Salt Extraction From Lake Qaroun, EGYPT as a Means to Improve Environment

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ABSTRACT:

Lake Qaroun, Egypt is a closed lake which occupies the northern part of the Fayoum depression. It is fed only by agricultural drainage water. By time the lake become very salty. Salt extraction proved to be a viable tool to improve its environment and keep its function as a drainage reservoir to the province.

1. INTRODUCTION

Lake Qaroun is located north of Fayoum province, 112 km south-west of Cairo, Egypt (fig1).

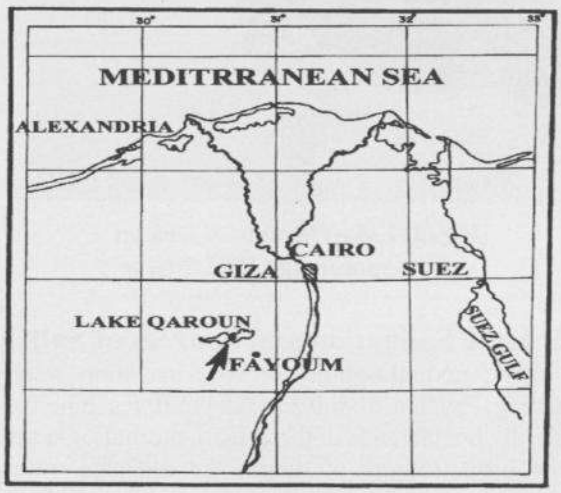

Fig (1) Location Map

The lake is 44 meter below sea level. Its water depth ranges from 1 to 8 meters. The lake surface area covers nearly 240 km^2. It is fed only by drainage water arising from the cultivated land in the Fayoum depression area as the lake occupies its deepest part. In prehistoric times the depression was flooded intermittently during high floods by Nile water. Silt covered most of the depression, hence giving the depression soil its fertile nature. When inhabited the area became one of the major agricultural and densely populated centers of the country. Later on the lake began to shrink to reach finally its present day location and area. (1), (2)

Owing to the leaching action of the incoming water, the salt concentration in the lake has increased progressively. Lake Qaroun has no outlet and looses water by evaporation. The lake receives more than 400 million $m^3$of drainage water every year (Table1). This quantity is almost equal to the quantities evaporated per year hence the water level in the lake is nearly fixed and stable. By time the build up of salts increased progressively to the extent which seriously affected fish life, the main crop of the lake. Continuous evaporation and absence of any fresh water supply coupled with silting have caused Lake deterioration, shrinkage in area, and rarity of fish population.

2. THE FAYOUM DEPRESSION

The Fayoum depression (12000 km^2) is semi circular in outline and has 50 km in diameter. The surface of the depression slopes gradually towards Lake Qaroun. The Fayoum depression is unique among the western Desert depressions because it is connected with the Nile through a canal named Bahr Youssif. The lowest natural point in the Fayoum is -44 m Only challenged by Qattara depression which lies – 134m.(2) The area of cultivation resulting from the siltation of the depression through many epics when the Nile water broke through the water divide between the Nile and the depression. The cultivated area estimated to cover 1450 Km^2 on which now live more than two million inhabitants.

Nile irrigation water supply to the Fayoum depression amount to 2.3 billion m^3/ year, 20 % of which with its salt load ends up into lake Qaroun. As a result, the total dissolved salts in lake water progressively increased and in the last 5 decades it reached high levels which endangered the fish life and seriously affected the lake environment. (4)

2.1. Drainage Canals

The agricultural drainage water reaches the lake through a complicated system in a well-organized water drainage net, which ends by three major drainage canals reaching the lake, namely are El Bats, El Wadi and Dayer. (3)
Seeping water to the lake is by natural gravity.
Table (1)
TDS and quantities of drainage water reaching lake Qaroun 1990-1998

Year	Average TDS g/l	Total Quantities million m3
1990	1.89	495
1995	1.89	380
1997	2.20	485
1998	2.26	453

(Source MPWWR 1999)

3. LAKE QAROUN WATER

The characteristics of lake Qaroun water are unique and non comparable neither with the sea water nor with the natural alkaline springs even if the total T.D.S Looks identical. The lake water is higher in sulphate content and lower in chlorides (Table 2). It is also higher in magnesium and lower in sodium ions compared to sea water. Consequently the lake water is exceptionally rich in sodium sulphate and magnesium salts and is slightly poor in sodium chloride.

