Alleviation of Salinity Excess in Lake Qarun Using Reverse Osmosis Desalination Plants and (ZLD) Technique

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Abstract: Lake Qarun is a closed lake. It does not have any outlet, where it is considered as a reservoir basin to be used as a release for flood control and water storage. The lake is the final destination of all types of natural and artificial drainage water. It is turning into a salt water lake from a fresh water lake. As a result of the increasing rate of population growth and more rigorous cultivation, irrigation and other human activities as well as evaporation. The salinity of Lake Qarun rose from 3.5 g/l in 1890's to 34 g/l in 1992, and it is predicted to reach almost 45 g/l by 2025. Such salinity can deteriorate the lake ecosystem; solutions for salinity problems should be initiated. Many studies had been carried out to alleviate water excess problem, but the problem still exist. This present study assesses the possibility of using desalination plants, in particular the zero liquid discharge (ZLD) technique, as a possible solution for the salinity problems. It presents a vision for decision maker, using two reverse osmosis desalination plants with capacity of 35,000 cubic meters per day for each plant, using zero liquid discharge technique for producing water and extracting the salts. The production of salts from saline water of Lake Qarun can lead to the reduction of salinity and consequently, improving the ecosystem. It can stop the increase in salinity and reducing salinity by 2.5% or more every year, and consequently decrease it to 50% throughout 20 years or less. Carrying out research goals, samples locations were recorded and surface water samples were collected. All data of temperature, evaporation, wind speed, and TDS (Total dissolved salts) were collected. The data were dealt for calculation of water balance, increase in salinity, evaporation, amounts of salts and its economic values in Lake Qarun. Furthermore, the relation among water level, time in months, volume of evaporated water from lake, and salinity were derived. In addition the expected salinity of Lake Qarun for future years was determined. It is concluded from the present study that the total annual evaporation rate is 179.385 cm. The annual volume of water lost by evaporation from Lake Qarun is 414.5 x 10^6 m³ /year. Using desalination plants, especially ZLD technique in Egypt, can be viable as a possible solution for the salinity problems and has an economic value about 123.636 million $/year from salt extraction, and more than 255,500 palm trees / year can be added.

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1. Introduction

Lake Qarun, is one of the biggest inland saline closed lakes. Nile water irrigation is the life blood of AI-Fayoum region and over the years it has increased and deteriorated with the reuse of drainage water. One of the reasons, for increasing salinity is the increase in the total dissolved solids, of the drain water over many years (Abdel Wahed, 2015). The lake is the deepest area in the River Nile flood plain, making it the final destination of both natural (subsurface flow) and artificial (agricultural) drainage in the Fayoum Depression. Since the lake has no natural outlet (Wolters et al., 1989), the drainage water impounded is subject to concentration by evaporation. An average of about 385 10^6 kg of salts are washed out annually from cultivated land and conveyed to the lake. A volume of fresh water nearly equal to that of the inflowing water is lost annually from the lake through evaporation, while the dissolved salts are left in the lake (Meshal, 1977). The lake reject water is subjected to gradual evaporation resulting in an increase in its salinity (Gorgy, 1959). The increase in salinity has been attributed mainly to the evaporative concentration of drainage water within the lake (Ball, 1939; Meshal, 1977; Rasmy and Estefan, 1983). When a fresh water lake starts turning gradually saline most of the fresh water flora and fauna die, some adapt and survive for some time, until the salinity increases beyond their ability to adapt and these also disappear. The surrounding flora also starts disappearing until the whole area is dead, thus an ecological disaster happens and entire area becomes inhabitable for nature as well as men. The salinity of Lake Qarun rose from 3.5 g/l in 1890's to 26 g/l in 1950, and some studies predicted that it would reach almost 50 g/l by 2005 – 2010 (Meshal, 1977). Also (Abdel Wahed, 2015) studied the water salinity of lake Qarun, the study concluded that evaporation from lake is the main cause of increasing salinity. Many studies had been carried out to alleviate water excess problem, but the problem still exist. The strategy of controlling water level and salinity in lake Qarun is depending mainly on preventing drainage water to reach lake using interceptor drain or diverting water to depressions like upper and lower Al Ryan lakes; also evaporating lake water using solar plants to extract salts like EMISAL plants; lifting water of lake using pipes and lift stations at the western part of lake, the study proposed to lift water up to 90 meters above surface water level of lake. The water will be discharged into natural valley ended by 60 km^2 depression; extraction of ground water near lake using wells along the southern part of lake to reduce water level; reducing water level of lake using the environmental dredging to remove heavy metals from bed sediment and increasing capacity of lake; evaporating lake water by partially closing some areas of lake using regulators to control water levels and extract salts; using desalination plants. Thinking about the solutions of this problem, desalination is one of solutions, where it is widely used in some areas in Egypt, as a main source for fresh water supply for domestic sector, due to the scarcity of renewable natural fresh water resources. The largest number of desalination plants can be found in the Sinai and Red Sea areas, some other areas have already started building desalination plants (Reda, 2014). (Dawoud, 2006) stated that; wastewater from desalination plants are known by brine, concentrate or reject water.

By definition, reject water is any water stream in a desalination process that has higher salinity than the feed. Reject water is the highly concentrated water in the last stage of the desalination process that is usually discharged as wastewater. Zero Liquid Discharge (ZLD) method is one of the most attractive solutions, to the salinity intensification environmental problem. ZLD refers to process that wholly remove water from desalination reject water, so the end product is a solid deposit of precipitate salts. In ZLD desalination process, not only reject waters will stop to be an environmental hazard, but also the recovery of desalination process will reach values near the 100%. (Reda, 2014) studied the usage of (ZLD) technique to standing reverse osmosis desalination plants in Egypt, which contribute to 90% of desalinated water in Egypt. Economic and financial evaluations for the ZLD technique to produce salts were carried out to ensure the feasibility of the proposed technique. It was concluded from the study that, the usage of ZLD technique for all reverse osmosis (RO) type of desalination plants in Egypt, adds more than 5 $\$/m^3$ of reject water, it has some opportunities for economic return, and finally it protects the environment.

2. Objectives

This present study assesses the probability of using the ZLD technique as a possible solution for the excess of drainage water problems of Lake Qarun. The aim of this paper also is to demonstrate the total amounts of different salts in water of Lake Qarun. For achieving the goals of this research the relation among water level, time in months, volume of evaporated water from lake, and salinity were derived. Also the expected salinity of Lake Qarun for future years was determined. This study assesses the possibility of using desalination plants, in particular the (ZLD) technique, as a possible solution for the salinity problems.

3. Materials and Methods

3.1 Characterization of the study area

The study stated that Lake Qarun is the only enclosed saline lake in Egypt. It is located in the western desert part of Fayoum Depression and lies 83 km southwest of Cairo. The lake is located between longitudes of 30° 24` & 30° 49` E and latitude of 29° 24` & 29° 33` N (Abdel-Satar et al., 2010). Lake shape is described as an elongated rectangular shape with average dimensions 45 km length, 5.7 km width and 4.2 m depth in average. It is bounded from the south and east by the urban and cultivated areas and from the north and west by the unoccupied desert areas as shown in Figure (1-a). The lake receives huge mixtures of untreated agricultural, industrial, sewage, and household effluents (about 450 million m^3/year) from El-Fayoum province (Gohar, 2002). Lake Qarun as it is known now has shrunk in size and is presently nearly 44 meters below sea level. It plays an important part in the agriculture and ecology of Fayoum region as it receives the drainage water from the irrigation canals. Lake Qarun water is currently alkaline, saline and turbid. The lake comprises two main basins. The western basin has a maximum depth of 8.4 m whereas the eastern basin is shallower with a maximum depth of less than 5 m (Flower et al., 2006). The water temperature ranges seasonally between about 15°C and 33°C (Ball, 1939; El Sayed and Guindy, 1999). Surface water temperature is minimum (15°C) in winter (December and January), while a maximum of 33°C occurs in summer (July and August) Currently, the mean minimum and maximum annual temperatures are 14.5°C and 31°C, respectively. Relative humidity in the lake area is directly proportional to air pressure and inversely proportional to wind speed. It fluctuates between 40% in May and 59% in December, with annual average 49% (Abd Ellah, 1999). Wind speed is low during winter (2.5 m s^{-1}), and maximum in summer (5.5 m s^{-1}). The dominant direction is north-west; in winter, it changes to north-east. (Ali and Abdel Kawy, 2012) stated that the annual mean off relative humidity varies between 50% and 62%. The climate in Lake Qarun region is generally arid (Baioumy et al., 2010). The valley of

Wadi El-Rayan is an area of 1759 km^2, 113 km^2 of which are the governing water body of the Wadi El Rayan lakes. It is placed about 65km southwest of city and 80 km west of the Nile River. The Wadi has been used for man-made lakes from agricultural drainage which has made a storage area as a reservoir of the two separate Wadi El Rayan Lakes. The reservoir is composed of a 50.90 km^2 upper lake and a 62.00 km^2 lower lake as shown in figure (1-b), Controlling water level and salinity in Lake Qarun is depending mainly on preventing drainage water to reach lake using interceptor drain or diverting water to depressions like upper and lower Al Ryan lakes.

