The Formation Models of Gypsum Barrier, Chemical Temporal Changes and Assessments the Water Quality of Sawa Lake, Southern Iraq

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Abstract

This study deals with formation models of gypsum barrier, chemical temporal changes, and assessments of the Sawa Lake within the Al- Muthanna province, Southern Iraq, it is a very important issue to find the water quality and water assessments of this lake. Eleven water samples are collected from Sawa Lake. Many scientific concepts are used such as major cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}), major anions ($SO_4^{=}$,Cl^{-},HCO_3^{-} and $CO_3^{=}$) with minor anions (PO_4^{3-}, NO_3^{-}) and H_2S . Trace elements (Pb, Cd, Zn, As, Ni, Co, Cu, Mn, Fe, As, Sr And B) and bacterial test were analyzed in each sample. Total dissolved solids (TDS), electrical conductivity (EC), pH and temperature (T) were directly measured in the field. The equilibrium state between the concentration and evaporation contributed actively to build the salt wall surrounded the lake. The building wall of the Lake is a barrier of gypsum, which is in a dynamic state between construction and dissolution.The length of gypsum barrier surrounding the lake is 12.5 km with 3-6 m high. Gypsum wall collapse occurs in abundance in the sites that face the wind which activates the erosion processes.

The chemistry of Sawa Lake during 1977, 1983 and 2003 was Na- $SO_4^{=}$; then it was changed to be as Mg-Cl from during 2007and 2011 (present study). This study revealed that theSawa Lake water is as unsuitable for drinking, livestock and irrigationpurposes.

Keyword: Water chemistry, Gypsum barrier, Sawa Lake, Water assessment-Iraq.

موديل تكوين الجدار الجبسي والتغيرات الكيميائية الزمنية وتقييم نوعية مياه بحيرة ساوة، جنوب العراق

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الخلاصة:

تهتم هذه الدراسة بموديل تكون الجدار ألجبسي لبحيرة ساوه و بالتقييمالكيميائي لنوعية المياه، والتغييرات الزمنية الكيميائية للبحيرة، بحيرة ساوه تقع غرب السماوه ضمن محافظة المثنى، جنوب العراق. تم جمع احدى عشرة عينة ماء من البحيرة، جميعها حللت للايونات الموجبة الرئيسية (Ca^{2+},Mg^{2+},Na^{+} and K^{+})والايونات السالبة الرئيسية ($SO_4^{=}$,Cl^{-},HCO_3^{-} and $CO_3^{=}$)والايوناتالسالبه الثانوية (PO_4^{3-}, NO_3^{-}) وH_2S العناصر النادرة (Pb, Cd, Zn, As, Ni, Co, Cu, Mn, Fe, As, Sr and B) والتحاليل البكترية بالإضافة إلى الأملاح الصلبة الذائبة الكلية والتوصيلية الكهربائية والرقم الهيدروجيني والحرارة حيث تم قياسها في الحقل.يحيط بالبحيرة جدار جبسي، حيث تلعب عمليات الترسيب دور أساسي في عملية تكون هذا

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الجدارألجبسي بواسطة التوازن بين والترسيب و التبخر. يبلغ محيط الجدار 12.5 كم وارتفاعه 3 إلى 6 أمتار. تتكون كهوف بسبب عمليات الاذابه للجدار ألجبسي.

بينت الدراسة إنكيمياء مياه بحيرة ساوه خلال الأعوام 1977،1983، 2003 كانت صوديه– كبريتيه، تختلف عن 2007 و2011

(الدراسة الحالية) حيث تغيرات إلى مغنسيوم– كلوريد. كما صنفت الدراسة نوعية مياه هذه البحيرة على أنها غير صالحه لأغراض الشر ب وسقي الحيوانات والري.

1. Introduction

Sawa Lake is the strange lake in Iraq characterizes by the highest salinity value among the Iraqi inland waters. It is a mix-mesohaline water body of no inflow and outflow **[1]**. The lake is an elongated closed basin with no tributary of surface water available to it.The Lakelies betweenlongitudes (44 59 29.01E and 45 01 46.61E) and Latitudes (31 17 43.10N and 31 19 49.79N). Swan Lake is located about 23 km to the west of Al-Samawa city [2]. This lake was fed by ground waters of the Euphrates, Dammam and Um ErRudhuma aquifers through a system of joints, cracks and fissures from these aquifers beneath it. Its water level fluctuates during dry and wet seasons **[1].**

It is a land locked lake with maximum length 4.74 km and maximum width 1.77 km isolated by a gypsum barrier with total path of 12.5 km surrounded the lake.The Lake is free of mechanical sediments. Generally, there is no mechanical deposition except that fine particles derived mainly from the atmosphere [2]. Its water does not dry up because of the equilibrium state between water feed up and evaporation [1]**.** The lake is an elongated shape with a NW-SE trend, parallel the Abu -Jir Fault Zone, figure 1.