Table (2)
Lake Qaroun water analysis as compared to sea water

Description	Sea water	Lake water
Specific gravity	1.020	1.026
T.D.S	34.480	35.297
Carbonates	0.000	0.030
Bicarbonates	0.140	0.355
Sulphates	2.600	9.354
Chlorides	18.980	13.040
Calcium	0.400	0.492
Magnesium	1.270	1.365
Sodium	10.540	9.935
Other Ions	0.530	0.726
Calcium Carbonate	0.000	0.050
Calcium Bicarbonate	0.186	0.471
Calcium Sulphate	1.204	1.209
Magnesium Sulphate	2.188	6.760
Magnesium Chloride	3.245	0.000
Sodium Sulphate	0.000	4.593
Sodium Chloride	27.657	21.488

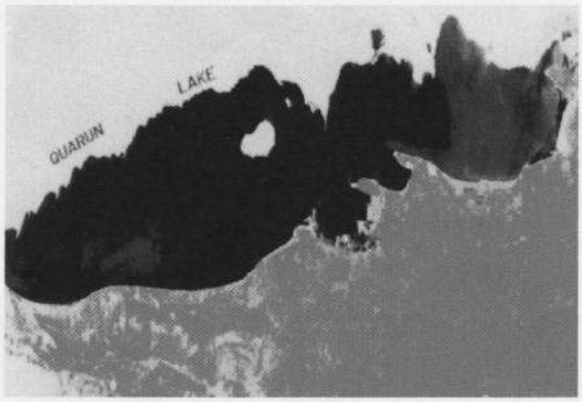

Fig (2) Lake Qaroun as seen on spot image 1995

3.1. Lake Salination and Sources of Salt

The normal salinity of Nile irrigation water reaching Fayoum from 0.3 to 0.5 gm./l. reaching 0.8 gr./l. at the tail ends of the irrigation canals. On the other hand, salinity of ranges the drainage water coming from the two main drainage canals El Bats and El Wady reaches about 1.9 and 2.30 gr./l respectively. Drainage water is sometimes reused in irrigation either directly or after mixing with Nile water, partly as a mean of reducing drainage flows and partly to alleviate water shortages in newly reclaimed areas in the province. This led to further salination of the drainage water reaching the lake.

Climate played an important role in the lake salination. The area is hot and dry, rainfall is rare and sun shines for more than 300 days a year. Temperature in summer reaches an average 28°C but can reach nearly 50 °C in some days. Winter nights are very cold and water may reach frost. The high rate of evapo-transpiration throughout the year make

the Fayoum and the lake region one of the most arid places in Egypt.
Records of lake salinity available since 1900 showed that the salinity increased from less than 10 gr./l. up to 36 g/l by the year 1998. Salinity was expected to increase to 40-45 gr./l. by 2000-2005.Yet extracting salts through the ongoing salt extraction project has its effect in minimizing this rate .

The irrigation of the Fayoum fields with the relatively high salinity Nile water, coupled with the drainage water reuse to irrigate reclaimed new desert lands surrounding the depression resulted in the increase in the soil salinity. Soil salinity maps show gradual increase of salt content from the center of the depression towards the perifries. This salination affected the soil productivity and soil fertility.(4)

To reduce soil salinity, gypsum is added to the cultivated lands for soil improving and conditioning. In 1998 Fayoum province consumed some 44000 metric ton of gypsum for this purpose.

Table (3)
Quantities of gypsum added
for soil improvement, 1995-1998(in 000T.)