Fayoum Depression and Al Rayan Depression are geologically integrated, and were in a period of geological history with fresh water and were connected together, so that both were serving the other. Egypt opened a tunnel with length of about 8 km after the inundation of Fayoum Depression in 1973, the delivery of water to the tunnel to the Al Rayan Depression is through an open channel, which led to the emergence of the two lakes, the upper and lower lakes in the Al Rayan Depression, which in turn were a major cause of changing the environmental aspects of the Al Rayan Depression to prosperity and the emergence of new environmental systems and also became an important station for bird migration. Wadi Rayan as a protected area is suffering in recent times for many reasons, including the lack of connecting water to the lakes, thus increasing the salinity and the use of the upper lake to irrigate new reclaimed lands and other reasons. The high level of water in Lake Qarun led to the dipping of a lot of the South Coast with great tourism and economic value, which led the concerned authorities to reduce the quantities of water entering Fayoum Depression from Lahun Dam and Bahr Youssef, to reduce the amounts of agricultural drainage water, which led to the salinity of the soil.Which has negatively affected the amount of water reaching Al Rayan Depression, where the agriculture in this region depends on the agricultural drainage water, which reached the salinity of the upper lake to about 3000 parts per million due to the difference between the amount of arriving water and evaporation. The result of this problem is the deterioration of the environmental situation in Qarun and Wadi Al Rayan Depressions as a result of the water management which leads to further deterioration.

3.2 Sample collection and analysis

Abdel Wahed et al., (2015) studied in summers (June 2010, June 2011 and June 2012) the geochemistry and water quality of Lake Qarun, where surface water samples were collected from Lake Qarun, the main recharge sources (El-Bats and El-Wadi drains) and the Nile water (Bahr Yousef). Samples locations were recorded with a hand held Garmin-GPS device. Measurements of electrical conductivity (EC), pH, and temperature were carried out in the field using a SG78- Seven Go Duo pro (pH/Ion/Conductivity) portable meter. TDS (Total dissolved salts) was measured by the total summation of dissolved major ions. Another study had been carried out by Ministry of Environment; the data of this study also were taken as a preliminary database for calculation of salinity of Lake Qarun. Data were collected for water salinity in Lake Qarun, for years (2011, 2012, 2013, 2014, 2016, and 2017) from the field campaigns of annual reports of the Egyptian Environmental Affairs Agency (Ministry of Environment) and National Institute of Oceanography and Fisheries, during the periodical program of northern lakes monitoring starting from 2009. Data from 2011 to 2017 for rainfall, temperature, evaporation, and wind speed for Lake Qarun, at longitudes of 30° 24` & 30° 49` E and latitude of 29° 24` & 29° 33` N, were collected from Environment and Climate Change Research Institute (ECRI). Data from another study had been carried out by (Meshal, 1977) for the comparison between different methods for annual evaporation, and the estimation of annual evaporation from (1939 to 2018) of Lake Qarun was used in this study.

4. Results and discussion

4.1 Water Budget of Lake Qarun

The lake is used now as a general reservoir for agricultural drainage wastewater as well as treated and untreated domestic and industrial waste water. The lake gains agriculture drainage water of about 338 10^6 m^3 /year from El-Bats and El-Wadi drains and about 67.8 10^6 m^3/year from groundwater while it losses about 415 10^6 m^3/year by evaporation (Meshal, 1977; Abd Ellah, 1999; Keatings et al., 2007; El-Shabrawy and Dumont, 2009). So, the net water budget is negative by 9.2 10^6 m^3/year. A volume of fresh water nearly equal to that of the inflowing water is lost annually from the lake through evaporation (Meshal, 1977).

Meshal and Morcos (1981) calculated the water budget of Lake Qarun using this from:

$$(I + R + G) - (E + O) = S \qquad (1)$$

Where the terms are the time average of: I = inflow of drainage water, R = rainfall, G = seepage, E = evaporation, O = outflow and S = water balance. The monthly net gain or loss shows that there is seepage from the lake during July, August and November and seepage to the lake during the rest of the year. The study showed that the annual gain through seepage is 65 × 10^6 m^3, where water level usually rises in spring and drops in late summer and early autumn. The minimum (−44.1 m) is in

September, while the maximum (−43.4 m) in May. Then the lake gains water (338 × $10^6 m^3/y$) from El-Bats and El-Wadi Drains; losses (415 × 10^6 m^3/y) are by evaporation and by pumping to The Egyptian Company for Salts and Minerals (EMISAL) (19 × 10^6 m^3/y). It is concluded that the water budget is negative during 7 months (from January to July), and positive during the rest of the year. The net budget is negative by about 96 × 10^6 m^3/y. Abd Ellah (1999) studied the salinity and water budget in Lake Qarun (AI-Fayoum region), the study indicated that, in the 1980's the annual drainage was 350 x 10^6 m³, and the water flow was 381 x 10^6 m³. Many studies had been carried out to estimate the water budget of Lake Qarun, like Meshal (1977), Abd-Ellah (1999), Allam (2000), Keatings (2007), Mohunta (2008), El-Shabrawy and Dumont (2009),and Abd Elwahd (2015). The different data from different studies are tabulated in table (1), to make comparison among these data; equation (1) can be rewritten as follow:

Q_{in}- Q_{out} = $Q_{resdual}$…………………………….. (2)

The comparison between tabulated data showed that, Meshal (1977) calculated the water budget of Lake Qarun, the study showed negative water balance by (-9.2) million cubic meter/year, the total amount of water discharged to Lake includes seepage and drainage water is 405.8x10^6 m^3/year, while the total amount of water lost by evaporation and pumped to EMISAL from Lake is 415.0x10^6 m^3/year, the study didn't take the annual amounts of water from rainfall which approximately equals to 12,240,000 m^3/year. Also, Abd-Ellah (1999) studied the water budget of Lake Qarun, the study showed negative water balance by (-49.2) million cubic meter/year. Allam (2000) studied the water budget of Lake Qarun, the study showed negative water balance by (-5.0) million cubic meter/year. Mohunta (2008) studied the water budget of Lake Qarun, the study showed negative water balance by (-1.0) million cubic meter/year. Abd Elwahd (2015) studied the water budget of Lake Qarun, the study showed negative water balance by (-31.0) million cubic meter/year. It is obvious that the results of previous studies have some doubts because the real observations show an excess of water in Lake Qarun. The previous studies can be recalculated taking the amount of gained water by rainfall or lost by evaporation, the corrected water balance by Mohunta (2008) is 1.64 m^3x10^6, and the corrected water balance by Abd Ellah (1999) is -46.66m^3x10^6, the corrected water balance by Allam (2000) is 12.64m^3x10^6, the corrected water balance by Meshal (1977) is -6.56m^3x10^6, the corrected water balance by Abd Elwahd (2015) is -28.36m^3x10^6. It is noticed from table (1) that Meshal (1977) didn't take the amount of evaporated water by EMISL which is about 15 m^3x10^6 during calculations of water budget, then the water balance according to equation (2) is 8.44 m^3x10^6,but if the amount of pumped water to EISAL is 19 m^3x10^6, then the water balance is 12.44 m^3x10^6. Allam (2000) gave Qin 430 m^3x10^6, Qout 420 m^3x10^6, and then the water balance is 12.64 m^3x10^6. Mohunta (2008) gave Qin 450 m^3x10^6, and Qout 436m^3x10^6, and then the water balance is 16.64 m^3x10^6. Then the annual average of added water balance to Lake Qarun can be taken as 13.9 m^3x10^6.