Sawa Lake is characterized by their ability to build up a salty wall around (formed essentially from gypsum). This wall considered as water hosting barrier prevents spills and overflow. The high of surrounded wall reaches to 6 m. The mechanismof the 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 directly precipitation of gypsum from solution and crystallization on the bottom. 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 nuclei then evaporate under high temperature forming strange shapes of gypsum masses resembling cauliflower. The salty sediments along the coast represent a natural sculpture exhibition. It is beautiful sculptures extend around the lake, especially the southern and eastern coasts which faced the wind. The aquatic environment characterized by saline water with average TDS 21543ppm, it represents the marine environment in the desert. A similarity to the case of sea water encourages us to call it the Sea of Iraq.

The lake is surrounded gypsum barrier contains caves formed by to the dissolution processes.In case of unbalanced masses, caves get collapse causing increase the area of the lake. Fish and algae are the most importance aquatic organisms. Fish characterized by soft appearance, small size, they do not exceed 10 cm, and eyes that quickly disappear after the death. It was classified as *Aphaniusdispar*species belongs to genus*Aphanius*, Cyprinodontidatae Family, Cyprinodontiformes Order, Actinoptrygii Class, Chordata Phylum of Animalia Kingdom. ***Pomatiopsis Tryon*** which is *Gastropoda*genus lives in brackish water from Oligocene to Recent also was found at the lake bottom.

2. Study area

The study area is a part of a gypsiferous plain, and it is characterized by a flat land, as a reminder of 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 2.7 m per Kilometer [3]. This area is also characterized by several important phenomena such a Sabkha and sand dune [3]**.**

The climatologic factors are derived from meteorological station in Samawa, during period (1990-2011), which indicate that the investigated area is characterized by arid climate, The highest minimum and maximum temperatures range between (27.6– 44.6) °C, the mean annual rainfall is 110 mm, and the highest values of evaporation occur during July (506 mm) with the lowest values occurring in January (89 mm). The wind blowing in the study area most of the day of the year is N-W winds and speeds of 4.1 m/s since the wind blowing in the study area most of the day of the year is N-W winds during 1990-2011 [4]. Some wind reversals occur chiefly during winter causing reversal of the slip - face below the crests of the dunes, but apparently having a little regional effect on sediment transport in the study area [5]. Latitudes and Longitudes coordination for each sampling site are accurately determined by using the Global Positioning System GPS Table 1. The sample sites are fixed on map figure 1. This studyaimsto propose amodelof the gypsumbarrier surrounding the lake, monitorchemicalchangesof waterwithtime, and assess the water quality of the lake for drinking, livestock and irrigation purposes.

Table 1- Location and coordination of the study area

SAMPLE NO.	Coordination		
	Longitude	Latitude	Elevation of (m)
1S	N 31 18 0.5	E 45 01 44.5	13
2S	N 31 18 36.5	E 45 00 50.7	13.5
3S	N 31 19 42.5	E 45 00 14.0	11
4S	N 31 19 39.0	E 44 59 44.8	11
5S	N 31 18 50.1	E 44 59 36.5	12
6S	N 31 18 18.1	E 45 00 25.2	11
7S	N 31 18 07.1	E 45 00 56.4	13
8S	N 31 17 52.2	E 45 01 14.7	13
9S	N 31 17 46.6	E 45 01 22.7	14
10S	N 31 17 48.0	E 45 01 38.7	14
11S	N 31 17 19.7	E 45 01 13.9	13