Year	1995	1996	1997	1998
Quantity	25	18	39	44.5

(Reference Irrigation Dept. Fayoum Governorate)

No sewerage system exists in rural Fayoum. About three quarters of the population depend on site sewerage and discharge directly to agricultural irrigation or drainage canals causing high peak organic load. Several sewerage treatment plants are recently constructed in the main cities to improve sewerage systems.

3.2. RESULTS OF RECENT STUDIES

A hydrographic survey of lake Qaroun was carried out by El Gaser et.al, (5) showed that the lake surface area which was about 256 km^2.by 1968 became nearly 243 km^2 by 1992.

In the same period the average lake depth varied between 5.2 m to 4.8 m. This means that in 24 years the lake bottom was raised for some 40 cm i.e. 1.65 cm/year. Shrinkage in the Lake area and the rise of its bottom affected the lake water volume. In 1968 the lake water volume was 1053 million m^3.In 1992 it became 924 million m^3, which show that the lake lost nearly 12% of its volume and storage capacity .

A recent study by FWMP (6) showed that the water volume by 1998 ranges between 976 and 859m^3, reference to a lake water level of –43.50 m. These studies showed that the lake water volume is decreasing by time causing serious environmental effects.

As to the lake salinity it was clear that in 1998 the average lake water salinity varied between 33.9 and 37.6 g/l with a water level fluctuation of 0.5 meter. The study also showed that if the water level would decrease below -43.90 MSL the average total dissolved solids will exceed 40 g/l. If water level is increased to -43.50 MSL the salinity well drop to 36 g/l. and even below.

In this study FWMP (6) it was also recorded that the surface of the lake (excluding Island and inner lakes) changed between 215 and 211 km^2 at a volume 976 and 859 million m^3. The lake volume multiplied by the salinity gives the total salt bulk. A salt bulk comparison was made between 1988 and 1998 (6). During these years the salt bulk increased with almost 4 million ton T.D.S.. That means an average yearly salt inflow of 400 000 ton with reference to a lake level of -43.50 MSL. The calculated present rate of increase of salination is 0.36 gram per litter per year.

The total amount of salt in the lake depends on the existing quantity of salt and the quantity of salt which enters the lake through the drains minus the salt extracted by the ongoing project. Salinity also depends on the relation between amount of salt in the lake and the volume of water. For that reason the salinity becomes higher at low lake level.

The water level at lake Qaroun is fixed at -43.5m. MSL; Just to receive a sum of 400 million $m^3$of drainage water per year. If the water level increases, flooding of the neighboring agricultural lands and recreations facilities will take place.

The study FWMP. (6) showed that salt accumulation in the period of 1987 - 1998 was influenced by the salt factory which started salt extraction since 1993. The salt factory is designed to extract only about 300 000Ton salt bulk at full capacity per year.

3.3. Measures taken and salt extraction

The danger facing the Lake as a result of the increase in salinity was realized since long time. Several proposals were submitted to alleviate this danger but neither of them becomes a reality. Of these proposals extraction of excess salts was accepted as a sound solutions.

To realize the feasibility of salt extraction a preliminary study by the British White Young Engineering 1997, (7) followed later on by a study carried out by D.S.S.(8) through an AID grant resulted in formulating a project to extract 300000 t/y of salt to minimize the rate of increase in Lake salination.

These studies proved that it is feasible to extract100000 t/y sodium sulphate 200000 t/y Sodium chloride, 20000 t/y Magnesium salts. To materialize this study and to implement the project an area in the form of a natural bay of 5 km^2 were cut from southern coast of the lake west of Shakhuk village. This area was divided into 4 successive evaporation ponds to prepare the brine for salt extraction. Fig (3) These ponds were designed with adjusted depths to allow natural flow from one pond to the other. The water in the ponds is left to be evaporated to the required volume and concentration took place by solar energy only. The first pond covers an area of 2 million m^2 and receives water directly from the lake through a pumping station. The TDS of this pond is left to reach 80.g/l., before it is allowed to overflow by gravity into the second pond which has an area of about 1.3 million m^2. In this pond the concentration rises to 120 g/l. before it is allowed to pass into the third pond. This pond has an area of approximately 1 million. m^2. Here the brine is left to reach 220 g/l. before it over flows to the fourth and last pond which covers an area about 0.6 million m^2. The TDS in this fourth pond finally reaches 340 g/l. and the brine now becomes ready for salt extraction. (9), (10)

The salt concentration in each pond is controlled and adjusted before being permitted to overflow into the next pond. The salt concentration and salt balance in the ponds are eventually maintained and controlled by pumping the required amounts of lake water to the first pond.

