cd at three water wells close to the lake ranges from 0.03 ppm to 0.06 ppm with the average 0.04 ppm. Cd in Sawa Lake is higher than that in sea water (0.00011 ppm).

### 3-3-4-5 Nickel (Ni)

Many types of igneous rocks are contained Ni. The main mineral of nickel is pentlandite. The average content of this element is 80 ppm in the earth crust (Rankama and Sahama, 1950).

The predominate form in natural waters is Ni and it forms soluble hydroxides, nickel is distinguished by high ability to adsorption, nickel carbonate may be the controlling species (Boyd, 2000).Nickel occurs in acidic oxidation environment (Drever, 1997). It enters groundwater and surface waters from erosion and dissolution of rocks and soils, as well as from biological cycles, industrial processes, and waste disposal. The added fertilizers to the agricultural soil also supply a considerable amount of Ni. Iraqi fertilizers contain Ni as TSP (88 ppm), CAP (85ppm), NP (50ppm), and NPK (48 ppm) (Al-Qaraghuli, 2005).

In this study, during dry period, Ni ranges between below detection limit to 0.66 ppm with 0.3 ppm in mean (Table 3-7), but during wet period, it ranges from 0.5 to 1.16 ppm with 0.72 ppm in mean. Nickel in the wells water ranges from 0.04 to 0.34 ppm with the mean of 0.22 ppm (Table 3-8). Ni content in Sawa Lake is higher its concentration in the sea water (0.0054 ppm).

### 3-3-4-6 Cobalt (Co)

Cobaltite is the main mineral of cobalt which mainly occurs within igneous rocks. The bulk of Co is incorporated in silicate minerals being concealed in their structure. If no sulfide minerals are present, the silicates carry all the cobalt of the rock. Cobalt does not form hydrosilicates during the weathering. It remains in the weathering solutions as bicarbonate or colloidal hydroxide. The weathering of the earth crust rocks may yields 19 ppm Co, Cobalt is similar to Ni and could be adsorbed on Fe and Mn nodules (Rankama and Sahama, 1950). Cobalt is a toxic element when exceed the permissive limit in drinking water (Parsad, 2008).

The added fertilizers to the agricultural soil also supply a considerable amount of Co. Iraqi fertilizers contain Co as TSP (2o ppm), MAP (16ppm), NP (10 ppm), and NPK (10 ppm) (Al-Qaraghuli, 2005).

In this study, during dry period, Cobalt ranges from below detection limit to 0.33 ppm with 0.09 ppm in mean (Table 3-7), but during wet period, it ranges from 0.14 to 0.6 ppm with mean 0.33 ppm. Cobalt in well water ranged from 0.009 ppm to 0.16 ppm with the mean 0.08 ppm (Table 3-8). Co in Sawa Lake is higher than the sea water (0.00027 ppm).

### 3-3-4-7 Arsenic (As)

Arsenic is found in the earth's crust at an average level of 2 ppm. Most natural soils contain low levels of arsenic, but industrial wastes and pesticide applications may increase concentrations. Background concentrations in soil range from 1 to 40 ppm, with a mean value of 5 ppm (ATSDR, 1993).

The amount of As sorbed from solution increases as the free iron oxide, magnesium oxide, aluminum oxide or clay content of the soil increases. Under reducing conditions, arsenite dominates in soil (Haswell et al., 1985). The surfaces of aluminum oxides/hydroxides and clay may play a role in arsenic adsorption.

In this study, during dry period, Arsenic ranges from 0.79 to 0.87 ppm with 0.82 ppm in mean (Table 3-7). Arsenic in Sawa Lake is higher than its content in sea water (0.003 ppm).

### 3-3-4-8 Iron and manganese (Fe and Mn)

Iron is a very common element found in many of the rocks and soils of the earth's crust. It is also an essential trace element for animal growth. Soluble ferrous iron is present in natural water with a low Eh. Water from some thermal stratified lakes maybe devoid of oxygen and thus contains ferrous iron. When such water becomes oxygenated, the ferrous iron oxidizes to ferric iron and precipitate well-oxygenated surface waters normally contain no dissolve iron. In some cases, iron is found where ground water containing ferrous iron is discharging into a lake through spring (Obiefuna and Sheriff, 2011).

Iron and manganese ions both are commonly found in water and are essential elements required in small amounts by all living organisms. Concentrations of iron and manganese in groundwater are often higher than those measured in surface waters. The most common sources of iron and manganese in ground water are naturally occurring, for example from weathering of iron and manganese bearing minerals and rocks. Iron ions are formed as dissolved ferrous ion, ($Fe^{+2}$) in natural water and hot springs under reductive conditions; where it transforms to ferric Ions ($Fe^{+3}$) under oxidizing conditions (Boyd, 2000).

Iron tends to be immobile in oxidized reduced and alkaline environments, but in acidic environment it appears to be mobile. The added fertilizers to the agricultural soil also supply a considerable amount of iron. Iraqi fertilizers contain Fe as TSP (0.32 ppm), MAP (0.34 ppm), NP (0.32ppm), and NPK (0.18 ppm) (Al-Qaraghuli, 2005).

Manganese is available in the biotitie and hornblende minerals. However, human activities are also responsible for much of the manganese contamination in groundwater in some areas (EPA, 2004).

In this study, during dry period, Fe ranges from 0.02 to 1.43 ppm with 0.62 ppm in average (Table 3-7), but during wet period, it ranges from 0.15 to 0.64 ppm with 0.44 ppm in average, Iron in wells water ranged from below detection limit to 0.39 ppm with the average 0.2 ppm (Table 3-8). Iron shows high concentration in Sawa Lake water among other heavy metals.

During dry period, Mn ranges from 0.04 to 0.87 ppm with 0.13 ppm in mean (Table 3-6), but during the wet period decreases and it ranges from below detection limit to 0.24 ppm with 0.06 ppm in mean. The concentration of Mn at three water wells adjacent the lake ranges from below detection limit to 0.03 ppm with the mean 0.01 ppm. Manganese and Iron contents are higher than that in sea level (0.002 ppm) and (0.01 ppm) respectively.

### 3-3-4-9 Strontium (Sr)

Carbonate rocks and natural waters exhibit a wide range in the concentration composition of strontium, it comprises about 0.03% of the earth' crust (Fleischer, 1962). Strontium is only a micro constituent in most terrestrial animals, but several species of marine animals contain considerable quantities of strontium in their skeletons (Odum, 1951). It may be reach a concentration of 60 ppm during seawater evaporation, and then most of it precipitates with calcium sulfate. The amount of sulfate in the water influences the amount of strontium that remains in solution. Carbonate sediments contain up to 1200 ppm of strontium; and secondary gypsum, up to 1100 ppm. Seawater contains about 8 ppm of strontium (Goldschmidt, 1958).

The strontium ion like calcium ion chemically and replaces it in the lattice of some minerals. Strontium concentration in the water depends on the ion exchange process with mud's limestone and associates water Oilfield water. The average concentration of this ion in the groundwater ranges between 2-10 ppm (Hem, 1989). The waters of the study area are rich with this ion.

In this study, during dry period, Sr ranges from 38.3 to 42.7 ppm with 37 ppm in mean (Table 3-6). This element may be reflects the mixing with deep water source. A high concentration of Sr concentration was detected in Sawa Lake that could be evidence for deep source water associated with hydrocarbons. Strontium content in Sawa Lake is higher than that in the sea water (8 ppm) (Figure 3-7).

### 3-3-4-10 Boron (B)

Tourmaline and soluble borates are the source of B which is may be produced by weathering and these are aqueous species source of B (Rose et al., 1981). Its existence is accompanied with the increase of chloride and sodium concentration (Hem, 1991). At a low level of concentration, boron is a necessary nutrient form lost plants; at a somewhat higher level of availability in the soil it is generally toxic (Rose et al., 1981). Boron toxicity occurs mainly in dry areas, especially in alkaline soils (Bradford, 1966; Marschner, 1986; Leyshon and Jame, 1993). Boron is often found in high concentrations in association with salinity problems (Keren and Bingham, 1985; Holloway and Alston, 1992; Adcock et al., 2007). If boron is less than 0.7 ppm it is not harmful for plant. If it occurs between 0.7 ppm and 3 ppm it will be moderately harmful; but it becomes highly harmful when exist in more than 3 ppm. Even in concentrations as low as 1-2 mg/l. Boron can cause leaf burn and is poisonous to most ornamental plants. Plants are more sensitive to boron than turf grass, which can usually tolerate boron levels as high as 10 ppm. The average of boron rates in ground water in Karbala-Najaf localities with time is 3 mg/l and this average is more than the average of boron in sediment filtration of the same localities (2.6 mg /l) (Al-Dabbas and Al-Jumili, 2005).

During the dry period, boron (B) ranges from 92 to 342 ppm with mean of 167 ppm (Table 3-7). Boron in sea water is 4.5 Turekian (1968). The concentration of B in Sawa Lake is very high and about 37.5 times more than in sea water (Figure 3-8).

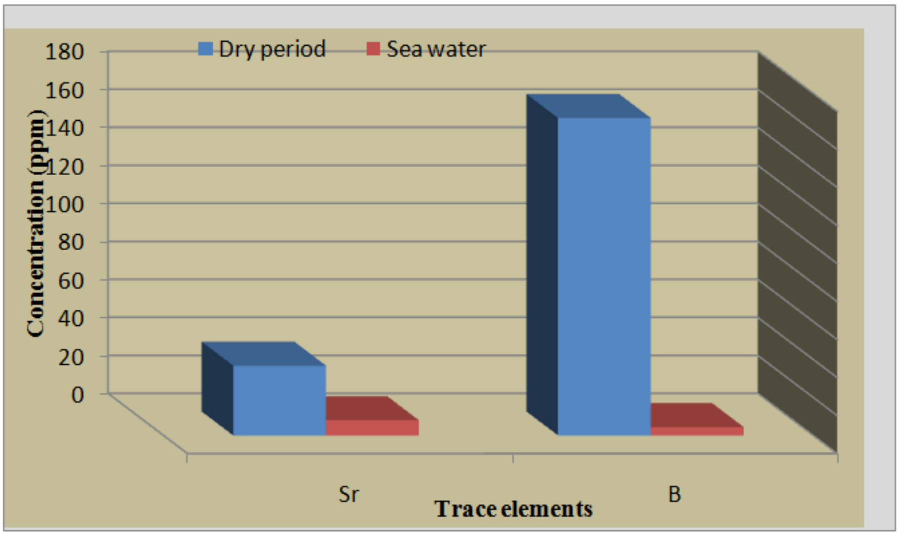

Figure 3-7: Concentrations of Strontium and boron for the dry period and sea water

## 3-4 Biological tests

### 3-4-1 Bacteriological tests

It is necessary to test the lake water in terms of bacteriological tests periodically for the purpose of management and protection. The most important tests Fecal coliform and Escherichia coli (E. coli); these are signs of water pollution animal and human feces.

In present study, during dry period, a total of eleven water samples collected from Sawa Lake, samples (1S, 2S, 3S, 4S, 5S, 7S, 8S, 12S, 13S, 14S and 15S) were analyzed for bacterial tests include aerobic bacteria (colony/ml), free living algae and priozoa (MPN/100ml), Faecal Streptococcus (MPN/100ml). Sawa Lake doesn't contain colon bacteria, *streptococci* and anaerobic bacteria *clostridium perfrgene* (Table 3-9), because the lake is isolated and far from biogenic activities. There is rising in numbers of aerobic bacterial colonies with decrease or missing for probable total numbers of facultative anaerobic bacteria such as Ecoli, *streptococci*, *clostridium perfrgenen* ssp. These species may don't have the adaptation mechanism for chemical and physical conditions of the lake such as BOD, COD, DO., because these species are killed with increased of oxygen concentration also their osmotic pressure impact by salts concentration of the lake water. On the hand, note that distribution of aerobic bacteria have adaptation mechanism to tolerant salts and oxygen especially when they species are linked to the salt (Lonores et al., 1999; Greenwood, 2002a).

Heterogeneous distribution of flagellated diatom in the Sawa Lake water, they are ranging between 19 and 600 colony/ml, as for the Ciliophora was found in the sample no. 15 (Table 3-9). The negative result for molds and yeast because most of them saprophytic nutrition live on consume organic compounds that are not existed in sufficient quantities especially when COD increases in salty water. Also, they impact the osmosis of the cell that swell on and die (Bass et al., 2007 and Moore et al., 2011).

In respect to algae, freeing protozoa in the Sawa Lake water were existed in all samples this might be belong to include these organism an unique adaption mechanism such as possess contractile vacuole that regulate inside environment of microorganism (Lonores et al., 1999).

Table 3-9: Result of biological test of the Sawa Lake water during dry period. Negative = pathogen doesn't found it in the samples

| Sample No. | **Total number for aerobic bacteria (colony/ml)** | **Free living algae and Prozoa** | **Colon bacteria** | ***Streptococcus*** | **Anaerobic bacteria *Clostridiumsperfrge nen*** | **Yeast and molds** |
|---|---|---|---|---|---|---|
| **1S** | 19 | Free living flagellated diatom | Negative | | | |
| **2S** | 600 | Free living protozoa | Negative | | | |
| **3S** | 26 | Free living flagellated diatom | Negative | | | |
| **4S** | 350 | Free living flagellated diatom | Negative | | | |
| **5S** | 225 | Free living flagellated diatom | Negative | | | |
| **7S** | 150 | Free living flagellated diatom | Negative | | | |
| **8S** | 550 | Free living flagellated diatom | Negative | | | |
| **12S** | 300 | Free living flagellated diatom | Negative | | | |
| **13S** | 90 | Free living flagellated diatom | Negative | | | |
| **14S** | 105 | Free living protozoa , diatoms , ciliophora | Negative | | | |
| **15S** | 66 | Ciliophora , diatoms | Negative | | | |
| **Range** | 19- 600 | ---- | ---- | | | |
| **Ava.** | 226 | ---- | **----** | | | |

## 3-4-2 Dissolved Oxygen (DO)

Dissolved oxygen is defined as the measure of water quality indicating free oxygen dissolved in water. The quantity of dissolved oxygen in water is typically expressed in ppm or mg/l. Since oxygen is soluble in water, the amount of dissolved oxygen in water is in the state of dynamic equilibrium. The solubility of the dissolved oxygen is proportional to the temperature and pressure of the water, therefore the concentration of dissolved oxygen in water is affected by many factors including ambient temperature, atmospheric pressure, and ion activity (Michael, 2006)

Sources of DO in water include atmospheric aeration and photosynthetic activities of aquatic plants. Many chemical and biological actions in ground water and surface water depend directly or indirectly on the amount of available oxygen. It is necessary in aquatic systems for the survival and growth of many aquatic organisms and is used as an indicator of the health of surface-water bodies (Michael, 2006). Maintaining the proper concentration of dissolved oxygen in the aeration basin is necessary to keep microorganisms alive and allow break down of organic waste. These microorganisms turn organic wastes into inorganic by products; specifically, $CO_2$, water and sludge (Michael, 2006).

During wet period, dissolved oxygen (DO) ranges from 7.8 to10 ppm with 8 ppm in average (Table 3-10). Dissolved oxygen during this period appears to be suitable for living organism. There is negative relationship between DO and temperature (Figure3-8).The decrease of DO value in some sites in Sawa Lake belongs to the density of organism which consumes the DO for their living activities.

Table 3-10: Dissolved oxygen, biological oxygen demand and chemical oxygen demand in the Sawa Lake, during wet period.

| **Sample no.** | **DO** | **BOD** | **COD** | **Quality**** |
|---|---|---|---|---|
| | **ppm** | | | |
| **3 S** | 10 | 4.6 | 7 | Critical |
| **6 S** | 8.2 | 6 | 11 | Critical |
| **9 S** | 9 | 4.8 | 9 | Critical |
| **14 S** | 7.8 | 5.7 | 10.4 | Critical |
| **19 S** | 8.7 | 5 | 9.7 | Critical |
| **Range** | 7.8 -10 | 4.6 - 6 | 7-11 | ---- |
| **Average** | 8 | 5.2 | 9.4 | Critical |
| ***I.S** | >5 | >5 | >5 | ---- |

*I.S : Iraqi standard No. 417, 1996, Quality**; Pandey et al., 2005

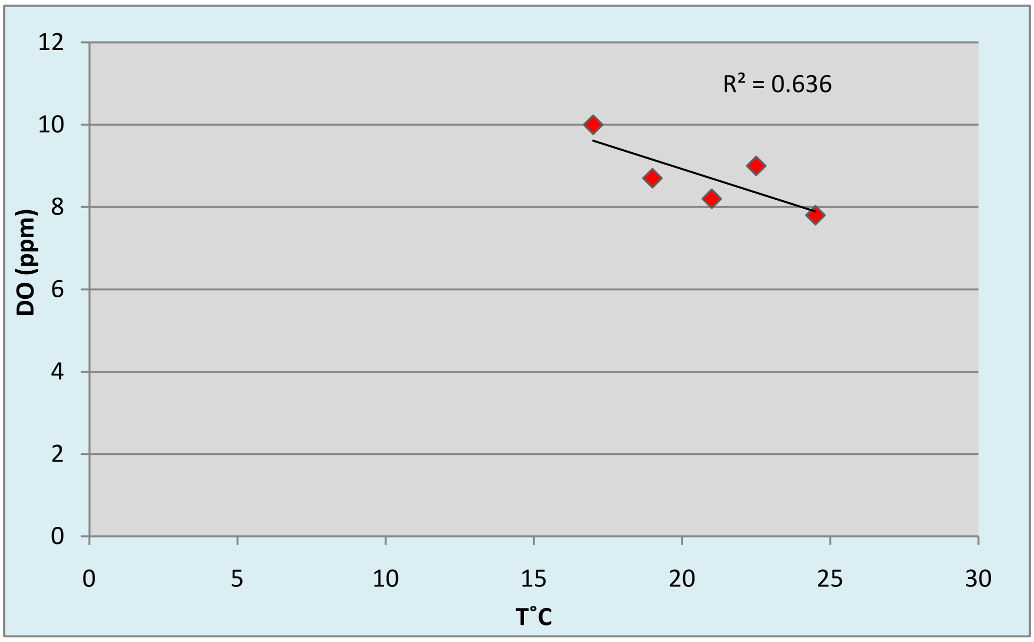

Figure 3-8: Relationship between dissolved oxygen (DO) and temperature (T) at wet period.

### 3-4-3 Biological oxygen demand (BOD)

Biological oxygen demand is defined as the change in the concentration of dissolved oxygen when a sample is incubated in the dark at 20 °C for five days. Microorganisms such as bacteria are responsible for decomposing organic waste. When organic matter such as dead plants, leaves, grass sewage, or even food waste is present in a water supply, the bacteria will begin the process of breaking down this waste. When this happens, much of the available dissolved oxygen is consumed by aerobic bacteria, robbing other aquatic organisms of the oxygen they need to live upon. Biological Oxygen Demand (BOD) is a measure of the oxygen used by microorganisms to decompose these wastes. If there is a large quantity of organic waste in the water supply, there will also be a lot of bacteria present working to decompose this waste. In this case, the demand for oxygen will be high (due to all the bacteria), so the BOD level will be high. As the waste is consumed or dispersed through the water, BOD levels will begin to decline.

When BOD levels are high, dissolved oxygen (DO) levels decrease because the oxygen that is available in the water is being consumed by the bacteria. Since less dissolved oxygen is available in the water, fish and other aquatic organisms may not survive.

Water contains 1-2 mg/l BOD representing very good quality water indicating that not much organic waste present in the water supply. Water contains 3-5 mg/l BOD represent fair or moderately clean. Water contains 6-9 mg/l BOD represents poor water. Water contains 10 mg/l or more BOD represent very poor according to Iraqi Standard No. 417, 1996(Table 3-10). The pollution index according to Pandey, et al,( 2005) is listed in Table 3-11.

During wet period, BOD ranges from 4.5 ppm to 6.4 ppm with 5.2ppm in average. This result indicates that the Sawa Lake is of critical BOD position. Organic matter is oxidized to $CO_2$ and $H_2O$ by organism; this causes a decrease in the amount of DO. BOD in Sawa Lake appears to be indicating a heterogeneous distribution pattern of organism in this lake. DO decreases with increase BOD indicating strong negative relationship (Figure 3-9).

Table 3-11: Pollution Index of water quality (Pandey et al., 2005).

| Water type | $BOD_5$(ppm) |
|---|---|
| Very clean | <1 |
| Clean | 2 |
| May be clean | 3 |
| Critical | 5 |
| Polluted | >10 |

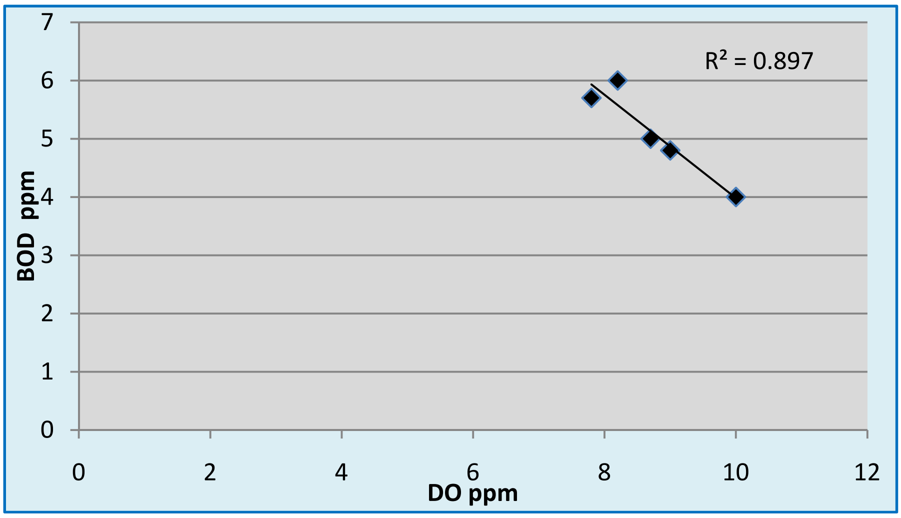

Figure 3-9: Relationship between dissolved oxygen (DO) and Biological oxygen demand (BOD) during wet period.

### 3-4-4 Chemical oxygen demand (COD)

This test is the measure of amount of $O_2$ needed to oxidize organic and non-organic materials found in water. The measurements of COD are often higher than the biological oxygen demand due to the oxidization taking place (Abawi and Hassan, 1990).

During wet period, COD ranges from 7 ppm to 11 ppm in the Sawa Lake with 9.4 ppm in mean (Table 3-10). COD in Sawa Lake appears to be heterogeneous indicating the distribution pattern of organism in this lake. The COD appears to be concordant with BOD and they have positive relationship (Figure 3-10).

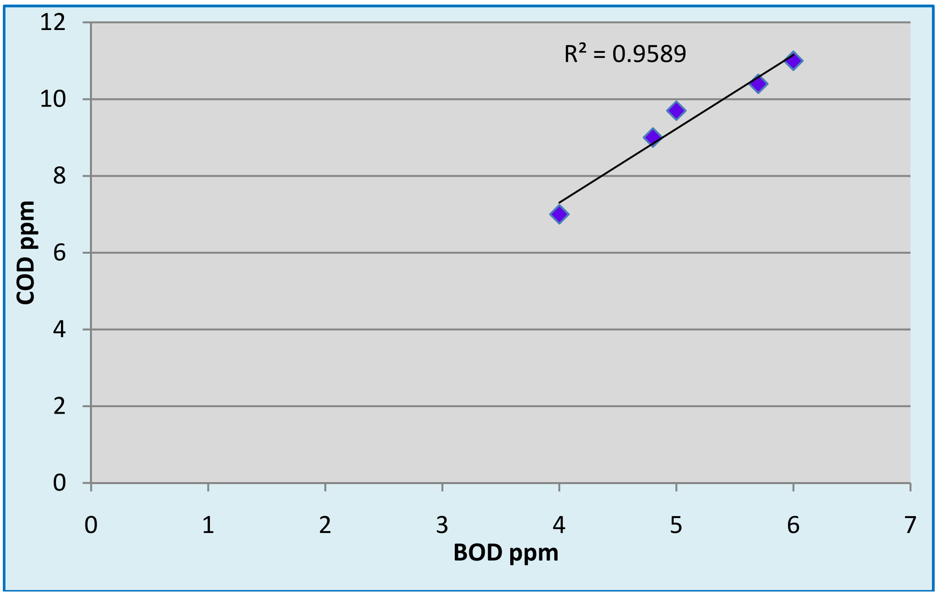

Figure 3-10: Relationship between chemical oxygen demand (COD) and biological oxygen demand BOD.

### 3-4-5 Organic compounds of the Sawa Lake

The Fourier Transform Infra-red (FTIR) can thus provide information on a wide range of organic and minerogenic components, e.g., carbohydrates, humic substances, silicates and carbonates (Calace et al., 1999; Stehfest et al., 2005; Mecozzi and Pietrantonio, 2006).

CH, OH C=O, C=C and C=Clin FTIR spectra suggested that organic species had been disintegrated to more simple organic molecules in the water of the lake (Figure 3-11).The infrared spectrum showes the structural composition of the humic acid present in the water.

This results indicated that the humic acids of water might contain the phenolic hydroxyl groups, hydroxyl group, conjugated double bond of aromatic family (C=C), and free carboxyl groups. The humic had stronger absorption band of CH and $CH_3$ in aliphatic group than that found in humic acid (Sharma, 1999 and Russell 1987).The C=O bond may originated from organic matters in the lake bottom

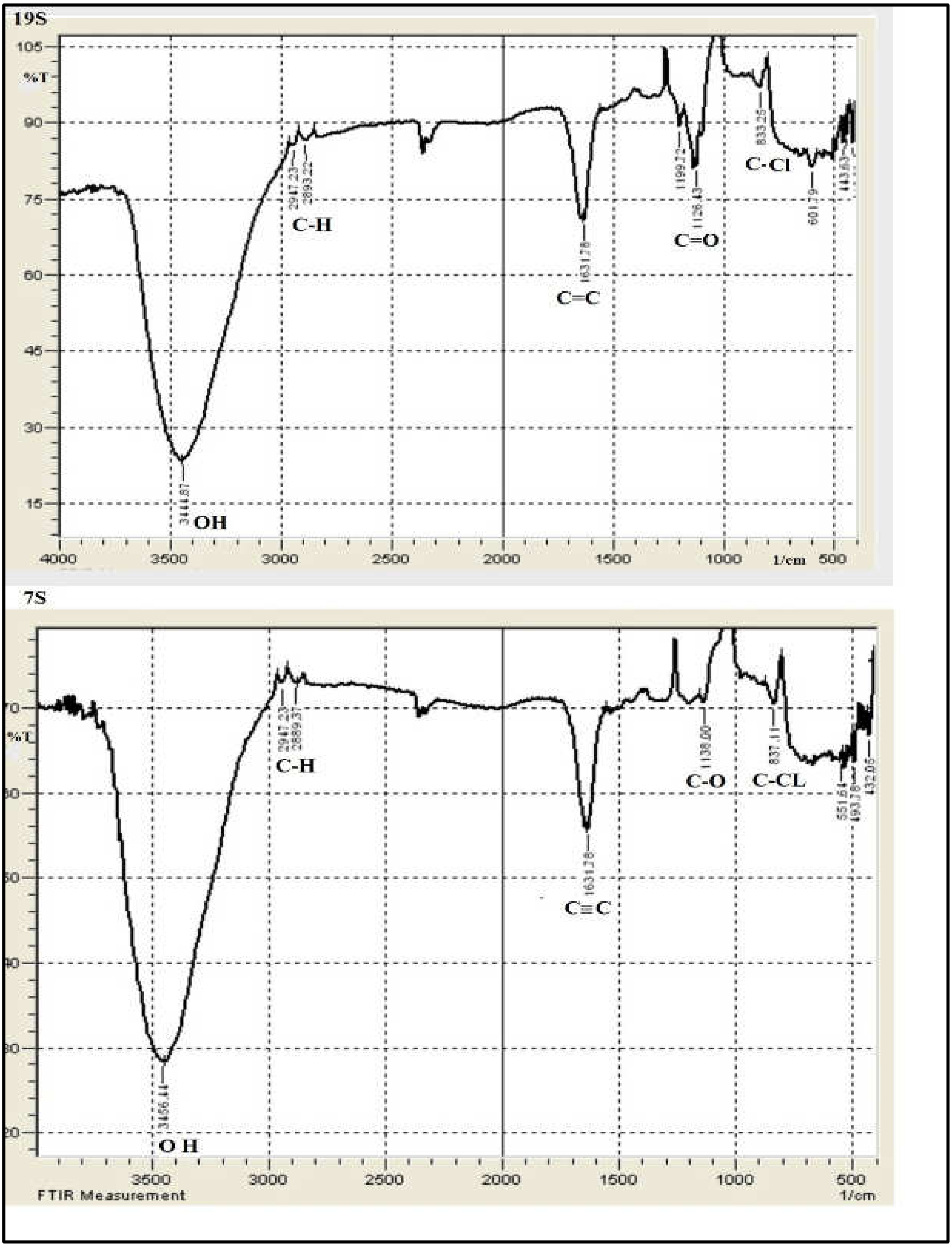

Figure 3-11: FTIR graph of the Sawa Lake water samples.

## 3-5 Radiation measurement

Knowledge of the distribution of radionuclides levels in the environment is important for assessing the radiation exposure to the public. Potential health hazards from natural radio nuclides in water have been considered worldwide; and many countries have adopted the World Health Organization (WHO) recommended guideline activity concentration values of different radionuclides in drinking water (WHO, 2004). Radiological quality of drinking water depends on the presence of natural occurrence of radioactive elements, technological processes involving naturally occurring radioactive materials, and from medical and industrial use of radioactive materials (Trimble, 1968).

Water from sedimentary rocks such as lst, s. st, and shale, as well as igneous rocks, volcanic intermediate and basic rocks usually have radon concentrations of 5-70 Bq/L which is to be expected since these types of rocks generally have low uranium concentrations (Akerblom and Lindgren, 1997).

Isotopes $^{226}$Ra, $^{137}$Cs, $^{228}$Ac, $^{232}$Th, $^{238}$U, $^{214}$Bi in water sample (2S, 6S, 9S, 13S and 19S) of Sawa Lake are below detection limit. Results show only nuclides of $^{40}$K which means that there ranges from 2.3 to 9.4 Bq/L with mean of 7 Bq/L (Table 3-12) (Figure 3-12).

