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CHLORINITY/CONDUCTIVITY RATIO/ SALINITY RELATIONSHIPS OF LAKE QARUN WATER (EGYPT)

BY

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ABSTRACT

Unesco established the new Practical Salinity Scale based on measurements of conductivity ratio of seawater using KCL standard solution. The practical salinity scale and the algorithm to calculate practical salinity are meant for use in all seawaters. However, the application of those equations on Lake Qarun waters lead to erroneous results in salinity. These, due to, the ionic composition in the Lake is different from seawater. Three Equations (E_2), (E_6) and (E_7) gave salinities which are the averages of 62.15%, 85.41% and 99.79% in the Lake. Equations (E_3) and (E_4) give salinity which is the average 78.39%. Equation (E_9) give salinity with the averages of 91.63% ($0.9500 \geq R_{15}$) and 112.48% ($0.9500 < R_{15}$). As chlorinity-salinity relationship (r) is 0.9757 and conductivity-salinity (r) is 0.9701. Therefore the new empirical Equations were established in Lake Qarun. The present work provides the bases for accurate estimation of salinity in Lake Qarun by applying the recent standard oceanographic methods. The new empirical Equations (E_5) and (E_8) are to be reliable and give accurate estimation of salinity in the Lake.

INTRODUCTION

Lake Qarun is an inland closed -and saline basin. It receives its water (agricultural drainage water) through some drains. The Lake lies between Latitudes 29^0 24' and 29^0 33' N & Longitudes 30^0 25' and 30^0 50' E (fig., 1). Its area is 240 km^2 and volume of one km^3. Lake Qarun water is rich in Sulfate; therefore the Egyptian Company for Salts and Minerals (EMISAL) was created on its coast. This project was started in 1986 (EMISAL, 1996).

Application of the International Oceanographic Equations for salinity determination by chlorinity, conductivity ratio in Lake Qarun might lead to erroneous results. Since the composition of seawater differ than that in the Lake (Abd Ellah, 1999). The present study aims to establish empirical relationships between chlorinity, conductivity ratio and salinity for the water in Lake Qarun.