In the first three evaporation ponds the suspended matter and the least soluble salts i.e. the calcium carbonate, the calcium bicarbonate and calcium sulphate are deposited together with silica, alumina and iron oxides. and thus the brine in pond No.4 becomes nearly free of these salts and ready for the free recovery of the more soluble and economic salts i.e. the sodium sulphate, the sodium chloride and the magnessium and other salts.

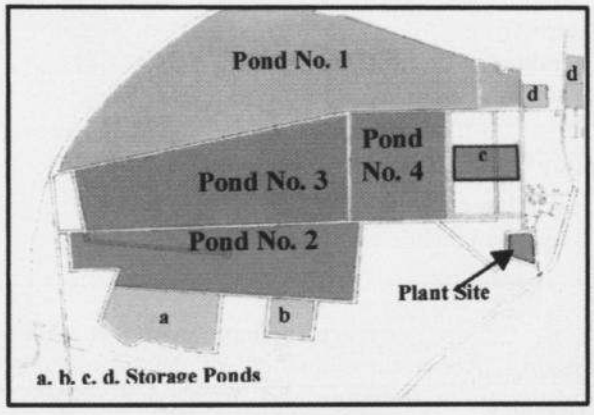

Fig (3) Evaporation ponds

Gradual evaporation in the ponds results in decreasing the volume of solutions in the first three ponds by 80% , 50% and 25% successively until the brine reaches the 4^{th} and last pond, where the volume reaches 10% of the originally pumped water from the lake.

Analysis of the concentrated brine in pond 4 as percentage of the total dissolved solids is as follows: sodium sulphate 12%, Sodium chloride 68%, magnesium salts 16%, others 4%. These salts should be extracted in the same order as given above.

4. SALT EXTRACTION

Based on the results of the Feasibility study, a project was formulated to extract salts from the brine in the pond No. 4.

4.1. Extraction of Sodium Sulphate

The brine of pond 4 is pumped to the sodium sulphate plant, at 200-250 m^3/h, where it is cooled down to 1°C in successive steps. At this temperature, sodium sulphate decahydrate Na_2SO_4-$10H_2O$ (Glauber's salt) crystallizes out. It is then separated from the mother liquor by centrifuge The Glauber salt is then subjected to heating at 50°C to be transformed to the anhydrous sodium sulphate Na_2SO_4 by dehydration. The other salts remain in solution and drained out.

Production sodium sulphate started in October 1992. The designed production capacity of the plant is 100000 t/y . The product proved to be stable and of good quality as shown from the following analysis:

Table (4)
Chemical Analysis of Sodium Sulphate

	Content
Na_2SO_4	> 99.2 %
Chlorides as NaCl Max.	0.5 %
Carbonates (as $CaCO_3$)	Max 0.01 %
Bicarbonates (as $CaCO_3$)	Max. 0.25 %
Heavy Metals	below permissible
Iron content	below permissible
pH (1% solution)	6.5 – 7.5

The produced sodium sulphate is free flowing, crystalline and granular. The colour is white showing a colour : index -80% of $BaSO_4$.

The sodium sulphate produced is mainly used in detergents. Smaller quantities are used as an additive in glass, textile, and paper pulp industries. Most of the production is consumed domestically. The serplus is exported to some neighboring countries.

4.2. The Remaining Effluent After The Sodium Sulphate Recovery:

The effluent remaining after the sodium sulphate recovery is pumped out of the plant and is stored in auxiliary ponds waiting for further processing. The pumping rate to these ponds is in the range of 150-200 m^3/h. Analyses of this effluent is shown in table(5)

Table (5)
Average analysis of Mother Liquor 1998 in g/l.