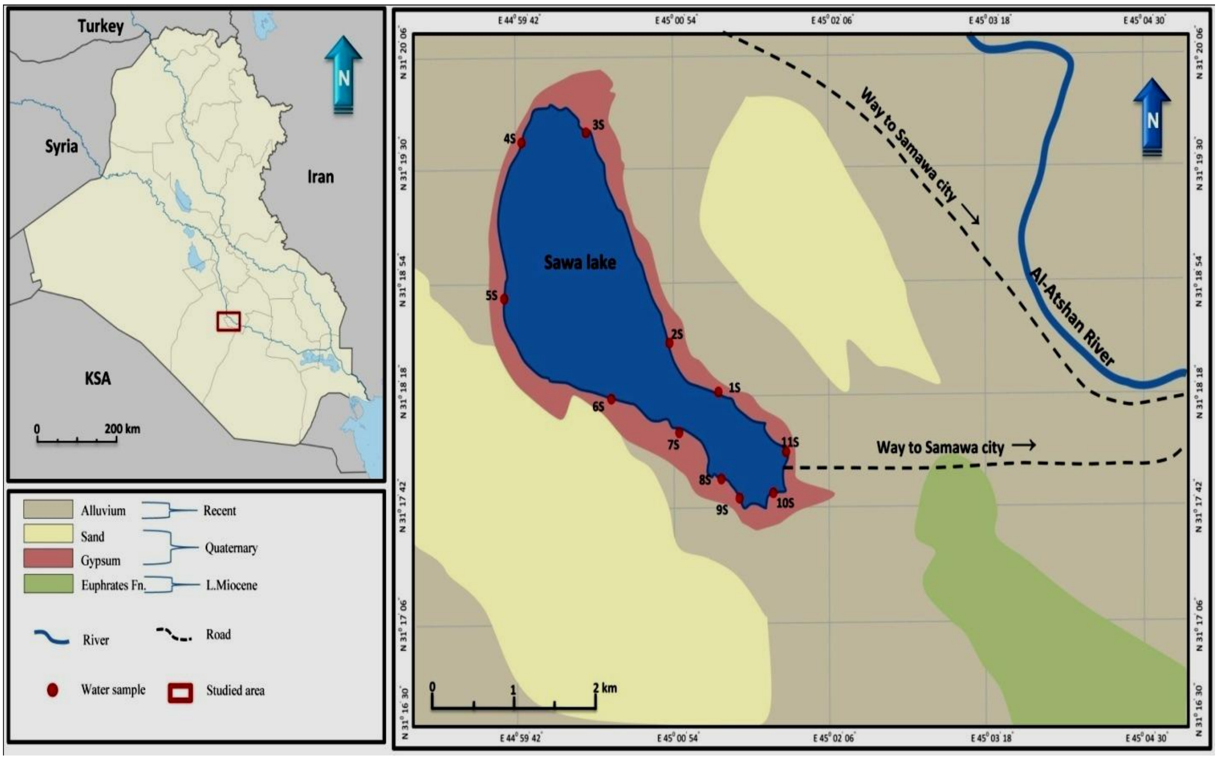

Figure 1- Location map shows the study area and sampling sits,[modified 1].

3. Geological setting

The lithostratigraphy are represented by the Rus, Dammam, Euphrates, and Quaternary deposits [6 and7].The RusFormation (L. Eocene) of semi berried lagoon is composed anhydrites alternate with marl, shale, limestone and dolomite [8]. DammamFormation (U-M. Eocene) is a shallow neritic composed limestone and dolomite porous often fissured and locally karstified[6]. Euphrates Formation

(L. Miocene) is a shallow marine consists of limestone inter beds with clay and marl [9] in the lower part;upper part is shelly and marly limestone lower part cavernous basal conglomerate[6], interfingering with Gar Formation.Quaternary deposits (Holocene and Pleistocene) and recent deposits are continental sediments composed deposits and inland sebkha, gypcrete and salt deposits [10] Figure 2.Eocene–Holocene deposits are exposed arround the studied area. The Euphrates Formation host the Sawa Lake.

The structure factor is specifically represented by Abu-Jir Fault Zone which cuts the region toward the NE - SW. The fault planes formed secondary permeability, allowing deep-water ascension upwards. The rise of water from a confined aquifer from the site under the lake caused increase the speed of movement of water, and this caused expedite the dissolution rate, especially for layers of gypsum and anhydrite belong to the Russ Formation. Sawa Lake has no inlet and outlet flow, and its level fluctuates between summer and winter from 1 to 3 meters approximately. The SawaLake site is structurally and tectonically distinct. It lies on the eastern side of the Salman sub zone near to 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 formed the area often relativelyunstable. The fault planes formed secondary permeability, allowing deep-water ascension upwards. In addition to the structural situation, the stratigraphic column is the other factor played a major role in the processing of the lake formation. The geological formations beneath the Sawa Lake are aquifers such as Umm ErRadhuma, Dammam and Euphrates Formations