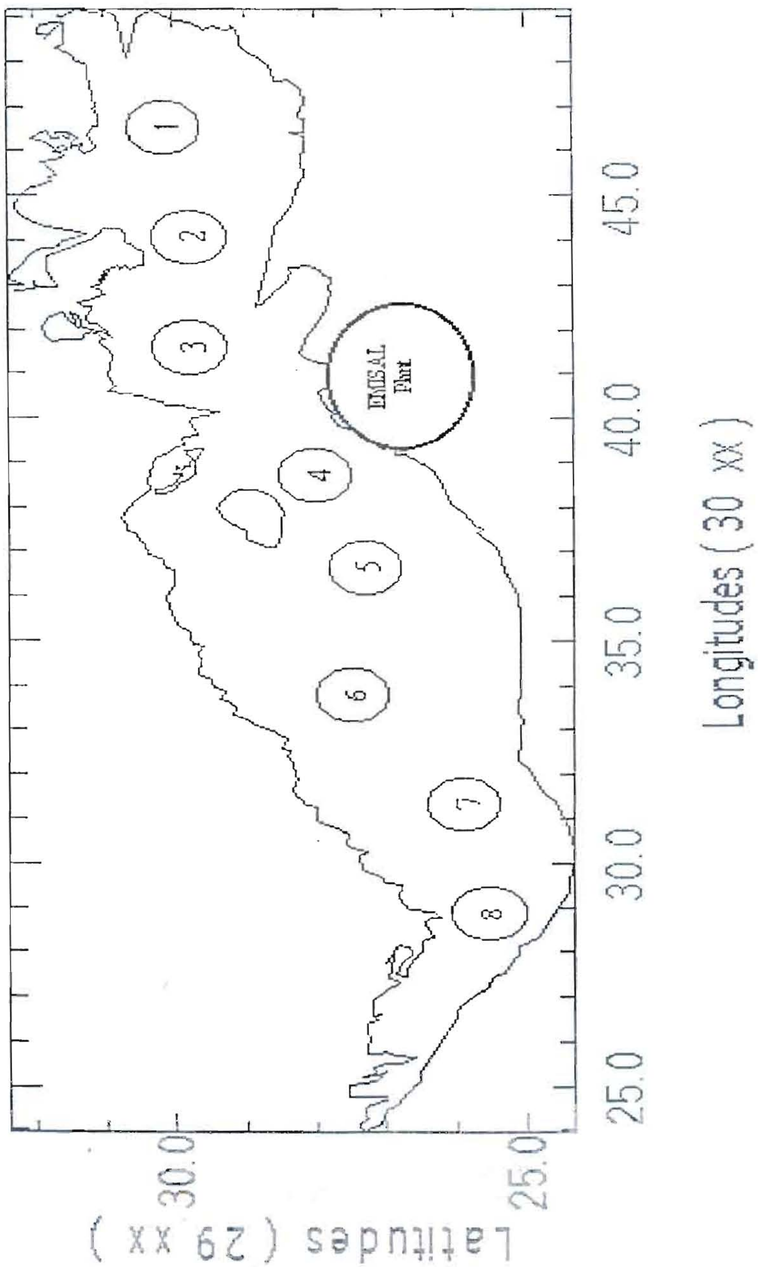


Fig. 1: Sampling stations location in Lake Qarun

METHOD OF ANALYSIS

During 1999-2000, eight seasonal cruises were done in Lake Qarun. Eight hydrographic stations were established to cover the Lake. 128 water samples (surface & near bottom) were taken; 96 water samples were chosen to determine Chlorinity/ Conductivity ratio/ Salinity relationships. Each sample was analyses for chlorinity, conductivity ratio and salinity. The chlorinity was determined by titrating against a silver nitrate solution using a Knudsen burette. The calculations of chlorinity were made according to method of APHA (1992). The conductivity ratio was measured by a salinometer, Model RS-10 (using KCL standard solution), (Poission et al, 1991). The salinity was determined by the direct gravemetric method (APHA, 1992) .

RESULT AND DISCUSSION

In theory, the determination of the dissolved salt concentration needs to calculate the concentration of the other major constituents (Lewis, 1978). In practical this is not quite so simple (Bryden, 1973). Since the chloride is the most common dissolved ion and one have the easiest to determine precisely (Pipkin et al, 1977 and Lewis, 1980). The classical method for determining the chlorinity is known as the Kundsen titration. This method is relatively fast and accurate, if carried out carefully (Poission, 1980). There is, between chlorinity and salinity, a linear (empirical) relationship, which is accurate enough for all practical purposes. The Knudsen and the Cox salinity scales (Cox et al, 1970) were used prior to Practical Salinity Scale, which superseded both of these scales in calculations. These scales were defined as follows in UNESCO, 1991.

The Knudsen scale (Knudsen et al, 1902) [$S_K = 0.030 + 1.8050Cl$ --------- (1)] Based (solely) on the definition of chlorinity as the chloride-equivalent mass ratio of chlorides to the mass of seawater (Grasshoff, 1976). The Cox scale (Fofonoff, 1985) [$S_{cox} = 1.80655Cl$ --------- (2)] defining salinity as proportional to chlorinity to satisfy mass conservation principle and also chosen to coincide with the Knudsen scale at salinity of 35.

The electrical conductivity may be a more accurate parameter of total salt content than have chlorinated alone (Lewis & Perkin 1981, Poisson, 1981 and Mantyla, 1987). The recent practical salinity, of the sample of seawater, is defined in terms of the ratio R_{15} of the electrical conductivity of the seawater sample at temperature of 15 ^{0}C and pressure of one atmosphere, to that of a potassium chloride (KCL) solution, in which the mass fraction of KCL is 32.4356×10^{-3}, at the same temperature and pressure (UNESCO,1981). The practical salinity is defined in terms of the ratio R_{15} by the following equation:

$$S = a_0 + a_1 R_{15}^{(1/2)} + a_2 R_{15} + a_3 R_{15}^{(3/2)} + a_4 R_{15}^{(2)} + a_5 R_{15}^{(5/2)} \quad \text{--------------} \quad [3]$$