4.2 Rate of Evaporation of Lake Qarun

Increasing in salinity is due to the excess of agricultural drainage water and other types of drainage water. One of the factors affecting salinity is water surface area of the Lake. The increase in water surface area leads to increase in evaporated water which indirectly increases salinity. Also the variation of water levels affects the water surface area and consequently the salinity. Ali and Abdel Kawy, (2012) studied the land degradation risk assessment of El Fayoum Depression. The study stated that lake area lies in Egypt's arid belt, which characterized by hot long dry summer and mild short winter, in addition to low seasonal rainfall and a high evaporation rate, where Fayoum district climatic data shows that the mean annual rainfall is 7.2 mm/year. The lowest evaporation rate (1.9 mm/day) is recorded in January while the highest value (7.3 mm/day) is recorded in June. Some measurements indicated a rate of 284 mm/month (9.46 mm/day) in Aug. and 41 mm/month (1.36 mm/day) in Dec. Evaporation is one of main factors affecting the level of the lake and the salinity. Many studies have been done by (Ball, 1939; Meshal, 1977; Rasmy and Estefan, 1983) on evaporation and salinity of the lake. The 20th century's increase in salinity was mainly attributed to evaporative concentration of drainage water within the lake. Ball (1939) first measured evaporation directly and found an annual average of 177 cm (4.85 mm/day). Gorgy (1959) gave an annual average of 185 cm (5.06 mm/day), using the energy budget method. Meshal & Morcos (1981) estimated 190 cm (5.21 mm/day), and Abd Ellah (1999) gave 174 cm (4.76 mm/day). Based on data from 2011 to 2017 for rainfall, temperature, evaporation, and wind speed for Lake Qarun, at longitudes of 30° 24` & 30° 49` E and latitude of 29° 24` & 29° 33` N, that were collected from Environment and Climate Change Research Institute (ECRI). The evaporation rate can be calculated using the collected data. The data of daily evaporation rate used to calculate the annual evaporation rate by multiplying number of days in each month by daily evaporation rate. Where average annual evaporation rate (cm) = ∑ (daily evaporation rate x number of days in each month)/12. It can be formulated in simple formula as follow:

$E_a = \sum (E_d \times N_d) / 12$……………………. (3)

Where: E_a is the average annual evaporation rate (cm), E_d is daily evaporation rate, N_d is the number of days in each month (31 days for January, March, May, July, August, October, and December), February 28.5 days, and 30 days for the remaining months. Analysis of data is tabulated as shown in Table (2) and showed that the total annual evaporation rate is 179.385 cm. the comparison among different methods for estimation of evaporation is shown in Figure (2).

4.2.1 Annual Volume of Water Lost by Evaporation from Lake Qarun

The annual volume of water lost by evaporation from Lake Qarun can be calculated using the formula as follow:

$V = (E \times A_p \times 365 \text{ days}) / 1000$…………… (4)

Where: V is the annual volume of water lost by evaporation (million cubic meters / year), E is the evaporation rate by mm / day, A is the surface area of Lake (km^2) can be calculated using equations of Reda (2015). Area (A_p) = c-m (W.L). Where: (c), and (m) are constants. WL= f (t), $1 \leq t \leq 12$, January equals 1, November equals 11.where (c) equals 1391, and (m) equals 26.5. Using the above equation, the total area of Lake Qarun is 231.7 km^2. Substituting the evaporation rate by 4.94 mm / day in equation (4), the annual volume of water lost by evaporation from Lake Qarun is 414.5 x 10^6 m^3 /year. Table (1) shows the estimation of annual lost water by evaporation from Lake Qarun. Comparing the present value of the annual volume of water lost by evaporation from Lake Qarun, and the other previous studies, it is found that. Abd Ellah (1999) gave an evaporation amount of 415.3 x 10^6 m^3 /year. Allam (2000) stated that the annual evaporated water is 420 x 10^6 m^3 /year. Mohunta (2008) reviewed many studies about the evaporation from Lake Qarun, the study concluded to the amount of evaporated water can be assumed to be about 450 x 10^6 m^3 /year.

4.3 Salinity of Lake Qarun

In the sixties of the last century, as a result of the increasing of agricultural drainage water of lands to Lake Qarun, in Fayoum Governorate, water level had been increased in lake. So the lake inundated neighboring agricultural lands. The solution of that problem was using the Al Rayan Depression, taking part of Fayoum wastewater to control this problem. A plan had been designed to transfer water from the agricultural lands south of Fayoum to Al Rayan Depression. It had an open part (7 kilometers) and part of a tunnel (8 kilometers). This water was created in the upper lake during the seventies and then in the early eighties of the last century, the water in the waterfalls affected the attractiveness of the tourist area and formed the lower lake in the Valley of Al Rayan to become the second lake in the Al Rayan Depression and still continuing to this time. These two man-made lakes have added a great advantage to the landscape of the Al Rayan Depression and have provided habitat for a variety of wetland and intercontinental wildlife from migratory birds. It also allowed for various uses of new lands (agriculture, fishing and recreation). Some solutions for water management of the problem had been launched. Firstly: the interceptor drain project, which is an existing solution, In order to decrease the level of Lake Qarun, reducing the amount water coming from the Nile, to minimize the effects of agricultural drainage water, which affected the important tourist southern lands in the lake, as a result led to many problems with owners of those lands. The project takes most of the water from El Wady drain towards the lakes of the Valley of Al Rayan instead of going to Lake Qarun. The maximum capacity of this project is 100 million cubic meters per year. The project uses the open channel, which is the old canal. The old tunnel will be used, but the mechanical part of the project uses two 1.2 m diameter pipes to pump water from the bottom of El Wady drain towards Al Rayan for a length of 27 km, and use water to irrigate agricultural land in the neighboring area of fresh water from the Nile Valley to be suitable for irrigation. About one billion cubic meters of water are discharged into Lake Qarun, which increases the water level. And this means that the deduction of about 100 million cubic meters and keep about 900 million cubic meters. Then the amounts of discharged water are very small and don't affect on water level in Lake Qarun, which is the main problem and if the project will solve all the problems after more than one hundred year. During this time an increase in the salinity of the lake is expected to approximately 40 g / l almost like sea water, so the salinity will increase, then it will not solve problem. Secondly: water balance project, by connecting all minor drains that discharge in the lake to the proposed main drain, by assembling them in one channel along the southern shore of Lake Qarun. Then all of the water from the western part of the lake was raised to a height of up to 90 meters to the Al Rayan Depression, which requires a lot of complex engineering equipment, as well as taking away lots of land in the project road, which will cause many problems with the local population, in addition to the severe deterioration in Lake Qarun as a result of depriving it of water flowing from agricultural drains, and turning it mostly towards Al Rayan, which means the destruction of the lake naturally and the destruction of fragile ecosystems, plus economic destruction of lake because it constitute the source of fish for many fishermen. Thirdly: the disposal of the lake's excess water in the low lands of Wady Al Rayan. By pumping the excess water to proposed new two lakes, which are two old lakes in the shape of the Upper and Lower Lakes in the Rayan Valley, which will make it easy to pump quantities of fresh Nile water. Using radar images to reach the form of valleys and places of water collection, the two new lakes together reach about 100 square km, in the northern part of Al Rayan Depression in the west of Lake Qarun. The proposed project will contribute to revive Fayoum Depression, because it needs to wash the soil, raise the degree of fertility, and decontamination accumulated to refresh it again and raise its productivity, while at the same time reduces the lake's high salinity, which led to the deterioration of the ecosystem. The proposed two new lakes, will reach the degree of salinity to a low level in Lake Qarun, as a result of the use of one of the two new lakes in the production of salt, which is located in the east, and the second to supply and discharge water. The proposed project is good as an idea but it impossible for implementation because the geology of Al Rayan Depression and nature of Lake Qarun area is very complicated to implement this project. El Shabrawy and Dumont, (2009); and Baioumy et al., (2010) studied the salinity of lake Qarun and the study concluded to the drop in the lake level and the accumulation of salts led to salinity increase; Lake Qarun was only slightly brackish until about 1884. Salinity increased from 8.5 g/l in 1905 to 38.0 g/l in 1980 due to two factors: natural climate variability and human activity. Meshal, (1973); Anonymous, (1997); and Ali, (2003) also studied the salinity of Lake Qarun, the study stated that, salinity increased further, to 30.9‰, 38.7‰ and 42.8‰ in the 1971, 1995 and 1999–2000, respectively. Soliman (1989) predicted a further increase in salinity in the twenty-first century, finally leading to a biologically “dead water body”. Sabae & Ali, (2004) noticed that a decrease to 32.4‰ was, however, recorded in 2003. Naguib (1958) mentioned that salinity of the lake was 17.8–25.5 g/l in 1953– 1955, salinity of the lake has strongly increased in the course of the twentieth century. In 1906, it was 10.5 g/l, but reached 18 g/l in 1919–1925. During the last 100 years the huge changes in structure and functioning of biota in the lake due to salinity increases. Ishak and Abdel-Malek, (1980); Abd Ellah, (2009); El Shabrawy and Dumnont, (2009); in addition to, Baioumy et al., (2010) showed that there was a strong salinity increase since 1901 (12 g/l) to approximately 34–39 g/l in 1995–2000. Long-term studies on the lake by Naguib, (1958); Soliman, (1990); Ali, (2002); Sabae and Ali, (2004); as well as Abdel-Satar et al., (2010) provided evidence for a current increase of concentrations of the major nutrients due to a growing impact of water discharge from drains. To reduce the salinity increase in the lake, the rate of increase in salinity should be calculated, to do that data were collected from different studies starting from 1901 until 2017. Data were collected for water salinity in Lake Qarun, for years (2011, 2012, 2013, 2014, 2016, and 2017) from the field campaigns of annual reports of the Egyptian environmental affairs agency (ministry of environment) and national institute of oceanography and fisheries, during the periodical program of northern lakes monitoring starting from 2009. The average salinity of Lake Qarun from 2011 to 2017 is 32.86 g/l as shown in Table (4), also the analysis showed that there is an increase in salinity per year equals 0.36 g/l as shown in Figure (3) the expected salinity until 2030 can be expected as shown in Figures (4), (5) and as shown in Tables (5), (6) from derived equation as follows:

S (g/l) = 0.36 (t) +31.38………………….. (3)

Where S = Salinity (g/l), t = time in years, starting time from 2010, where (t) equals 0, and for 2011 (t) equals 1, and for 2012 (t) equals 2 and so on. Making salt balance for Lake Qarun, the residual incoming water is 13.9 m^3x10^6, the average salinity of lake Qarun in the past 10 years is 32.86 g/l, then the total salt amount is (32.86 g/l) x (13.9x 10^6 m^3) = 456.754 x 10^6 kg = 456754 ton/year. EMISAL is extracting 421000 ton/year of salts; the balance of salt is 35754 ton / year. For one month salt gained is 2979,5 ton/month, The daily amount of salt is 99.3 ton/day, so the water needed to pump it for proposed reverse osmosis desalination plant can be easily calculated dividing the gained salts per day by the average salinity of Lake Qarun, the daily amount of water is 3022.42 m^3/day. This amount of water can maintain salinity as it is at the same level of salinity, but to reduce salinity it is needed to pump another amount of water, the average salinity of Lake Qarun is 32.86 g/l, then to reduce 1% of salinity it is needed to remove amount of salts equal the volume of lake times 0.3286 kg. Then it is needed about 320,000 ton / year to reduce salinity by 1%. These amounts calculated using average area of lake 231.7 km^2, average depth 4.2 m, where the calculated volume is 973.14 x 10^6 m^3. The water needed to pump to reduce salinity by 1% is 26,660 m^3/ day. Reducing 50% of salinity needs 50 years. The salinity can be reduced during 40 years if the salinity be reduced by 0.82 g/l every year. Then the total amount of water needed to reduce salinity by 2.5% is 24,328,500 m^3, when the volume of Lake Qarun water is 973.14 x 10^6 m^3, and the total amount of salt is 799,434.5 ton/year. If it is required to reduce salinity by 2.5% every year, the amount of salt to be extracted every day is 2,190.23 ton/day, and the amount of water which should be pumped to the proposed reverse osmosis plant is (66653.42 m^3/day). The Egyptian Company for Salts and Minerals (EMISAL) project has been beneficial in reducing the rate of increase of salinity but not completely controlling it. EMISAL depends on solar ponds to extract salts by evaporation, then the change in temperature or evaporation rate affects the production of salts during the different months of year as shown Figure (6),where the values from May to October are high values with respect to the values from November to April, then to get fixed production during the year, thinking goes to desalination plants, but the cost and the reject water from desalination plants are two important factors, because the reject water (brine) is high saline water and can deteriorate the ecosystem in Lake Qarun or the surrounding areas. The most desalination plants in Egypt are reverse osmosis about 90%, and then the proposed desalination plants in this study are RO. The addition of crystallizer and evaporator to the system of reverse osmosis desalination plants (RO) can recycle the reject water to near 100% of distilled water, in this case the reject water is as a very condensed salt liquid and the process is called near zero liquid discharge (NZLD). If the final product of desalination processes is dry salts and desalinated water only, then the process is called zero liquid discharge, it can be achieved by adding dryer and package unit, in addition to the crystallizer and evaporator to the reverse osmosis desalination plant. The reduction in salinity comes from the reduction in evaporated amounts of water from the lake. The salinity of Lake Qarun has been increasing over period of time. Thinking about another project of higher capacity, to extract all the salts, which can stop the increase in salinity, and perhaps reduce it slightly is a must. Two plants with capacity of 35 m^3/day for each one are required, to reduce salinity by 2.5% every year, and maintain the level of salinity without changing in the lake, by substituting the difference in salt balance, between gained and lost salts. The locations of proposed desalination plants are shown in Figure (7).

4.4 Extraction of Salts Using ZLD Technique in Lake Water

The extraction of salts to reduce salinity of Lake Qarun has been discussed above, where (EMISAL) project has been beneficial in reducing the rate of increase of salinity but not completely controlling it. This paper presents feasibility for salt production from Lake Qarun using ZLD technique. It concentrates on reverse osmosis type of desalination plants in Egypt. The aim of this paper is to demonstrate the yearly amounts of salts in water to decrease salinity of the lake. It presents also the added value of salts according to the international prices in 2018 for each type of salts. Then the thinking about another project of a capacity near to the balanced water is a must, to extract all the salts, which can stop the increase in salinity, and perhaps reduce it to some extent. Two plants with capacity of 35 m^3/day for each one are required, to reduce salinity by 2.5% every year. The locations of proposed desalination plants are shown in Figure (7) and Table (7). The proposed first location (1) is an extension for (EMISAL) project, where the cost of land and transportation of raw material can be minimized. The proposed second location (2) is in the southern west of Lake Qarun, because the water samples in this location are high in salinity and near from (EMISAL) project. The proposed third location (3) is in the northern west, because it is located near from Egyptian west desert, the land cost is less than the other locations, the samples of water indicated also high in salinity, and it is a chance to reclaim this area or make green belt for palm trees or decorative trees to save the lake from sand dune movements. The calculation showed that the economic return from reject water is more than 5 $/$m^3$ of reject water. After obtaining the total amount of salts, the total amount of each salt, and its income in accordance with the international prices in year 2018 are shown in Table (8), which can be collected to use it in different agricultural and industrial purposes.