T.D.S	279.330	Mg^{++}	0.219
CO_3	0.333	Ca^{++}	13.572
HCO_3	0.493	Na^{+}	82.036
SO_4	23.623	Others	10.537
Cl^{-}	148.517		

The calculated amount of recoverable sodium chloride from this effluent amounts to 200000 t/y. Extracting sodium chloride and the residual magnesium and other salts was hampered and delayed due to financial reasons facing the project. The effluent accumulated since 1992, the starting year of the sodium sulphate production is stored in auxiliary ponds. In some of these ponds the effluent became dry and a thick sodium chloride layer of 70 to 100 cm is formed overlying a viscous bittern composed mainly of magnesium salts together with residual potassium, boron and bromine salts. Due to the limited available areas for keeping the effluent for longer time, the dry sodium chloride in the ponds was harvested and piled out of these ponds to give chance to receive more effluent in these evacuated auxiliary ponds. The viscous bittern below the dry sodium chloride is also pumped out and is stored in other auxiliary ponds for further processing.

4.3. The Amount of Salt Recently Extracted from the Lake:

An amount of the 7 million tons of salt was extracted since the beginning of project implementation of the sodium sulphate in 1984, through pumping some 150 million m3 of lake water to the evaporation ponds. These salts were distributed as follows :

1. 5.5 million ton as salt in the evaporation ponds as feed to the plant for salt extraction.
2. 600 000 ton as concentrated effluent after the recovery of sodium sulphate in auxiliary ponds left for evaporation, and drying.
3. 200 000 - ton of raw dry sodium chloride – harvested after drying.
4. 450000 -ton as sodium sulphate were extracted and marketed.

5. 80 000 - ton -Bittern rich in magnesium and other salts in auxiliary ponds.

This amount of extracted salts from the Lake has a great effect in reducing the salinity of the Lake water and the amount of salt reserve in the lake. Salt extraction will certainly have a direct positive effect on the lake environment in course of few coming years.

5. ENVIRONMENTAL HAZARDS FACING THE LAKE

As was stated before the lake Qaroun serves as a reservoir and collecting place for most of the drainage water generated in the province, yet the lake is endangered and is subject to loose it function as a drainage reservoir for the following reasons :

1. Sand dunes and wind blown sands attack the lake from north and north west, causing the continuous shallowness of the lake bottom and the shrinkege of the lake area in these direction.
2. The drainage water reaching the lake is rather turbid and the turbidites usually settles near the coast, causing the shallowness of the lake in this vicinity and further inside.

These two points are responsible for the rising of the lake bottom and the decrease in lake storage capacity by time.

The quality of the drainage water reaching the lake has been constantly more saline, where as various types of algae specially near the shores and shallow areas where noticed. These last two points are also of importance in the deterioration of the lake as a source of salt production.

6. CONCLUSION

Lake Qaroun of Egypt is a unique feature in the Western Desert of Egypt as it is a closed lake receiving only the Fayoum province agricultural drainage water and loosing it only by evaporation.

The drainage water quality and its salt balance is not always stable and the changes depend on many factors such as the agricultural crops, the reclaimed areas, the Fayoum soil improvement schemes, the amount and type of fertilizers used etc. Preservation and saving the lake environment are of vital importance to every individual living in the Fayoum province.

Salt extraction from the lake proved to be of utmost importance to sustain the lake environment through economically viable tools. The amount of salt to be extracted should either equal to or exceed the salt supply by the drainage water. The amount of salt extracted by the ongoing project which reaches only about 300000 t/y. is not enough to maintain the lake salinity as it is now.

It is recommended to intensify salt extraction operations to the extent which can recover at least the annual added salt quantities and to extract some of the accumulated salt bulk to secure the lake environment from further deterioration. The lake might loose its function as a drainage reservoir when transformed by time to a dead lake.

Efforts should be directed to keep the lake function as a drainage reservoir a fishery and also as a touristic place .

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