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

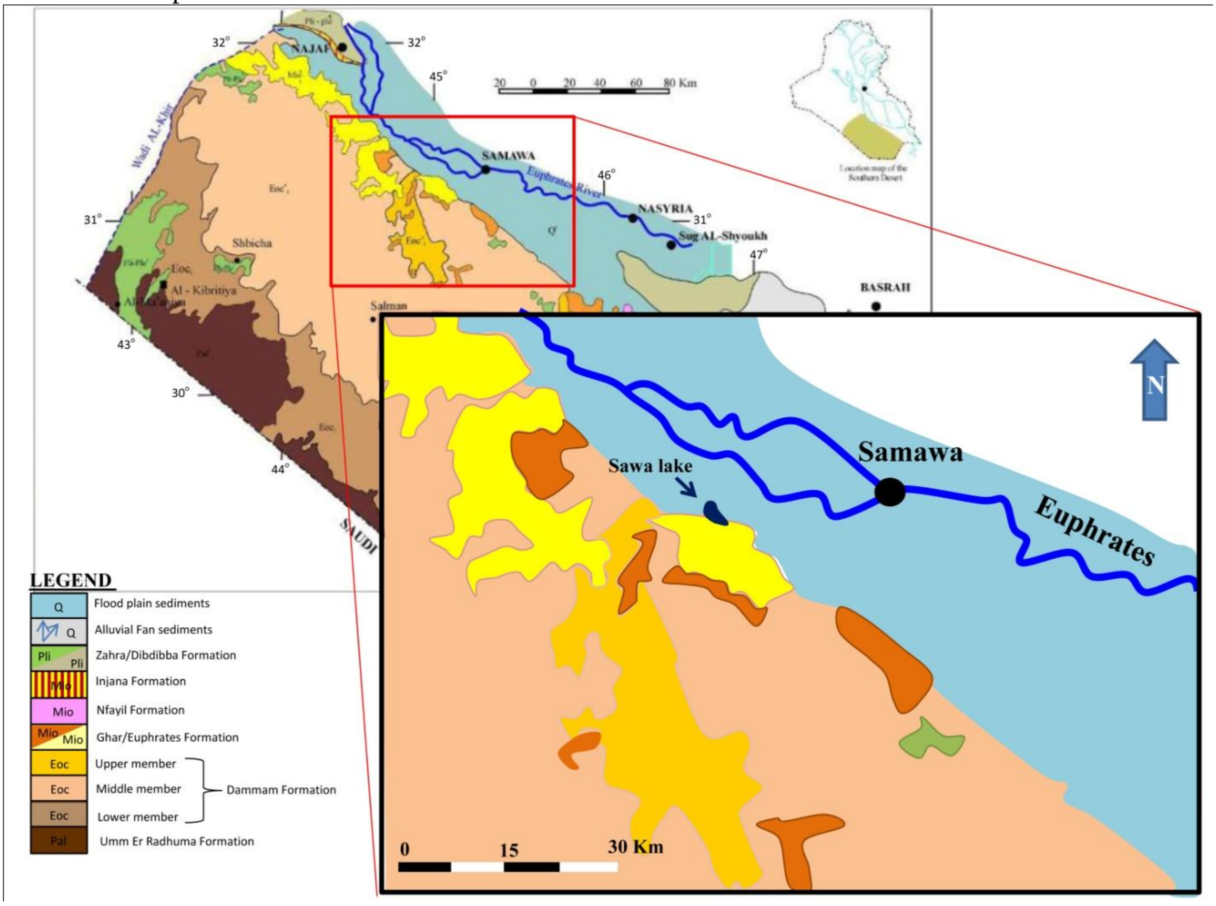

Figure 2- Geological map of the study area and the surrounding areas, Modified [10].

4. Field work and methods

Field and laboratory works are carried out. All analyses of physical, chemical and biological properties are completed in Iraq. Eleven sampleson the lake shore were collected during 7/10/2011.I L polyethylene bottle was used forn water collection for physic-chemical analyzes. All equipments used for sample collection, storage, and analysis of chemical components were cleaned using deionized water. Such cleaning and storage procedures ensure that there are no detectable contaminants in the sampling equipment [11]. Water samples from Sawa Lake are analyzed by many methods, water samples are analyzed for Cations (K^+ and Na^+ by Elico-Flame Photometer method),($Mg^{2+}$and Ca^{2+} by titration with EDTA method), whereas anions Cl^- was determined by titration with $AgNO_3$ method , $SO_4^{=}$, PO_4^{3-}, NO_3^-were analyzed by UV-visble spectrophotometer, HCO_3^-, CO_3^-were analyzed by titration with HCl and Bromocrysolgreen + methyl red indicator method. Trace elements (Zn, Pb, Cd, Ni, Fe, Mn, Co, As, Cu, B and Sr) were determined by atomic absorption spectrometer at the Service Laboratory in Chemistry Department, College of Science, University of Baghdad.

Many parameters are measured locally in the field; these include 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 the device due to the high salinity. The used device is TDS-EC-pH and T meter produced by HANNA instrument, type H19811, made in Germany. This device is calibrated by buffer solutions which are a standard solution for pH and TDS to attain suitable reading. H_2S gas is precipitated directly in the field by a chemical method; then H_2S was determined in the Geochemical Laboratory of geology department at College of Science, University of Baghdad. Water samples for biological tests 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. Free living algae and prozoa, bacteria colony were isolated and identified, then count by unit per ml. Bacterial tests was measured in the Laboratory of Water Treatment's Technology at the Ministry of Science and Technology.

5. Results and discussions

5.1 The formation models of gypsum

Sawa Lake is a land locked Lake; it has no beach lying within the (stable shelf) of Iraq [12]. It has a salt rim formed from gypsum barrier that rises between 3- 6m above the land and surface water [13]. The gypsum barrier prevents the surface water to enter the lake. Sawa Lake elevated above the sea water by18.5m [13 and 14]. It is a salty lake with maximum length 4.74 km and maximum width 1.77 km isolated by a 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 [13].

The mechanism of the buildup of the wall is closely linked to the process of evaporation of the over 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. The salt sediments (mostly gypsum) along the coast represent a natural sculpture exhibition [13].It is no doubt a groundwater fed through a system of joints, cracks and fissures from the aquifers beneath (like Dammam and Euphrates).

Sawa Lake bottom is made up of gypsum masses similar to the barrier. The wind transports a fine sand and clay from nearby sand dunes and by dust storms to the lake bottom [5 and 13]. The lake and its surrounding area is 17-20 m above sea level [13].

The barrier of gypsum which represents the wall of the lake contains caves formed by to the dissolution processes which formed caves[13]. In case of unbalanced masses, some parts of the lake wall and caves get collapse causing increase the area of the lake [13].