An economic and financial evaluation for the ZLD produced salts was carried out to ensure the feasibility of the proposed technique, the derived equation by Reda (2014) can be modified. Then the variables which are affecting the reject water investment are the cost of extracted salts (ES), the cost of new desalinated water from reject water (AW), the cost of reject water disposal by traditional methods (CBD), the cost of zero liquid discharge units (CZLD), and the cost of environmental preservation (CEC). The equation which represents the cost benefit analysis factor of reject water (BCB) can be written as follows

$$(BCB) = (ES) + (AW) + (CBD) + (CEC) - (CZLD) - (TC) - (MC) \quad (4)$$

Where:-

(BCB) is the reject water cost benefit analysis factor; (ES) is the cost of extracted salts; and (AW) is the cost of new desalinated water from reject water;

(CBD) is the cost of reject water disposal by traditional methods; (CZLD) is the cost of zero liquid discharge units; and (CEC) is the cost of environmental preservation;

(TC) is the transportation cost; and (MC) is the marketing cost.

The term (BCB) is directly proportional to (ES), (AW), and (CBD). But inversely proportional to the term (CZLD), for simplicity of calculation and data available the terms (CEC), (TC), and (MC) can be neglected in these financial analysis and calculations, but they are very important factors and governments should take them into their considerations. Excel spread sheets had been carried out to achieve the goal of the study, where it aims to, solving the problem of reject water disposal from desalination plants, in particular the reverse osmosis type which comprises 90% of desalination plants in Egypt, the solution starts from knowing the currently and expected amounts of reject water and ended by suggesting adding evaporators, pumps, packaging units, auxiliary equipment, and crystallizers to RO plants as hybrid unit, the added equipment will constitute zero liquid discharge (ZLD) technique, consequently the prices of all parts were gathered from specified internet sites, according to the international prices in 2018,where the transportation and marketing were not included in the prices. The analysis depended on the previous studies, which are concerned in economic return of reject water calculations.

4.4.1 Calculation of new desalinated water quantity and cost from reject water (AW)

The cost of desalinated water from the RO plants is dependent on many factors like water salinity, source of water brackish or sea water, technology of desalination, the energy used, the capacity of plant if it is more or less than one million gallon per day or ten million gallon per day (1MGD or 10 MGD), the method of disposing reject water and other factors, but references mentioned that the cost of desalinated cubic meter ranges from 0.75 to 1.25 $ (El Banna H., 2001), the term (AW) will be 0.75$ per m^3.

4.4.2 Cost of reject water disposal by traditional methods (CBD)

The cost of the reject water disposal plays an important role in the selection of the method as it could range from 5 to 33% of the total cost of desalination (Mohamed et al., 2005). The cost of reject water disposal from desalination plants is about $250,000 for one MGD and the cost of one gallon/day is equal to $0.25 x10^{-3}$, then the cost of one m^3 of reject water will be $0.066. Robin A. Foldager (2003) studied the economic return of different traditional methods of reject water disposal from desalination plants; the methods which had been studied were the inland reject water disposals include deep-well injection and the storage in evaporation ponds. Another concentrate disposal method centers on the use of salinity gradient solar ponds (SGSPs). Solar pond technology provides an avenue for utilizing reject concentrate to power the desalination unit. These costs are calculated by updating an economic model developed in 1992. The results of calculations showed that costs associated with each disposal option have gone down over time and that evaporation ponds usually present the lowest cost alternative. The costs of different methods of reject water disposal for 1000 gallon /day are:

No.	Type of reject water disposal	1MGD	M^3/d	10MGD	M^3/d
1-	evaporation ponds	$ 0.38/1000g/d	$0.10	$ 0.38/1000g/d	$0.10
2-	deep-well injection	$ 2.79/1000g/d	$0.74	$ 2.09/1000g/d	$0.55
3-	salinity gradient solar ponds	$ 2.78/1000g/d	$0.73	$ 1.95/1000g/d	$0.52

Then the cost of reject water disposal (CBD) can be taken as $0.066 to $0.74 for m^3/day

4.4.3 Cost of zero liquid discharge units (CZLD)

The ZLD System removes dissolved solids from the wastewater and returns distilled water to the process. Reverse osmosis (membrane filtration) may be used to concentrate a portion of the waste stream and return the clean permeate to the process. In this case, a much smaller volume (the reject) will require evaporation, thus enhancing performance and reducing power consumption. In many cases, falling film evaporation is used to further concentrate the reject water prior to crystallization. These crystals are removed and dewatered. The water vapor from evaporation is condensed and returned to the process. Solids from pretreatment are generally mechanically dewatered in a plate-and-frame filter press. The filtrate is simply recycled back to the beginning of the pretreatment system. The crystals from the crystallization process can also be mechanically dewatered, but corrosion resistant materials are usually necessary due to the high salt concentrations present. The crystals can be dewatered in a filter press or centrifuge allowing much higher solids concentrations as a result. The filtrate (or concentrate) is then returned to the crystallizer. The process can be repeated and the produced salts can be packaged to be ready for marketing, the new produced distilled water can be directed to the product water of the plant as a new added value for the ZLD process. From the aforesaid steps of ZLD system, it could be concluded that the main important parts in the system are the evaporator, and the crystallizer. The pumps and dryers are auxiliary parts, but for reject water investment a packaging unit should be added to the system to bind the extracted salts in sacks or plastic covers for commercial use. Then the cost of (CZLD) will include the capital cost (constructions- main and auxiliary equipment-testing and commissioning),the operation and maintenance cost which include (salaries-chemicals-fuel-spare parts-other consuming materials) and training, management and research activities, the percentages of different costs can be quoted from the cost of desalination plants as shown in table (9).Then the cost of (CZLD) according to the capacity of the desalinated plants, for plants (equal or less than) ≤ 150 m^3/day, will be as follow, according to the international prices of equipment in 2014 (Http://offer.alibaba.com).

Evaporator cost = 4(evaporators) x$50000 (evaporator price) = \$200000, it needs four evaporators where the evaporation rate equal 48m3/day; Crystallizer cost = 4x\$40000 =\$ 160000; Auxiliary unit cost = 4x\$20000 = \$80000; Packaging unit cost = \$80000, Total capital cost =\$520000; Operation and maintenance cost = 43% x \$520000 = \$223600; Total cost =\$520000+\$223600 = \$743600; Getting the cost of ZLD technique unit needs to calculate the amortization factor of equipment loan with yearly interest rate (6%) and equipment life (30 years) using this equation. The amortization capital cost (ACC) = (TCC)/M = \$743600/ M = \$743600/ 13.69 =\$ 54,317.Where M (amortization factor of equipment loan) = $((1+i)^n - 1)/ i \times (1+i)^n = (1+0.06)^{30} - 1/ 0.06 \times = (1+0.06)30 = 13.69$. Where (I) is the yearly interest rate (6%) and n is the equipment life (30 years). CZLD = ((ACC) + (OM))/ Pa = (\$ 54,317 + \$223600)/ pa = \$277917/54750 m^3/year = 5.076 \$/ m^3; (Pa) is the annually product water = daily unit capacity x 365 days = 365 days x150 m^3/d = 54750 m^3/year. The cost of reject water disposal using ZLD technique for $1m^3$ = 5.07 \$/ m^3.