Table 3-12: Results of radioactivity of the water samples in Sawa Lake.

| **Sample no.** | Volume of sample | The specific activity(Bq/Kg) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Series of $^{238}$ U/ $^{226}$Ra | | Series of $^{234}$Th | | $^{40}$K | $^{137}$Cs |
| | | $^{214}$Bi or $^{214}$Pb | U/Ra Isotopes | $^{228}$Ac or $^{208}$Ti | $^{234}$Th Isotopes | | |
| **2S** | 1 liter | B.D.L | B.D.L | B.D.L | B.D.L | 7.2 | B.D.L |
| **6S** | 1 liter | B.D.L | B.D.L | B.D.L | B.D.L | 7.9 | B.D.L |
| **9S** | 1 liter | B.D.L | B.D.L | B.D.L | B.D.L | 6.4 | B.D.L |
| **13S** | 1 liter | B.D.L | B.D.L | B.D.L | B.D.L | 2.3 | B.D.L |
| **19S** | 1 liter | B.D.L | B.D.L | B.D.L | B.D.L | 9.4 | B.D.L |
| **Range** | ---- | ---- | ---- | ---- | ---- | -2.3<br>9.4 | ---- |
| **Mean** | ---- | ---- | ---- | ---- | ---- | 7 | ---- |

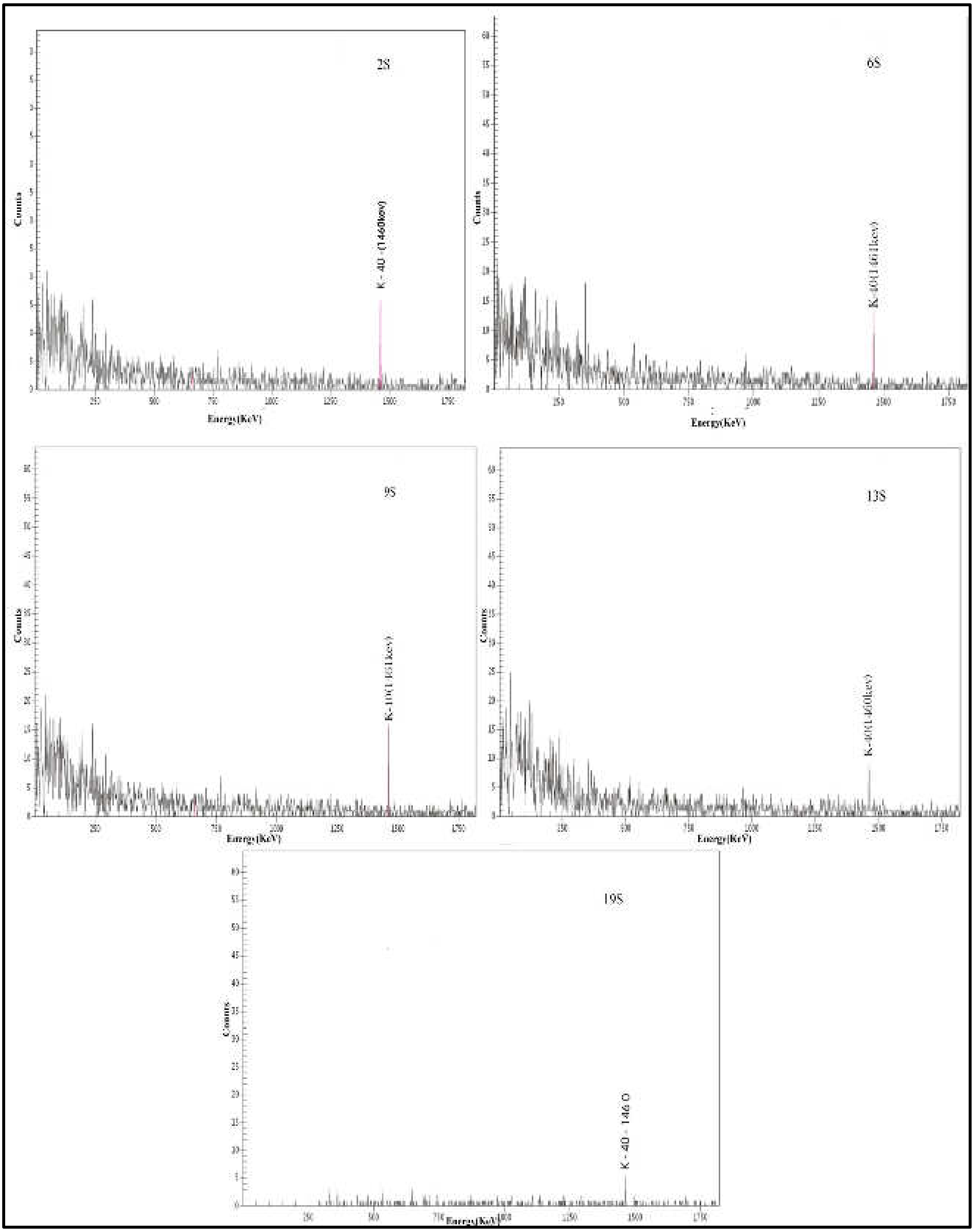

Figure 3-12: Gamma spectra of the water samples of Sawa Lake.

## 3-6 Marine organism and environment

Fish and algae are the most importance aquatic organism. Fish in Sawa Lake characterized by soft appearance, small size, they do not exceed 15 cm in length but mostly about less than 10 cm; eyes of these fish quickly disappear after the death. It can be classified as:

Animalia Kingdom

Chordata Phylum

Actinoptrygii Class

Cyprinodontiformes Order

Cyprinodontidatae Family

*Aphanius* Genus

Also fossil are found at the lake bottom, *Pomatiopsis Tryon* which belongs to *Gastropoda* genus lived in brackish water from the Oligocene to Recent (Clarkson, 2004). It occurs in coastal zones, oasis pools with hyper saline to fresh water.

## 3-7 Discussion

The water of Sawa Lake is characterized by high TDS, which is 21570 ppm at dry period and 22368 ppm at wet period. Sawa Lake has alkali pH due to ascend water from depth through cracks, joints, fractures and faults existed in limestone, dolomite, gypsum and anhydrite. These rocks belong to the Um Er Radhuma formation, Dammam and Euphrates and Rus formations. All these formations have soluble substances and provide the lake with water that ascends upward in response to the general piezometric pressure. Sawa Lake, according to Todd, (2007) has a brackish water characterized by an abundance Mg and Cl that are a predominate ions.

In comparison with sea water $Ca^{2+}$, $Mg^{+2}$ and $SO_4^{=}$contents in Sawa Lake are higher than of seawater; whilst, $K^+$, $Na^+$ and $Cl^-$ are lower than of sea water. The cations are ordered as $Mg^{2+} > Na^+ > Ca^{2+} > K^+$ whereas anions are $Cl^- > SO_4^= > HCO_3^-$. The possible source of $Ca^{2+}$ is gypsum and anhydrite whereas $HCO_3^-$ is limestone (Hem, 1985). Trace elements appear to be concentrated in Sawa Lake. Zn, Pb, Cu, Cd, Ni, Co, As, Fe, Mn, Sr, and B have concentrations higher than of sea water and higher than of 1raqi specifications for drinking water, except Zn tend to be with the limit of standard. Arsenic in Sawa Lake is 273 times higher than its concentration in the sea water, while, boron was also extremely concentrated. Boron content in average recorded in Sawa Lake as 37.5 times higher than B in sea water.

The chemistry of Sawa Lake is compared with the groundwater collected from 3 wells near the lake. Water chemistry of Sawa Lake appears to be different from the wells indicating a different origin for each but both Sawa Lake and wells belong to groundwater.

Aerobic bacteria are found in the Sawa Lake with average total count of 226 colony/ ml. Bacteria beside other micro- organism consume oxygen in the lake, but the aquatic plant and atmosphere add oxygen to the water. In term of BOD, the average of biological oxygen demand (BOD) is 5.2 ppm during wet period. According to the Iraqi standard and Pandey, et al, 2005, the water of Sawa Lake is bad and critical quality water. The COD in the Sawa Lake shows that the quality of this water is very bad because the COD is 9.4 ppm and exceed the limit of I.S., 1996.

Radiation level in Sawa Lake value is low and within acceptable limit. FTIR reveals the presence of some organic compound in the lake that may be attributed to the humic acid, aromatic family and phenols hydroxyl group.

Nitrates and phosphates are plant nutrients and can cause plant life and algae to grow quickly and thereafter they will die. This contributes to the organic waste in the water, which is then decomposed by bacteria. Acidic rain causes increasing nitrate, carbonate and bicarbonate in water because dissolution processes (Biswal et al., 2010).

The lake contains little of phosphates and nitrates because of the presence of plants and algae that consume these compounds vital in their effectiveness and help accelerate their growth within the lake water. Nitrate during the dry period appears within the limit of standards, whilst, out of limit during the wet period. This is good evidence for agricultural pollution.

Hassan (2007) mentioned that the Sawa Lake is similar to the Euphrates river rather than the well nearby it or sea waters. This study indicates the water of Sawa Lake is not similar of the Euphrates River rather than adjacent wells and sea water, but vice-versa, the Euphrates River is widely different from the Sawa Lake.

# Chapter Four

## Water Quality and Assessments

# 4-Water quality and assessments

## 4-1 Preface

It is very important issue to find water quality and water assessments. Many scientific concepts are used to reveal the actual fact for Sawa Lake water. This chapter is designated to serve this target. Hydrochemical formula, Piper, Stiff and Sholler diagrams are applied. The Sawa Lake water is tested and classified for drinking, livestock, irrigation, industry and building purposes. WQI software is applied to classify the water quality.

## 4-2 Water quality

Water quality changes in response to precipitation, evaporation, infiltration discharge or flow quantity and anthropogenic activities (Alley et al. 2002). Hydrochemical formula, Piper, Stiff, and Shoeller diagrams are computed and illustrated respectively in order to determine the water quality as follows:

### 4-2-1 Hydrochemical formula

The hydrochemical formula is a formula that expressed the water type. It is defined as the major cations and anions that exceed 15% that arranged in descending order in epm % ( Ivanov et al., 1968). Concentrations of cation and anion in epm of the Sawa Lake water during dry and wet periods are listed in Tables from 4-1 to 4-4.

The general hydrochemical formula is described as:

$$TDS\ (mg)\frac{\text{Anions (epm\%)in descending order}}{\text{Cations (epm\%)in descending order}}pH$$

Hydrdrochemical formula of the Sawa Lake water during both periods of dry and wet periods are listed in Tables from 4-5 and Table 4-6 respectively.

From the hydrochemical formula, it is found that, the Sawa lake has similar formula during both periods (Dry and wet). During dry and wet periods, the lake is characterized by the following average formula respectively:

$$\mathrm{TDS}_{(22.2\ \mathrm{gm/l})}\ \frac{\mathrm{Cl}(63.4)\ \ \mathrm{SO4}(36.4)}{\mathrm{Mg}(68.4)\ \ \mathrm{Na}(21.3)}\ \mathrm{PH}_{(8.5)}$$

$$\mathrm{TDS}_{(22.0\mathrm{gm/l})}\ \frac{\mathrm{Cl}(65)\ \ \mathrm{SO4}(34)}{\mathrm{Mg}(86.5)\ \ \mathrm{Na}(20)}\mathrm{pH}_{(8.4)}$$

The hydrochemical formulas above show that the Mg and Cl are predominant in the lake and the water type is Mg-Na-$SO_4$-chloride. Groundwater collected from wells is characterized by hydrochemical formula dissimilar to Sawa Lake formula, which is:

$$\mathrm{TDS}_{(4.7\mathrm{gm/l})}\,\frac{\mathrm{SO4}(61.1)\quad \mathrm{Cl}(33.2)}{\mathrm{Mg}(69.3)\quad \mathrm{Ca}(20.16)}\ \mathrm{pH}_{(8.2)}$$

This formula indicates an Mg-Ca- Cl-sulfate water type.

Accordingly, the water type of Sawa Lake is chloride, whilst water of wells is sulfate. This is good evidence of the different sources.

Table 4-1: Concentrations of cations and anions of the Sawa Lake during the dry period.

| S. No. | $Ca^{+2}$ | $Mg^{+2}$ | $K^+$ | $Na^+$ | Σ cations | $SO_4^=$ | $Cl^-$ | $CO_3^=$ | $HCO_3^-$ | Σ anions |
|---|---|---|---|---|---|---|---|---|---|---|
| | epm | | | | | | | | | |
| **1S** | 33 | 238 | 7 | 81 | 359 | 146 | 249 | 0.1 | 0.6 | 397 |
| **2S** | 34 | 229 | 7 | 80 | 351 | 14 | 242 | 0.1 | 0. 5 | 385 |
| **3S** | 36 | 293 | 6 | 81 | 418 | 142 | 242 | 0.1 | 0.4 | 385 |
| **4S** | 33 | 302 | 5 | 81 | 422 | 141 | 246 | 0.1 | 0.4 | 388 |
| **5S** | 36 | 249 | 7 | 80 | 373 | 140 | 251 | 0.1 | 0.5 | 393 |
| **6S** | 35 | 285 | 8 | 35 | 410 | 153 | 240 | 0.1 | 0.3 | 393 |
| **7S** | 33 | 235 | 6 | 81 | 356 | 131 | 249 | 0.1 | 0.5 | 381 |
| **8S** | 35 | 295 | 7 | 82 | 419 | 147 | 247 | 0.07 | 0.5 | 395 |
| **9S** | 37 | 277 | 6 | 81 | 402 | 137 | 247 | 0.07 | 0.5 | 385 |
| **10S** | 34 | 273 | 6 | 81 | 395 | 135 | 240 | 0.2 | 0.4 | 375 |
| **11S** | 34 | 275 | 7 | 80 | 397 | 137 | 232 | 0.06 | 0.5 | 370 |
| **12S** | 36 | 237 | 7 | 81 | 362 | 138 | 241 | 0.1 | 0. 5 | 380 |
| **13S** | 31 | 232 | 5 | 80 | 349 | 143 | 240 | 0.1 | 0.5 | 384 |
| **14S** | 33 | 244 | 7 | 81 | 365 | 134 | 258 | 0.2 | 0.5 | 394 |
| **15S** | 32 | 246 | 5 | 82 | 366 | 143 | 245 | 0.2 | 0.3 | 390 |
| **16S** | 32 | 237 | 7 | 82 | 358 | 141 | 360 | 0.1 | 0.5 | 382 |
| **17S** | 33 | 274 | 6 | 83 | 395 | 141 | 271 | 0.2 | 0.4 | 413 |
| **18S** | 32 | 268 | 5 | 79 | 384 | 163 | 254 | 0.2 | 0.3 | 419 |
| **19S** | 32 | 274 | 6 | 81 | 393 | 131 | 237 | 0.1 | 0.5 | 370 |
| **20S-A** | 30 | 234 | 5 | 80 | 350 | 143 | 243 | 0.2 | 0. 6 | 388 |
| **20S-B** | 32 | 259 | 5 | 81 | 378 | 145 | 258 | 0.3 | 0.5 | 405 |
| **20S-C** | 32 | 268 | 7 | 82 | 390 | 131 | 240 | 0.1 | 0.1 | 372 |
| **20S-D** | 36 | 252 | 6 | 82 | 376 | 148 | 255 | 0.2 | 1.2 | 405 |

Table 4-2: Concentrations of cations and anions (epm%) of the Sawa Lake during the dry period.

| **S. No.** | **$Ca^{+2}$** | **$Mg^{+2}$** | **$K^{+}$** | **$Na^{+}$** | **$SO_4^{=}$** | **$Cl^{-}$** | **$CO_3^{=}$** | **$HCO_3^{-}$** |
|---|---|---|---|---|---|---|---|---|
| | **epm%** | | | | | | | |
| **1S** | 9.28 | 66.2 | 1.8 | 22.6 | 36.9 | 62.9 | 0.02 | 0.15 |
| **2S** | 9.7 | 65.12 | 2 | 23 | 36.8 | 63.0 | 0.03 | 0.14 |
| **3S** | 8.6 | 70 | 1.6 | 19.5 | 36.9 | 62.9 | 0.03 | 0.11 |
| **4S** | 7.9 | 71.4 | 1.29 | 19.3 | 36.4 | 63.5 | 0.03 | 0.12 |
| **5S** | 9.7 | 66.9 | 1.9 | 21.4 | 35.8 | 64.0 | 0.02 | 0.13 |
| **6S** | 8.6 | 69.5 | 2 | 19.7 | 38.9 | 60.9 | 0.02 | 0.07 |
| **7S** | 9.2 | 65.9 | 1.8 | 22.9 | 34.5 | 65.3 | 0.03 | 0.12 |
| **8S** | 8.3 | 70.3 | 1.7 | 19.6 | 37.3 | 62.5 | 0.01 | 0.14 |
| **9S** | 9.3 | 68.9 | 1.6 | 20.1 | 35.7 | 64.1 | 0.01 | 0.14 |
| **10S** | 8.66 | 69.3 | 1.4 | 22.5 | 35.9 | 63.9 | 0.04 | 0.11 |
| **11S** | 8.7 | 69.2 | 1.7 | 20.2 | 37 | 62.8 | 0.01 | 0.13 |
| **12S** | 10 | 65.6 | 1.9 | 22.4 | 36.5 | 63.3 | 0.03 | 0.13 |
| **13S** | 9 | 66.5 | 1.54 | 22.9 | 37.3 | 62.5 | 0.03 | 0.13 |
| **14S** | 8.9 | 66.9 | 2 | 22.19 | 34.2 | 65.5 | 0.06 | 0.12 |
| **15S** | 8.8 | 67.3 | 1.49 | 22.3 | 36.78 | 63 | 0.04 | 0.09 |
| **16S** | 8.9 | 66.2 | 1.8 | 23 | 36.9 | 62.8 | 0.03 | 0.13 |
| **17S** | 8.3 | 69.2 | 1.5 | 20.9 | 34 | 65 | 0.05 | 0.09 |
| **18S** | 8.3 | 69.7 | 1.35 | 20.6 | 38.91 | 60.9 | 0.056 | 0.08 |
| **19S** | 8.2 | 69.58 | 1.4 | 20.7 | 35.56 | 64.2 | 0.03 | 0.14 |
| **20S-A** | 8.7 | 66.8 | 1.5 | 22.9 | 37.0 | 62.8 | 0.04 | 0.14 |
| **20S-B** | 8.4 | 68.5 | 1.4 | 21.5 | 35.8 | 63.9 | 0.08 | 0.13 |
| **20S-C** | 8.3 | 68.7 | 1.78 | 21 | 35.2 | 64.5 | 0.21 | 0.03 |
| **20S-D** | 9.6 | 67.03 | 1.5 | 21.8 | 36.5 | 63 | 0.05 | 0.3 |
| **Mean** | 8.6 | 68.4 | 1.6 | 21.3 | 36.4 | 63.4 | 0.04 | 0.13 |

Table 4-3: Concentrations of major cations and anions of the Sawa Lake and the well water during the wet period.

| **S. No.** | **$Ca^{+2}$** | **$Mg^{+2}$** | **$K^{+}$** | **$Na^{+}$** | **Σ cations** | **$SO_4^{=}$** | **$Cl^{-}$** | **$CO_3^{=}$** | **$HCO_3^{-}$** | **Σ anions** |
|---|---|---|---|---|---|---|---|---|---|---|
| | **epm** | | | | | | | | | |
| **1S** | 37 | 257 | 7 | 84 | 385 | 144 | 279 | 1.5 | 2 | 429 |
| **2S** | 31 | 252 | 7 | 82 | 373 | 137 | 265 | 1.2 | 3 | 410 |
| **3S** | 34 | 238 | 7 | 82 | 362 | 136 | 269 | 0.06 | 3.5 | 411 |
| **4S** | 45 | 216 | 6 | 82 | 350 | 129 | 250 | 1.5 | 5 | 388 |
| **5S** | 37 | 216 | 7 | 84 | 345 | 130 | 259 | 2 | 5 | 398 |
| **6S** | 48 | 285 | 7 | 81 | 423 | 131 | 240 | 0.1 | 0.3 | 393 |
| **7S** | 45 | 216 | 7 | 82 | 351 | 129 | 241 | 2 | 3 | 377 |
| **8S** | 41 | 278 | 6 | 82 | 408 | 135 | 242 | 1 | 3 | 383 |
| **9S** | 44 | 269 | 7 | 81 | 402 | 135 | 243 | 2 | 4 | 386 |
| **10S** | 43 | 275 | 5 | 79 | 402 | 142 | 271 | 2 | 5 | 422 |
| **11S** | 36 | 272 | 5 | 82 | 396 | 133 | 270 | 2 | 5 | 412 |
| **12S** | 36 | 284 | 7 | 82 | 409 | 141 | 235 | 2 | 3 | 383 |
| **13S** | 46 | 315 | 5 | 81 | 448 | 142 | 257 | 2 | 4 | 408 |
| **14S** | 42 | 308 | 5 | 83 | 438 | 126 | 271 | 3 | 4 | 407 |
| **15S** | 35 | 302 | 5 | 82 | 425 | 143 | 254 | 2 | 5 | 406 |
| **16S** | 37 | 282 | 6 | 82 | 407 | 131 | 244 | 2 | 6 | 384 |
| **17S** | 34 | 308 | 6 | 82 | 431 | 131 | 276 | 3 | 4 | 417 |
| **18S** | 43 | 306 | 6 | 83 | 438 | 143 | 260 | 2 | 6 | 413 |
| **19S** | 39 | 301 | 5 | 80 | 427 | 133 | 247 | 2 | 6 | 390 |
| **20S-A** | 34 | 317 | 6 | 82 | 441 | 129 | 269 | 2 | 4 | 406 |
| **20S-B** | 34 | 291 | 7 | 82 | 423 | 134 | 260 | 2 | 6 | 404 |
| **20S-C** | 36 | 313 | 5 | 84 | 439 | 137 | 265 | 2 | 5 | 412 |
| **20S-D** | 36 | 267 | 5 | 82 | 391 | 130 | 171 | 3 | 7 | 413 |
| **1W** | 26 | 78 | 0.5 | 19 | 124 | 69 | 31 | 0.2 | 9 | 111 |
| **2W** | 32 | 105 | 0.5 | 17 | 155 | 69 | 62 | 0.2 | 7 | 142 |
| **3W** | 26 | 99 | 0.5 | 13 | 138 | 57 | 48 | 0.1 | 4 | 122 |

S= Sawa lake, W= Well water

Table 4-4: Concentrations of major cations and anions (epm%) of the Sawa Lake and the well water during the wet period.

| **S. No.** | **$Ca^{+2}$** | **$Mg^{+2}$** | **$K^{+}$** | **$Na^{+}$** | **$SO_4^{=}$** | **$Cl^{-}$** | **$CO_3^{=}$** | **$HCO_3^{-}$** |
|---|---|---|---|---|---|---|---|---|
| | **epm%** | | | | | | | |
| **1S** | 9.6 | 66.7 | 1.9 | 21.7 | 33.8 | 65.3 | 0.3 | 0.49 |
| **2S** | 8.3 | 67.6 | 1.9 | 22 | 33.7 | 65.2 | 0.2 | 0.8 |
| **3S** | 9.5 | 65.8 | 1.9 | 22.7 | 33.2 | 65.8 | 0.1 | 0.8 |
| **4S** | 12.8 | 61.7 | 1.9 | 23.5 | 33.5 | 64.7 | 0.4 | 1.3 |
| **5S** | 14 | 65.5 | 1.6 | 23 | 32.8 | 65.46 | 0.4 | 1.2 |
| **6S** | 11.5 | 67.4 | 1.7 | 19 | 32.8 | 65 | 0.4 | 1.6 |
| **7S** | 12.7 | 61.7 | 2 | 23.5 | 34.4 | 64 | 0.48 | 0.89 |
| **8S** | 10 | 68 | 1.6 | 20 | 35.5 | 63.5 | 0.2 | 0.6 |
| **9S** | 10.9 | 66.9 | 1.7 | 20.3 | 35 | 63 | 0.4 | 1.2 |
| **10S** | 10.7 | 68.3 | 1.4 | 19.7 | 33.8 | 64.5 | 0.5 | 1.2 |
| **11S** | 9 | 68.7 | 1.3 | 20.7 | 32.5 | 56.8 | 0.3 | 1.2 |
| **12S** | 8.8 | 69.3 | 1.6 | 20 | 36.8 | 61.7 | 0.5 | 0.9 |
| **13S** | 10.3 | 70.2 | 1.2 | 18.2 | 34.9 | 63.5 | 0.5 | 1.03 |
| **14S** | 9.6 | 70.2 | 1.2 | 18.8 | 31.2 | 67 | 0.66 | 1 |
| **15S** | 8.2 | 71 | 1.3 | 19.4 | 35.4 | 62.7 | 0.54 | 1.3 |
| **16S** | 9.2 | 69 | 1.5 | 20 | 34 | 63.7 | 0.4 | 1.56 |
| **17S** | 8 | 71 | 1.5 | 19 | 31.6 | 66.6 | 0.7 | 1 |
| **18S** | 9.7 | 69.9 | 1.4 | 18.9 | 34.7 | 63.3 | 0.6 | 1.3 |
| **19S** | 9.2 | 70 | 1.3 | 18.9 | 34.2 | 63.7 | 0.46 | 1.6 |
| **20S-A** | 7.7 | 72 | 1.4 | 18.7 | 31.8 | 66.4 | 0.5 | 1.2 |
| **20S-B** | 8.2 | 70.7 | 1.7 | 19.4 | 33.3 | 64.6 | 0.45 | 1.6 |
| **20S-C** | 8.2 | 71 | 1.2 | 19 | 33 | 64.8 | 0.4 | 1.2 |
| **20S-D** | 9 | 68 | 1.4 | 21 | 31.6 | 65.8 | 0.8 | 1.63 |
| **Mean** | 9.7 | 68.5 | 1.5 | 20 | 34 | 65 | 0.4 | 1.2 |
| **1W** | 21 | 63.2 | 0.4 | 15.3 | 63 | 28.6 | 0.1 | 8 |
| **2W** | 20.9 | 67.5 | 0.3 | 11.2 | 49.7 | 45.5 | 0.1 | 4.7 |
| **3W** | 18.5 | 71.4 | 0.3 | 9.7 | 55.9 | 40.8 | 0.08 | 3.1 |
| **Mean** | 20.16 | 69.3 | 0.3 | 11.9 | 61.1 | 33.2 | 0.4 | 4.4 |

S= Sawa lake, W= Well water

Table 4-5: Hydrochemical formula and water type of Sawa Lake during dry period.

| Sample No. | Hydrochmical formula | Water type |
|---|---|---|
| 1S | $\mathrm{TDS}_{(21.5\ \mathrm{gm/l})}\frac{\mathrm{Cl}\ (63)\ \mathrm{SO4}\ (35.7)}{\mathrm{Mg}\ (82.9)\mathrm{Na}\ (23)}\mathrm{pH}(9.3)$ | Mg- Na- $SO_4$ -chloride |
| 2S | $\mathrm{TDS}(21.0\ \mathrm{gm/l})\frac{\mathrm{Cl}\ (63)\mathrm{SO4}\ (37)}{\mathrm{Mg}\ (65)\mathrm{Na}\ (23)}\mathrm{pH}(\ 9.6)$ | Mg- Na- $SO_4$ - chloride |
| 3S | $\mathrm{TDS}(20.2\mathrm{gm/l})\frac{\mathrm{Cl}\ (62)\mathrm{SO4}\ (37)}{\mathrm{Mg}\ (70)\mathrm{Na}\ (19)}\mathrm{pH}(9.0)$ | Mg- Na- $SO_4$ -chloride |
| 4S | $\mathrm{TDS}(22.0\ \mathrm{gm/l})\frac{\mathrm{Cl}(\ 63)\mathrm{SO4}\ (36)}{\mathrm{Mg}(\ 71)\mathrm{Na}\ (19)}\mathrm{pH}(9.0)$ | Mg- Na- $SO_4$ -chloride |
| 5S | $\mathrm{TDS}\ (21.5\ \mathrm{gm/l})\frac{\mathrm{Cl}\ (64)\mathrm{SO4}\ (35.8)}{\mathrm{Mg}\ (67)\mathrm{Na}\ (21.4)}\mathrm{pH}(9.0)$ | Mg- Na- $SO_4$ -chloride |
| 6S | $\mathrm{TDS}(22.1\mathrm{gm/l})\frac{\mathrm{Cl}\ (60.9)\ \mathrm{SO4}\ (38.9)}{\mathrm{Mg}\ (69.5)\mathrm{Na}\ (19.7)}\mathrm{pH}(8.5)$ | Mg- Na- $SO_4$ -chloride |
| 7S | $\mathrm{TDS}(20.7\mathrm{gm/l})\frac{\mathrm{Cl}\ (65)\ \mathrm{SO4}\ (34.5)}{\mathrm{Mg}\ (65.9)\mathrm{Na}\ (22.9)}\mathrm{pH}(8.4)$ | Mg- Na- $SO_4$ -chloride |
| 8S | $\mathrm{TDS}(22.9\mathrm{gm/l})\frac{\mathrm{Cl}\ (62.5)\ \mathrm{SO4}\ (37.3)}{\mathrm{Mg}\ (70.3)\mathrm{Na}\ (19.6)}\mathrm{pH}(8.3)$ | Mg- Na- $SO_4$ -chloride |
| 9S | $\mathrm{TDS}(21.6\mathrm{gm/l})\frac{\mathrm{Cl}\ (64.1)\ \mathrm{SO4}\ (35.7)}{\mathrm{Mg}\ (68.9)\mathrm{Na}\ (20)}\mathrm{pH}(8.3)$ | Mg- Na- $SO_4$ -chloride |
| 10S | $\mathrm{TDS}(21.0\ \mathrm{gm/l})\frac{\mathrm{Cl}\ (63.9)\ \mathrm{SO4}\ (35.9)}{\mathrm{Mg}\ (69.3)\mathrm{Na}\ (20.5)}\mathrm{pH}(8.3)$ | Mg- Na- $SO_4$ -chloride |
| 11S | $\mathrm{TDS}(20.9\mathrm{gm/l})\frac{\mathrm{Cl}\ (62.8\ )\ \mathrm{SO4}\ (37)}{\mathrm{Mg}\ (69.3)\mathrm{Na}\ (20.2)}\mathrm{pH}(8.1)$ | Mg- Na- $SO_4$ -chloride |
| 12S | $\mathrm{TDS}(20.9\mathrm{gm/l})\frac{\mathrm{Cl}\ (63.3)\ \mathrm{SO4}\ (36.4)}{\mathrm{Mg}\ (65.6)\mathrm{Na}\ (22.4)}\ \mathrm{pH}\ (8.4)$ | Mg- Na- $SO_4$ -chloride |
| 13S | $\mathrm{TDS}(20.8\mathrm{gm/l})\ \frac{\mathrm{Cl}\ (62.5)\ \mathrm{SO4}\ (37.3)}{\mathrm{Mg}\ (66.5)\mathrm{Na}\ (22.9)}\ \mathrm{pH}\ (\ 8.2)$ | Mg- Na- $SO_4$ -chloride |
| 14S | $\mathrm{TDS}(21.4\mathrm{gm/l})\frac{\mathrm{Cl}\ (65.5)\ \mathrm{SO4}\ (34.2)}{\mathrm{Mg}\ (66.9)\mathrm{Na}\ (22.1)}\ \mathrm{pH}\ (\ 8.3)$ | Mg- Na- $SO_4$ -chloride |
| 15S | $\mathrm{TDS}(21.3\ \mathrm{gm/l})\frac{\mathrm{Cl}\ (63.7)\ \mathrm{SO4}\ (36.787)}{\mathrm{Mg}\ (67.3)\mathrm{Na}\ (22.3)\ \ )}\ \mathrm{pH}\ (8.4)$ | Mg- Na- $SO_4$ -chloride |
| 16S | $\mathrm{TDS}(20.9\ \mathrm{gm/l})\frac{\mathrm{Cl}\ (62.8)\mathrm{SO4}\ (36.9)}{\mathrm{Mg}\ (66.2)\mathrm{Na}\ (23)}\mathrm{pH}\ (8.3)$ | Mg- Na- $SO_4$ -chloride |
| 17S | $\mathrm{TDS}(22.5\ \mathrm{gm/l})\ \frac{\mathrm{Cl}\ (65)\ \mathrm{SO4}\ (34)}{\mathrm{Mg}\ (69.2)\mathrm{Na}\ (20.9)}\ \mathrm{pH}\ (\ 8.3)$ | Mg- Na- $SO_4$ -chloride |
| 18S | $\mathrm{TDS}(22.0\ \mathrm{gm/l})\frac{\mathrm{Cl}\ (60.9)\mathrm{SO4}\ (38.9)}{\mathrm{Mg}\ (69.68)\mathrm{Na}\ (20.6)}\mathrm{pH}(\ 8.3)$ | Mg- Na- $SO_4$ -chloride |
| 19S | $\mathrm{TDS}(20.0\ \mathrm{gm/l})\ \frac{\mathrm{Cl}\ (64.2)\ \mathrm{SO4}\ (35.5)}{\mathrm{Mg}\ (69.5)\mathrm{Na}\ (20.7)}\ \mathrm{pH}\ (8.3)$ | Mg- Na- $SO_4$ -chloride |
| 20S-A | $\mathrm{TDS}\ (21.0\ \mathrm{gm/l}\ )\frac{\mathrm{Cl}\ (62.8)\mathrm{SO4}\ (37)}{\mathrm{Mg}\ (66.8)\mathrm{Na}\ (22.9)}\mathrm{pH}\ (8.3)$ | Mg- Na- $SO_4$ -chloride |
| 20S-B | $\mathrm{TDS}(22.0\ \mathrm{gm/l})\frac{\mathrm{Cl}\ (63.9)\ \mathrm{SO4}\ (35.8)}{\mathrm{Mg}\ (68.5)\mathrm{Na}\ (21)}\ \mathrm{pH}\ (8.3)$ | Mg- Na- $SO_4$ -chloride |
| 20S-C | $\mathrm{TDS}(33.1\mathrm{gm/l})\ \frac{\mathrm{Cl}\ (64.5)\ \mathrm{SO4}\ (35.2)}{\mathrm{Mg}\ (68.7)\mathrm{Na}\ (21.1)}\ \mathrm{pH}(\ 8.3)$ | Mg- Na- $SO_4$ -chloride |
| 20S-D | $\mathrm{TDS}(33.1\mathrm{gm/l})\frac{\mathrm{Cl}\ (63)\ \mathrm{SO4}\ (36.5)}{\mathrm{Mg}\ (67)\mathrm{Na}\ (21.8)}\ \mathrm{pH}\ (8.4)$ | Mg- Na- $SO_4$ -chloride |
| Average | $\mathrm{TDS}(22.2\mathrm{gm/l})\frac{\mathrm{Cl}\ (63.4)\mathrm{SO4}\ (36.4)}{\mathrm{Mg}\ (68.4)\mathrm{Na}\ (21.3)}\ \mathrm{pH}(8.5)$ | Mg- Na- $SO_4$ -chloride |