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 has 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 button. 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) [15]. The second is the evaporation pumping mechanism that states movements of groundwater depends on the vertical hydraulic gradient from its level or from the bottom to the evaporation- susceptible area [16]. Gypsum deposition can occur as a result of the mixing of high-density solutions situated at the bottom of the lake with less dense layers situated at the top. Sedimentation occurs in many areas within the lake depends on the solutions at the water level [17]. Gypsum was deposited at the bottom in case of high water level and on the coast of the lake at low water level [18].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 which may dissolve forming a salt crust and reaches above the water surface. Gypsum grows with time in forms according to the pathway of feeding. Thus we find variable forms of gypsum on the water surface and near the shore 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. These algae contribute to build gypsum barrier after her death becomes its body like a sponge, also the organic matter able to absorb 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.

5.2 Temporal changes in the chemistry of lake water

The temporal changes in water chemistry of Sawa Lake have been studied by monitoring the result of water chemistry since 1977 till 2011 and the results are listed in Table 2. The results of water chemistry in duration of 1977, 1983, 2003 and 2007 were obtained from the previous studies then are compared with the present study which represents the duration of 2011.

Since 1977, TDS has increased from 17771 ppm (Figure3). 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). It increased highly during 2003 and reached to 1630 ppm. Thereafter, it is recorded in value (2937 ppm) during 2007. In the present study, Mg has been 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 the highest value (1700 ppm). In the present study, Ca recorded the lowest value (679 ppm) in 2011 (Figure 4).

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 2011 (Figure 4). 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 242 during 2011.

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 5). Thereafter, sulfate decreased during 2007 sharps to 4271 ppm. In the present study, sulfate is 6702.9 ppm during 2011. 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 the present study, it was 8809 in 2011 (Figure 5). 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 30 ppm. 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(present study), 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 in the lake is decreased

Table 2- Results of the water chemistry of Sawa Lake since 1977 to 2011.

Parameters		Jamil, 1977[1]	Al-Rawi et Al., 1983[6]	Al-Muqdady, 2003[19]	Hssain, 2007[2]	Present Study 2011
T.Č		----	----	----	15.2	28.7
PH		----	----	8.8	8.9	8.5
EC (μs/cm)		----	----	31000	18700	36518
TDS	ppm	18920	18824	29440	17771	21543
Ca^{+2}	ppm	1060	950	884	1700	679
Mg^{+2}	ppm	1028	1042	1630	2936	3118
Na^{+}	ppm	3220	3086	6481	1571	1876
K^{+}	ppm	112	152	275	164.5	242
$SO_4^{=}$	ppm	6432	5571	9777	4271	6702
Cl^{-}	ppm	5148	5406	7968	6925	8809
HCO_3^{-}	ppm	120	87	193	203	30

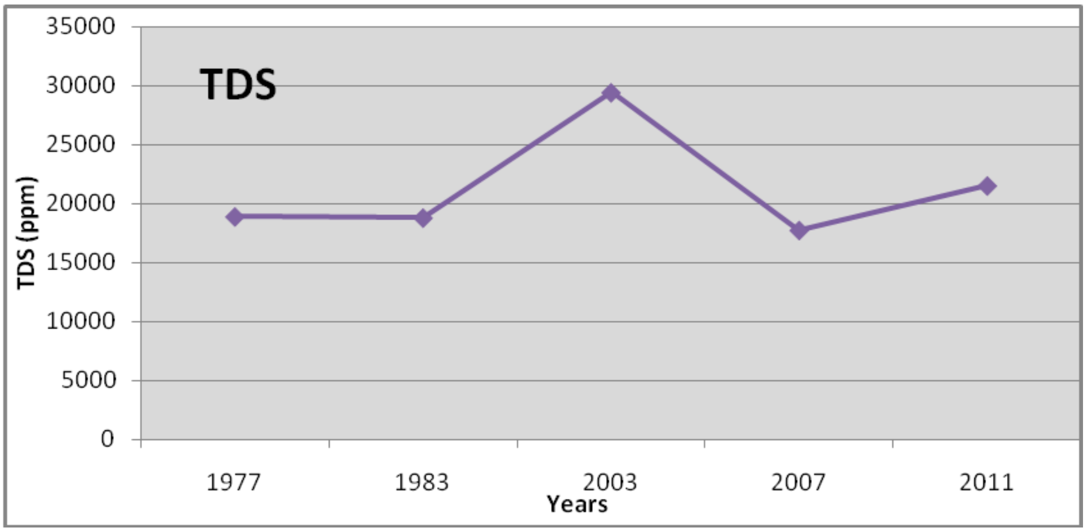

Figure 3- TDS variation during 35 years ago.