4.4.4 Cost of extracted salts (ES)

The salts which constitute more than 97% of brine solution are NaCl, MgCl2, CaCl2, and Na2So4. The international prices of these salts are not including transportation and marketing; the prices are according to the international prices in 2014 (Http://offer.alibaba.com). Then the average prices = (150+400+120+150) /4= 205\$/ton**.** For one cubic meter of brine the amount of salts will be 34.4 kg/m^3. For ZLD the evaporated sea water should be 100% and contains 5% of dissolved salts, and then the salts would be 0.95%x34.4 kg/m^3. The salts in $1m^3$=.97x0.95x0.0344=0.0317 ton/m^3, for RO plants the recovery ratio is 35% to 45%, then the concentration of salts in brine will be 1.535x0.0317ton/m3=0.048 ton/m^3. The value of extracted salts from $1m^3$ of brine = 0.048 ton/m^3x205\$/ton = 9.97\$/m^3. Applying equation (1) of economic return for brine disposal, then, (BCB) = 9.97\$/m3 + 0.75 \$/m^3 + \$0.066 - 5.076 \$/ m^3+ 0.0= 5.71 \$/m^3. Brine (reject water) cost benefit analysis factor (BCB) will be 5.71 \$/m^3.Using the same technique for calculation of reject water cost benefit analysis carried out by Reda (2014), and using the analysis of water of Lake Qarun carried out by Mansour et al., (2000),which concluded that the percentage of salts composing the TDS in Lake Qarun water are NaCl (61%), $MgSO_4$ (17.9%), Na_2So_4 (12.4%), $CaSo_4$ (3.6%), Ca $(HCO_3)_2$ (3.01%), $CaCO_3$ (0.2%), and others (1.8%). Many Excel spread sheets had been made to calculate yearly amounts and income during one year using ZLD technique for Lake Qarun water as a solution for salinity excess. The calculations showed that, the salt (NaCl) has the biggest total yearly amounts and income during one year, where the yearly income is 39012376.76\$/ year. It is obvious that from Table (8), the total yearly income for all salts is 123636457.5\$/year. Also the return income of salts NaCl, $MgSO_4$, Na_2So_4, and Ca $(HCO_3)_2$ are more valuable than other salts.

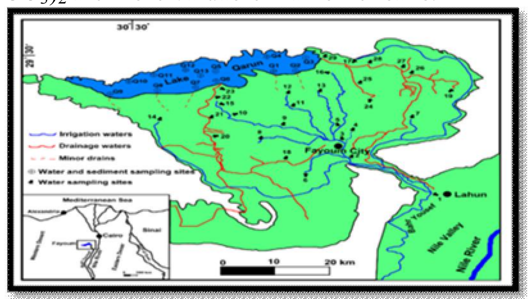

Figure (1-a) Lake Qarun locations of samples (Abd El Wahed, 2015)

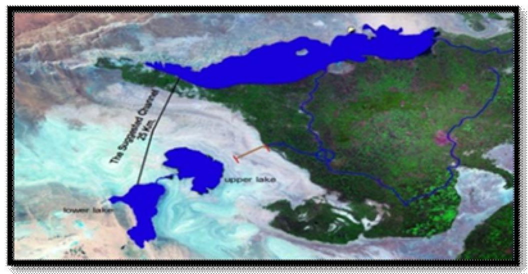

Figure (1-b) upper and lower lakes of Wadi El-Rayan (Report of EEAA, 2015)

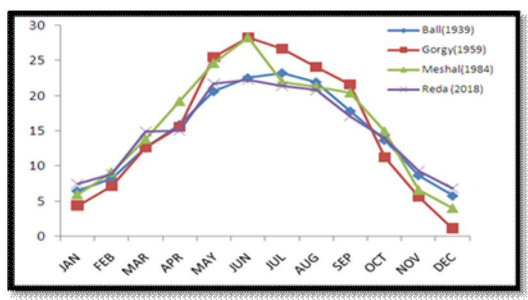

Figure (2) comparison between different methods for annual evaporation of Lake Qarun

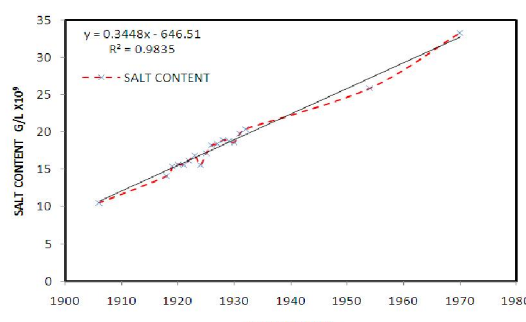

Figure (3) shows salinity from (1901) to (1970) of Lake, Meshal (1977), modified

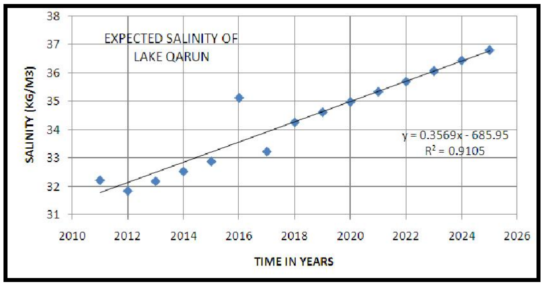

Figure (4) shows the expected salinity from recent data (2011 to 2025) of Lake Qarun

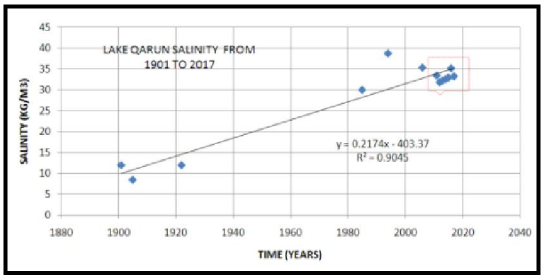

Figure (5) shows Lake Qarun expected salinity for data (from 1901 to 2017)

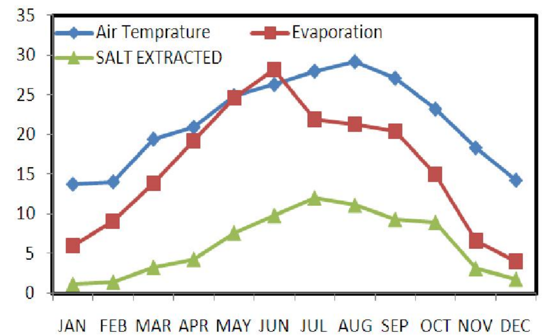

Figure (6) shows the effect of temperature and evaporation rate on extracted salts of Lake

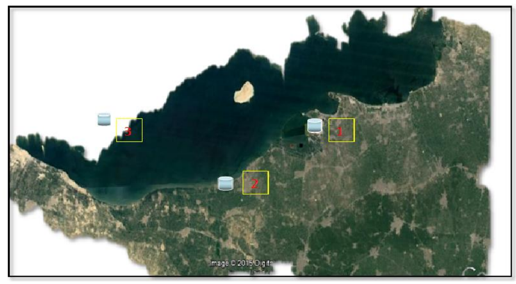

Figure (7) Lake Qarun proposed locations of RO plants

Table (1) comparison among different methods of water budget calculation of Lake Qarun

	Inflow m^3x10^6			outflow m^3x10^6			Correction of Qbalance		
All values $x10^6$	Qin		total (in)	Qout		total (out)	Qbalance	Rainfall mm	Qbalance-corr.
Mohunta (2008)	450	0	450	0	436	436	14	2.64	16.64
AbdEllah (1999)	381	0	381	15	415.3	430.3	-49.3	2.64	-46.66
Allam (2000)	430	0	430	0	420	420	10	2.64	12.64
Meshal (1977)	338	67.8	405.8	0	415	415	-9.2	2.64	-6.56
Abd Elwahd (2015)	338	65	403	19	415	434	-31	2.64	-28.36
Average values	387.4	26.56	413.96	6.8	420.26	427.06	-13.1	2.64	-10.46

Table (2) shows lost and gained water of Lake Qarun, modified after Meshal (1977)

VALUE	1996	WATER	WATER	EMISAL	DRAINS	EMISAL	DIFFERENCE BETWEEN
$X10^6$KG	MONTH	INFLOW	LOSS	WATER PUMPED	SALT GAIN	SALT EXTRACTED	SALT EXTRACTED AND SALT GAINED
1	JAN	8.54	9.173	0.313	30.982	11.714	19.268
2	FEB	27.66	17.395	0.387	58.315	14.356	43.959
3	MAR	30.39	20.067	0.904	55.707	32.981	22.726
4	APR	34.18	31.427	1.192	57.65	43.017	14.633
5	MAY	20.86	52.372	2.106	44.801	76.448	-31.647
6	JUN	17.48	57.756	2.581	45.645	98.082	-52.437
7	JUL	15.34	52.9	3.033	38.262	120.41	-82.148
8	AUG	19.56	57.744	2.727	53.066	111.262	-58.196
9	SEP	37.28	46.943	2.329	58.936	93.18	-34.244
10	OCT	39.72	36.651	2.25	74.036	89.775	-15.739
11	NOV	43.71	25.038	0.806	66.714	31.53	35.184
12	DEC	43.38	7.869	0.468	106.783	17.784	88.999
	TOTAL	338.1	415.335	19.096	690.89	740.527	-49.637