Table 4-6: Hydrochemical formula and water type of Sawa Lake and wells during wet period.

| Sample No. | Hydrochmical formula | Water type |
|---|---|---|
| 1S | TDS(21.7gm/l)$\frac{Cl\ (65.3)SO4\ (33.8)}{Mg\ (66.7)Na\ (21.7)}$ pH ( 8.4) | Mg-Na-$SO_4$-chloride |
| 2S | TDS(22.2gm/l)$\frac{Cl\ (65.2)\ SO4\ (33.6)}{Mg\ (67.6)Na\ (22)}$ pH(8.4) | Mg-Na- $SO_4$-chloride |
| 3S | TDS(22.1gm/l)$\frac{Cl\ (65.8)\ SO4\ (33.3)}{Mg\ (65.8)Na\ (22.7)}$ pH(8.4) | Mg-Na-$SO_4$-chloride |
| 4S | TDS(21.2gm/l)$\frac{Cl\ (64.7)\ SO4\ (33.4)}{Mg\ (61.7)Na\ (23.5)}$ pH(8.4) | Mg- Na- $SO_4$- chloride |
| 5S | TDS(21.4gm/l)$\frac{Cl\ (65.5)\ SO4\ (32.8)}{Mg\ (62.1)Na\ (23.1)}$ pH(8.3) | Mg- Na- $SO_4$- chloride |
| 6S | TDS(22.7gm/l)$\frac{Cl\ (65.1)\ SO4\ (32.8)}{Mg\ (67.4)Na\ (19.2)}$ pH(8.3) | Mg- Na- $SO_4$- chloride |
| 7S | TDS(20.7gm/l)$\frac{Cl\ (64.2)\ SO4\ (34.4)}{Mg\ (61.7)Na\ (23.5)}$ pH(8.4) | Mg- Na-$SO_4$- chloride |
| 8S | TDS(21.7gm/l)$\frac{Cl\ (63.5)\ SO4\ (35.5)}{Mg\ (68.2)Na\ (20.2)}$ pH(8.5) | Mg- Na-$SO_4$- chloride |
| 9S | TDS(21.9gm/l)$\frac{Cl\ (63.2)\ SO4\ (35.2)}{Mg\ (67)Na\ (20.3)}$ pH(8.3) | Mg- Na-$SO_4$- chloride |
| 10S | TDS(23.1gm/l)$\frac{Cl\ (64.5)\ SO4\ (33.8)}{Mg\ (68.3)Na\ (19.7)}$ pH(8.3) | Mg-Na-$SO_4$- chloride |
| 11S | TDS(22.5gm/l)$\frac{Cl\ (65.8)\ SO4\ (32.5)}{Mg\ (68.7)Na\ (20.7)}$ pH(8.3) | Mg- Na-$SO_4$- chloride |
| 12S | TDS(21.8gm/l) $\frac{Cl\ (61.7)\ SO4\ (36.9)}{Mg\ (69.4)Na\ (20.1)}$ pH(8.3) | Mg- Na-$SO_4$- chloride |
| 13S | TDS(23.2gm/l) $\frac{Cl\ (63.5)\ SO4\ (34.9)}{Mg\ (70.2)Na\ (18.2)}$ pH(8.4) | Mg- Na- $SO_4$- chloride |
| 14S | TDS(29.9gm/l)$\frac{Cl\ (67)\ SO4\ (31.2)}{Mg\ (70)Na\ (9.6)}$ pH(8.4) | Mg-Na- $SO_4$- chloride |
| 15S | TDS(22.8gm/l)$\frac{Cl\ (62.7)\ SO4\ (35.4)}{Mg\ (71.1)Na\ (19.4)}$ pH(8.4) | Mg-Na-$SO_4$- chloride |
| 16S | TDS(21.7gm/l)$\frac{Cl\ (63.7)\ SO4\ (34.2)}{Mg\ (69.2)Na\ (20.1)}$ pH(8.4) | Mg-Na-SO4- chloride |
| 17S | TDS(23.1gm/l)$\frac{Cl\ (66.7)\ SO4\ (31.6)}{Mg\ (71.4)Na\ (19.1)}$ pH(8.3) | Mg-Na-$SO_4$- chloride |
| 18S | TDS(23.3gm/l)$\frac{Cl\ (63.3)\ SO4\ (34.7)}{Mg\ (69.9)Na\ (18.9)}$ pH(8.5) | Mg-Na-$SO_4$- chloride |
| 19S | TDS(22.5gm/l)$\frac{Cl\ (63.7)\ SO4\ (34.2)}{Mg\ (70.5)Na\ (18.9)}$ pH(8.4) | Mg-Na-$SO_4$- chloride |
| 20S-A | TDS(22.8gm/l)$\frac{Cl\ (66.4)\ SO4\ (31.8)}{Mg\ (72)Na\ (18.7)}$ pH(8.3) | Mg-Na-$SO_4$- chloride |
| 20S-B | TDS(22.5gm/l)$\frac{Cl\ (64.4)\ SO4\ (33.3)}{Mg\ (70.7)Na\ (19.4)}$ pH(8.3) | Mg-Na-$SO_4$- chloride |
| 20S-C | TDS(23gm/l)$\frac{Cl\ (64.8)\ SO4\ (33.5)}{Mg\ (71.3)Na\ (19.2)}$ pH(8.4) | Mg-Na-$SO_4$- chloride |
| 20S-D | TDS(22.5gm/l)$\frac{Cl\ (65.9)\ SO4\ (31.7)}{Mg\ (68.3)Na\ (21)}$ pH(8.4) | Mg-Na-$SO_4$- chloride |
| Average | TDS(22gm/l)$\frac{Cl\ (65)\ SO4\ (34)}{Mg\ (685)Na\ (20)}$ pH(8.3) | Mg-Na- $SO_4$-chloride |
| 1W | TDS(4.4gm/l)$\frac{SO4\ (63.1)Cl\ (28.6)}{Mg\ (63.2)Ca\ (21.1)\ Na(15)}$ pH(8.3) | Mg-Ca-Cl-sulfate |
| 2W | TDS(5.2gm/l)$\frac{SO4\ (49.7)Cl\ (45.4)}{Mg\ (67.5)Ca\ (20.9)}$ pH 8.2 | Mg-Ca-Cl-sulfate |
| 3W | TDS(4.7gm/l)$\frac{SO4\ (56)Cl\ (40.8)}{Mg\ (71.5)Ca\ (18.5)}$ pH 8.1 | Mg-Ca-Cl-sulfate |
| Average | TDS(4.7gm/l)$\frac{SO4\ (61.1)Cl\ (33.2)}{Mg\ (69.3)Ca\ (20.16)}$ pH(8.2) | Mg-Ca-Cl-sulfate |

**S= SawaLake, W= well water**

## 4-2-2 Piper diagram

Piper diagram is an illustration displays major cations and anions in meq/l graphically. This diagram is proposed by Piper since1944 in order to classify water. Thereafter, the diagram is divided into seven fields (a, b, c, d, e, f, and g) as shown in Figure 4-1. All samples of Sawa Lake for the two periods (dry and wet respectively) have occupied the e-field (Figure 4-2). Sawa Lake is rich with Mg, Na and Cl during both periods. On the general diagram of Piper, it is noticed that concentrations $Ca^{2+}$ and $SO_4$, $CO_3^{=}$ and $HCO_3$ are less than those of other ions. This is due to deposition of calcium sulfate (gypsum deposits) after saturation and increasing evaporation of lake water. The common ions exist in very high concentrations are $Na^{+}$, $Mg^{2+}$ and $Cl^{-}$. All the collected water samples are located in the upper half of the rhombic-shaped (class e) which means that in the normal earth alkaline water chloride under both examined.

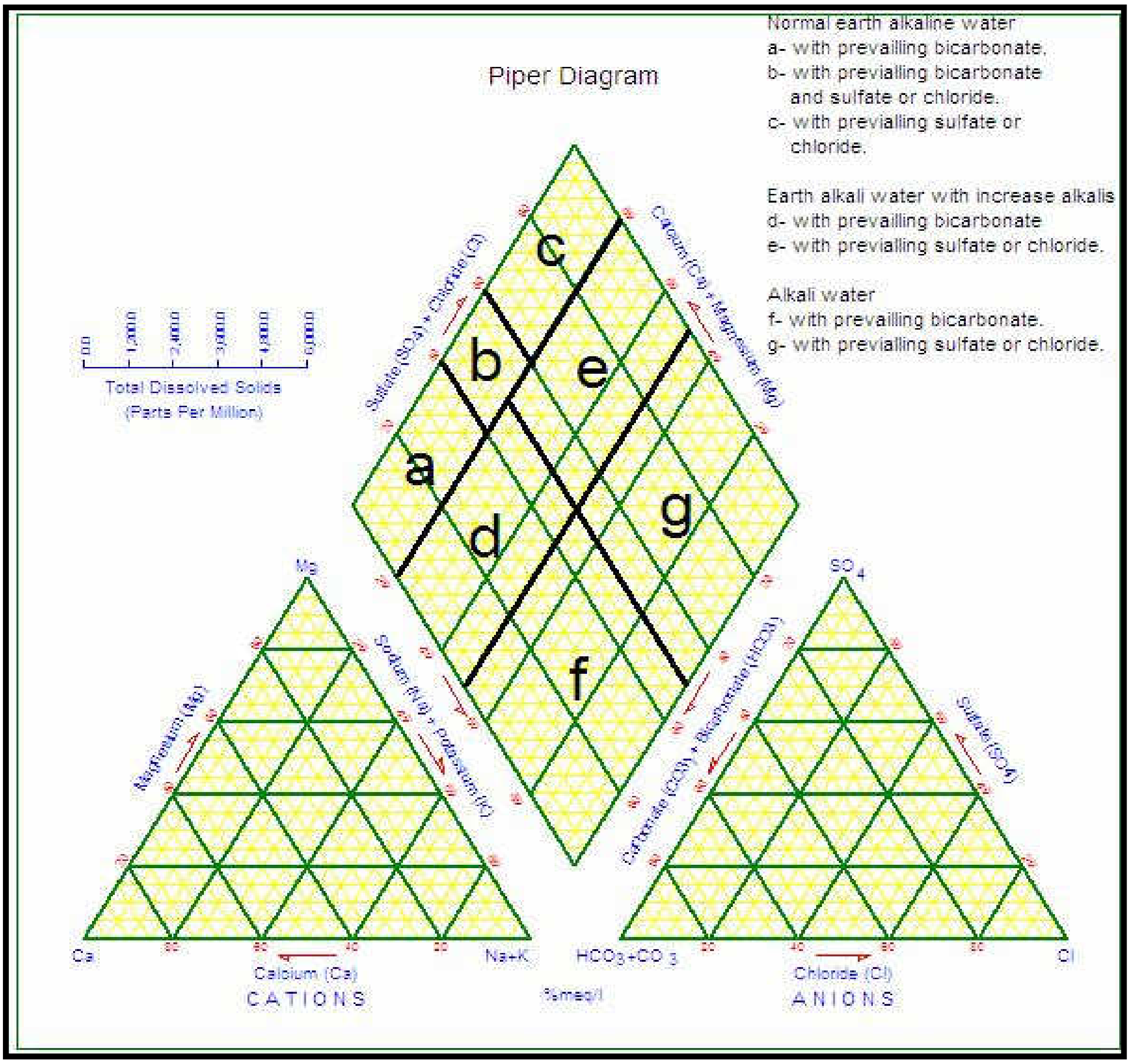

Figure 4-1: piper diagram displays the seven field of water quality.

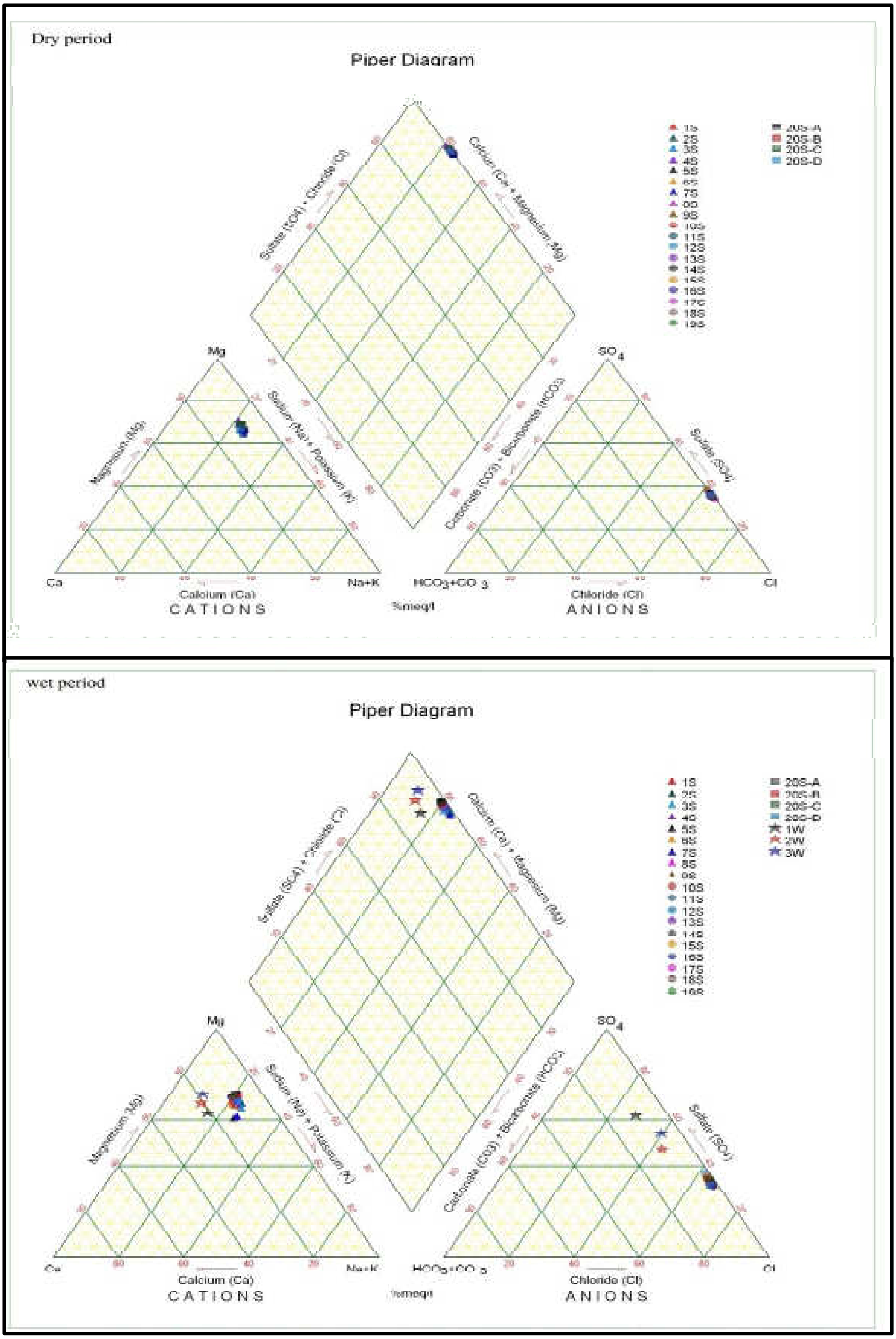

Figure 4-2: Piper diagram illustrates the Sawa Lake water of dry and wet periods.

### 4-2-3 Stiff diagram

It is a pattern diagrams suggested by Stiff, (1951) for representing chemical analyses by four parallel axes. Concentrations of cations are plotted to the left of a vertical zero axis and anions to the right; all values are in equivalents per liter (eq/L or epm).The resulting points, when connected, from an irregular polygonal pattern; waters of a similar quality define a distinctive shape (Todd, 2007).

Through review of the Stiff diagram for the dry and wet periods respectively, the value of $Mg^{2+}$, $Na^{+}$ and $Cl^{-}$ concentrations in the study area are high, which prove the $Mg^{2+}$, $Na^{+}$ and $Cl^{-}$concentrations increases, while $Ca^{2+}$ and $SO_4^{2-}$ decrease due to precipitation of gypsum (Figure 4-3). Stiff diagram present a uniform polygons for all samples of Sawa Lake indicating that all samples has same chemical formula, where $Mg^{2+}$ and $Cl^{-}$ are prevailing. Stiff diagram of wells water display a different origin which are characterized by $Mg^{2+}$ and $SO_4^{=}$ (Figure 4-4).

### 4-2-4 Shoeller Diagram

In logarithmic of Shoeller (1972), the ionic concentrations (meq/l or ppm) are plotted on a logarithmic scale along the equidistant by a zigzag line. When the cations and anions concentrations of several analyses are represented on one sheet, the major grouping or trends the data can be discerned visually.

The parallel lines indicate equal ion ratios and the total concentrations of the cations and anions can be inferred from this diagram. Figure 4-5 depicts all samples of represented water samples of Sawa Lake. It is evident from the diagram that all of samples are relatively poor in carbonates and bicarbonates and comparatively rich in chloride and sulfates. The samples of lake water rich with $Mg^{2+}$ and relatively with $Na^{+}$ and $K^{+}$. Calcium has lower concentration among cations due to gypsum precipitation. It appears to be almost fit with the hydrochemical formula results. Despite of the feature of Schoeller Diagram is uniform; therefore, it can be summarized the type, family, and group of Sawa Lake as mean in both periods ( dry and wet) as well as the water wells (Table 4-7).

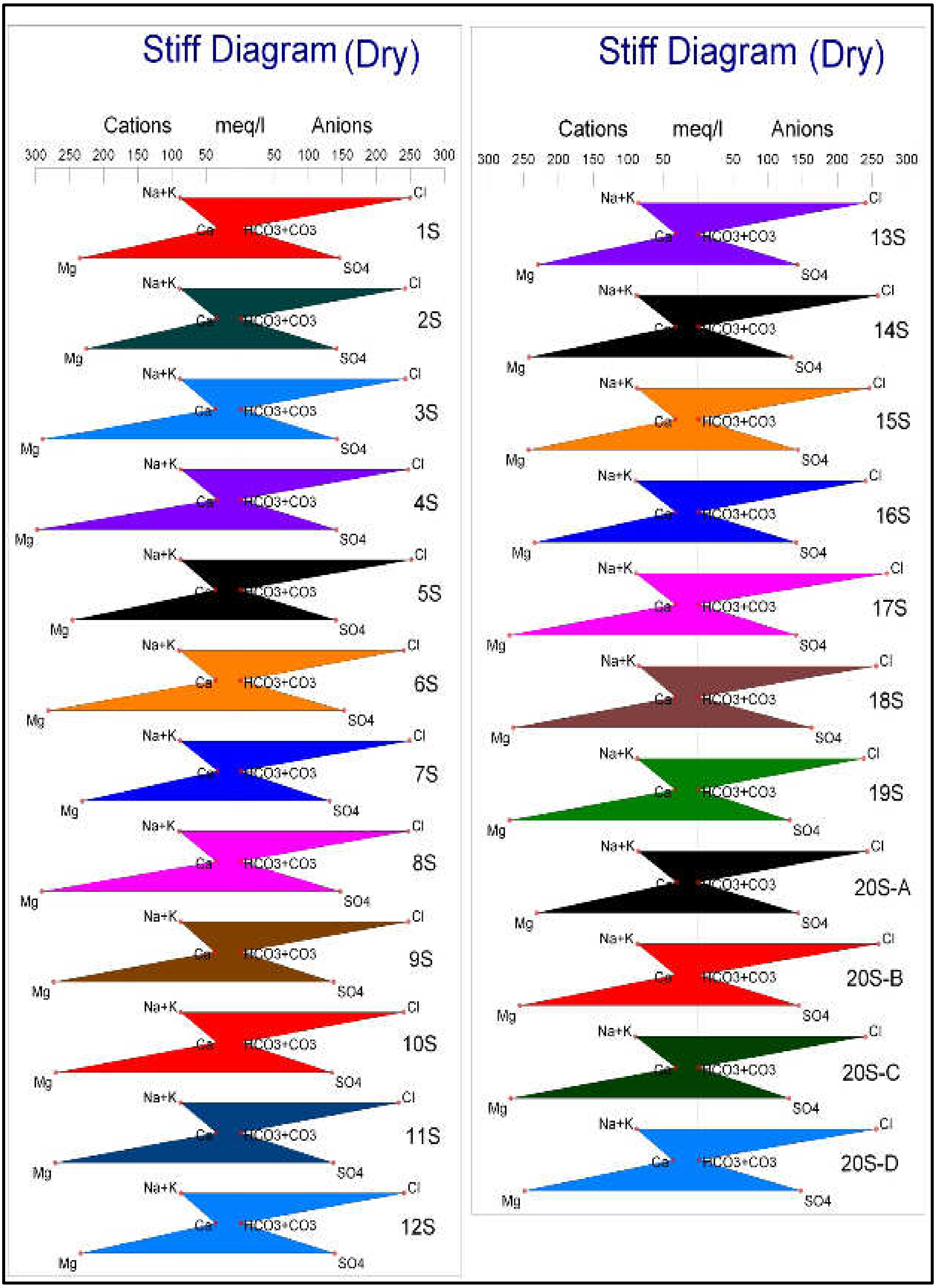

Figure 4-3: Stiff diagram of the samples for dry period.

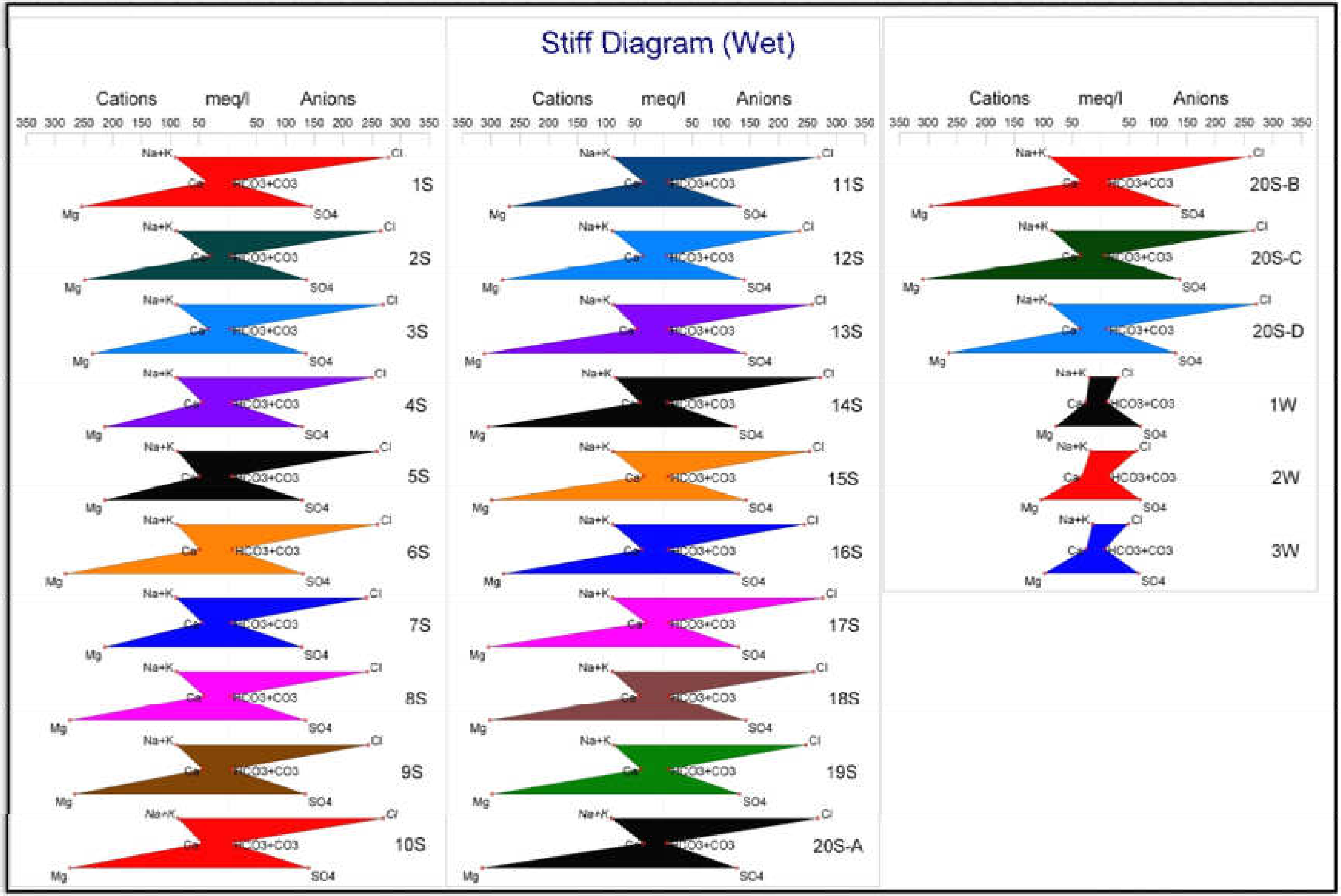

Figure 4-4: Stiff diagram illustrates the Sawa Lake and wells water of wet period

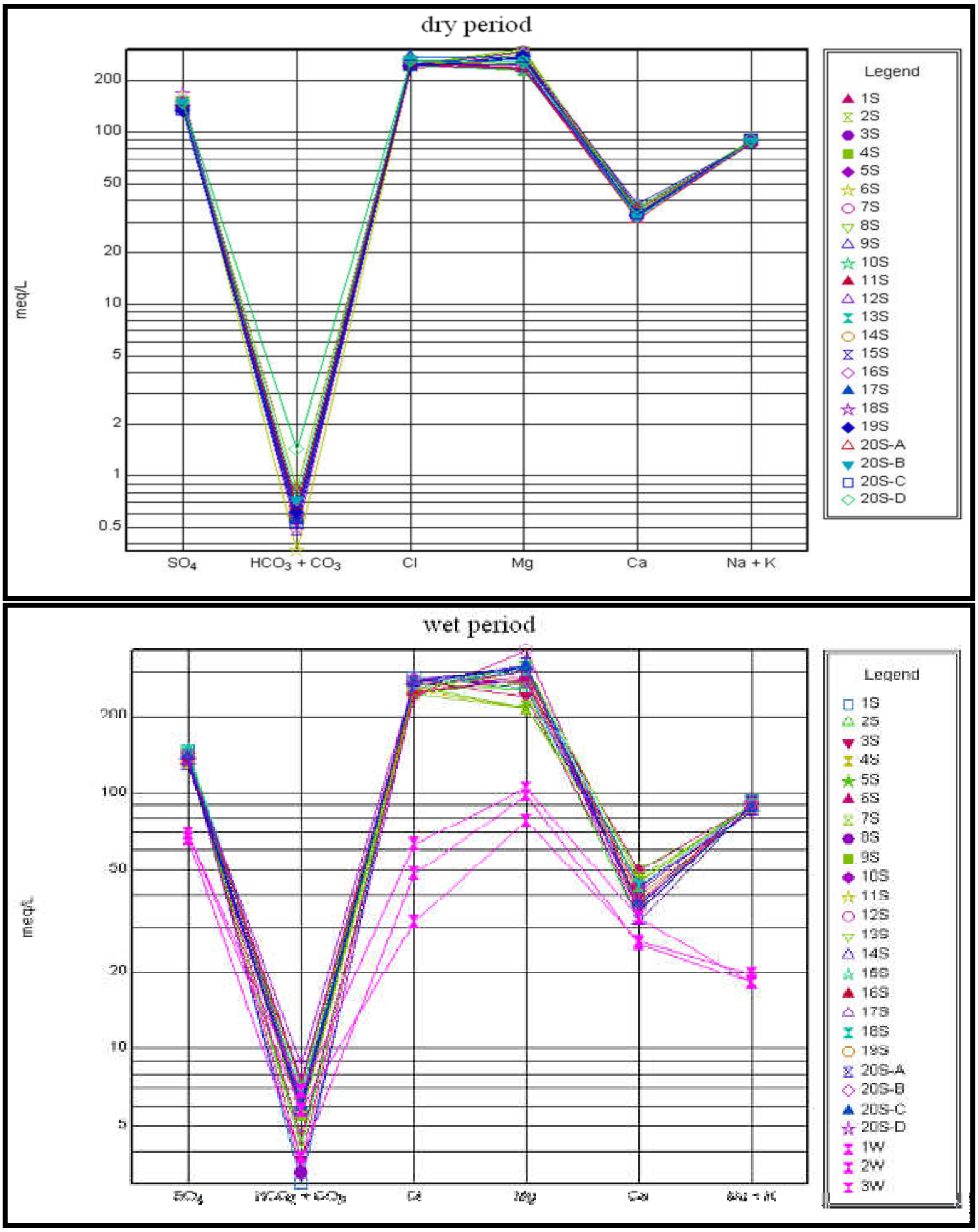

Figure 4-5: Shoeller's diagram illustrates the Sawa Lake water of the dry and wet periods

Table 4-7: The dominant cations and anions in the Sawa Lake and wells water for two periods

| **Present study** | **Types** | | **Family** | **Group** |
|---|---|---|---|---|
| | **Anions** | **Cations** | | |
| Dry Period Sawa Lake | $rCl>SO_4>HCO_3$ | $rMg>Na>Ca$ | Mg-Cl | Cl |
| Wet Period Sawa Lake | $rCl>SO_4>HCO_3$ | $rMg>Na>Ca$ | Mg-Cl | Cl |
| Wet period Wells | $rSO_4>Cl>HCO3$ | $rMg>Ca>Na$ | Mg- $SO_4$ | $SO_4$ |

### 4-2-5 Sawa Lake origin

The Sawa Lake site is structurally and tectonically distinct. It lies in the eastern side of the Salman sub zone near the western side of the Mesopotamian plain. By this location, it appears to be situated on the intersection of the Abu-Jir Fault Zone and the Samawa lineament. The intersection of these faults form an area what is often relatively unstable. The fault planes formed secondary permeability, allowing deep-water ascending upwards. In addition to the structural situation, the stratigraphic column is the other factor that played a major role in the process of the lake formation. The geological formations beneath the Sawa Lake are aquifers such as Umm Er Radhuma, Dammam and Euphraties formations.