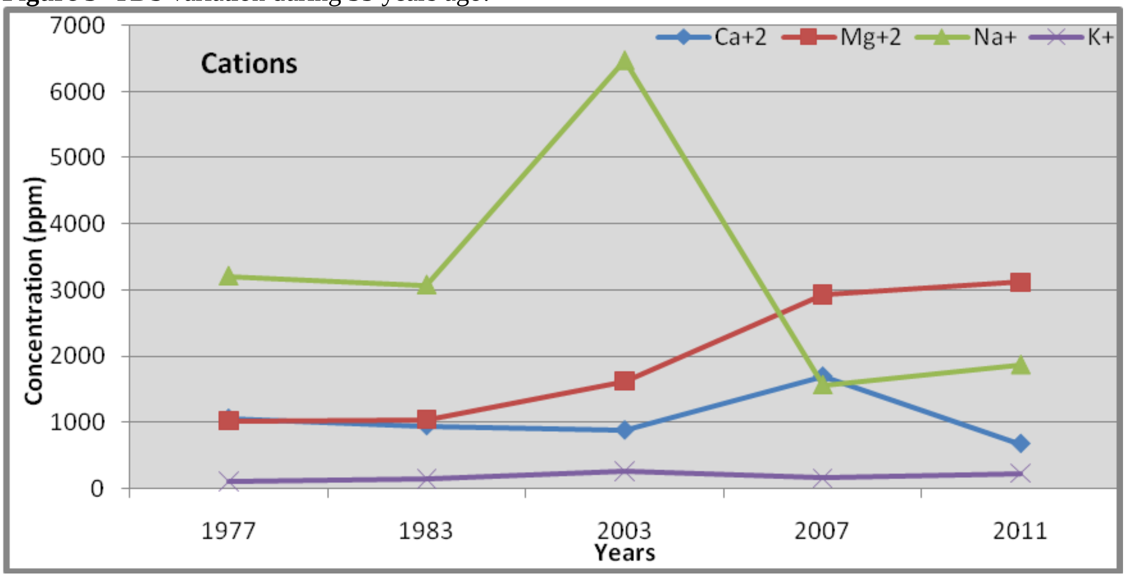

Figure 4- Cations variation during 35 years ago

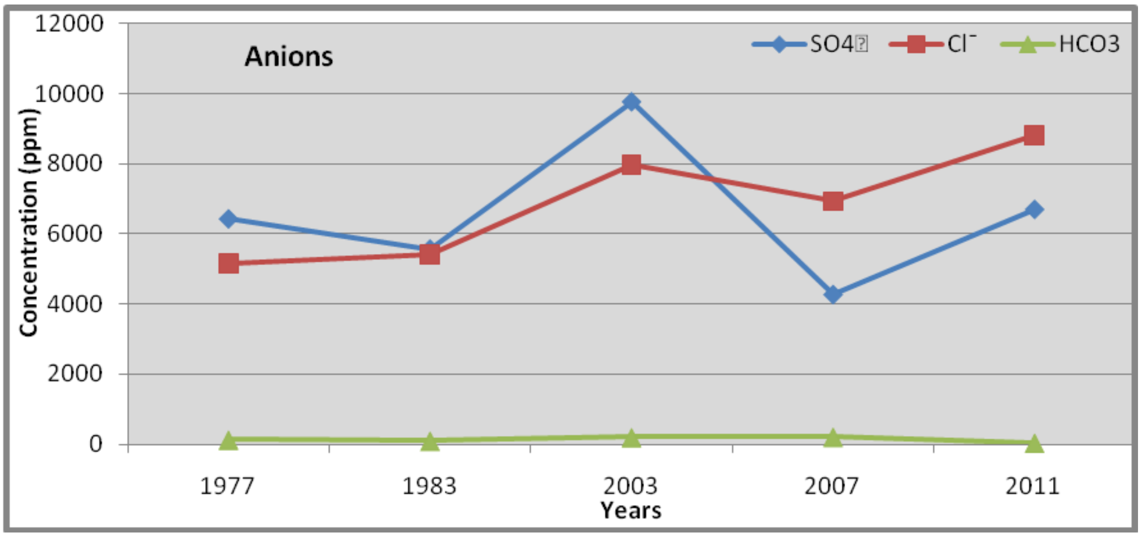

Figure 5- Anions variation during 35 years ago.

5.3 Water Quality

In order to identify water quality, it should be assessed according to their uses for different purposes. The assessment (drinking, livestock and irrigation) is carried out and described below:

5.3.1 Water suitability for drinking

A very high TDS is a clear function that the water of Sawa Lake is not permissible for drinking. However,for the purpose of evaluating the suitability of water of Sawa Lake for human drinking, the fundamental physical, chemical, biological parameters and some heavy metals are compared with the [20].The results of water analyses are listed in Tables 3, 4 and 5. All parameters except Zn appear to be out of with the standards and not permissible for drinking Table 6. Nitrate is a good evidence for agricultural pollution, there is no agricultural pollution (Table 6). The total count of aerobic bacteria is 226 colony/ml; table 4 list some information of biological tests. Nitrate, pH and Zn and Cu are lower than the guidline standard (Table 6).

Table 3- Physical- chemical components (ppm) of Sawa Lake during the dry period compared with Iraqi Standard [20].