Table (3) shows the estimation of annual evaporation from (1939 to 2018) of Lake Qarun

Estimated Evaporation in cm from Lake Qarun					
No.	MONTH	Ball (1939)	Gorgy (1959)	Meshal (1977)	Present study (2018)
1	JAN	6.5	4.39	5.99	7.44
2	FEB	8.2	7.16	9.12	8.835
3	MAR	12.6	12.67	13.83	14.88
4	APR	15.9	15.57	19.19	15
5	MAY	20.6	25.42	24.59	21.7
6	JUN	22.5	28.29	28.21	22.2
7	JUL	23.2	26.66	21.9	21.39
8	AUG	21.9	24.03	21.25	20.77
9	SEP	17.8	21.56	20.43	17.1
10	OCT	13.7	11.25	14.93	13.95
11	NOV	8.7	5.67	6.61	9.3
12	DEC	5.8	1.16	4.03	6.82
TOTAL		177.4	183.83	190.08	179.385

Table (4) shows the estimation of annual lost water by evaporation from Lake Qarun

Month	No.	WL	Area of Lake (km^2)	Days	E (mm/day)	Water volume m^3
Jan	1	43.69	233.2	31.0	2.4	17351196.0
Feb	2	43.49	238.5	28.5	3.1	21072800.3
March	3	43.28	244.1	31.0	4.8	36319104.0
April	4	43.51	238.0	30.0	5	35697750.0
May	5	43.64	234.5	31.0	7	50895180.0
Jun	6	43.77	231.1	30.0	7.4	51303090.0
July	7	43.89	227.9	31.0	6.9	48751018.5
August	8	44.02	224.5	31.0	6.7	46622419.0
Sept.	9	44.14	221.3	30.0	5.7	37840590.0
October	10	43.97	225.8	31.0	4.5	31498402.5
Nov.	11	43.85	229.0	30.0	3.1	21294675.0
Dec.	12	43.72	232.4	31.0	2.2	15851044.0
			Av. 231.7	Tot. 365.5	Av. 4.9	Tot. 414497269.3

Table (5) shows prediction of salinity until 2025 of Lake Qarun, modified, Meshal (1973)

TIME YEARS	SALT CONTENT	TIME YEARS	SALT CONTENT	TIME YEARS	SALT CONTENT	TIME YEARS	SALT CONTENT	TIME YEARS	SALT CONTENT
1906	10.50	1931	19.80	1982	36.88	1996	41.71	2011	46.88
1918	14.10	1932	20.40	1983	37.23	1997	42.06	2012	47.23
1919	15.40	1954	25.83	1984	37.57	1998	42.40	2013	47.57
1920	15.70	1970	33.24	1985	37.92	1999	42.75	2014	47.92
1921	15.60	1971	33.09	1986	38.26	2000	43.09	2015	48.26
1922	16.20	1972	33.44	1987	38.61	2001	43.43	2016	48.61
1923	16.80	1973	33.78	1988	38.95	2002	43.78	2017	48.95
1924	15.60	1974	34.13	1989	39.30	2003	44.12	2018	49.30
1925	17.10	1975	34.47	1990	39.64	2004	44.47	2019	49.64
1926	18.20	1976	34.81	1991	39.99	2005	44.81	2020	49.99
1927	18.40	1977	35.16	1992	40.33	2006	45.16	2021	50.33
1928	18.90	1978	35.50	1993	40.68	2007	45.50	2022	50.68
1929	18.80	1979	35.85	1994	41.02	2008	45.85	2023	51.02
1930	18.60	1980	36.19	1995	41.37	2009	46.19	2024	51.37
1931	19.80	1981	36.54	1996	41.71	2010	46.54	2025	51.71

Table (6) shows the expected salinity until 2030 of Lake Qarun

EXPECTED SALINITY IN (G/L) UNTIL 2030			
TIME (YEARS)	SALINITY (G/L)	TIME (YEARS)	SALINITY (G/L)
1901	12	2018	34.26
1905	8.5	2019	34.62
1922	12	2020	34.98
1985	30	2021	35.34
1994	38.7	2022	35.7
2006	35.3	2023	36.06
2011	33.4	2024	36.42
2012	31.84	2025	36.78
2013	32.185	2026	37.14
2014	32.53	2027	37.5
2015	32.88	2028	37.86
2016	35.126	2029	38.22
2017	33.23	2030	38.58

Table (7) Locations of proposed RO plant using ZLD technique at Lake Qarun

LOCATION	SAMPLE NO.	SALINITY
EAST	Q1	34557
EAST	Q2	34994
EAST	Q3	28830
EAST	Q4	34627
MIDDEL	Q5	35297
MIDDEL	Q6	34333
MIDDEL	Q7	36792
WEST	Q8	38846
WEST	Q9	36855
WEST	Q10	38243
WEST	Q11	39124
NORTH WEST	Q12	39042
NORTH WEST	Q13	36977
MEAN		36040

Table (8) total income in $ / year/ton of different salts which form Lake water (2018)

Salts	% Salts in Qarun water	international Prices $/ton	Ave.price $/ton	Average TDS in kg/m^3	Amount of each Salt in t/m^3	Total income $/year
NaCI	61%	70-90	80	32.86	487654.71	39012376.76
$MgSO_4$	17.90%	100-150	125	32.86	143098.68	17887334.63
Na_2So_4	12.40%	200-500	350	32.86	99129.81	34695433.43
$CaSo_4$	3.6	400	400	32.86	28779.62	11511848.88
$CaCO_3$	0.20%	800	800	32.86	1598.87	1279094.32
Ca $(HCO_3)_2$	3.01%	200	200	32.86	24062.96	19250369.52
Others	1.80%	0	0	32.86	0.00	0
Total						123636457.5

Table (9) production cost percentages of desalination plants (El Banna H., 2001)

No.	Item	% of product water cost
1-	Capital cost (constructions- main and auxiliary equipment-testing and commissioning)	56.3%
2-	The operation cost (salaries-chemicals-fuel)	24.4%
3-	The maintenance cost (fuel-spare parts-other consuming materials)	9.2%
4-	Training, management and research activities	10.2%
5-	Total of operation and maintenance cost	43.7%
	Total cost of production	100%

Conclusion

It is concluded that the total annual evaporation rate of Lake Qarun is 179.385 cm. The annual volume of water lost by evaporation from Lake Qarun is 414.5 x 10^6 m^3 /year. Using desalination plants, especially ZLD technique, can be viable as a possible solution for the salinity problems and has an economic value about 123.636 million $/year from salt extraction. The balance of salt is 35754 ton / year. For one month salt gained is 2979, 5 ton/month, the daily amount of salt is 99.3 ton/day, so the daily amount of water is 3022.42 m^3/day. This amount of water can maintain salinity as it is at the same level of salinity, but to reduce salinity it is needed to pump another amount of water, the average salinity of lake Qarun is 32.86 g/, then to reduce 1% of salinity it is needed to remove amount of salts equal the volume of Lake times 0.3286 kg. Then it is needed about 320,000 ton / year to reduce salinity by 1%. This amount calculated using average area of Lake 231.7 km^2, average depth 4.2 m, where the calculated volume is 973.14 x 10^6 m^3. The water needed to pump to reduce salinity by 1% is 26,660 m^3/ day. The salinity can be reduced during 40 years if the salinity be reduced by 0.82 g/l every year. Then the total amount of water needed to reduce salinity by 2.5% is 24,328,500 m^3, when the volume of Lake Qarun water is 973.14 x 10^6 m^3, and the total amount of salt is 799,434.5 ton/year. If it is required to reduce salinity by 2.5% every year, the amount of salt to be extracted every day is 2,190.23 ton/day, and the amount of water which should be pumped to, the proposed reverse osmosis plant, is 66,653 m^3/ day. It could be concluded from the research that, ZLD technique can be a possible solution for the excess of drainage water problems. The production of salts from saline water of Lake Qarun leads to the reduction of salinity and so, improving ecosystem. Proceeding of desert can be stopped on the certain parts of northern areas of the lake. Economic forestry and agriculture can be practiced around the project, more than 255,500 palm trees / year (added water 24328500 m^3 x water duty for each palm tree 100 m^3 / year x efficiency 5% = 255,500 palm tree / year) can be added.