These formations are mostly carbonate characterize by their response to dissolution. Karst is the distinct phenomena and scattered in these formations. Rus Formation is the main anhydrite. The main factor that contribute to the formation of the depression of the lake is the dissolution of anhydrite from the Rus Formation. This process adds calcium and sulfate to the ascended ground water. The high content of sulfate and calcium supports this opinion. The shape of lake has trend NW-SE which is the same trend of Abu-Jir Fault Zone. The recharge areas of the aquifers that beneath the lake are from adjacent high lands, and the piezometric pressure raise the water upward to fill the lake depression.

Origin of the lake water is a marine partially mixed with the meteoric water stored in aquifers. The hydrocemical function ratios prove conclusively that the lake water is marine coming from a deep source. According to Ivanov, et al. (1986) water can be classified according to its origin. The functional ratios of rNa / rCl is less than one, rNa –rCl / $SO_4$ is negative and $rSO_4/rCl$ is positive and less than one (Table 4-8). All these hydrochemical functions indicate that the water of Sawa Lake is of marine origin. It is not fit exactly with the result of the hydrochemical of sea water (Table 4-8) because of the mixing processes with the meteoric water. Processes (diagenesis) like dissolution could give an interaction between ground water and marine sediments of the area (fossil water) (Pulido-Bosch et al., 1999).

The groundwater collected from area close to the Sawa lake is of meteoric origin (Table 4-8), where rNa / rCl is greater than one, rNa –rCl / $SO_4$ is positive and $rSO_4$ /rCl is high and greater than one (Table 4-8). This conclusion indicates that the water of Sawa Lake is of different origin of the adjacent groundwater.

In the Sawa Lake, rCa/rCl is 0.13 and 0.15 in dry and wet periods respectively; rMg/ rCl is 1.05 and 0.86 in dry and wet periods respectively. It is obviously that the Ca is less than Mg. The decrease in Ca concentration is not due only to marine origin, but also the consumption of calcium in the building of the barrier gypsum that surrounds the lake. This conclusion is similar to the conclusions of Jamil, 1977.

Table 4- 8: Hydrochemical functions of study area water for the dry and wet periods.

| Present study | $rNa^+ / rCl^-$ | $rNa^+ - rCl^- / SO_4^=$ | $r\ SO_4^= / rCl^-$ | Water Origin |
|---|---|---|---|---|
| Dry period | 0.32 | -1.19 | 0.56 | Marine |
| Wet period | 0.31 | -1.33 | 0.51 | Marine |
| Wells | 1.04 | 0.02 | 1.41 | Meteoric |
| Sea water | 0.8 | -1.59 | 0.1 | Marine |

### 4-3 Water assessment

In order to identify water quality, it should be assessed according to their uses for different purposes. Some assessments related to drinking, livestock, irrigation, industry and building are carried out and described below:

#### 4-3-1 Suitability for drinking

For the purpose of evaluating the suitability of water of Sawa Lake and waters in the adjacent wells for human drinking, the fundamental physical, chemical, biological parameters and some heavy metals are compared with the Iraqi standard, 2009 (Table 4-9). All parameters during both dry and wet periods except Zn appear to be out of the standards and impermissible for drinking. Nitrate is good evidence for agricultural pollution. During the dry period, it appears within the limit of standards for $NO_3^-$, whilst it tends to be higher than the standard during the wet period.

Table 4-9: Physico-chemical parameters and trace elements of Sawa Lake and wells compared with standards.

| **Parameters (ppm)** | **Present study** | | | **Iraqi Standard, 2009** | **Decision** |
|---|---|---|---|---|---|
| | **Dry period Sawa lake** | **Wet period** | | | |
| | | **Sawa Lake** | **well** | | |
| pH | 8.5 | 8.4 | 8 | 6.5-8.5 | Permissible |
| TDS | 21570 | 22368 | 7566 | 1000 | Impermissible |
| EC (µs/cm) | 36601 | 36427 | 12883 | 1530 | Impermissible |
| $Ca^{2+}$ | 657 | 789 | 562 | 150 | Impermissible |
| $Mg^{2+}$ | 3121 | 3327 | 1130 | 100 | Impermissible |
| $Na^{+}$ | 1868 | 1881 | 302 | 200 | Impermissible |
| $SO_4^{=}$ | 6790 | 6476 | 3258 | 400 | Impermissible |
| $Cl^{-}$ | 8750 | 9199 | 1680 | 350 | Impermissible |
| $NO_3^{-}$ | 12 | 95 | 164 | 50 | Permissible during the dry period, impermissible for lake and wells during the wet period |
| TH | 14485 | 15614 | 6039 | 500 | Impermissible |
| B | 167 | ND | ND | 0.5 | Impermissible |
| Zn | 0.09 | 0.08 | 0.03 | 3 | Permissible |
| Pb | 1.16 | 1.2 | BDL | 0.01 | Impermissible for lake, impermissible for wells |
| Co | 0.09 | 0.33 | 0.07 | ---- | ---- |
| Cd | 0.1 | 0.12 | 0.04 | 0.003 | Impermissible |
| Cu | 1.1 | 0.06 | BDL | 1 | Impermissible during the dry period), permissible for lake and wells during the wet period |
| Ni | 0.3 | 0.7 | 0.22 | 0.02 | Impermissible |
| Fe | 0.62 | 0.44 | 0.16 | 0.03 | Impermissible |
| Mn | 0.3 | 0.06 | 0.01 | 0.1 | Impermissible during the dry period), permissible for lake and wells during wet period |
| TB | 226 | ND | ND | --- | ---- |

**ND= Not determined; BDL= below detection limit (detection limit 0.001), TB=Total bacteria count.**

### 4-3-2 Suitability for livestock

Altoviski (1962) suggested the specifications in which the limiting parameters of cations and anions and the total dissolved solids are considered a base for assessing. It is shown in Table 4-10. It can be seen that, the water of Sawa Lake has higher limits for animal drinking except for $Na^{+}$ and $Ca^{2+}$. Consequently, it is impermissible for animal drinking during dry and wet periods whereas the wells are permissible with the risk of $Mg^{2+}$.

Table 4-10: Water specifications for livestock according to Altoviski, 1962.

| **Ion** | **Present study** | | | **Very good** | **good** | **permissible use** | **Can be used** | **The higher limits** |
|---|---|---|---|---|---|---|---|---|
| | **Dry period Sawa lake** | **Wet period** | | | | | | |
| | | **Sawa lake** | **well** | | | | | |
| $Na^{+}$ | 1868 | 1881 | 302 | 800 | 1500 | 2000 | 2500 | 4000 |
| | P | P | V.G | | | | | |
| $Ca^{2+}$ | 657 | 789 | 562 | 350 | 700 | 800 | 900 | 1000 |
| | G | P | P | | | | | |
| $Mg^{2+}$ | 3121 | 3327 | 1130 | 150 | 350 | 500 | 600 | 700 |
| | H | H | H | | | | | |
| $Cl^{-}$ | 8750 | 9199 | 1680 | 900 | 2000 | 3000 | 4000 | 6000 |
| | H | H | G | | | | | |
| $SO_4^{=}$ | 6790 | 6476 | 3258 | 1000 | 2500 | 3000 | 4000 | 6000 |
| | H | H | P | | | | | |
| TDS | 21570 | 22368 | 7566 | 3000 | 5000 | 7000 | 10000 | 15000 |
| | H | H | P | | | | | |

**V.G= Very good, G=Good, P= Permissible, C= Can be used, H=High.**

### 4-3-3 Suitability for irrigation

Agricultural uses need specific water of suitable quality to avoid harming plants and soil damage. The Sawa Lake and adjacent wells were assessed for irrigation by assuming the following factors:

#### 4-3-3-1 Magnesium hazard

Szabolcs and Darab (1964) proposed magnesium hazard (MH) value for irrigation water as given below:

$MH= Mg^{2+}/ (Ca^{2+} + Mg^{2+}) *100$

If MH >50 is considered harmful and unsuitable for irrigation, If MH <50indicates that the water is not harmful for irrigation (Naseem et al., 2010)

In the present study, MH in dry period is 89, whereas it is 87 at wet period (Table 4-11). This indicates that the Sawa Lake is unsuitable for irrigation because the high MH during the two periods. In wells, MH (76) is less than Sawa Lake but at the same time, it is unsuitable for irrigation because of the magnesium hazard of water wells.

Table 4-11: MH, SAR, Salinity (TDS and EC) values of the Sawa Lake and wells water.

| **Present study** | **MH** | **SAR** | **Salinity** | | **Na %** |
|---|---|---|---|---|---|
| | | | **TDS** | **EC** | |
| Dry period Sawa Lake | 89 | 6.8 | 21570 | 36601 | 41 |
| Wet period Sawa Lake | 87 | 6.7 | 22368 | 36427 | 39 |
| Wet period Wells | 76 | 2 | 7566 | 12883 | 19 |

### 4-3-3- 2 Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio gives a clear idea about the adsorption of sodium by soil. It is the proportion of sodium to calcium and magnesium, which affect the availability of the water to the crop (Singh and Singh, 2008). It is calculated using the following equation, where all ions are in meq/l:

$$SAR=\frac{Na^{+}}{\sqrt{\left(\frac{Ca^{2+}+Mg^{2+}}{2}\right)}}$$

During dry and wet periods, the average of SAR is 6.8 and 6.7 respectively (Table 4-11). In term of SAR, water appears to be permissible for irrigation (Table 4-12).

### 4-3-3- 3 Total Dissolved Solids (TDS)

Salts of calcium, magnesium, sodium, potassium present in the irrigation water may prove to be injurious to plants. When present in excessive quantities, they reduce the osmotic activities of the plants and may prevent adequate aeration. The TDS value of the study area is 21570 ppm for dry period while, it is 22368 ppm. TDS of wells groundwater reaches 7566 ppm (Table 4-11) (Robinove et al., 1958). Water of both Sawa Lake and wells are classified as unsuitable for irrigation use (Table 4-12).

### 4-3-3- 4 Electrical Conductivity (EC)

Conductivity is a measure of the ability of water to conduct an electric current. It is used to estimate the amount of dissolved solids. It increases as the amount of dissolved mineral (ions) increases. The value of electrical conductivity (EC) in the study for the dry and wet periods is listed in Table (4-11).Water of both Sawa Lake and wells are classified as unsuitable for irrigation use.

### 4-3-3-5 Percentage of sodium (Na %)

This factor also named soluble sodium percentage (SSP). The percentage of sodium (Na %) is also an important factor for the evaluation of water quality for irrigation purposes. The increase of sodium ratios in irrigation water has a direct impact on plant growth or stunted growth, as well as, it has an effect on the quality of the soil (Wilcox, 1950). It is the ratio of Na in epm in water to the total cations epm multiplied by 100. Irrigation water with Na% > 60% may result in Na accumulation and possibly a deterioration of soil structure, infiltration, and aeration (Hakim et al., 2009).

The calculation of Na% can be done by using the equation of Todd, 1995:

$$\%Na = [Na + k] \times 100 / [Ca + Mg + Na + K]$$

All ionic concentrations are expressed in meq/l.

Sawa Lake at dry period is classified as permissible, while, at wet period, is classified as a good in term of Na%. The wells water is classified as excellent for irrigation in term of Na% (Table 4-12).

### 4-3-3- 6 Don Classification

Don (1995) depended on specific parameters to determine the water suitability for irrigation purposes; these are such as SAR, EC, TDS, and Na%.

The comparison of these parameters in the water samples with the classifications of Don (Table 4-12) show that the water quality of Sawa Lake (two periods) is unsuitable in terms of EC, TDS, and pH. With respect of sodium adsorption ratio and percentage of sodium, the lake water is permissible. Finally, Sawa Lake is not permissible for irrigation, but wells can be used with some risk.

Table 4-12: Water assessments according to classification of Don (1995) for irrigation waters.

| **Present study** | **EC µs\cm** | **TDS ppm** | **SAR** | **Na%** | **pH** | **Water Quality** |
|---|---|---|---|---|---|---|
| Standard | < 250 | < 175 | <3 | < 20 | <6.5 | Excellent |
| Dry period Sawa Lake | 36601 | 21570 | 6.8 | 41 | 8.5 | |
| Decision | U | U | P | P | U | |
| Standard | 250–750 | 175-525 | 3-5 | 20-40 | 6.5-6.8 | Good |
| Wet period Sawa Lake | 36427 | 22368 | 6.7 | 39 | 8.4 | |
| Decision | U | U | P | G | U | |
| Standard | 750–2000 | 525-1400 | 5-10 | 40-60 | 6.8-7.0 | Permissible |
| Wet period wells | 12883 | 7566 | 2 | 19 | 8 | |
| Decision | U | U | E | E | D | |
| Standard | 2000–3000 | 1400-2100 | 10-15 | 60-80 | 7- 8 | Doubtful |
| Standard | >3000 | >2100 | >15 | > 80 | >8 | Unsuitable |

**E= Excellent, G= Good P= Permissible, D= Doubtful, U= Unsuitable**

### 4-3-3-7 Ayers and Westcot classification

They depended on five groups that represent the hydrochemical changes including the salinity; cations and anions concentrations measured by (epm) unit, nutrients which measured by (ppm) unit and the influence of other miscellaneous materials.

Sawa Lake water (wet and dry periods) according to the Ayers and Westcot (1989) classification is not suitable for irrigation purposes in terms of the five groups (higher than the limit) except bicarbonates and SAR and pH (Table 4-13).Wells adjacent to the lake are also not suitable according to this classification in some parameters and are suitable for other parameters.

Table 4-13: Assessments of Sawa Lake and wells water with specification standards for irrigation waters according to Ayers and Westecot, 1989.

| **Group** | | **Index** | **Unit** | **Present study** | | | **Usual range** | **Decision Sawa Lake** | **Decision Wells** |
|---|---|---|---|---|---|---|---|---|---|
| | | | | **Sawa Lake** | | **wells** | | | |
| | | | | **Dry period** | **Wet period** | | | | |
| 1 | Salinity | EC | µS/cm | 36601 | 36427 | 7566 | 0-3000 | Impermissible | Impermissible |
| | | TDS | ppm | 21570 | 22368 | 12883 | 0-2000 | Impermissible | Impermissible |
| 2 | Cations | $Ca^{+2}$ | epm | 33 | 39 | 28 | 0-2 | Impermissible | Impermissible |
| | | $Mg^{+2}$ | epm | 260 | 277 | 94 | 0-5 | Impermissible | Impermissible |
| | | Na | epm | 81 | 82 | 13 | 0-40 | Impermissible | Permissible |
| 3 | Anions | $Cl^{-}$ | epm | 246 | 259 | 47 | 0-30 | Impermissible | Impermissible |
| | | $SO_4^{=}$ | epm | 141 | 135 | 69 | 0-20 | Impermissible | Impermissible |
| | | $HCO_3^{-}$ | epm | 0.5 | 5 | 5 | 0-10 | Permissible | Permissible |
| | | $CO_3^{-}$ | epm | 0.2 | 2 | 0.2 | 0-0.1 | Impermissible | Impermissible |
| 4 | Nutrients | $NO_3^{-}$ | ppm | 12 | 95 | 164 | 0-10 | Impermissible | Impermissible |
| | | $NO_2^{-}$ | ppm | ---- | ---- | ---- | 0-50 | ---- | ---- |
| | | $PO_4^{-3}$ | ppm | 13 | 15 | 11 | 0-2 | Impermissible | Impermissible |
| | | K | ppm | 6.3 | 6.2 | 19 | 0-2 | Impermissible | Impermissible |
| 5 | Miscellaneous | pH | 1-14 | 8.5 | 8.4 | 8 | 6-8.5 | Permissible | Permissible |
| | | B | ppm | 167 | ND | ND | 0-2 | Impermissible | ----- |
| | | SAR | | 6.8 | 6.7 | 2 | 0-15 | Permissible | Permissible |

## 4-3-4 Suitability for industry

Requirements for the quality of water used in different industrial processes are different and almost every industrial application has its own standards (Hem, 1991).In some industries, such as in the pharmaceutical or paper industries, the quality of water used is comparable to the distilled water in purity, while in some other industries, such as the operation of modern steam boilers with higher vapor pressure, distilled water may need to be purified. The quality of Sawa Lake and wells water are compared with these suggested limits.

All parameters are impermissible for industries (Table 4-14), except pH that appears suitable for some industries; but this is not enough to make water suitable for industry.

Table 4-14: Water Quality Standards for industrial uses (after Hem, 1991).

| **Parameters** | **Present study** | | | **Textile** | **Chemical pulp and paper** | | **Wood chemicals** | **Synthetic rubber** | **Petroleum products** | **Canned, dried, frozen fruits and vegetables** | **Soft-drinks bottling** | **leather tanning** | **Hydraulic cement manufacture** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Dry period** | | **Wet period** | | **Unbleached** | **Bleached** | | | | | | | |
| | **Sawa Lake** | | **Well** | | | | | | | | | | |
| **$Ca^{+2}$** | **657** | **789** | **562** | | **20** | **20** | **100** | **80** | **75** | **--** | **100** | **--** | **--** |
| | **X** | **X** | **X** | | | | | | | | | | |
| **$Mg^{+2}$** | **3121** | **3327** | **1130** | **0** | **12** | **12** | **50** | **36** | **30** | **--** | **--** | **--** | **--** |
| | **X** | **X** | **X** | | | | | | | | | | |
| **$Cl^-$** | **9463** | **9199** | **1680** | **0** | **200** | **200** | **500** | **--** | **300** | **250** | **500** | **250** | **250** |
| | **X** | **X** | **X** | | | | | | | | | | |
| **$HCO_3^-$** | **31** | **284** | **323** | **0** | **--** | **--** | **250** | **--** | **--** | **--** | **--** | **--** | **--** |
| | **X** | **X** | **X** | | | | | | | | | | |
| **$SO_4^{2-}$** | **7690** | **6476** | **3258** | **0** | **--** | **--** | **100** | **--** | **--** | **250** | **500** | **250** | **250** |
| | **X** | **X** | **X** | | | | | | | | | | |
| **TDS** | **21570** | **22368** | **7387** | **100** | **--** | **--** | **1000** | **--** | **1000** | **500** | **--** | **--** | **600** |
| | **X** | **X** | **X** | | | | | | | | | | |
| **pH** | **8.5** | **8.4** | **8** | **2.5 – 10.5** | **6 – 10** | **6 – 10** | **6.5 – 8** | **6.5 – 8.3** | **6 – 9** | **6.5 - 8.5** | **--** | **6 - 8** | **6.5 - 8.5** |
| | **X &S** | **X&S** | **X&S** | | | | | | | | | | |

***All units are in (ppm). X=unsuitable, s=suitable**

## 4-3-5 Suitability for building purposes

Classification suggested by Altoviski, (1962) has been adopting to be compared with the water of Sawa Lake and wells. In the present study, all ions in the lake with the exception of bicarbonates have exceeded the permissible limit. This indicates that the water of the lake is unsuitable for building purposes. The water of wells appears appropriate of all ions, $SO_4^{=}$ , $Mg^{2+}$ and $Ca^{2+}$which are higher than the permissible limit (Table 4-15).

Table 4-15: Result of water specification for building purposes (Altovisiki, 1962) compared with the results of Sawa Lake and adjacent wells.

| **Ions** | **Present study Average (ppm)** | | | **Permissible limit (ppm)** |
|---|---|---|---|---|
| | **Dry period** | **Wet period** | | |
| | **Sawa Lake** | **Sawa Lake** | **Wells** | |
| **$Na^+$** | **1868** | **1881** | **302** | **1160** |
| | **X** | **X** | **S** | |
| **$Ca^{2+}$** | **657** | **789** | **562** | **437** |
| | **X** | **X** | **X** | |
| **$Mg^{2+}$** | **3121** | **3327** | **1130** | **271** |
| | **X** | **X** | **X** | |
| **$Cl^-$** | **8750** | **9199** | **1680** | **2187** |
| | **X** | **X** | **S** | |
| **$SO_4^{2-}$** | **6790** | **6476** | **3258** | **1460** |
| | **X** | **X** | **X** | |
| **$HCO_3^-$** | **31** | **284** | **323** | **350** |
| | **S** | **S** | **S** | |

**X=unsuitable, s=suitable**

## 4-3-6 Water quality index (WQI)

Water quality index software program (WQI) is applied to classify the water quality of the Sawa Lake water. Nine different parameters as averages are fed as input to the program; these are:

1- Temperature
2- pH
3- Dissolved Oxygen
4- Turbidity
5- Fecal Coli form
6- Biochemical Oxygen
7- Total Phosphates
8- Nitrates

9- Total Solids

All application and results of WQI are presented in the Appendix. The Water quality index categories is listed in Table 4-16

Table 4-16: The legend of water quality index program.

| Water Quality Index Legend | |
|---|---|
| **Range** | **Quality** |
| 90-100 | Excellent |
| 70-90 | Good |
| 50-70 | Medium |
| 25-50 | **Bad** |
| 0-25 | Very bad |

The output of WQI program is listed in Table 4-17 which indicate that water quality of Sawa Lake is bad during dry and wet periods.

Table 4-17: Water quality index (WQI) of the Sawa Lake water during dry and wet periods.

| Factors | dry period | | wet period | |
|---|---|---|---|---|
| | **value** | **WQI** | **value** | **WQI** |
| Fecal coli form (colonies/100ml) | 226 | 36 | ND | ----- |
| TDS (mg/l) | 21570 | 20 | 22368 | 20 |
| Dissolved oxygen (mg/l) | ND | ---- | 8 | 6 |
| pH | 8.5 | 66 | 8.4 | 70 |
| Turbidity | 0 | 99 | 0 | 99 |
| Biological oxygen demand (mg/l) | ND | --- | 5 | 56 |
| Nitrate (ppm) | 12 | 48 | 95 | 3 |
| Phosphate (ppm) | 13 | 2 | 15 | 2 |
| Temperature ºC | 29 | 11 | 20 | 22 |
| Final Water Quality Index | ---- | **40** | **----** | **32** |
| Evaluation | **----** | **Bad** | **----** | **Bad** |

ND= not determined

## 4-4 Temporal changes in water chemistry of Sawa Lake

The temporal changes in water chemistry of Sawa Lake are studied by monitoring the result of water chemistry since 1977 till 2012 and the results are listed in Table 4-18. The results of water chemistry in duration of 1977, 1983, 2003 and 2007 were obtained from the previous studies that are compared with the present study which represents the duration of 2011 and 2012.

Since 1977, TDS increased from 17771 ppm to 22368 ppm in 2012 (Figure 4-6). The highest value of TDS is 29440 ppm during 2003. A high variation was detected in the water chemistry of Sawa Lake.

Magnesium was not highly changed between 1977 and 1983; it changed between 1028 ppm to 1042 ppm (Figure 4-7). It increased highly during 2003 and reached to 1630 ppm. Thereafter, it recorded in value (2937 ppm) during 2007. In the present study, Mg is recorded to have the highest concentration since 1977.

Calcium, in 1977 was 1060 ppm, and then decreased to be 950 ppm during 1983, and 884 ppm during 2003. In 2007, Ca was in highest value (1700 ppm). In present study, Ca recorded the lowest value (657 ppm) in 2011 and (789 ppm) in 2012 (Figure 4-7).

Sodium still unchanged highly in the duration of 1977 t0 1983, but it was sharply increased and recorded the highest value of 4681 ppm during 2003. Then it was sharply decreased in duration between 2003 and 2007 to be 1517 ppm. Thereafter, it was decreasing slightly from 2007 to 2012 (Figure 4-7).

Potassium in 1977 was 112 ppm; then increased to 152 ppm in 1983. In 2003, it sharply increased to 275 ppm, and return to 165 ppm in 2007. In the present study, K was 245 ppm and 215 during 2011 and 2012 respectively.

Sulfate was 6476 ppm in 1977; it decreased slightly to 5571 during 1983. Then, it sharply increased during 2003 and reached to 9777 ppm (Figure 4-7). Thereafter, sulfate decreased during 2007 sharply to 4271 ppm. In the present study, sulfate is 6790 ppm and 6476 ppm during 2011 and 2012 respectively.

In 1977 or before 35 years ago, chloride was 5148 ppm and then slightly increased to be 5406 ppm. In 2003, it sharply increased to 9777 ppm, but it decreased again in 2007 to be 4271 ppm. In present study, it was 6790 and 6576 ppm in 2011 and 2012 respectively (Figure 4-7).

In 1977, bicarbonate was 120 ppm; then decreased to 87 ppm in 1983. It was increased during 2003 to be 193ppm and 203 ppm in 2007. In the present study, there is high variation between the dry and wet period (31-284 ppm respectively).The present study (2012) record the highest value of $HCO_3$ since 35 years ago.

The review of the water chemistry of Sawa Lake revealed good conclusion that is, during 1977, 1983 and 2003 the water chemistry was characterized by Na-$SO_4^{2-}$ as a dominant ions, whilst during 2007, 2011 and 2012, the water chemistry was changed to be characterized by Mg-$Cl^-$. This change in water chemistry is due to the climatic changes toward the aridity. The increase of temperature and lack of precipitation caused deposition a large quantity of gypsum in the lake bottom. This case depleted $SO_4^=$ in the water of the lake. Then by the sequence precipitation of salts, other ions increased according to its solubility. Also this means that the recharge water to the lake is decreased.