SAM. N0.	TDS PPM	EC MS/CM	TSS PPM	PH	T°C	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	$SO_4^{=}$	HCO_3^{-}	$CO_3^{=}$	PO_4^{3}	NO_3^{-}	H_2S	TH
						Ppm											
1S	21646	36798	13	9.3	30	667	2854	1870	265	8852	7024	38	3	0	13	190	13369
2S	21918	37699	12	9.0	27	726	3520	1871	263	8607	6824	27	4	3	13	160	16247
3S	21613	36309	11	9.0	30	724	2991	1843	278	8910	6743	32	3	20	9	250	14073
4S	20838	35425	14	8.4	28	659	2816	1875	253	8826	6304	30	3	3	9	260	13193
5S	21649	37020	19	8.3	27	751	3328	1857	248	8756	6592	34	2	11	10	230	15522
6S	21047	35569	24	8.1	28	695	3301	1850	265	8250	6579	31	2	0	14	290	15272
7S	20958	35838	15	8.2	29	632	2788	1841	211	8514	6864	31	4	0	13	170	13011
8S	21415	36191	18	8.4	30	647	2956	1878	213	8714	6872	23	5	35	12	160	13737
9S	22578	37705	15	8.3	29	654	3288	1902	235	9620	6752	25	7	23	12	190	15116
10S	20882	35708	14	8.3	29	650	3284	1874	219	8422	6304	32	4	19	14	220	15089
11S	22103	37354	10	8.3	29	639	3108	1869	215	9180	6952	32	10	23	15	ND	14340
Range	20838-22578	35425-37705	10-24	8.1-9.3	27-30	632-751	2788-3520	1841-1902	211-287	8250-9620	6304-7024	23-38	2-10	0-35	9-15	60-290	13011-16247
Av.	21543	36519	15	8.5	28.7	659	3118	1876	242	8809	6702	30	4	13	12	214	14479
*I.S	1000	1530	----	6.5-8.5	----	150	100	200	----	350	400	----	----	0.4	50	----	500
**S. W.						400	1350	10500	380	19000	2600	142	----	----	----	----	----

S. W, Sea water, ** [13]; *I.S= [12]; ND= Not determined

Table 4- Result of biological test of the Sawa Lake water, negative = pathogen doesn't found in the samples

Present Study	Total number for aerobic bacteria (colony/ml)	Free living algae And prozoa	Colon bacteria	*Streptococcus*	Anaerobic bacteria *clostridium sperfrgenen*	Yeast and molds
Average	226	Free living flagellated diatom	Negative			

Table 5- Trace elements concentration in the Sawa Lake compared with Iraqi standard [20].

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	0.03	0.83	0.06	0.12	0.36	BDL	0.79	0.50	0.1	41. 9	150
5S	0.11	BDL	0.08	0.12	0.6	BDL	0.80	0.69	0.1	40.7	162
6S	0.13	1.67	0.09	0.09	0.48	BDL	0.86	0.38	0.14	42.3	200
7S	0.12	0.57	0.04	0.11	0.28	BDL	0.82	0.41	0.11	38.3	183
8S	0.02	1.51	0.09	0.10	BDL	0.13	0.81	0.7	0.14	42.7	200
9S	0.05	1.85	0.11	0.05	0.48	0.23	0.8	0.02	0.07	42.7	108
10S	0.09	2.26	0.07	0.08	0.12	0.17	0.82	1.2	0.10	40.7	179
11S	0.02	1.01	0.11	0.08	0.50	0.07	0.83	0.66	0.04	40.7	196
Range	0.02-0.13	BDL - 2.26	0.04-0.11	0.04-0.15	BDL-0.66	BDL-0.23	0.79-0.86	0.02-1.43	0.04-0.87	38.3-42.7	104-200
AV.	0.07	1.22	0.08	0.09	0.42	0.16	0.82	0.67	0.17	40	161
***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***

** [21]; *** [22]; *I.S= [20];BDL= below detection limit (detection limit 0.001)

Table 6- Physico-chemical parameters and trace elements of Sawa Lake compared with standards and dicision of its suitability for drinking.

Parameters (ppm)	Present study	Iraqi Standard, 2009	Decision
pH	8.5	6.5-8.5	Permissible
TDS	21543	1000	Impermissible
EC (µs/cm)	36518	1530	Impermissible
Ca^{2+}	679	150	Impermissible
Mg^{2+}	3118	100	Impermissible
Na^{+}	1876	200	Impermissible
$SO_4^{=}$	6702.9	400	Impermissible
Cl^{-}	8809	350	Impermissible
NO_3^{-}	12	50	Permissible
TH	14479	500	Impermissible
B	161	0.5	Impermissible
Zn	0.07	3	Permissible
Pb	1.22	0.01	Impermissible
Co	0.15	----	----
Cd	0.09	0.003	Impermissible
Cu	0.08	1	permissible
Ni	0.42	0.02	Impermissible
Fe	0.67	0.03	Impermissible
Mn	0.17	0.1	Impermissible
TB	226	---	----

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

Trace elements occur in high concentration and higher than their concentration of the Sea water particularly B and Sr (Table 5).