References

1. Abd Ellah, G.R., (1999). Physical Limnology of Fayoum Depression and Their Budget. Ph. D. Thesis. Faculty of Sciences, South Valley University, Aswan, p. 140.
2. Abdel-Satar A. M., Goher M E, and Sayed M F. (2010). Recent environmental changes in water and sediment quality of Lake Qarun, Egypt. J. Fish. Aquat. Sci., 5 (2): 56-69.
3. Abdel-Malek S. A., and Ishak M M. (1980). Some ecological aspects of Lake Qarun, Fayoum, Egypt. Part II. Production of plankton and benthic organisms. Hydrobiology, 75 (3): 201-208.
4. Ali and Abdel Kawy, (2012). Land degradation risk assessment of El Fayoum Depression, Egypt. Arabian Journal of Geosciences, Vol.6, pp2767-2776.
5. Ali, M. H. H. and Fishar, M. R. A. (2003). Accumulation of trace metals in some benthic invertebrate and fish species relevant to their concentration in water and sediment of Lake Qarun, Egypt. Egyptian. J. Aquat. Res., 31(1):289-302.
6. Ali, M.H.H. (2002). Impact of agricultural and sewage effluents on the ecosystem of Lake Qarun, Egypt. Ph.D. Thesis, Fac. Sci., Al-Azhar Univ., 307 pp.
7. Allam A.R. (2000). Development available water resources in the history of El Fayoum Oasis; EEAA, Environmental Sector Programme.
8. Anonymous, (1997). Investigation of Lake Qarun ecosystem. Final Report Submitted to USAID, National Institute of Oceanography and Fisheries, Cairo, Egypt.
9. Baioumy, H.M., Kayanne, H., and Tada, R., (2010). Reconstruction of lake-level and climate changes in Lake Qarun, Egypt, during the last 7000 years. J. Great Lakes Res. 36,318–327.
10. Ball. J. (1939). Contribution to the geography of Egypt. Govt. Survey and Mines Department, Cairo press, pp. 178289.
11. Dawoud M. A., Allam A. R., El Shewey M. A., and Soliman S. M., (2006), “Using renewable energy sources for water production in arid regions: GCC countries case study”, in Arid Land Hydrogeology.
12. D.M. Mohunta (2008). Preventing an Ecological Disaster – The Saving of Lake Qarun. ECO Services International.
13. El Banna H., (2001) "Desalination Technology" part no. 1, page no.433, 116, 383, and 68- Arabic Text Book, Al Dar Elgamaia- Alexandria.
14. EI Raey, M. (2000). Salt extraction and biodiversity upgrading in Lake Oarun, Fayoum. EEAA, Environmental Sector Programme.
15. El Sayed, E., and Guindy, K.A., (1999). Hydrochemical investigation of El Fayium locality with special reference to the Sulphate enrichment phenomenon in Lake Qarun. Mansoura Sci Bull. 26 (1), 1–21.
16. El-Shabrawy G M. (2001). Ecological studies on Rotifera in Lake Qarun, El-Fayoum, Egypt. J. Egypt. Acad. Soc. Environ. Dev. (B - Aquaculture), 2: 1-18.
17. El-Shabrawy, G.M., and Dumont, H.J., (2009). The Fayum Depression and Its Lakes. In:

Dumont, H.J. (Ed.), The Nile: Origin, Environments. Limnology and Human Use. Springer Sciences and Business Media B.V, Netherlands, pp. 95–124.
18. Flower RJ, Stickley C, Rose NL, Peglar S, Fathi AA, and Appleby PG (2006). Environmental changes at the desert margin: an assessment of recent paleolimnological records in Lake Qarun, Middle Egypt. J Paleolimnol 35:1–24.
19. Gohar, M. E. M. (2002). Chemical studies on the precipitation and dissolution of some chemical elements in Qaroun Lake (Ph. D. thesis). Egypt: Fac. Sci., AL-Azhar Univ. Cairo, 359 pp.
20. Gorgy, S., (1959). The use of energy equations in the calculation of the rate of evaporation from Lake Qarun. Alexandria Inst. Hydrobiol. Alexandria, Notes Mem. 42, 1–26.
21. Http://offer.alibaba.com. (2018)./product/premiumKeyword.vhtml?SearchText=evaporators,crystalizers,packaging units, pumps.
22. Keatings, KIWI, Hawkes, I., Holmes, J.A., Flower, R.J., Leng, M.J., Abu-Zied, R.H., and Lord, A.R., (2007). Evaluation of ostracod-based palaeoenvironmental reconstruction with instrumental data from the arid Faiyum Depression, Egypt.
23. Mahmoud S.M. Abdel Wahed (2015). Geochemistry and Water Quality of Lake Qarun, Egypt. Lappeenranta, 2015, ACTA Universities-Lappeenrantaensis, 637, Diss. Lappeenranta University of Technology, ISBN 978-952-265-794-7.
24. Mansour, S.A.,S.S. Messeha and M.M. Sidky, (2000). Ecotoxicological Studies. Qualitative and Quantitative determination of salts composition in Lake Qarun water and its sources. Egypt. J. Aquat. Biol. Fish, 4:271-303.
25. Meshal, A. (1973). Water and Salt budget of Lake Oarun, Fayoum, Egypt., Ph.D. thesis. Alexandria University.
26. Meshal AH (1977). The problem of the salinity increase in Lake Qarun (Egypt) and a proposed solution. Journal du Conseil 37:137–143.
27. Meshal, A. and S. Morcos (1981). National Institute of Oceanography and Fisheries, Academy of Scientific Research and Technology, Egypt, 7, (3); 474-483.
28. Mohamed, A.M.O., Maraqa, M., and Al Handhaly, J. (2005). Impact of land disposal of reject brine from desalination plants on soil and groundwater. Desalination, 182, pp. 411433.
29. Naguib, M. (1958). Studies on the ecology of Lake Qarun, Fayoum, Egypt. Kieler Meeresforsch., 14; 187-22.
30. Rasmy, M., and Estefan, S.F., (1983). Geochemistries of saline minerals separated from Lake Qarun reject water. Chem. Geol. 40, 269–277.
31. Reda M.A. Hassan (2014) " Using ZLD Technique for Safe and Economic Disposal of Desalination Plant Brines in Egypt" Eleventh International Water Conference, 21-24 Dec. 2014, Sharm El-Sheikh, Egypt, Journal of Egyptian Academic Society for Environmental Development.
32. Reda M.A.H. (2015). Ecosystem Restoration Using maintenance Dredging in Lake Qarun, Egypt. Journal of American Science;11(12):55-65. ISSn:1545-1003.
33. Report of Egyptian Environmental Affairs Agency (Ministry of Environment) and Environment and Climate change Research Institute, (2015) during the study about the disposal of the Lake's excess water in the low lands of Wady Al Rayan, by pumping the excess water to proposed new two lakes.
34. Robin A. Foldager (2003) "Economics of desalination concentrate disposal methods in inland regions: deep-well injection, evaporation ponds, and salinity gradient solar ponds" A thesis submitted to the University Honors Program in partial fulfillment of the requirements for graduation with University Honors Major: Environmental Science -New Mexico State University Las Cruces.
35. Sabae, S.Z. and M.H. Ali, (2004). Distribution of nitrogen cycle bacteria in relation to physico-chemical conditions of a closed saline lake (Lake Qarun, Egypt). J. Egypt Acad. Environ. Dev., 5: 145-167.
36. Soliman. G.F. (1989). Bull. National Institute of Oceanography and Fisheries, Academy of Scientific Research and Technology, Egypt. 15(1): 75-92: 93-105.
37. Wolters W, Ghobrial NS, Van Leeuwen HM, and Bos MG (1989). Managing the water balance of the Fayoum Depression, Egypt. Irrigat. Drain Syst. 3:103–123.

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