Table 4-18: Results of the water chemistry of Sawa Lake since 1977 to 2012.

| **Parameters** | | **Jamil, 1977** | **Al-Rawi et al., 1983** | **Al-Muqdady, 2003** | **Hassan, 2007** | **Present study** | |
|---|---|---|---|---|---|---|---|
| | | **Surface** | | **October** | **Jan. and Feb.** | **Dry** | **Wet** |
| | | March | | | | 2011 | 2012 |
| T.C° | | ---- | ---- | ---- | 15.2 | 29 | 20 |
| PH | | ---- | ---- | 8.8 | 8.9 | 8.5 | 8.4 |
| EC (µs/cm) | | ---- | ---- | 31000 | 18700 | 36601 | 36427 |
| TDS | (ppm) | 18920 | 18824 | 29440 | 17771 | 21570 | 22368 |
| $Ca^{+2}$ | | 1060 | 950 | 884 | 1700 | 657 | 789 |
| $Mg^{+2}$ | | 1028 | 1042 | 1630 | 2936 | 3121 | 3327 |
| Na | | 3220 | 3086 | 6481 | 1571 | 1868 | 1881 |
| $K^+$ | | 112 | 152 | 275 | 164.5 | 245 | 215 |
| $SO_4^=$ | | 6432 | 5571 | 9777 | 4271 | 6790 | 6476 |
| $Cl^-$ | | 5148 | 5406 | 7968 | 6925 | 8750 | 9199 |
| $HCO_3^-$ | | 120 | 87 | 193 | 203 | 31 | 284 |

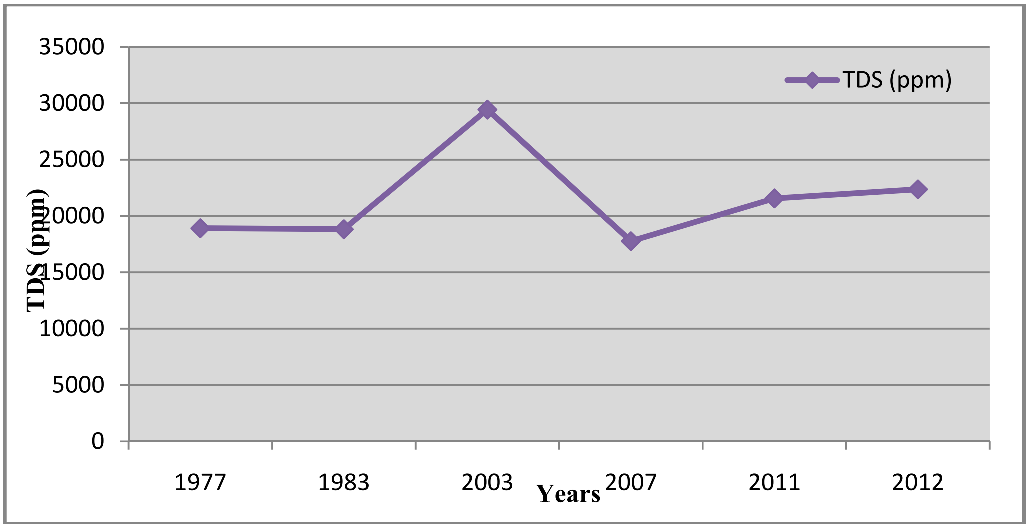

Figure 4-6: TDS variation during 35 years ago

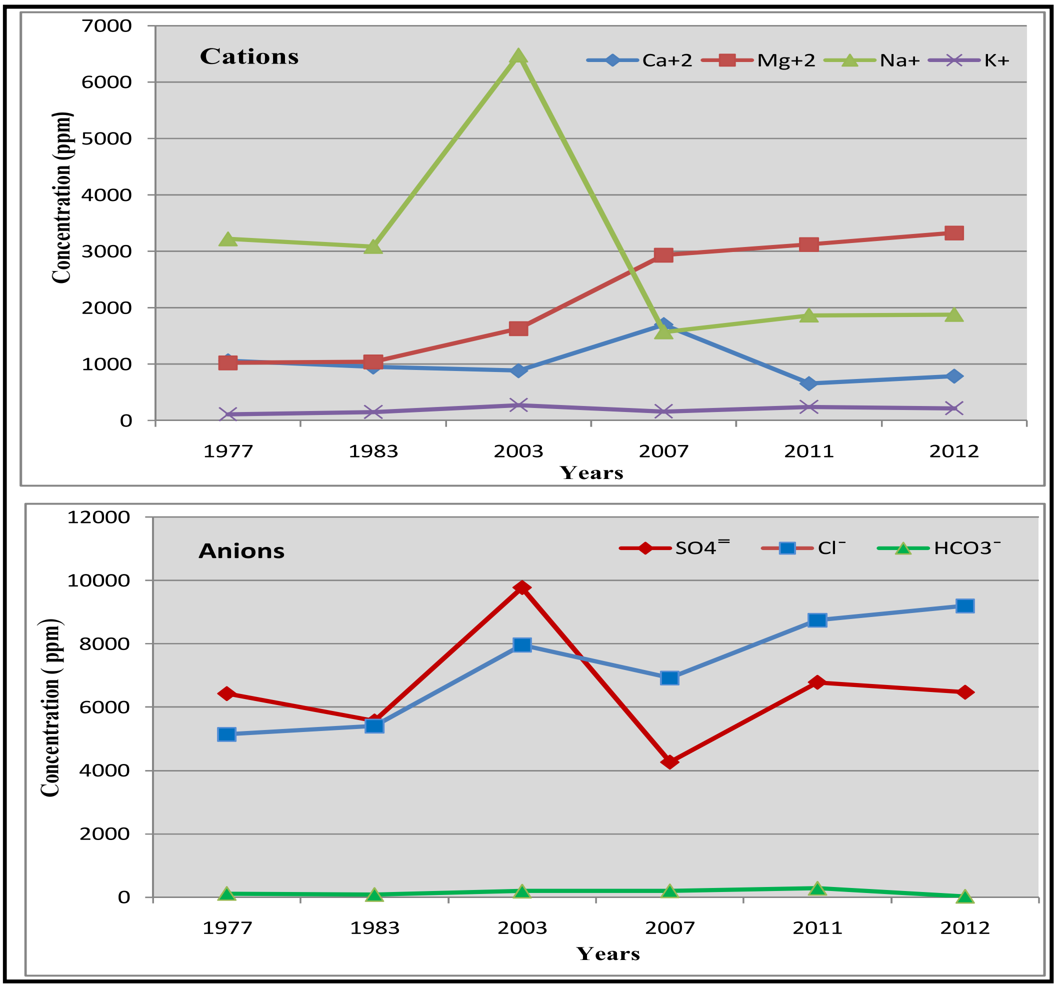

Figure 4-7: Cations and anions variation during 35 years ago.

## 4-5 Discussion

In respect of the dominance the $Mg^{+2}$and $Cl^-$, the hydrochemical formula of Sawa Lake gives the water type to be: $Mg^{2+}$-$Na^+$-$SO_4^=$-Chloride. The Sawa Lake water is characterized by the water quality of earth alkaline water with prevailing chloride. In attempt to discriminate the origin of water, the quality type for 3 samples collected from 3 wells near the Sawa Lake is described as: $Mg^{2+}$- $Ca^{2+}$-$Cl^-$Sulfate. Both of Sawa Lake and wells belong to groundwater.

The clear difference in the water quality between Sawa Lake and wells provide with a good hydrochemical evidence for the different origin or may be ascribed to the recharge condition. The origin of Sawa Lake is marine mixed with meteoric water from rain and from different aquifer beneath the lake like Euphrates, Dammam and Umm Er Radhuma aquifers. The high content of sulfate and calcium is a good evidence for the Rus Formation participation and supplying these ions ($Ca^{2+}$ and $SO_4^=$), because it is mainly composed of anhydrite.

Water quality of Sawa Lake, due to high TDS appears to be impermissible for drinking, livestock, irrigation, some industries and building purposes, whereas the well water is suitable for livestock with $Mg^{2+}$ risk, and for irrigation in term of SAR, pH, and Na%, and it's also possible to use for building uses with attention to high content of $Ca^{2+}$, $Mg^{2+}$and $SO_4^=$. The cause of increase of heavy metals in the lake water ascribed to its origin from marine water and may be partially mixed with oilfield water. $H_2S$ level in Sawa Lake water supports this conclusion which regards to oilfield water. The final assessments for water quality of Sawa Lake were achieved by using water quality index (WQI) program. The result of this program indicate to that the Sawa Lake has bad water quality during dry and wet periods according to the nine parameters (temperature, pH, DO, turbidity, bacteria, BOD, $PO_4^{3-}$, $NO_3^-$, and TDS).

# Chapter Five

## Mineralogy and Geochemistry

# 5- Mineralogy and Geochemistry

## 5-1 Preface

This chapter deals with mineralogy and geochemistry of the lake sediments. For mineralogy, 19 sediments samples (1S-t, 2S-t, 3S-t, 4S-t, 5S-t, 11S-t, 12S-t, 13S-t, 14S-t, 15S-t, 16S-t, 17S-t, 18S-t and 19S-t) were collected from the lake bottom near its border. These samples were studied using the polarized microscope and XRD. Some fossils also were collected and classified under microscope. For geochemistry, 9 samples were chosen and analyzed for major oxides ($SiO_2$, $Al_2O_3$, CaO, MgO, $Fe_2O_3$, $SO_3$, and Cl), loss on ignition (L.O.I), and for heavy metals ( Pb, Ni and Co and Fe). Radioactivity in 5 samples also was measured. Mineralogy were determined by using Fourier Transform Infrared (FTIR) technique.

## 5-2 Mineralogy

Bulk samples were investigated for identifying minerals using polarized microscope and X-ray technique. The lake sediments are formed of gypsum, halite, quartz and clay minerals. Gypsum appears predominant; its mean contributes 87% of the total sediments. Halite contributes 3%, quartz contributes 4% and clay minerals contribute only 5.5 % (Table 5-1) (Figure 5-1). The mineralogical composition of the Sawa Lake can be explained as follows

Table 5-1: Mineralogical composition % of salt sediments.

| **Sample number** | **Gypsum** | **Halite** | **Quartz** | **Clay minerals** |
|---|---|---|---|---|
| | % | | | |
| **3S-t** | 97.3 | 1.2 | 0.0 | 1.5 |
| **5S-t** | 77.8 | 15 | 0.0 | 1.0 |
| **9S-t** | 97.5 | 1.5 | 0.0 | 1.0 |
| **14S-t** | 95.3 | 2.7 | 0.0 | 1.5 |
| **19S-t** | 96.5 | 1.5 | 0.0 | 2.0 |
| **7S-t** | 91.7 | 0.3 | 4.0 | 4.0 |
| **10S-t** | 67.5 | 2.4 | 11.0 | 19.0 |
| **12S-t** | 77.1 | 1.9 | 11.0 | 10.0 |
| **14S-t** | 72.3 | 2.7 | 15.0 | 10.0 |
| **Range** | 67.5-97.5 | 0.3-2.7 | 0.0-15 | 1.5-19 |
| **Mean** | 87.0 | 3.0 | 4.5 | 5.5 |

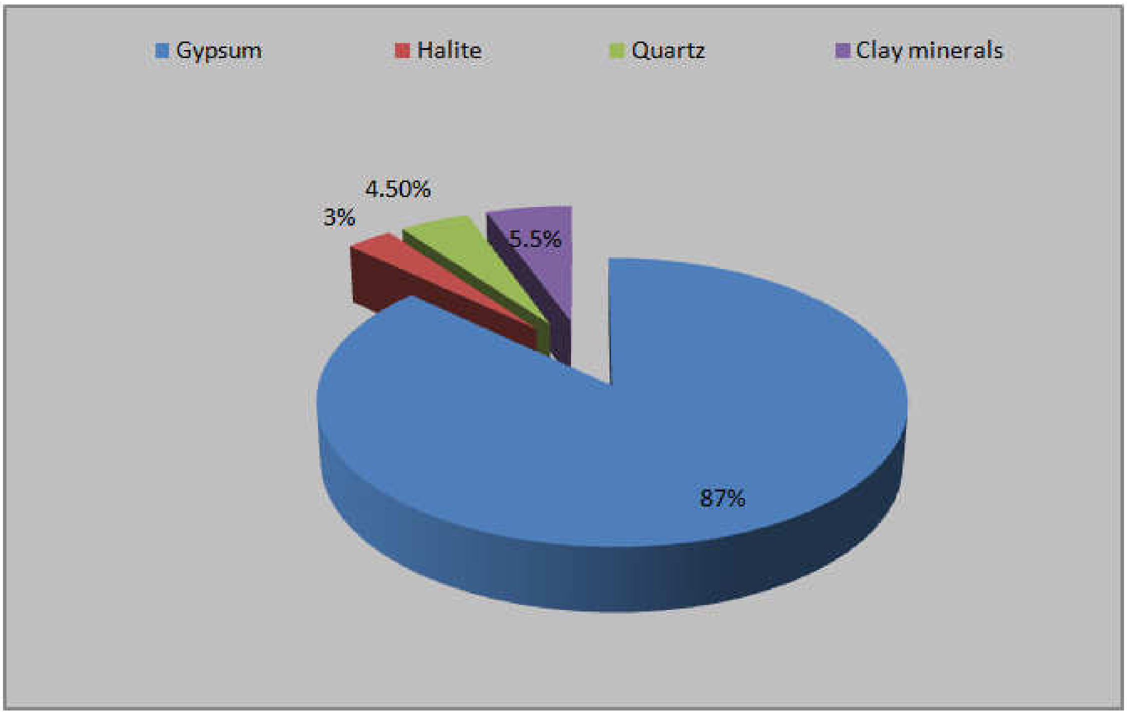

Figure 5-1: Pie shape illustrates the mineralogical composition (%) of the sediments of Sawa Lake.

### 5-2-1 Evaporites

Evaporites (chloride and sulfate) are common minerals of sediments in saline lake. They could be a good indicator in evolutionary history of the lake since chemical precipitation in a lake.

#### 5-2-1-1 Gypsum

Gypsum is a widely distributed as non-metallic mineral in several areas in Iraq. Gypsum is a naturally occurring mineral consisting of 79% calcium sulfate and 21% water (Reed, 1975). The white color of pure gypsum changes to gray, brown, or pink in the presence of impurities. When gypsum ($CaSO_4.2H_2O$) heated to 180°C, it loses 75% of its water, and becomes as hemi-hydrate phase (β phase) ($CaSO_4.1/2H_2O$), which is easily grounded to a powder commonly called plaster of Paris. After 230°C it loses the remaining half molecule, and then alters to anhydrite ($CaSO_4$) which is dehydrated calcium sulfate (Klein and Hurlbut, 1985), that may be altered to gypsum again by hydration. The conversion of gypsum to anhydrite causes 39% volume decrease (Artieda and Herrero, 1996) and 20.9% weight decrease (Eswaran and Zi-Tong, 1991).

When β phase is mixed with water, form a paste or slurry; water chemically recombines with hemi-hydrate, and the reaction will revert back to the original composition of gypsum (Founie, 2003).

In the study area (Sawa Lake), calcium sulphate minerals are the dominated evaporates lithofacies, consisting of the crystallization process, which depends directly on the concentration of solutions that are susceptible to evaporation. Crystallization happened either directly beneath the surface of the lake or occurs in the depths of the lake as a result of changes in temperature.

Gypsum occurs in the sediments of this lake as a dominant mineral. It ranges between 67.5% -97.5% with 87% as mean (Table 5-1) (Figure 5-1). It identified as the main mineral in the lake with massive internal structure as concentric circles (Figure 5-2).

Figure 5-2: Cross section of gypsum mass show the internal structure as concentric circles; sample no. 11S-t.

This mineral is determined by the XRD (Figures 5-3, 5-4, 5-5, 5-6, 5-7, 5-8, 5-9, 5-10, and 5-11).

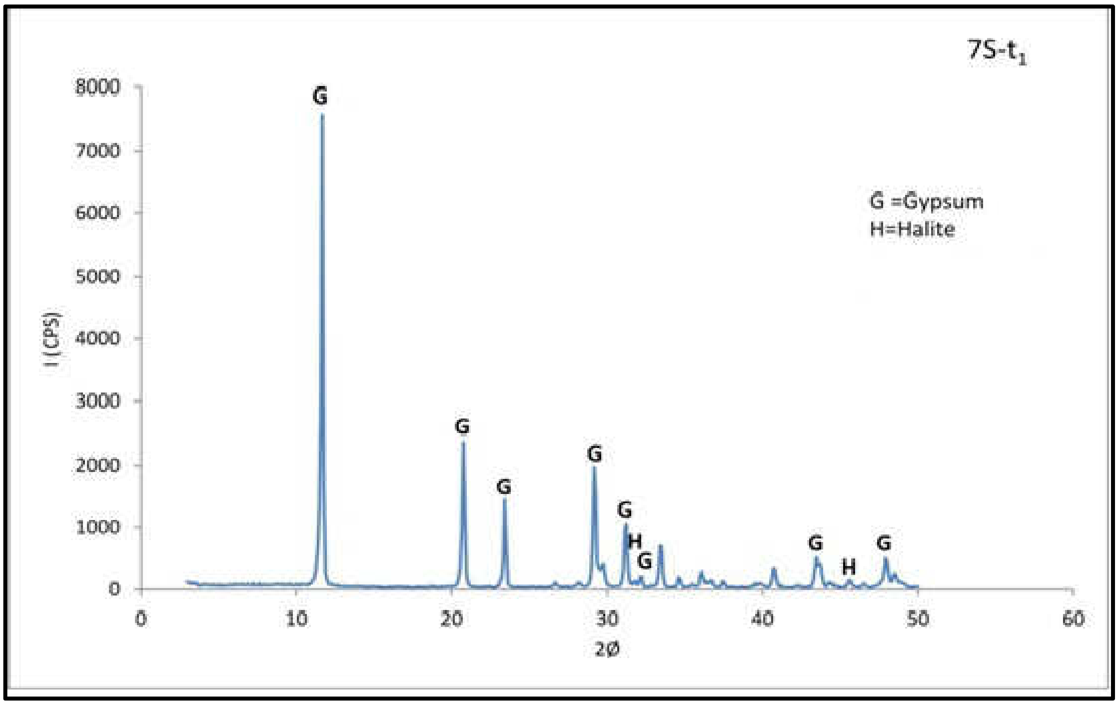

Figure 5-3: X-ray diffractograph of Sawa lake sediments;
Sample no. 7S-$t_1$.

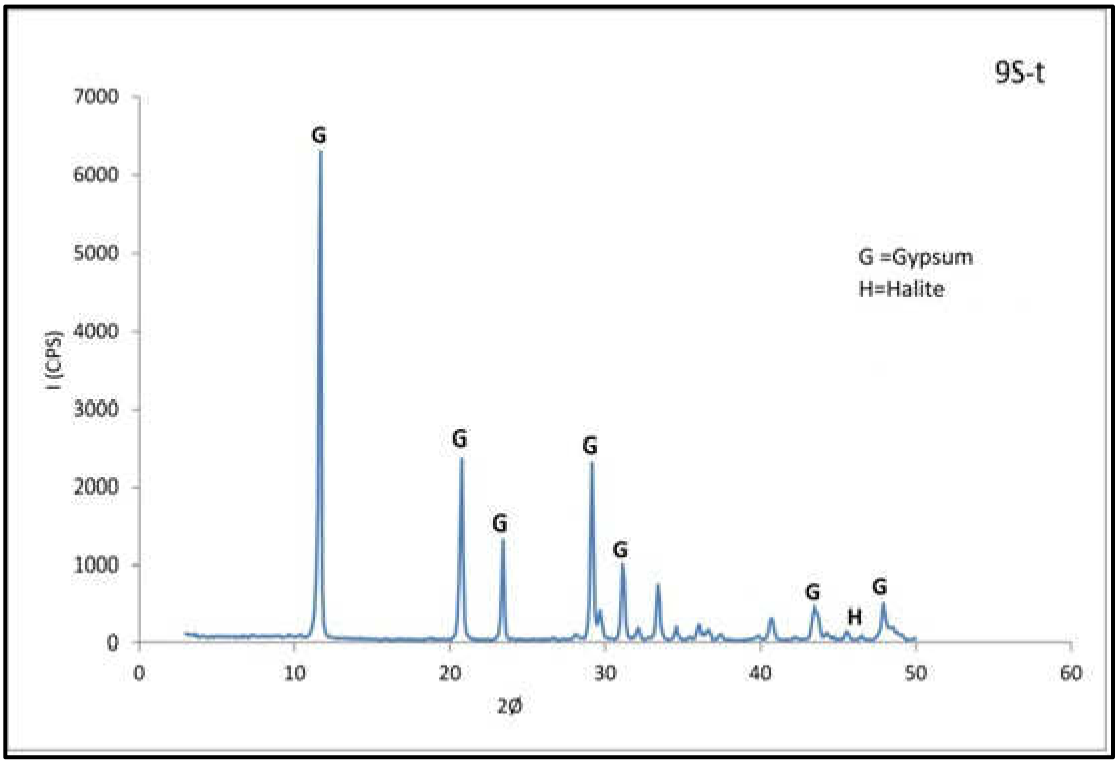

Figure 5-4: X-ray diffractograph of Sawa lake sediments sample no. 9S-t.

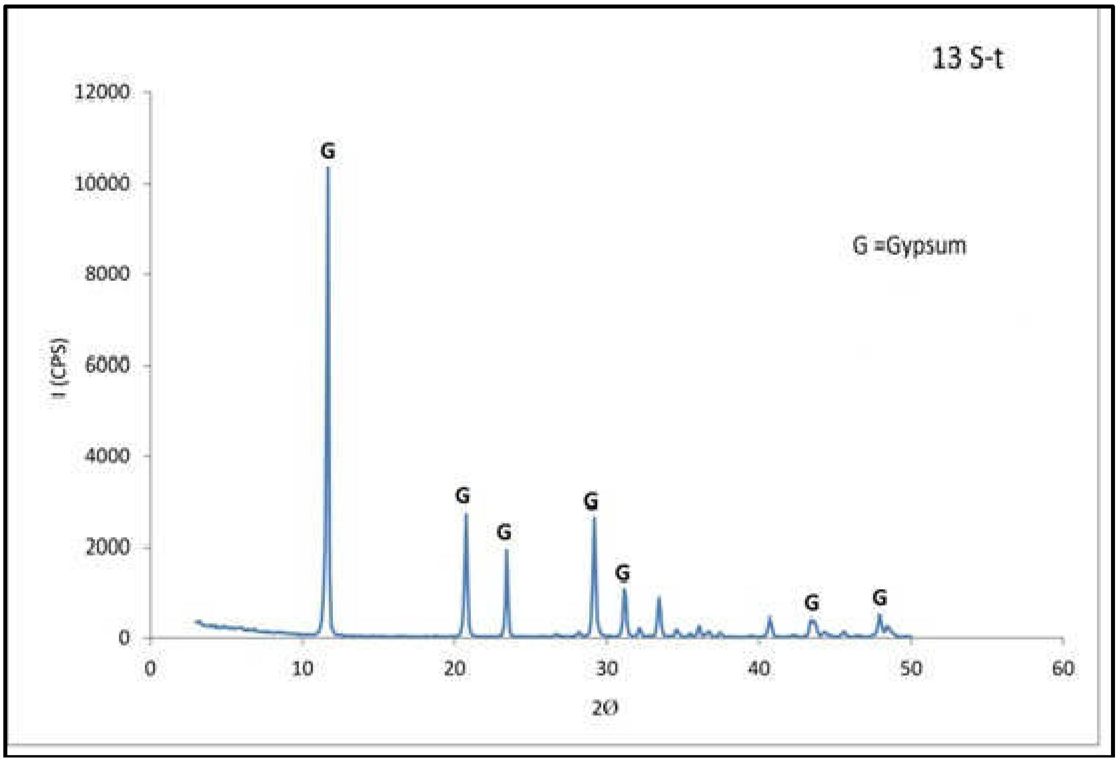

Figure 5-5: X-ray diffractograph of Sawa Lake sediments; sample no. 13S-t

Under microscope many features of gypsum are identified. Friable fractured gypsum grain (Plate 5-1a), multi-growth gypsum grains monoclinic system (Plate 5-1b), fibrous grains of gypsum with small new cut older grains (Plate 5-1c), tiny grains tend to be arranged in one direction (Plate 5-1d); a feature that occurs frequently. Curvature lath shape of gypsum grows within spaces among the older grains (Plate 5-1e). Striped granular gypsum is also observed (Plate 5-1f).

Aggregated gypsum (Plate 5-2a) and individual spinal grain are scattered within tiny grains (Plate 5-2b). Tiny spinal grains (Plate 5-2c) and fibrous gypsum (Plate 5-2d) are present. Growth gypsum crystals radiate outside (Plate 5-2e and Plate 5-2f).

Crystals of gypsum grow and aggregate around a central body to from balls (shapes of cauliflower) (Plate 5-3a). Cleavage in gypsum is very clear (Plate 5-3b). Gypsum grain shows fractures (Plate 4-3c) with wavy extinction.(Plate 5-3d).

Gypsum with algae (Plate 5-3e) and black spots may be organic matter (Plate 5-3f).

## Plate 5-1

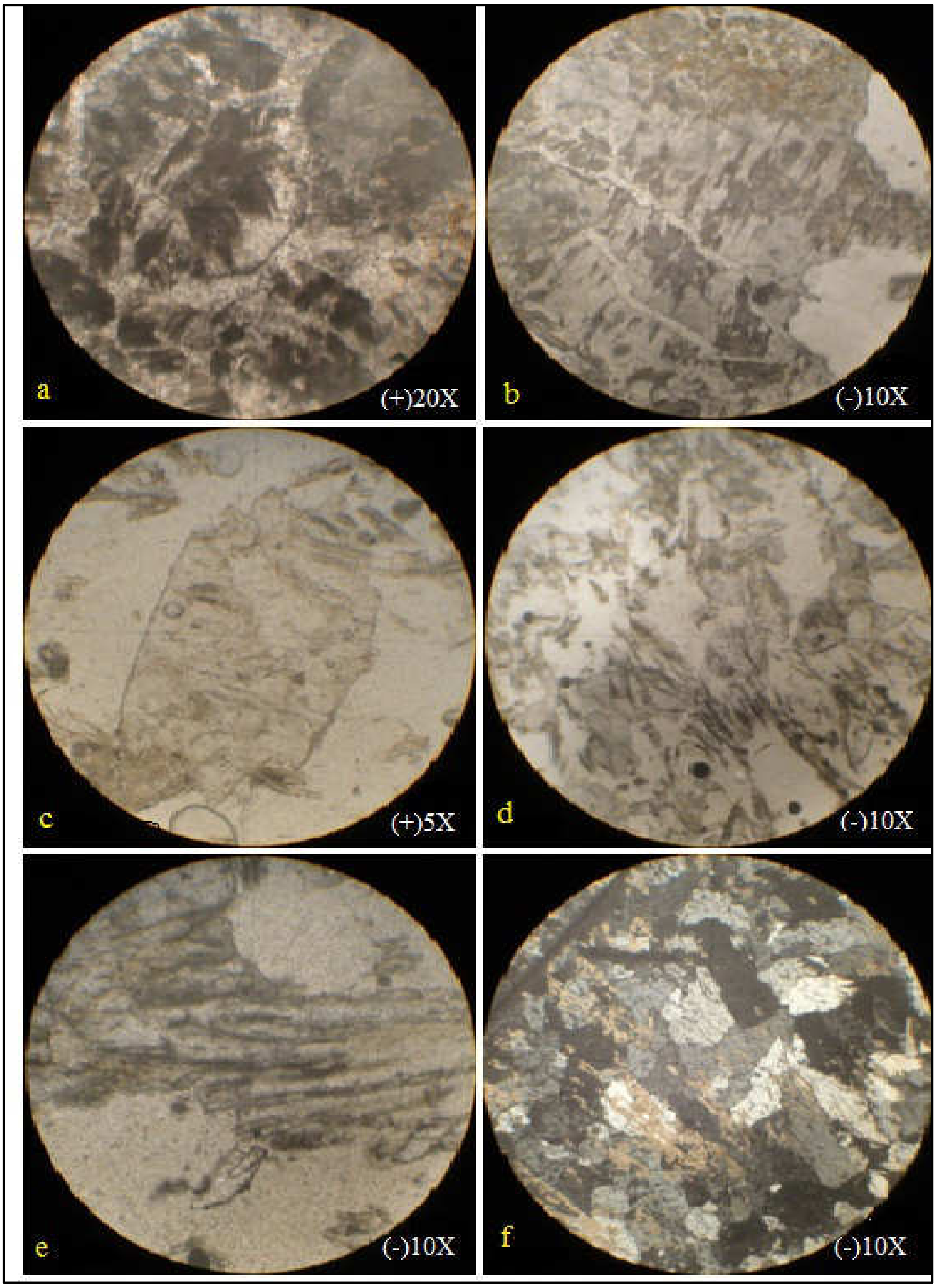

Plate 5-1a: Friable gypsum grain shows fractures, sample no. 1S-t.
Plate 5-1b: Multi-growth gypsum grain sample no. 2S-t.
Plate 5-1c: Fibrous grains of gypsum with small new cut older gypsum sample no. 2S-t.
Plate 5-1d: Tiny grains tend to be arranged in one direction 2S-t.
Plate 5-1e: Curvature lath shape of gypsum growth within spaces among the older grains no.3S-t.
Plate 5-1f: Striped granular gypsum with algae, sample no. 3S-t.