5.3.2 Water suitability for livestock

The specifications in which the limiting parameters of cations and anions and the total dissolved solids are considered a base for assessing [23]. The result is shown in Table 7. It was 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.

Table 7- Water specifications for livestock according to [23].

Ion	Present study	Very good	Good	Permissible use	Can be used	The higher limits
Na^+	1876 P	800	1500	2000	2500	4000
Ca^{2+}	679 G	350	700	800	900	1000
Mg^{2+}	3118 H	150	350	500	600	700
Cl^-	8809 H	900	2000	3000	4000	6000
SO_4^-	6702 H	1000	2500	3000	4000	6000
TDS	21543 H	3000	5000	7000	10000	15000

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

5.3.3 Water suitability for irrigation

Agricultural uses need specific water of suitable quality to avoid harmful plants and soil damage. The Sawa Lake was assessed for irrigation by assumption the following factors:

a. Magnesium hazard

Magnesium hazard (MH) value of irrigation water as given below [24]:

$MH= Mg^{2+}/ (Ca^{2+} + Mg^{2+}) *100$, If MH >50 is considered harmful and unsuitable for irrigation.

If MH <50 indicates that the water is not harmful for irrigation [25].

In the present study, the average of MH is 88.6. This indicates that the Sawa Lake is unsuitable for irrigation.

b. 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 [26]. The TDS value of the study area is 21543ppm for dry period. Based on TDS, the water of Sawa Lake can be classified as brackish water according to [23] and[27]. Water of Sawa Lake is classified as unsuitable for irrigation use.

c. 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. In the study area, the value of conductivity(EC) in the studyis listed in Table 8. Water of SawaLake is classified as unsuitable for irrigation use

d. 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 [28]showsthat the water quality of Sawa Lake is unsuitable in terms of EC, TDS, and pH (Table 8). In general, Sawa Lake is not permissible for irrigation.

Table 8- Water assessment according to the 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
Sawa Lake	365189	21543	6.8	35	8.5	
Decision	U	U	P	G	U	
Standard	250−750	175-525	3-5	20-40	6.5-6.8	Good
Standard	750−2000	525-1400	5-10	40-60	6.8-7.0	Permissible
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, Doubtful, U= Unsuitable

6. Discussions and conclusions

TDS of Sawa Lake is very high, and it belongs to brackish water. Swan Lake has an alkali pH due to ascend water from a depth through cracks, joints, fractures and faults existed in limestone, dolomite, gypsum and anhydrite. These rocks belong to the Rus, Um ErRadhuma, Dammam and Euphrates formations. All these formations have soluble substances and provide the lake with water that ascends upward in response to the general piezometric pressure.

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 ordered as: $Cl^{-} > SO_4^{=} > HCO_3^{-} > PO_4^{3-}$ $NO_3^{-} > CO_3$. Sawa Lake has water type Mg^{2+}-Na^{+}-$SO_4^{=}$-Chloride. In comparison with sea water Ca^{2+}, Mg^{+2} and $SO_4^{=}$contents in Sawa Lake are higher than of sea water; whilst, K^{+}, Na^{+} and Cl^{-} are lower than of sea water. The origin of Sawa Lake seems to be marine water, where the chemistry of water indicates a connate water mixed partially with meteoric water. The possible source of Ca^{2+} and HCO_3^{-} is limestone, gypsum and anhydrite [29].Rus Formation provides $SO_4^{=}$ and Ca^{2+} to be the ascended water that are feeding the Sawa Lake. H_2S gas arises from sulfate reduction by bacterial action. Significant concentrations of H_2S gas in all springs along the Abu-Jir Fault Zone. 600 ppm as average for the H_2S gas in 12 springs dissolved in the spring waters along the Abu-Jir fault Zone [30]. In Sawa Lake H_2S value ranges from 103 to 268 ppm with 191 ppm as average.

All trace elements (Zn, Pb, Cu, Cd, Ni, Co, As, Fe, Mn, Sr, and B) have concentration higher than the concentration of 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 inthe sea water. 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. Large blocks of gypsum collapse because of the absence of mass balance. These blocks fall in the lake and dissolve in water, causing the increased 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. Evaporation, saturation, capillary action, algae and organic matters are the important factors controlling the barrier building.

Hydrochemically, Sawa Lake water is classified as brackish to saline of alkaline water, Thechemistry of Sawa Lake characterized Mg-chloride. Genetically, the source of lake water is deep ground water of marine origin ascends upwards through cracks and joints to be mixed with shallower water of the aquifers underneath the Lake, especially the Euphrates, Dammam and Umm ErRadhumaaquifers ; then it reaches the surface, filling the depression with water forming the lake body. Sawa Lake appears to be impermissible for drinking, livestock and irrigation

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 and 2011 (present study) ; the water chemistry was changed to be characterized by Mg-Cl due to the climatic changes toward the aridity and decrease the recharge water in the study area. It is unsuitable for human drinking, animal drinking and irrigation.

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