**Plate 5-2**

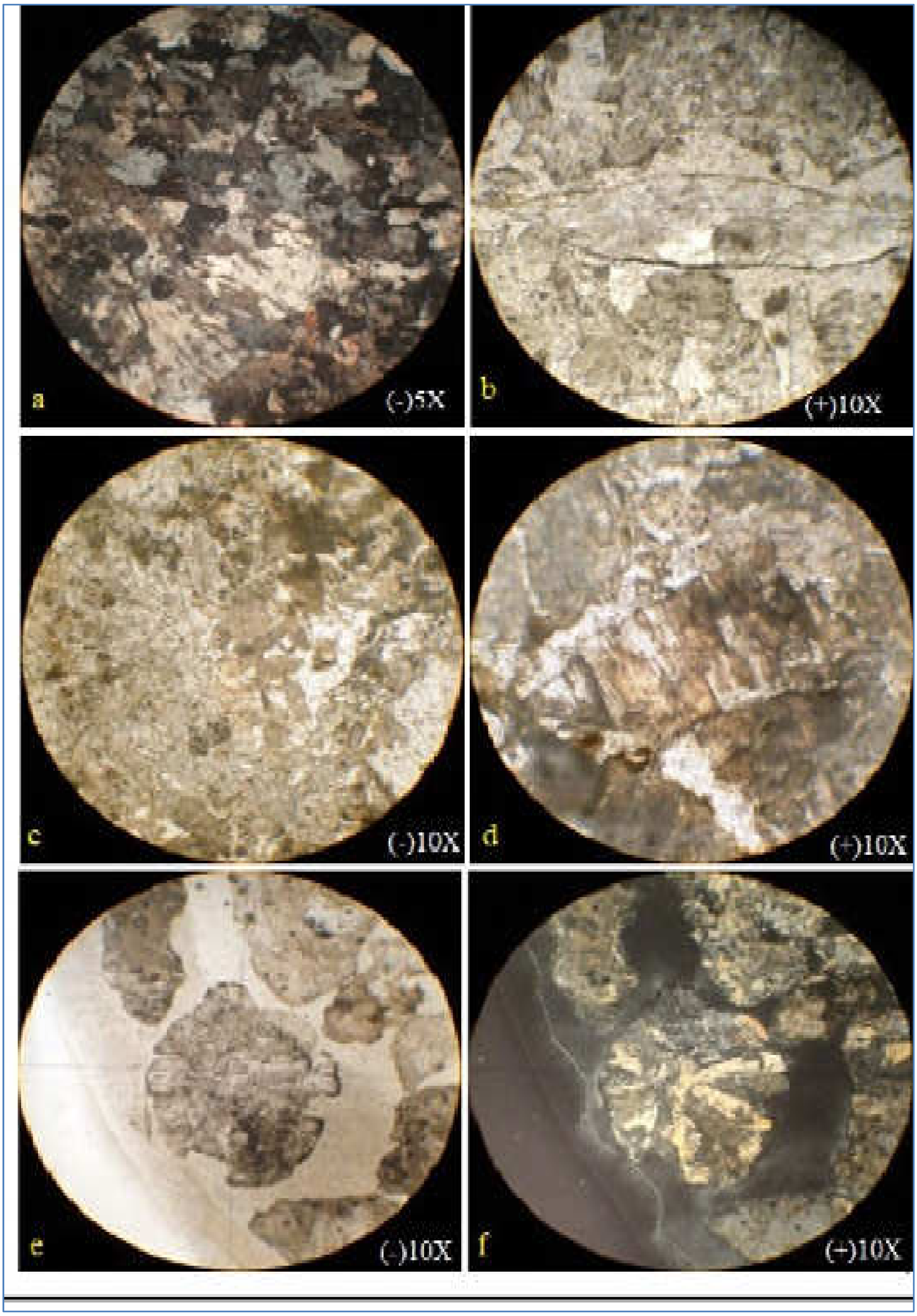

Plate 5-2a: Aggregated gypsum, sample no. 2S-t.
Plate 5-2b: Individual large spinal grain within small spinal grains of gypsum, sample no. 5S-t.
Plate 5-2c: Tiny spinal grains of gypsum, sample no. 5S-t salt.
Plate 5-2d: Fibrous gypsum, sample no. 6S-t salt.
Plate 5-2e: Growth gypsum crystals radials outside, sample no. 19S-t salt
Plate 5-2f: Growth gypsum crystals radials outside, sample no. 19S-t salt

**Plate 5-3**

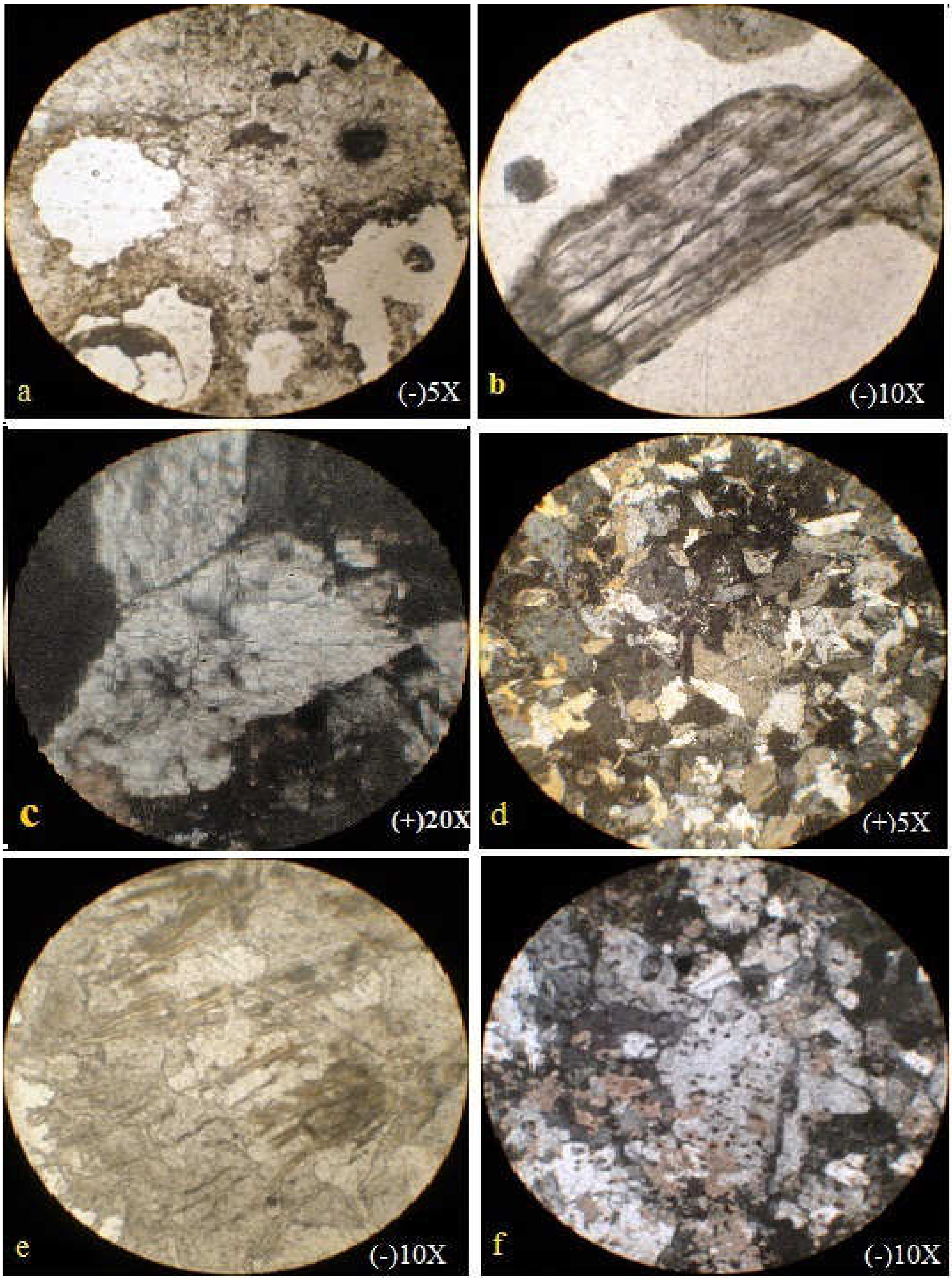

Plate 5-3a: The growth and collect crystals of gypsum around a central body to the balls configuration (shapes of cauliflower), sample no. 11S-t salt.
Plate 5-3b: Cleavage is perfect parallel in gypsum in perpendicular section on cleavage plane, sample no. 19S-t salt
Plate 5-3c: Gypsum grain shows fractures, sample no.1S-t
Plate5-3d: Wavy extinction gypsum, sample no. 4S-t salt
Plate 5-3e: Gypsum with algae, sample no. 9S-t salt.
Plate 5-3f: Black spots separated within gypsum, sample no. 9S-t salt

### 5-2-1-2 Gypsum plaster (plaster of Paris)

Gypsum plaster or plaster of Paris is produced by heating gypsum to about 150°C (Staff, 2008), as below:

$CaSO_4.\ 2H_2O + \text{Heat} \rightarrow CaSO_4\cdot\frac{1}{2}H_2O + 1\frac{1}{2}\ H_2O$ (released as steam).

When the dry plaster powder is mixed with water, it re-forms into gypsum. If plaster or gypsum is heated above 200°C, anhydrite will be formed, which will also re-form as gypsum if mixed with water (Deer et al., 1992).

This mineral is determined by XRD only (Figures 5-6 and 5-7), because this mineral is unstable in nature, quickly turn into to gypsum.

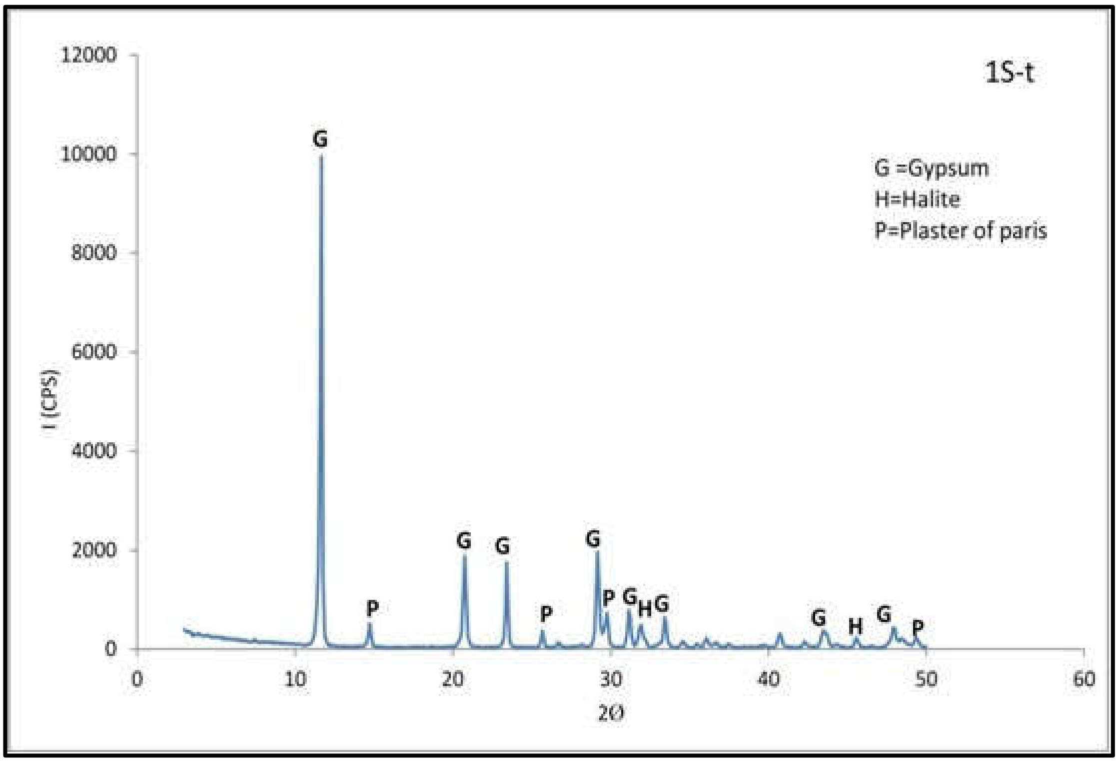

Figure 5-6: X-ray diffractograph of Sawa Lake sediments; sample no. 1S-t.

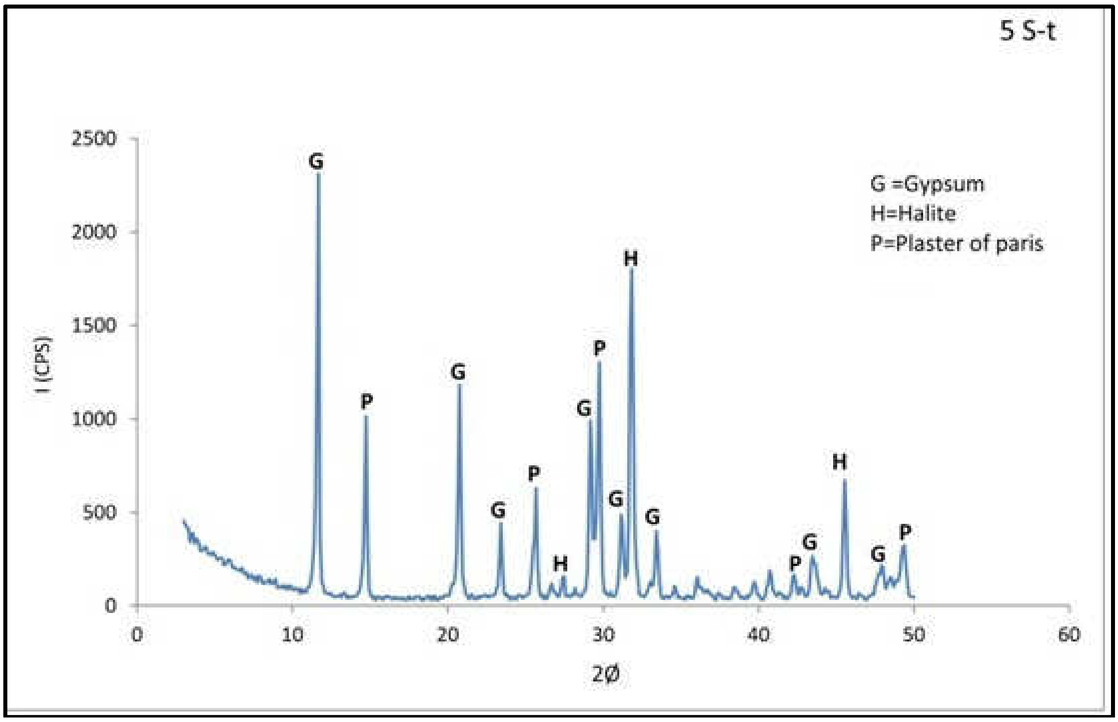

Figure 5-7: X-ray diffractograph of Sawa Lake sediments; sample no. 5S-t.

### 5-2-1-3 Halite

Commonly known as rock salt, it is sodium chloride (NaCl). Halite forms isometric crystals. The mineral is typically colorless or white, but may also be light blue, dark blue, purple, pink, red, orange, yellow or gray depending on the amount and type of impurities. It commonly occurs with other evaporate deposit minerals such as several of the sulfates, halides, and borates. Halite occurs in vast beds of sedimentary evaporate minerals that result from the drying up of enclosed lakes, playas, and seas. Salt beds may be hundreds of meters thick and underlie broad areas (Wikipedia, 2012). Halite spread widely in salt crust formed by evaporation of surface water and for being the last residual salts and first soluble sodium and the advantage of having the ability to stick on the clay minerals (Rankama and Sahama, 1950).

In Sawa Lake, there is very little halite quantity because of the high solubility of this mineral, so that it stays dissolved in solution. It was identified in only one sample using the polarized microscope (plate 5-4).

In the present study, Halite ranges between 0.3% -2.7% with 3% as mean (Table 5-1) (Figure 5-1). It is identified as the minor minerals in the sediments of Sawa Lake after gypsum. It is characterized by small peaks in many samples on X-ray chart (Figures 5- 8, 5-9 and 5-10). This is supported by chemical analyses which reflect low concentrations of Na and Cl.

Plate 5-4: Halite crystal from Sawa Lake sediments (7S-t1)

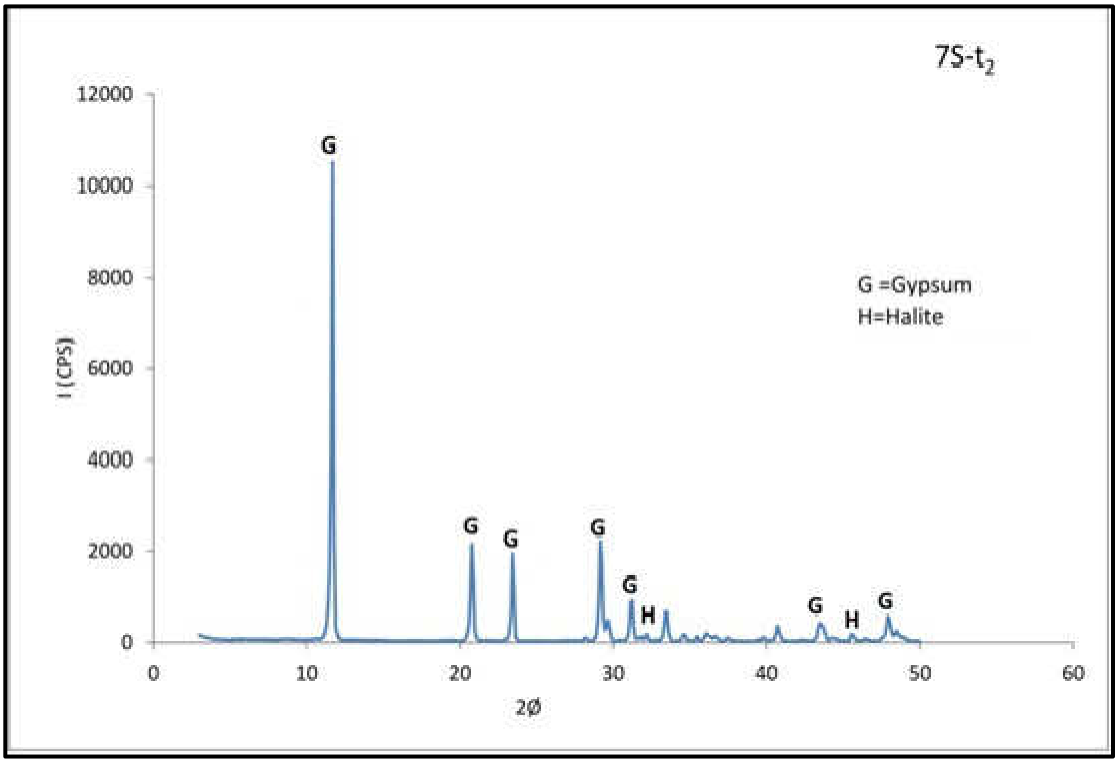

Figure 5-8: X-ray diffractograph of Sawa Lake sediments sample no. 7S-$t_2$.

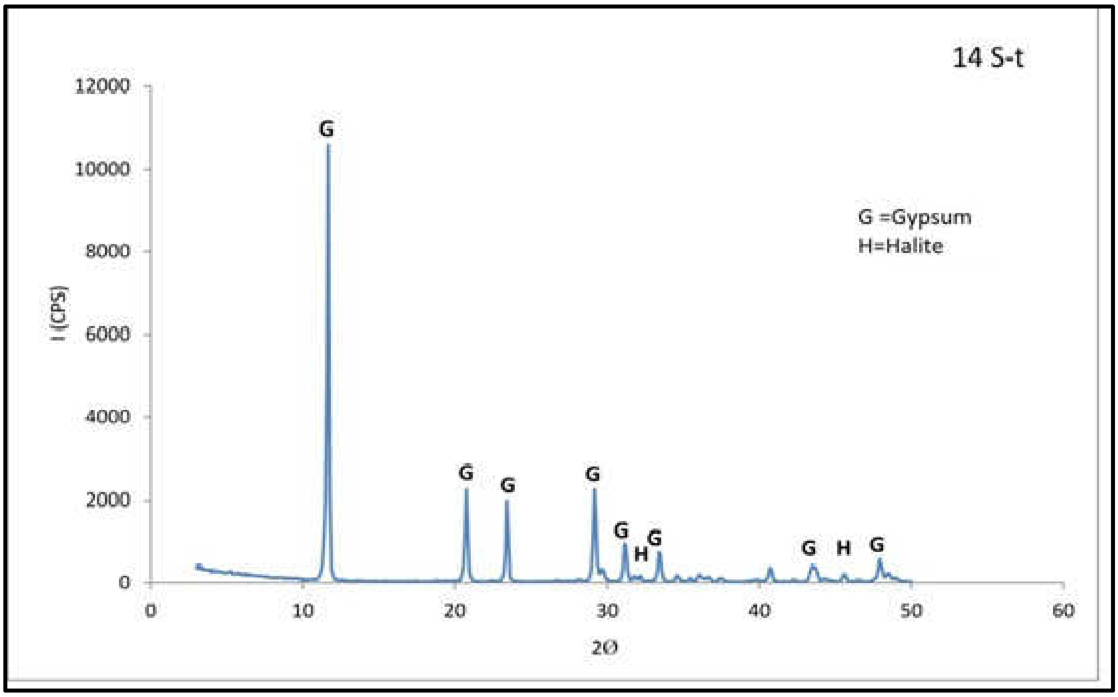

Figure 5-9: X-ray diffractograph of Sawa Lake sediments sample no. 14S-t

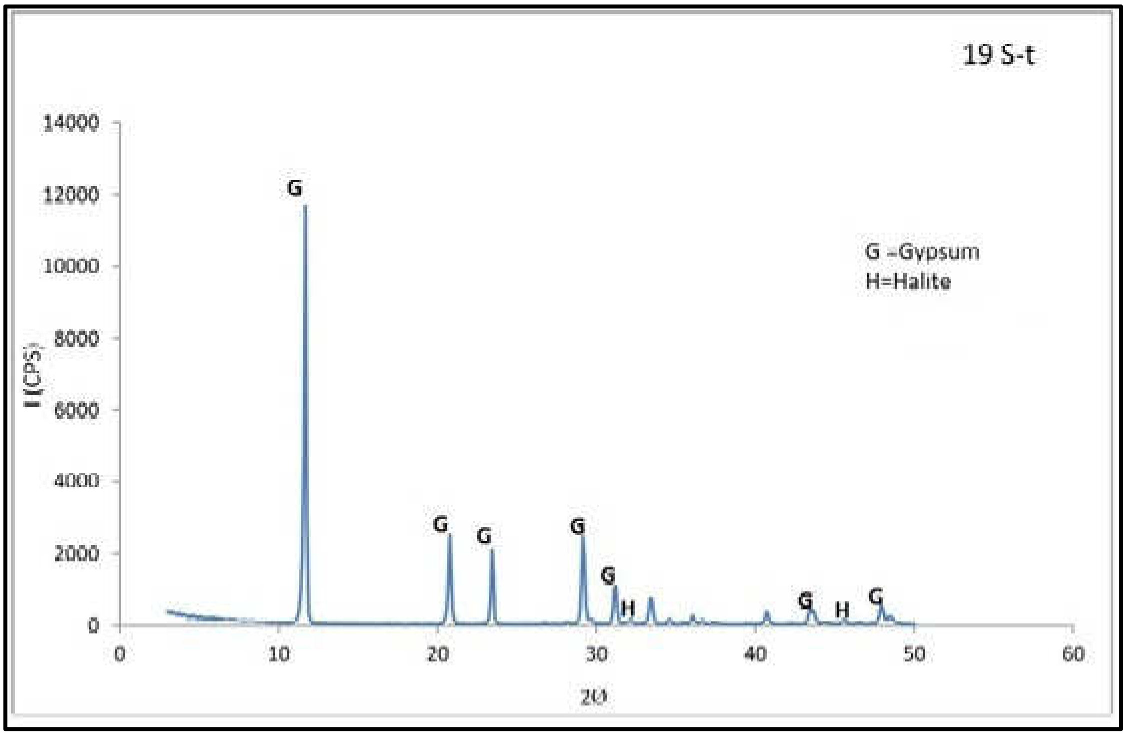

Figure 5-10: X-ray diffractograph of Sawa Lake sediments; sample no. 19S-t

### 5-2-2 Quartz

Quartz is the most commonly found mineral at the earth's crust, and occurs in igneous, metamorphic and sedimentary rocks. It is an essential constituent of acid igneous rocks; it is also a principal gangue mineral of veins radiating from intermediate and acid igneous rocks. Because of its resistance to weathering under ambient pH conditions, quartz accumulates as a principal constituent of sediments. Solubility of quartz increases dramatically in alkaline fluids (Wright and Lehmann, 1981).

In the study area, a small percentage of quartz varies between 0.0 -15%, and reaches 4.5% as mean in the sediments of Sawa Lake.

Probably, it is transported from Quaternary sediments by wind and dust storms. Sand dunes which are part of these deposits contain a high percentage of quartz. Percentage of quartz in sand dunes is mostly high. The general direction of sand dunes takes the prevailing wind direction, but local winds also play an effective role in spreading and distributing the sand dunes, thus it may come to the Sawa Lake (Abdul-Ameer, 2012). Peaks of quartz are quite clear in XRD patterns of samples no. 10S-t (Figure 5-11). It is definite in mineralogical composition but in a small amount (Table 5-1).

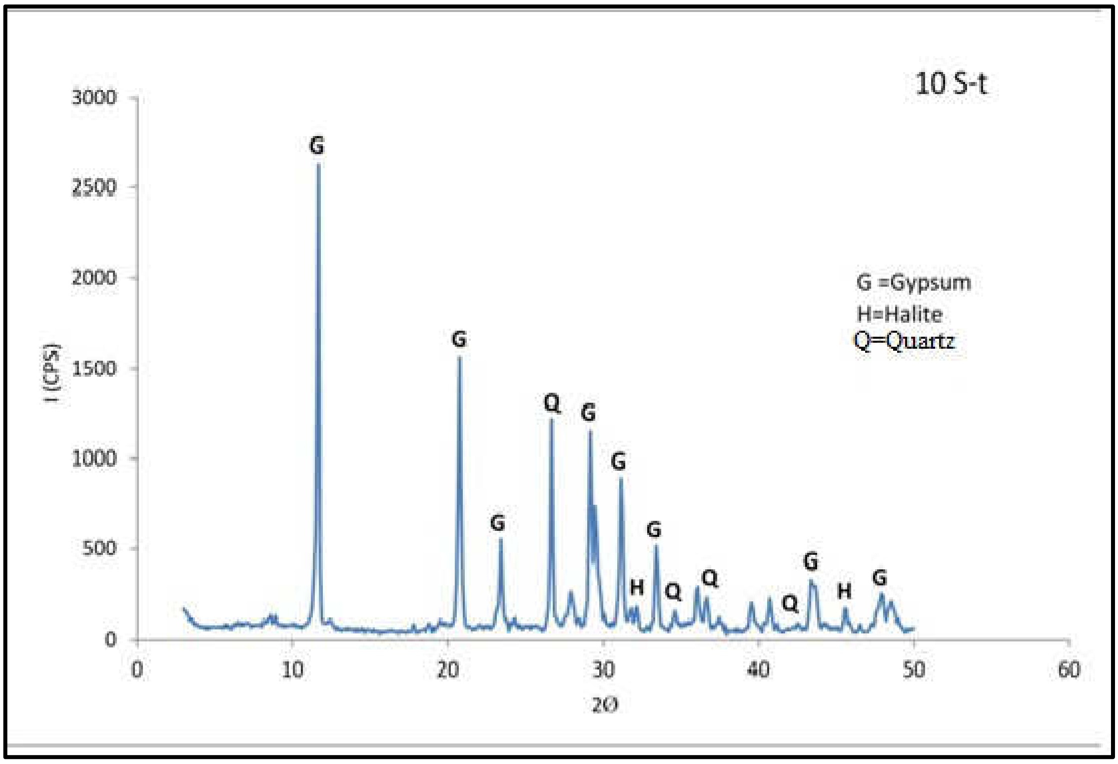

Figure 5-11: X-ray diffractograph of Sawa Lake sediments; sample no. 10S-t.

### 5-2-3 Clay minerals

The study of clay minerals has a great geological importance. It indicates the type of the source rocks, in addition to the nearness or farness of these rocks and the physical and chemical changes and nature of the climate and lastly sedimentary environment (Weaver, 1956). Clay minerals are important to indicate the changes in sedimentary environments when difference in the quality of clay minerals and in the distribution of stratification column (Grim, 1968 and Keller, 1970). Most of clay minerals are authogenic or formed as a result of the physical and chemical weathering process which happened on the various rocks, during the digenetic which happened on detrital materials transferred to the sedimentation basin. Also they have hydrothermal or volcanic origins (Velda, 1995). The types of clay minerals are controlled by the climate and the source rocks quality (Millot, 1970). Clay minerals in sediment of the Sawa Lake may come from the atmosphere via winds, irregular rainstorms. Also may be transported through undergrounds channels or new sediments from surrounding areas (Samaan, 1985).

The mineralogical composition of the clay minerals were computed in the study area (Table 5-1); it was participated in small amounts beside evaporates to form the sediments of the Sawa Lake. Clay minerals in the sediments of Sawa Lake varie between 1.5-19% with mean 5.5%. The highest amount of clay minerals was occurred in sample No. 10S-t. XRD analyses of this sample revealed absence of dolomite. Also the chemical results of this sample refer to considerable contents of $SiO_2$, $Al_2O_3$ and MgO. This composition indicates a palygorskite.

### 5-3 Fossils

Fossils are collected from the Sawa lake sediments, near its shore and identified under microscope. These fossils are *Pomatiopsis Tryon* which belongs to Gastropod. Gastropoda lives in brackish water from Oligocene to Recent (Clarkson, 2004). The shell of theses fossils are found as disseminated fragments within gypsum aggregates. it appears older than gypsum precipitation. Gypsum was precipitated filling the fossils shell (Plate 5-5a). Some fossil shells are free (empty) of gypsum (Plate 5-5 b, c and d).

The fossils which belong to the age of Oligocene and Miocene may be originated from the Dammam and Euphrates formations hosting the water of the lake, and by supplies the Lake with water. Fossil shells of good preservation were found (Plate 5-5e and Plate 5-5f) at the southern shore of the lake. This may be attributed to the wind that causes the wave to push the fossils toward the shore.

**Plate 5-5**

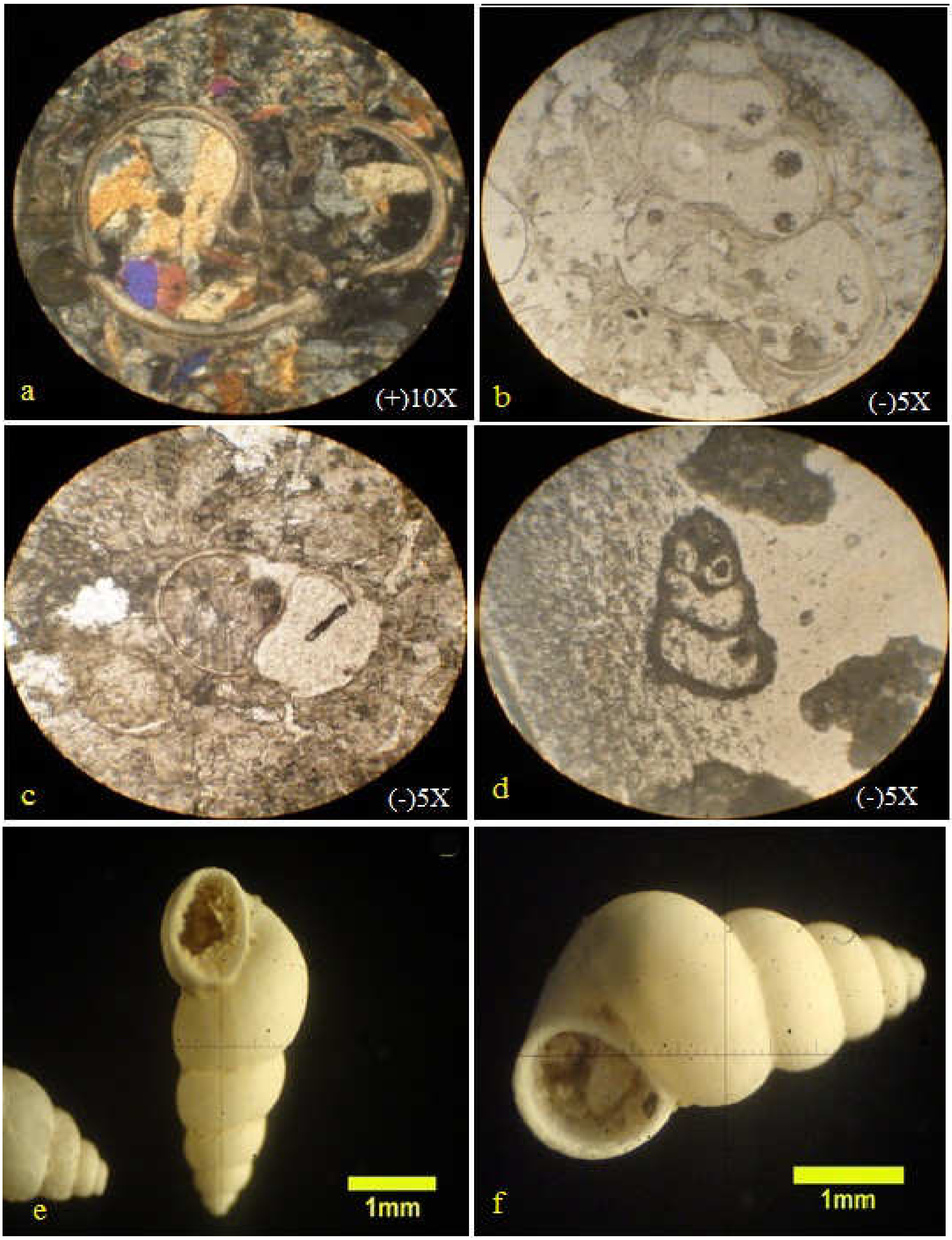

Plate 5-5a: Large grain of gypsum precipitated in fossil's shell, sample no. 4S-t salt.
Plate 5-5b: Fossils free of gypsum, sample no.9S-t salt.
Plate 5-5c: Fossils, sample no. 9S-t salt.
Plate 5-5d: Fossils, sample no. 9S-t salt.
Plate 5-5e: Fossils separated from sediments (*Gastropoda* genus).
Plate 5-5f: Fossils separated from sediments (*Gastropoda* genus).

## 5-4 Mineral identification by FTIR

The Fourier Transform Infra-red (FTIR) spectra were used for 3 samples which are no.7S-$t_1$, 7S-$t_2$, and 19S-t as analytical method. The great potential of the FTIR technique comes from the large amount of information's on minerogenic and organic substances provided by the FTIR spectra. Most importantly, it is a rapid, cost-saving technique, which only requires very small amounts (0.02 g dry weight) of sample material.

The (FTIR) absorption spectra of sediments give more information about mineralogy (Ramasamy et al., 2006). Figure 5- 12 showed FTIR - spectrum at the wave number range 500 - 4000 Cm-1, the stretching of OH group gypsum is illustrated FTIR spectrum at the range 3000-4000 $Cm^{-1}$( Marcio et. al., 2004). Also gypsum which shown the wave numbers 1620, 1685, 3545, 3483, 3402, 3244, $Cm^{-1}$ $SO_4$ line present it is shifted from 1000 $cm^{-1}$ to 1200 $cm^{-1}$, OH presents shifted from 1400 $cm^{-1}$ to 1700 $cm^{-1}$ indicating for the presence gypsum mineral (Al-Jobouri, 2011).

In the studies of clay minerals the absorption bands due to structural OH and Si–O groups play frequently an important role in the differentiation of clay minerals. The spectra of clay minerals show Si–O stretching and bending as well as OH bending absorptions in the 1300–400 $cm^{-1}$ range ( in general below 1200 $cm^{-1}$) (Russell, 1994) (Figure 5- 12). Si-O also refers to quartz as well as the silica originated from the clay minerals. FTIR is shown the Iodine and bromine which appear to be in complex compound in the sediments of Sawa Lake.

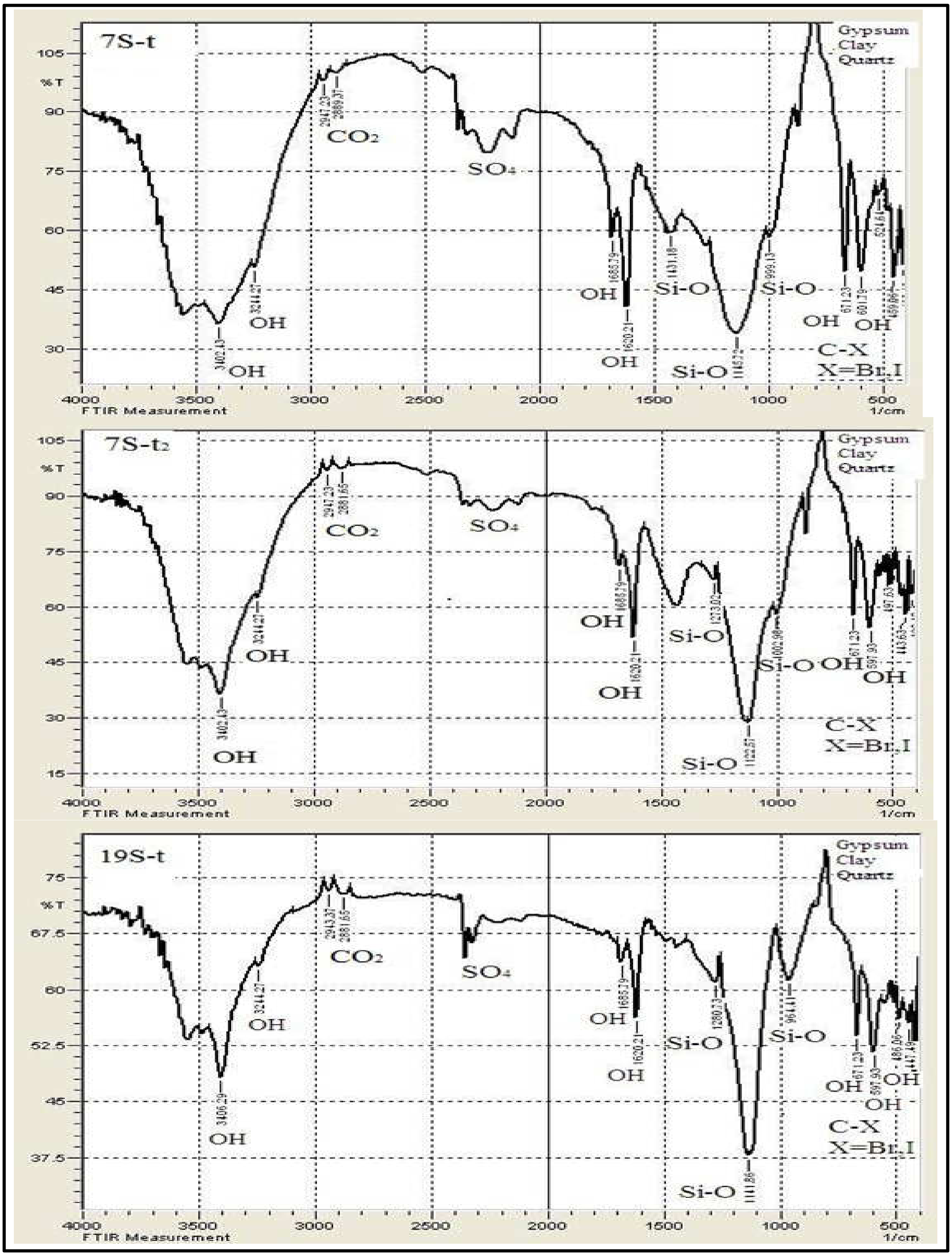

Figure 5-12: FTIR graph of the sediment of Sawa Lake.

## 5-5 Barrier surrounded Sawa Lake

Sawa Lake is a land locked Lake; it has no beach, lying within the (stable shelf) of Iraq as defined by Buday (1973). It has evaporite rim formed from gypsum barrier that rises between 3- 6m above the land and surface water (Figure 5-13) (Awadh and Muslim, 2012). The gypsum barrier prevents the surface water to enter the lake. Sawa Lake elevated above the sea level by18.5m (Al-Naqash 1977). It is a salty lake with maximum length 4.74 km and maximum width 1.77 km isolated by gypsum barrier with total path of 12.5 km surrounded the lake. Sawa Lake elevates above the surround land by about 1 to 4 m, and 5 to 7m above the Euphrates River (Awadh and Muslim, 2012).

The mechanism of buildup of the wall is closely linked to the process of evaporation of saturated solution with the slow simultaneous feeding from the bottom. The process of building the salty wall begins by direct precipitation of gypsum from solution. Gypsum precipitates directly from solution and crystallizes on the bottom and rim. This process is active in the shallow sites that represent the boundary of the lake. Gypsum grows with time and rises upward to be higher than the water level; hence capillary process absorbs water upward to the surface of crystallized gypsum. The early gypsum appears to be nuclei for late gypsum which precipitates as concentric layers. Strange shapes of gypsum masses resembling cauliflower formed (Figure 5-14). The salty sediments along the coast represent a natural sculpture exhibition (Figure 5-15). It is no doubt a groundwater fed through a system of joints, cracks and fissures from the aquifers beneath (like Dammam, Euphrates and Rus formation). The chemistry of lake water reflects the lithology of these formations.

Sawa Lake bottom is made up of gypsum masses similar to the barrier. Fine sand mixed with clay is present locally at bottom which is transported by wind from nearby sand dunes and dust storms and precipitated in the lake. The lake and its surrounding area is 17-20 m above sea level (Awadh and Muslim, 2012).

The barrier of gypsum which represents the wall of the lake contains caves formed by surface the dissolution processes (Figure 5-16) (Awadh and Muslim, 2012).In case of unbalanced masses, some parts of the lake wall and caves collapse causing increase the area of the lake (Awadh and Muslim, 2012) (Figure 5-17).This increase in the surface area doesn't mean increase the water level of the Sawa Lake, but it means there is changing in the morphology of the lake.

Figure 5-13: Gypsum barrier around Sawa Lake.

Figure 5-14: Cauliflower-like shape Gypsum forms the wall of Sawa Lake

Figure 5-15: Natural gypsum sculpture exhibition on the Shore of Sawa Lake.

Figure 5-16: Cave of equilateral triangle shape, 2m for each side.

Figure 5-17: The collapse of the lake wall due to chemical dissolving causing increase the surface area of the lake.

## 5-6 The formation models of gypsum

Sawa Lake has high salinity due to high concentration of major anions and cations. Sulfates and calcium are part of these ions. Gypsum is deposited immediately after the solution become saturated. Calcium is associated with sulfates and then crystallizes in the bottom of the lake. The rate of sedimentation in shallow areas is higher than in the deeper areas, because of the relative variation in evaporation. Since the bottom of the lake is not quite level, the deposited gypsum illustrates the form of a bottom. Consequently, near the lake shore overhangs of gypsum masses are existed. These masses have irregular shapes.

There are two accepted mechanisms explain the movement of water and deposition of evaporates in Sawa Lake. The first is the capillary action mechanism (the upward diffusion of salt water towards the top within the vadose zone by the capillary action to increased rates of evaporation on the surface of the lake) (Amiel and Friedman, 1971). The second is the evaporation pumping mechanism that states movments of groundwater depends on the vertical hydraulic gradient from its level or from the bottom to the evaporation- susceptible area (Hsü and Siegenthaler, 1969).

Sedimentation occurs in many areas within the lake depends on the solutions at the water level (Samaan, 1985). Gypsum was deposited at the bottom in case of high water level and on the coast of the lake at low water level (Raup, 1982). The gypsum mass still grows because it contains interstitial spaces, and cleavages planes. Capillary action plays a main role in the process of raise up water from the lake to the surface. During periods of high temperature, evaporation will be intense. This leads to grow gypsum in the form of Concentric balls (Figure 5-2) which may dissolve forming a gypsum bed (Figure 5-18) and reaches above the water surface (Figure 5-19).

Gypsum grows with time in forms according to the pathway of feeding. Thus we find variable forms of gypsum above water surface and near the shore of the lake. Developing of these forms takes a long time and passes several stages. This is what is noted by the presence of organic matter (black color) and green algae which participate in gypsum precipitation. Theses algae contribute to build gypsum barrier after her death becomes its body like a sponge, also the organic matter able to adsorb water. It contributes to the process of capillary raise water then evaporated under the sun causing deposition gypsum. This causes the growth of forms massive gypsum over the surface of the water.

Figure 5-18: gypsum bed (grow gypsum in the form of Concentric balls)

Figure 5-19: Irregular forms of gypsum developing above the lake water due to capillary action.

## 5-7 Geochemistry

### 5-7-1 Geochemistry of major oxides

Nine sediments samples are analyzed for $SiO_2$, $Al_2O_3$, CaO, MgO, $Fe_2O_3$, $Na_2O$, $K_2O$, $SO_3$, Cl and loss on ignition (L.O.I). Chemical analyses for these oxides, their ranges and averages are listed in Table 5-2.

Chemical analyses show quite clearly that the average of CaO (31%), $SO_3$ (34%) and LOI (18%) are dominant. These components reflect the prevalence of gypsum in the sediment of Sawa Lake. The averages of $SiO_2$ (8.0%), $Al_2O_3$ (1.5%), MgO (3.0%) and $Fe_2O_3$ (0.6%) are mainly belong to the clay minerals and silica sand grains. Chloride and sodium belongs to halite mineral, where averages of $Na_2O$ (1.5%) and Cl (2.0%) indicate the little amount of halite in the sediments of Sawa Lake. Figure 5-20 shows the average of chemical composition of sediments of the lake.

Table 5-2: Major oxides concentrations (%) of the Sawa Lake sediments.

| Sample No. | SO3 | CaO | L.O.I (OH) | $SiO_2$ | MgO | Cl | $Na_2O$ | $Al_2O_3$ | $Fe_2O_3$ | $K_2O$ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | | | | | | | | | | |
| **3S-t** | 42.49 | 34.0 | 17.1 | 2.8 | 1.67 | 0.45 | 0.33 | 0.4 | 0.2 | 0.05 | 99.5 |
| **5 S-t** | 35.26 | 27.0 | 12.72 | 1.86 | 3.59 | 10.75 | 7.44 | 0.3 | 0.1 | 0.39 | 99.4 |
| **9 S-t** | 42.28 | 33.93 | 18.47 | 1.26 | 2.28 | 0.6 | 0.32 | 0.3 | 0.04 | 0.03 | 99.5 |
| **14S-t** | 41.36 | 32.9 | 17.63 | 1.64 | 2.54 | 1.67 | 1.09 | 0.4 | 0.06 | 0.05 | 99.3 |
| **19S-t** | 44.8 | 32.7 | 18.66 | 0.95 | 0.88 | 0.71 | 0.31 | 0.5 | 0.06 | 0.03 | 99.6 |
| **7S-t** | 37.0 | 36.89 | 15.9 | 5.46 | 2.2 | 0.82 | 0.67 | 0.8 | 0.43 | 0.05 | 100 |
| **10S-t** | 19.5 | 25.7 | 20.0 | 21.0 | 5.0 | 1.26 | 1.69 | 3.8 | 1.6 | 0.15 | 99.7 |
| **12S-t** | 25.28 | 31.3 | 17.9 | 15.7 | 3.17 | 0.17 | 0.63 | 3.39 | 1.31 | 0.13 | 99.5 |
| **14S-t** | 16.33 | 2459 | 24.2 | 19.46 | 6.98 | 1.65 | 1.47 | 3.52 | 1.47 | 0.17 | 99.8 |
| **Range** | 16.33-44.8 | 24.5-36.89 | 12.72-24.2 | 0.95-21 | 0.88-6.98 | 0.17-10.75 | 0.31-7.44 | 0.3-3.8 | 0.04-1.6 | 0.03-0.39 | ---- |
| **Av.** | 34.0 | 31.0 | 18.0 | 8.0 | 3.0 | 2.0 | 1.5 | 1.5 | 0.6 | 0.11 | ----- |

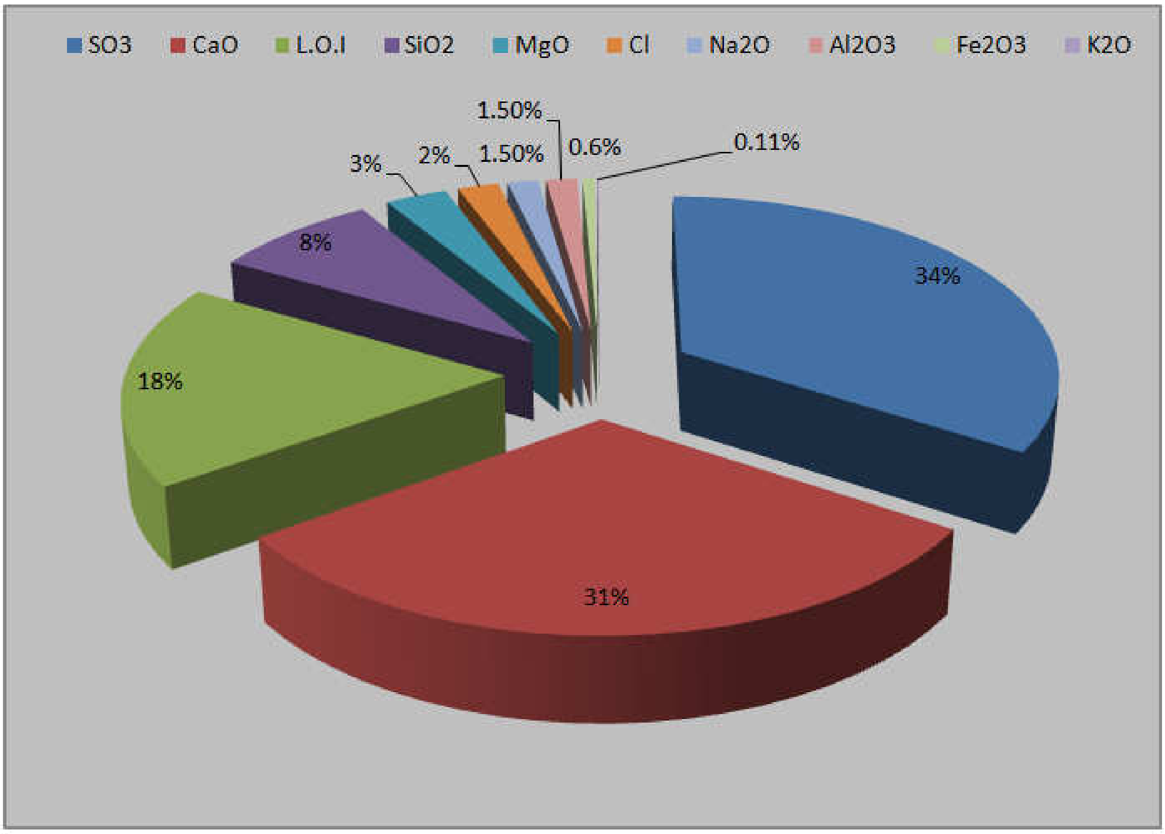

Figure 5-20: Pie shape illustrates the average chemical composition of the sediments of Sawa Lake.

### 5-7-2 Geochemistry of heavy metals

Sediment is a long-term sink for trace elements and it can be accumulated in sediments; thus, although they are necessary for the plants growth posing significant and persistent threat to organisms which feed on the sediments when their concentration become higher than the organisms need. Trace elements are normally produced from a variety of natural and anthropogenic sources (Dawson and Macklin, 1998). However, in aquatic ecosystems, metal pollution can also result from direct atmospheric deposition, geologic weathering or through the discharge of agricultural, industrial, municipal or residential waste products (Dawson and Macklin, 1998).Trace elements are important determinants of sediment quality because of their potential toxicity to living organisms (Förstner and Wittman, 1979).

Sediment samples were analyzed for Pb, Ni and Co. The mean concentration of lead (Pb) ppm in the lake sediments is 23 ppm; it appears to be twice higher than of global soil. It may restricted by tendency for adsorption to Mn-Fe oxides and insoluble organic matter (Rose et al., 1981). The average concentration of Co (19) ppm in the lake sediments is twice also higher than the global soil (Table 5-3). Nickel concentration (40) ppm in mean tends to be equal the global soil approximately. Iron appears to be in very low concentration (0.45%) in Sawa Lake sediments.

Table 5-3: The concentrations of heavy metals in the sediments of Sawa Lake.

| Sample no. | Pb | Ni | Co | Fe |
|---|---|---|---|---|
| | ppm | | | % |
| 7S-t | 21 | 25 | 17 | 0.16 |
| 10S-t | 22 | 48 | 23 | 0.6 |
| 12S-t | 21 | 45 | 22 | 0.5 |
| 14S-t | 29 | 46 | 16 | 0.55 |
| Range | 21-29 | 20-48 | 16-23 | 0.16-0.6 |
| Average | 23 | 41 | 19 | 0.45 |
| Soil global average (Lindsay, 1979) | 10 | 40 | 8 | 3.8 |

### 5-7-3 Radiation measurements

Natural radioactivity is widespread in the earth environment and it exists in various geological formations such as earth crust, rocks, soils, plants, water and air. When rocks are disintegrated through natural process, radionuclides are carried to soil by rain and flows (Taskin et al., 2009).

Studies have shown that activity concentrations of natural radionuclides in groundwater are connected to the activity concentrations of uranium and thorium and their decay products in the ground and bedrock. This is due to reaction of the water with the ground and bedrock and releasing quantities of dissolved components that depend on the mineralogical and geochemical composition of the soil and rock (Vesterbacka, 2007).

In this study, Gamma Spectrometer System based on high purity germanium detector with effecter 30% and resolution 2Kev at the energy line 1.33Mev energy-to peer Co-60 are used for investigating radiation in sediments samples (2S-t,6S-t,9S-t,13S-t and 19S-t).

Two radioactive decay series are detected; these are $^{232}$Th decay series and $^{238}$U decay series as well as $^{40}$K, while the $^{235}$U decay series and $^{137}$Cs were not detected( Figure 5-21). The detected decay series in the sediments of Sawa Lake can be described as follows:

#### 5-7-3 -1 $^{238}$U decay series:

Also commonly called the radium series ($^{238}$U, $^{234}$Th, $^{234}$Pa, $^{234}$U, $^{230}$Th, $^{226}$Ra, $^{218}$Po, $^{214}$Pb, $^{214}$Bi, $^{214}$Po, $^{210}$Pb,$^{210}$Bi, $^{210}$Po, $^{206}$ Pb). Uranium-238 ($^{238}$U or U-238) is the most common isotope of uranium found in nature. Around 99.284% of natural uranium is uranium-238, which has a half-life of 4.468 billion years (Mcclain et al., 2007). $^{238}$U radiates alpha-particles and decays (by way of thorium-234 and protactinium-234) into uranium-234. The relation between $^{238}$U and $^{234}$U gives an indication of the age of sediments that are between 100,000 years and 1,200,000 years in age (Encyclopædia Britannica, 2007).

In this study, $^{234}$Th, $^{226}$Ra, and Bi or Pb are detected. The $^{234}$Th ranges from 11.6 Bq/Kg to 27 Bq/Kg , while $^{226}$Ra varied between 42 Bq/Kg and 54 Bq/Kg. (Table 5-4). $^{214}$Bi or $^{214}$Pb ranges from 21.9 to 33.3 Bq/Kg. In the sediment of Baghdad, the $^{226}$Ra was 24-38 Bq/Kg (Shafik et al., 2011) . The Ra isotope in the lake sediments is higher than within Baghdad sediments (Table 5-5) indicated the enrichment of gypsum with Ra. This series concentrated in the sediment of Sawa Lake rather than in water.

In natural waters of pH 7-10, uranium ions in geologic formations form complexes with carbonate and become soluble, thereby entering the drinking water source (Cothern and Rebers, 1990). Radium becomes soluble at a lower pH (5 or less), and is, therefore, most likely to be present in acidic groundwater (USGS, 1998).

### 5-7-3 -2 $^{232}$Th decay series:

This series is commonly called the "thorium series." Beginning with naturally occurring thorium-232, this series includes the following elements: ($^{232}$Th, $^{228}$ Ra, $^{228}$Ac, $^{228}$Th, $^{224}$R, $^{220}$Rn, $^{216}$Po, $^{212}$Pb-, $^{212}$ Bi, $^{212}$ Po, $^{208}$Ti, $^{208}$Pb) and terminates with $^{208}$Pb which is stable isotope. $^{232}$Th has half-life of 14.05 billion years.

In the sediments of Sawa Lake, $^{228}$Ac or $^{208}$Tl ranges between 1.6-9.2 Bq/Kg, whilst the $^{212}$Pb ranges between 0.3-6.1 Bq/Kg, and $^{212}$Bi in sample no 19S-t is 3.8 Bq/Kg (Table 5-4).

$^{40}$K ranges between 12.3-35.1 Bq/Kg, whereas the activity of $^{137}$Cs which is represented one of the artificial radionuclides was below the detection limit (Table 5-4).

K isotope appears very low this may be attributed to the lack of clay minerals in the sediment of Sawa Lake. Generally, radioactivity appears be low, but it concentrated in sediments rather than in water.

When comparing the results of radiation level in Sawa lake sediments with sediments in the neighboring countries, it was found that the concentration of $^{40}$K and $^{232}$Th in the lake less than their concentration in that of the Turkey, Syria, Egypt and the Arabian Gulf, (the Iranian shoreline) (Table 5-5). The $^{226}$Ra isotope in the lake is higher than its concentration in these countries (Shafik et al., 2011).

Table5-4: Results of radioactivity of the salt sediments samples of Sawa Lake.

| **Sample number** | **The specific activity of radioactive isotopes (Bq/Kg)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Series of $^{238}$U** | | | **Series of $^{232}$Th** | | **$^{40}$K** | **$^{137}$Cs** |
| | **$^{214}$Bi or $^{214}$Pb** | **$^{234}$Th** | **$^{226}$Ra** | **$^{228}$Ac or $^{208}$Ti** | **$^{212}$Pb and $^{212}$Bi** | | |
| **2S-t** | 21.9 | | 54.9 | 1.6 | $^{212}$Pb2=0.3 | 12.3 | B.D.L |
| **6S-t** | 27.6 | 11.6 | 48.5 | 3.4 | $^{212}$Pb=0.6 | 35.1 | B.D.L |
| **9S-t** | 23.9 | 27 | 49.5 | 1.6 | $^{212}$Pb=0.5 | 14.6 | B.D.L |
| **13S-t** | 33.3 | 13.6 | 51.3 | 2.6 | $^{212}$Pb=0.4 | 28.7 | B.D.L |
| **19S-t** | 32.1 | ---- | 42 | 9.2 | $^{212}$Pb=6.1<br>$^{212}$Bi-=3.8 | 16.2 | B.D.L |
| **Range** | 21.9-33.3 | 11.6-27 | 42-54 | 1.6 - 9.2 | $^{212}$Pb=0.3-6.1 | 12.3-35.1 | ---- |
| **Average** | 28 | 17.4 | 49 | 4 | $^{212}$Pb1.58 | 21.4 | ---- |

Table 5-5: Activity concentrations and dose rates of natural radioisotopes in soil samples in some of the world regions (Abdi et al., 2008; UNSCEAR, 2001).

| **Region** | **$^{40}$K (Bq/kg)** | **$^{232}$Th (Bq/kg)** | **$^{238}$U (Bq/kg)** | **$^{226}$Ra (Bq/kg)** | **Dose rate (nGy/h)** |
|---|---|---|---|---|---|
| | Range<br>Av. | Range<br>Av. | Range<br>Av. | Range<br>Av. | Range<br>Av. |
| Syria | 87–780<br>270 | 10-32<br>20 | 10-64<br>23 | 13-32<br>20 | 52–67<br>29 |
| Turkey | 125-570<br>340 | 4-90<br>37 | 7-200<br>21 | ----<br>-- | ----<br>-- |
| Egypt | 29-650<br>320 | 2-96<br>18 | 6–120<br>37 | 5-64<br>17 | 8–93<br>22 |
| Arab Gulf (Iranian side) | 146-500<br>395 | 15-45<br>26 | 21–65<br>41 | 17-48<br>35 | 19-58<br>38 |
| *Baghdad (Sediments) | 216-614<br>377 | ----<br>-- | ----<br>-- | 24-38<br>31 | 16-29<br>21.4 |

* Baghdad (Sediments) = Shafik et al., 2011

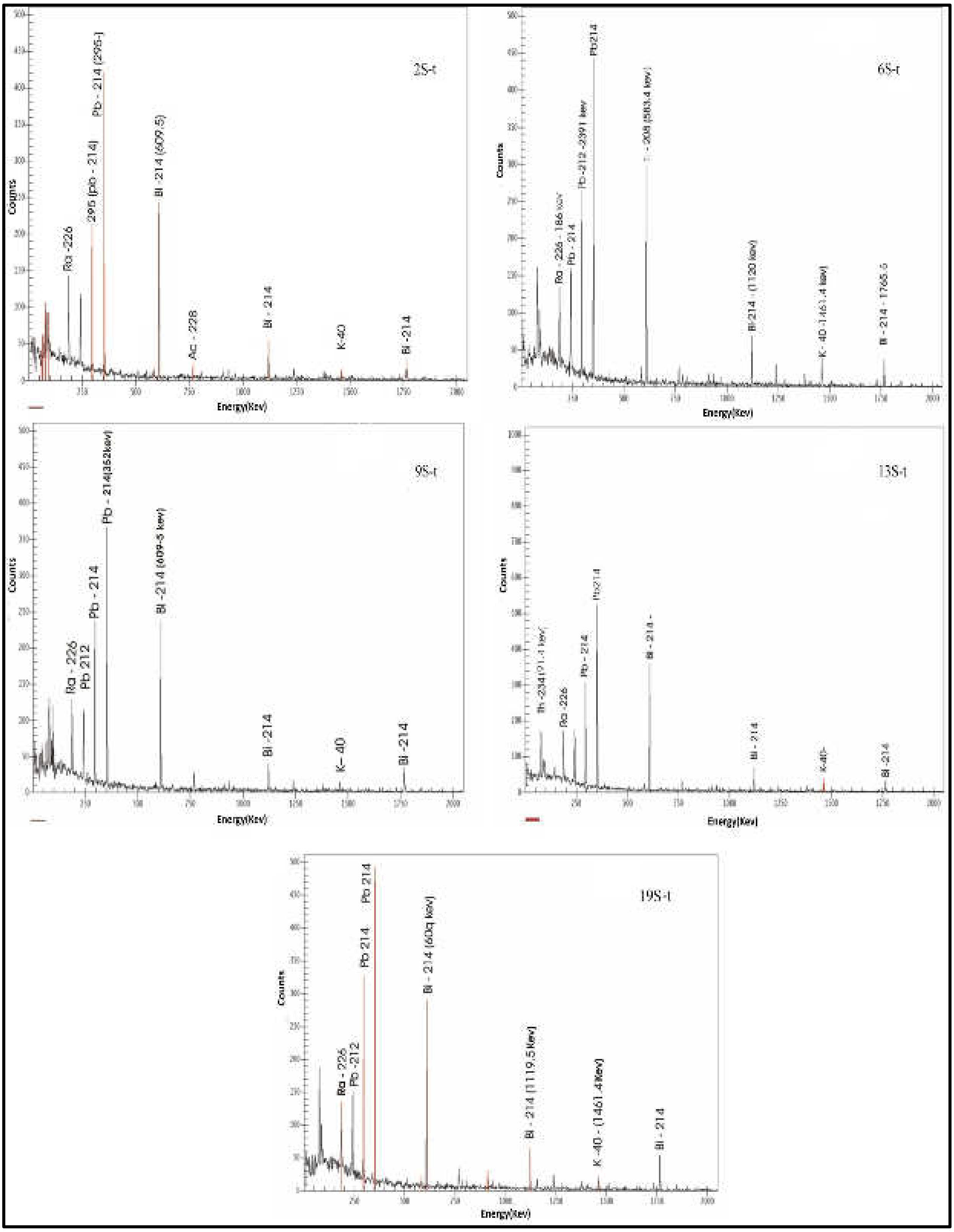

Figure 5-21: Gamma spectra of the sediments samples of Sawa Lake.

## 5-8 Discussion

Sediments have a prominent role in the interaction with water. Also, the chemistry of water plays a main role in the process of precipitation. Calcium is one of cation commonly found in the Sawa Lake, as well as sulfate. On this basis, gypsum was deposited as a major mineral forming the bottom and wall of the lake. Minerals follow completely the water chemistry. Despite the presence of $Na^+$ and $Cl^-$, very little halite is deposited. This is attributed to the instauration state and high solubility of $Na^+$. Mineralogical composition as follows

Gypsum (87%) > clay minerals (5.5%) > quartz (4.5%) > halite (3%). Capillary processes play a main role in precipitation of gypsum as well as organic matters and algae. Many features of gypsum are identified depending on nature of the dominant precipitation process. The equilibrium state between the concentration and evaporation contributed actively to building a salt wall encircling the lake. The wall of Lake is a barrier of gypsum, which is in a dynamic state between construction and dissolution. Wall collapse occurs in abundance in the sites that face the wind which activates the erosion processes. Large blocks collapse due to mass balance. These blocks fall in the lake and dissolve in water, causing increase concentration of calcium and sulfate once again. On the other hand, the landslides and collapse also cause increase the surface area of the lake. Here, it is worthy to refer to the state of balance between systematic construction and collapse.

Mineralogical composition reflects the geochemistry of lake sediments. The major oxides are ordered as: $SO_3 > CaO > SiO_2 > MgO > Cl > Na_2O = Al_2O_3 > Fe_2O_3$. Silica originates from quartz and clay minerals add $Al_2O_3$ and $K_2O$. Na and Cl belong to halite. L.O.I reflects OH emitted from gypsum as well as $SO_3$.

Heavy metals (Pb and Co) are twice higher than the global soil. The source of these metals may be external source such as gases emitted from automobile and factories such as plaster factory. Nickel tends to fit with global soil and seems to be lacking due to reduced condition. Two radioactive decay series are detected; these are $^{232}Th$ decay series and $^{238}U$ decay series as well as $^{40}K$. The sediments of Sawa Lake have a level radiation of $^{226}Ra$, $^{137}Cs$, $^{40}K$ and $^{228}Ac$, $^{232}Th$, $^{238}U$ with exception $^{137}Cs$. The radiation in water of Sawa Lake is missing except that of $^{40}K$. Accordingly, sediments forming-minerals were a source. Radiation is concentrated in salts. Gypsum can contain a high level of radiation so does the Iodine and bromine which appear to be in complex compounds as shown by FTIR.

# Chapter Six

## Conclusions and Recommendations

# 6- Conclusions and recommendations

## 6-1 Conclusions

From the present study, it can be concluded the following:

1. Sawa Lake has water type $Mg^{2+}$-$Na^{+}$-$SO_4^{=}$-Chloride during dry and wet periods, whereas the water type of wells adjacent to the Lake are $Mg^{2+}$-$Ca^{2+}$- $Cl^{-}$-Sulfate. This is a good evidence that, The Sawa Lake has origin that differs from the origin of adjacent shallow groundwater and the same time this lake and wells are groundwater. Hydrochemical function proves the lake is marine origin mixed with meteoric water from rain and from formations beneath the lake.
2. Rus Formation provided $SO_4^{=}$ and $Ca^{2+}$ to be the ascended water that feeds the Sawa Lake.
3. TDS of Sawa Lake is very high, and it is classified as brackish water. The dominant cation is Mg and the dominant anion is Cl. Cations in Sawa Lake can be ordered from highest to lowest as: $Mg^{2+} > Na^{+} > Ca^{2+} > K^{+}$ and anions are of order: $Cl^{-} > SO_4^{=} > HCO_3^{-} > PO_4^{3-}$ $NO_3^{-} > CO_3$. But the adjacent wells are slightly brackish water indicating a different origin.
4. All trace elements (Zn, Pb, Cu, Cd, Ni, Co, As, Fe, Mn, Sr, and B) have concentration higher than their concentration in sea water, especially boron which is found in very high concentration ( 167 ppm) , a 37.5 times higher than the B in sea water. Arsenic was 273 times greater than its concentration in sea water.

5.Sawa Lake has critical BOD. A heterogeneous distribution of DO, BOD, COD revealed in Sawa Lake is due to the irregularity of organisms population. BOD and COD display a negative relationship with DO. The limit of BOD in Sawa Lake is in critical range.

6. Two radioactive decay series are detected; these are $^{232}$Th decay series and $^{238}$U decay series as well as $^{40}$K, while the $^{235}$U decay series and $^{137}$Cs were not detected. The radioactive isotope concentrations were recorded in higher level in sediments rather than in water.

7.Sawa Lake has bad quality water according to WQI and appears to be impermissible for drinking, livestock, irrigation, some industries and building purposes. While wells water seems to be possible for livestock with $Mg^{2+}$ risk. For irrigation and for building, it may be used with due attention to the high content of $Mg^{2+}$, $Ca^{2+}$ and $SO_4^{=}$.

8.Dissolution of gypsum causes collapse, leading to expansion the surface area of the lake which increase evaporation and eventually decrease the water level in Sawa Lake.

9. Major components of Sawa Lake sediments oxides are $SO_3$ (34%), CaO (31%), and LOI (18%), $SiO_2$(8.0%), $Al_2O_3$ (1.5%), MgO (3.0%) $Fe_2O_3$ (0.6%), $Na_2O$ (1.5%) and Cl (2.0%). Gypsum (87%) appears to be dominant and the major mineral in the lake bed and in the lake wall, followed clay minerals (5.5 %), quartz (4.5%) and halite (3%).
10. The gypsum barrier surrounding Sawa Lake was self-built. Evaporation, saturation, capillary action, algae and organic matters are the important factors controlling the barrier building.
11. Fish and algae are the most significance marine organisms. Fish is characterized by soft look, tiny size, do not exceed 10 cm length, and eyes that rapidly disappear after the death.
12. The water chemistry of Sawa Lake has changed during 1977, 1983 and 2003, where the water chemistry was characterized by Na-$SO_4$ as a dominant ion, whilst during 2007, 2011 and 2012; the water chemistry was changed to be characterized by Mg-Cl.

## 6-2 Recommendations

From the present study, the following recommendations can be stated:

1. Aesthetically: field work reveals that the Sawa Lake is unique natural lake suitable to development of the tourism in southern Iraq.

2. There are considerable quantities of gypsum in sediments in the lake that can be exploited for different purposes.

3. Applying the stable isotopes such as $^2$H and $^{18}$O, as well as radioactive isotopes such as $^3$H and $^{36}$Cl in order to best assess groundwater recharge.

4. The water of Sawa Lake should not be used for drinking or for irrigation not only because impermissible for these purposes, but due to very high content of arsenic (As) and boron (B), at the same time, this study recommends to study the chemistry of heavy metals in Sawa Lake water in detail.

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# Appendices

## Ap-1: Water quality index (WQI)

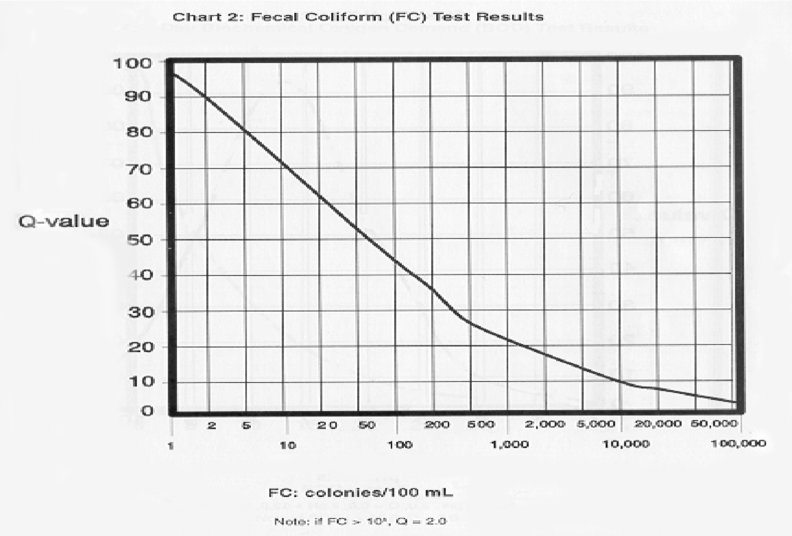
Water quality index software program (WQI) is applied to classify the water quality of the Sawa Lake water. Nine different parameters as averages are response to the program; these are:

1- Temperature
2- pH
3- Dissolved Oxygen
4- Turbidity
5- Fecal Coli form
6- Biochemical Oxygen
7- Total Phosphates
8- Nitrates
9- Total Solids

The WQI program is applied for the two periods (dry and wet). Water Quality Index (WQI) of the Sawa Lake water during the two periods is bad.

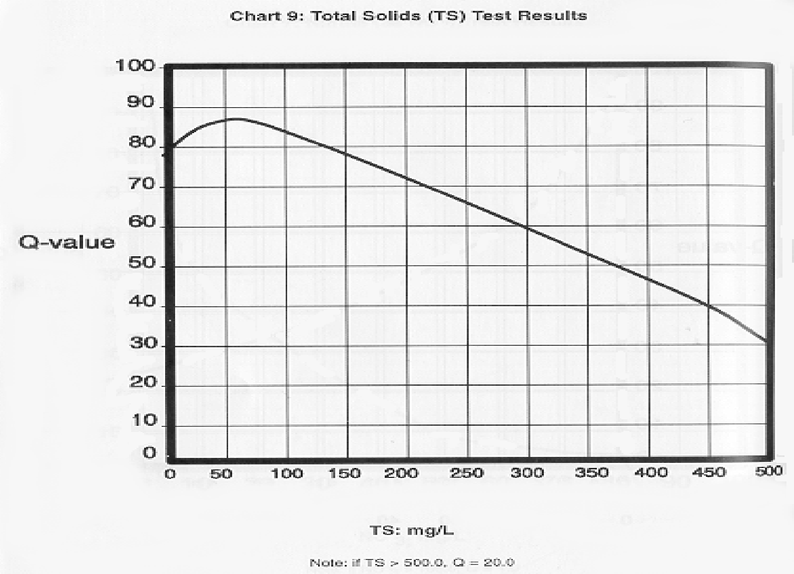
| Water Quality Factors and Weights | |
|---|---|
| Factor | Weight |
| Dissolved oxygen | 0.17 |
| Fecal coli form | 0.16 |
| pH | 0.11 |
| Biochemical oxygen demand | 0.11 |
| Temperature change | 0.10 |
| Total phosphate | 0.10 |
| Nitrates | 0.10 |
| Turbidity | 0.08 |
| Total solids | 0.07 |

## Water Quality Index: Fecal Coli



**Note:** If the number of fecal coli form colonies is greater than 100,000,the quality index equals 2
Fecal coli form: 226 (colonies/100 ml)
Water quality index: 36 (dry period)

## Water Quality Index: Total Solids



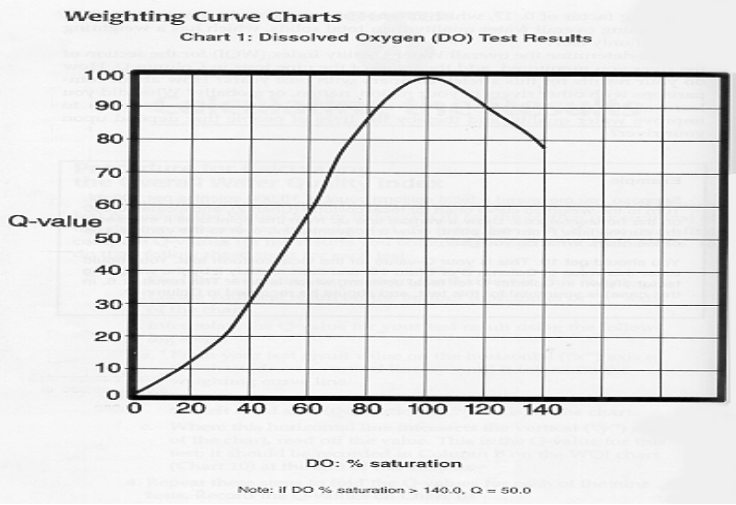
**Note:** If total solids are greater than 500 ppm,
The quality index equals 20.

Total solids: 21570 (ppm)
Water quality index: 20 (dry period)

Total solids: 22368 (ppm)
Water quality index: 20 (wet period)

Appendix **1** ......................................................................................................................

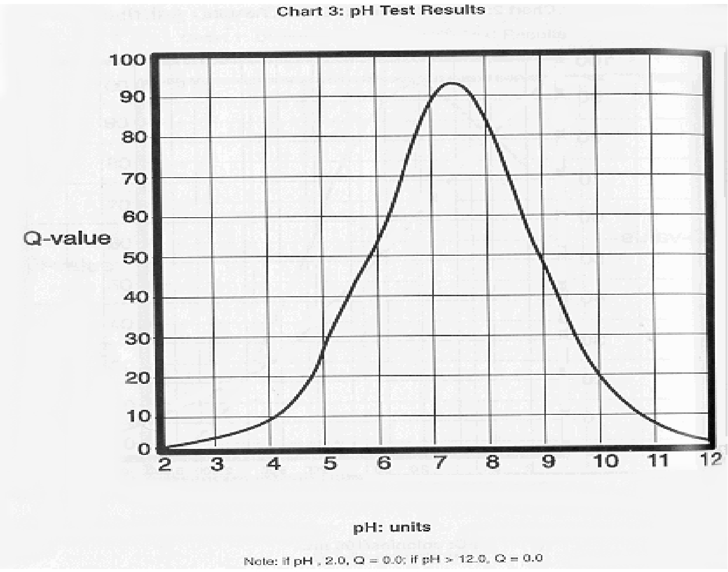
## Water Quality Index: DO sat (%)



**Note:** If dissolved oxygen is greater than 140%,
the quality index equals 50.

Convert dissolved oxygen (%sat) to water quality index.
Dissolved oxygen: 8 (%sat)
Water quality index: 6 (wet period)

## Water Quality Index: pH

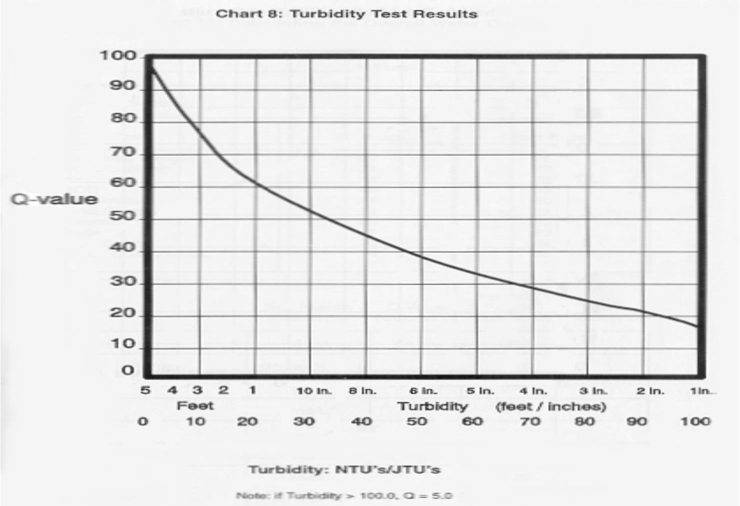


**Note:** If pH is less than 2.0 or greater than 12.0,
the quality index equals 0.

Convert pH to water quality index.
pH: 8.5 (units)
Water quality index: 66 (dry period)
pH: 8.4 (units) (wet period)
Water quality index: 66

## Appendix **1** ........................................................................................................................

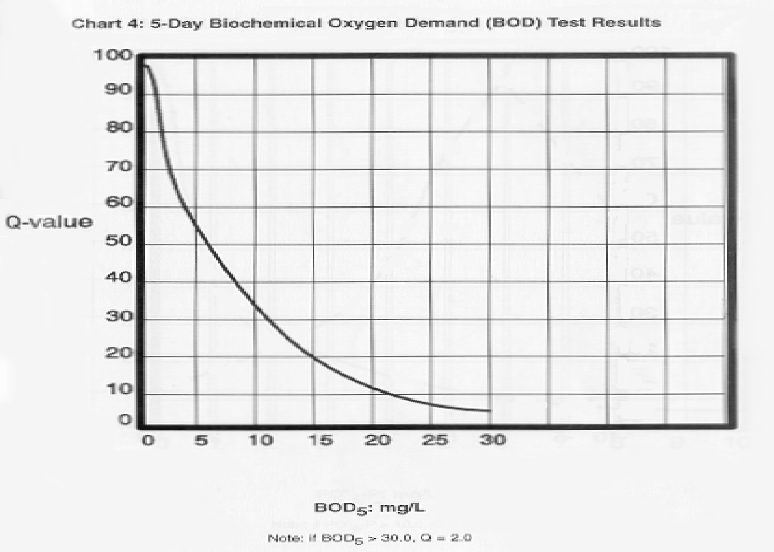
## Water Quality Index: Turbidity



**Note:** If turbidity is greater than 100 ntu,
the quality index equals 5.

Convert turbidity to water quality index.
Turbidity: 0 (NTU)
Water quality index: 99 (dry and wet periods)

## Water Quality Index: BOD

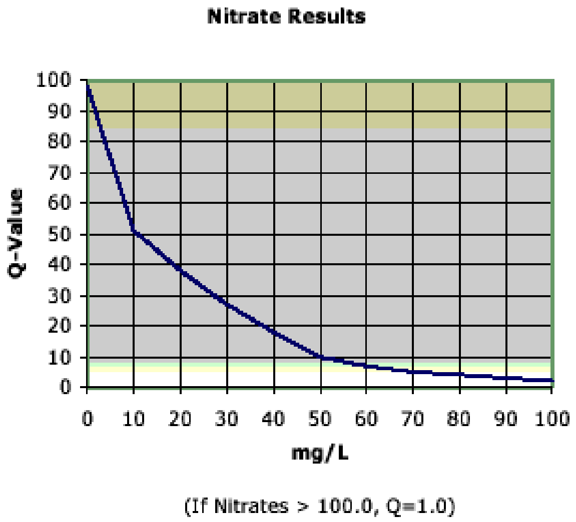


**Note:** If biochemical oxygen demand is greater than 30 ppm,
the quality index equals 2.

Convert biochemical oxygen demand (ppm) to water quality index.
Biochemical oxygen demand: 5(ppm)
Water quality index: 56 (wet period)

## Appendix **1** ..........................................................................................................

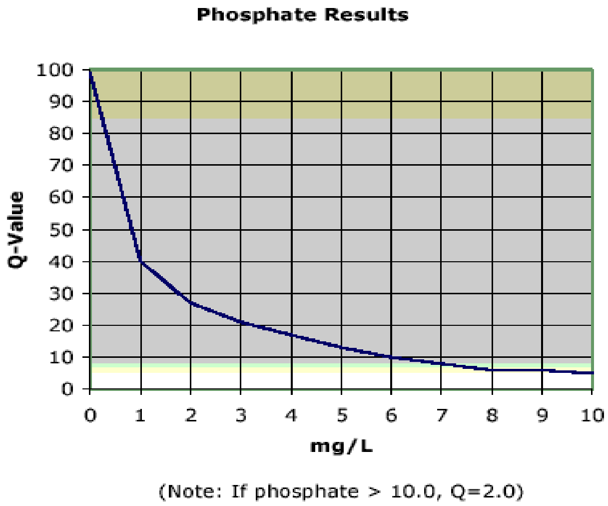
### Water Quality Index: Nitrate



**Note:** If nitrate nitrogen is greater than 100 ppm,
the quality index equals 1.
Convert nitrates (ppm) to water quality index.
Nitrates: 12 (ppm)
Water quality index: 48 (dry period)

Nitrates: 95 (ppm)
Water quality index: 3 (wet period)

### Water Quality Index: Total Phosphate



**Note:** If total phosphate is greater than 10 ppm,
the quality index equals 2.
Convert total phosphate (ppm) to water quality index.
Total phosphate: 13 (ppm)
Water quality index: 2 (dry period)
Total phosphate: 15 (ppm)
Water quality index: 2 (wet period)

| Water Quality Factors and Weights | | | |
|---|---|---|---|
| **Factor** | **Weight** | **Quality Index Dry period** | **Quality Index wet period** |
| Dissolved oxygen | 0.17 | ND | 6 |
| Fecal coliform | 0.16 | 36 | ND |
| pH | 0.11 | 66 | 70 |
| Biochemical oxygen demand | 0.11 | ND | 56 |
| Temperature change | 0.10 | 11 | 22 |
| Total phosphate | 0.10 | 2 | 2 |
| Nitrates | 0.10 | 48 | 3 |
| Turbidity | 0.08 | 99 | 99 |
| Total solids | 0.07 | 20 | 20 |

ND= not determined

**The water quality index is 40 at dry period.**

**The water quality index is 32 at wet period.**

As program result above, water quality index refers to that the Sawa Lake water during the dry and wet periods are bad.

Appendix **2** ......................................................................................................................................................

*Ministry of Environment*
*Radiation Protection Center*
*Radiation Research department*

**1- نوع النموذج : ( 5 ) رواسب ، (5 ) ماء**

**2 - رقم وتاريخ الكتاب : حسب كتاب جامعة بغداد / كلية العلوم والخاص بتسهيل مهمة طالبة الماجستير ( رؤى عيسى مسلم ) قسم علوم الارض ذي العدد ع /29 في 2012/1/4**

**3- تاريخ جلب النموذج :** 2012/1/17

**4 - تاريخ قياس النموذج : 7-2012/2/9**

**5- طريقة القياس : مباشرة بدون معاملة كيميائية**

**6- المنظومة المستخدمة : Canberra**

**7- نوع الكاشف : كاشف الجرمانيـوم**

**8- زمن القياس : 3600 (ثانية )**

**9- النتائج : ظهور النظائر المشعة وبالتراكيز التالية :-**

| رقم النموذج | الموقع | نوع النموذج<br>الوزن | الفعالية النوعية Bq/Kg | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | سلسلةU/Ra | | سلسلة Th | | K-40 | Cs-137 |
| | | | Bi-214<br>or<br>* Pb-214 | U/Ra<br>Isotopes | Ac-228<br>or<br>Tl-208** | Th<br>Isotopes | | |
| 1 | 6S | ترسبات<br>1 كغم | 27.6 | Th-234=11.6<br>Ra-226=48.5 | 3.4 | Pb-212=0.6 | 35.1 | B.D.L |
| 2 | 13S | ترسبات<br>1 كغم | 33.3 | Th-234=13.6<br>Ra-226=51.3 | 2.6 | Pb-212=0.4 | 28.7 | B.D.L |
| 3 | 9S | ترسبات<br>1 كغم | 23.9 | Th-234=27<br>Ra-226=49.5 | 1.6 | Pb-212=0.5 | 14.6 | B.D.L |
| 4 | 19S-A | ترسبات<br>1 كغم | 32.1 | Ra-226=42 | 9.2 | Pb-212=6.1<br>Bi-212=3.8 | 16.2 | B.D.L |
| 5 | 2S | ترسبات<br>1 كغم | 21.9 | Ra-226=54.9 | 1.6 | Pb-212=0.3 | 12.3 | B.D.L |

*** مكافي اليورانيوم – 238**

**** مكافي الثوريوم – 232**

**B.D.L (Below detection limit) اوطأ من حد الكشف**

**الفيزياوي** **مدير شعبة القياسات البيئية** **مدير قسم البحوث الاشعاعية**

*Ministry of Environment*
*Radiation Protection Center*
*Radiation Research department*

# استمارة فحص النماذج

**1- نوع النموذج : ( 5 ) رواسب ، (5 ) ماء**

**2 - رقم وتاريخ الكتاب : حسب كتاب جامعة بغداد / كلية العلوم والخاص بتسهيل مهمة طالبة الماجستير ( رؤى عيسى مسلم ) قسم علوم الارض ذي العدد ع /29 في 2012/1/4**

**3- تاريخ جلب النموذج :** 2012/1/17

**4 - تاريخ قياس النموذج : 7-2012/2/9**

**5- طريقة القياس : مباشرة بدون معاملة كيميائية**

**6- المنظومة المستخدمة : Canberra**

**7- نوع الكاشف : كاشف الجرمانيـوم**

**8- زمن القياس : 3600 (ثانية )**

**9- النتائج : ظهور النظائر المشعة وبالتراكيز التالية**

| رقم النموذج | الموقع | نوع النموذج الوزن | الفعالية النوعية Bq/Kg | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | سلسلةU/Ra | | سلسلة Th | | | |
| | | | Bi-214 or * Pb-214 | U/Ra Isotopes | Ac-228 or Tl-208** | Th Isotopes | K-40 | Cs-137 |
| 6 | 2S | ماء<br>1 لتر | B.D.L | B.D.L | B.D.L | B.D.L | 7.2 | B.D.L |
| 7 | 9S | ماء<br>1 لتر | B.D.L | B.D.L | B.D.L | B.D.L | 6.4 | B.D.L |
| 8 | 13S | ماء<br>1 لتر | B.D.L | B.D.L | B.D.L | B.D.L | 2.3 | B.D.L |
| 9 | 19S | ماء<br>1 لتر | B.D.L | B.D.L | B.D.L | B.D.L | 9.4 | B.D.L |
| 10 | 6S | ماء<br>1 لتر | B.D.L | B.D.L | B.D.L | B.D.L | 7.9 | B.D.L |

*** مكافي اليورانيوم – 238**

**** مكافي الثوريوم – 232**

**B.D.L (Below detection limit) أوطأ من حد الكشف**

**الفيزياوي** **مدير شعبة القياسات البيئية** **مدير قسم البحوث الاشعاعية**

## المستخلص

تم دراسة كيمياء ماء بحيرة ساوه وجيوكيمياء رسوبياتها، حيث تم جمع 23 عينة ماء من البحيرة خلال كل من الفترة الجافة (2011/10/7) والفترة الرطبة (2012/3/22)، فضلا عن ثلاث عينات مياه جوفيه تم جمعها من الآبار ألمجاوره للبحيرة في الفترة الرطبة. تم جمع 19 عينه رسوبية من البحيرة خلال الفترة الجافة لعام2011. تم تحليل عينات المياه للعوامل الفيزيوكيميائية التي شملت العكوره و اللون والطعم والرائحة والدالة الحامضية والمواد ألصلبه الذائبة الكلية والمواد الصلبه العالقة الكلية و الايصالية الكهربائية ودرجة الحرارة، والايونات ألموجبه الرئيسية ($Ca^{2+}$, $Mg^{2+}$, $K^{+}$, $Na^{+}$) والايونات ألسالبه الرئيسية ($CO_3^{=}$,$HCO_3^{-}$, $Cl^{-}$, $SO_4^{=}$) والايونات ألسالبه الثانوية ($PO_4^{3-}$ and $NO_3^{-}$ ) والعناصر النادرة (Pb, Cd. Ni, Fe, Mn, Co, As, Cu, B and Sr) والقياسات الاشعاعية $^{226}$Ra, $^{137}$Cs, $^{40}$K, $^{228}$Ac, $^{232}$Th, $^{238}$U, $^{214}$Bi ، كما تم إجراء التحليلات البايولوجية مثل كمية الأوكسجين المذاب (DO) والمتطلب الحيوي للأوكسجين (BOD) والمتطلب الكيميائي للأوكسجين (COD) وبعض التحاليل المجهرية للبكتريا والطحالب. قورنت نتائج تحاليل العوامل الفيزيوكيميائيه مع المعايير العالمية وأجريت تصنيفات متنوعة للمياه لغرض تقييم نوعية مياه البحيرة للإغراض المختلفة.

تم تصنيف مياه بحيرة ساوه إلى أنها مياه مختلطة–قاعدية، بينما المياه الجوفية المأخوذة من الآبار كانت مختلطة جزئيا خفيفة الملوحة تميل إلى القاعدية. اختلفت كيمياء مياه البحيرة عن المياه الجوفية للآبار، حيث تميزت نوعيه مياه البحيرة بكونها مياه مغنيسوم– كلوريديه أما مياه الآبار فكانت مغنسيوم– كبريتيه. مصدر مياه البحيرة هو مياه بحرية قديمة مخلوطة جزئيا مع الخزانات الجوفية ألواقعه تحت البحيرة وخاصة الفرات والدمام وأم ارضمه. تصعد المياه الجوفية العميقه إلى الأعلى مع أسطح الصدوع والتكسرات وتختلط مع المياه الأقل عمقا، ثم تصل إلى السطح مالئه المنخفض ومكونه جسم البحيرة. تبين ان تراكيز الايونات في الفترة الرطبة أعلى مما هي عليه في الفترة الجافة حيث اعزي السبب الى عمليات الاذابة وشطف العناصر التي تنشط في هذه الفترة.

كانت تراكيز العناصر النزرة (Zn, Pb, Cu, Cd, Ni, Co, As, Mn, Fe, Sr, B) في مياه البحيرة أعلى من تركيزها في مياه البحر، حيث تميز البورون و السترونتيوم بتراكيز عالية جدا.

تم الكشف عن سلسلتي تحلل إشعاعي، وهما سلسلة التحلل الإشعاعي للثوريوم ($^{232}$Th) وسلسلة التحلل الإشعاعي لليورانيوم ($^{238}$U)، هذا فضلا عن نظيري البوتاسيوم ($^{40}$K) و السيزيوم ($^{137}$Cs).

سجلت النظائر المشعة تركيزا عالية نسبيا في رسوبيات البحيرة اعلي مما هي عليه في الماء. ينخفض مستوى البوتاسيوم المشع بسبب ندرة المعادن الطينية في البحيرة، بينما يزداد مستوى الراديوم بسبب تركزه في الأملاح وخاصة الجبس.

تم تقييم مياه البحيرة للإغراض الشرب (الإنسان والحيوان) والسقي والصناعات والبناء وتبين إنها غير صالحه لهذه الأغراض. تم تطبيق برنامج معامل نوعية المياه WQI وتبين إن مياه البحيرة هي مياه رديئة النوعية.

الرسوبيات الميكانيكيه محدودة جدا في البحيرة إلا إن الترسيب الكيماوي هو الشائع والنشط في البحيرة. حيث تميزت الرسوبيات ألميكانيكيه بكونها حبيبات ناعمه و مصدرها في الغالب من الغلاف الغازي.

تم جمع 19 عينه رسوبية، وتم دراستها من الناحية المعدنية والجيوكيميائيه. تبين إن المعدن السائد في الرسوبيات هو الجبس (87% ) والمعادن الطينية (5.5%) وقليل من الكوارتز (4.5%) والهالايت (3% ).

يحيط بالبحيرة جدار ملحي، حيث يلعب الجبس دور أساسي في عملية بناء هذا الجدار بواسطة التوازن بين التبخر والترسيب. يبلغ محيط الجدار 12.5 كم وارتفاعه 6-3 متر. تتكون كهوف بسبب عمليات الإذابة للجدار ألجبسي، وتحصل كذلك انهيارات للجدار مما يسبب توسع المساحة السطحية للبحيرة. أمكن تميز عدة أشكال من الجبس. الاكاسيد الرئيسية في الرسوبيات هي $CaO$ (31%)، $SO_3$ (34%) ، L.O.I (18 %) والتي تعكس وفرة معدن الجبس. أما الاكاسيد الأخرى $SiO_2$ (8.0%)، $Al_2O_3$ (1.5%)، $MgO$ (3.0%)، $Fe_2O_3$ (0.6%)، $Na_2O$ (1.5%)، $Cl$ (2.0%) فهي تعكس وجود المعادن الطينية والكوارتز والهلايت.

تركزت العناصر الثقيلة وهي الرصاص (23 ppm) والنيكل (41 ppm) والكوبالت (19ppm) في رسوبيات البحيرة تركيزا أكثر مما هي عليه في معدلات الترب العالمية، بينما سجل الحديد تركيز منخفض.

**وزارة التعليم العالي والبحث العلمي**
**جامعة بغداد- كلية العلوم**
**قسم علم الأرض**

# هيدروجيوكيمياء بحيرة ساوه جنوب العراق

**رسالة مقدمة إلى**
**كلية العلوم- جامعة بغداد**
**وهي جزء من متطلبات نيل درجه ماجستير علوم**
**في علم الأرض (جيوكيمياء)**

من
رؤى عيسى مسلم القريشي
بكالوريوس علوم - علم الأرض – جامعة بغداد

بإشراف
الأستاذ المساعد الدكتور صالح محمد عوض

**رجب 1434** **حزيران 2013**