a_o=+0.0080 a_i= -0.1692 a_2=+25.3851 a_3=+14.0941

a_4=-7.026 a_5= +2.7081 $\sum a_i$ =35.00 $2 \leq s \leq 42$

UNESCO published Volume (3) of the International Oceanographic Tables (Unesco, 1981), which was prepared under the supervision of the Toint Panel on Oceanographic Tables and standards (JPOTS), (Millero & Poisson 1981). Volume (3) gives the value of electrical conductivity ratio (R_t) and the corresponding value of practical salinity of seawater, which was adopted by JPOTS in 1978. The tables in Volume (3) are valid for a practical salinity S from 2 to 42 (Poission et al, 1991), and temperature (°C) from -2 to 35 °C. UNESCO published Volume (4) of the International Oceanographic Tables giving proprieties derived from the International Equation of state of seawater (Unesco, 1987). Recently, UNESCO published Volume (5), to determine and present for seawater of high salinity between 42 and 50. The polynomium International Equation (salinity 42-50) was formed as:

$$S = 35R_{15} + (R_{15} - 1)\,[A_0 + 15A_2 + 225A_5 + 3375A_9 + R_{15}(A_1 + 15A_4 + 225A_8)$$
$$+ R_{15}^{(2)}(A_3 + 15A_7) + A_6 R_{15}^{(3)}] \quad \text{---------------} \quad [4]$$

where:

A_0 = +7.737 A_1 = -9.819 $A_2 = +3.473\text{x}10^{-2}$

A_3 = +8.663 $A_4 = -10.01\text{x}10^{-2}$ $A_5 = +3.188\text{x}10^{-3}$

A_6 = -2.625 $A_7 = +4.82\text{x}10^{-2}$ $A_8 = -6.682\text{x}10^{-4}$

$A_9 = -4.655\text{x}10^{-5}$

The application of the Equations (1), (2), (3) & (4), on water of Lake Qarun would lead to erroneous results in salinity owing to the differences in the ionic composition between the Lake and seawater (Meshal & Morcos, 1984; Moran et al, 1986; Abd Ellah, 1999 and Talling, 2001). Where the percentage of the main salts composition of seawater are; Chlorine (55.04), Sodium (30.61), Sulfate (7.68), Magnesium (3.69), Calcium (1.16), Potassium (1.10) and Bicarbonate (0.41), while other element represent 0.31 (Neumann & Pierson, 1966 and Weisberg & Parish, 1974). The Percentage of the main constitutes of Lake Qarun are; Chlorine (38.88), Sodium (28.58), Sulfate (26.08), Magnesium (4.42), Calcium (1.20) and Bicarbonate (0.56), while other solids represent 0.48 remaining (EMISAL, 1996).

For Lake Qarun data ($36.88 \leq S \leq 45.21$ and $12.54 \leq CL \leq 16.15$; Fig., 2-a), the new empirical Equation between chlorinity and salinity ($r = 0.9757$) follows as:

$$\boxed{S = 15.098 + 1.8656\ Cl} \quad \text{-------------} \quad (5)$$

The value of (r), between direct gravimetric salinity and those estimated from Equation (5), is 0.840 and the standard deviation (Std. Dev.) of 2.088. For Equations (1&2) and Equation (5), (r) is 0.9955, with (Std. Dev.) of 8.962 (Fig., 2-b).

Meshal & Morcos (1984) established, the first attempt, empirical relationship between salinity and chlorinity in the lake as [S= 0.216 + 2.470 Cl ---- (6)]. The value of (r), between Equation (6) and Equation (5), is 0.9959 and (Std. Dev.) is 5.339 (Fig., 2-b).

The second attempt was established by Abd Ellah (1999). The empirical equation was formed as [S = 16.376 + 1.771 Cl ---------- (7)]. The value of (r), between Equation (7) and Equation (5), is 0.9991 and (Std. Dev.) is 3.734 (Fig., 2-b). The variation between values of Equation (7) and values of Equation (5) is slight. The difference between Equations (6&7) and Equation (5) may be, due to various in chloride ions concentration of the Lake in long time.

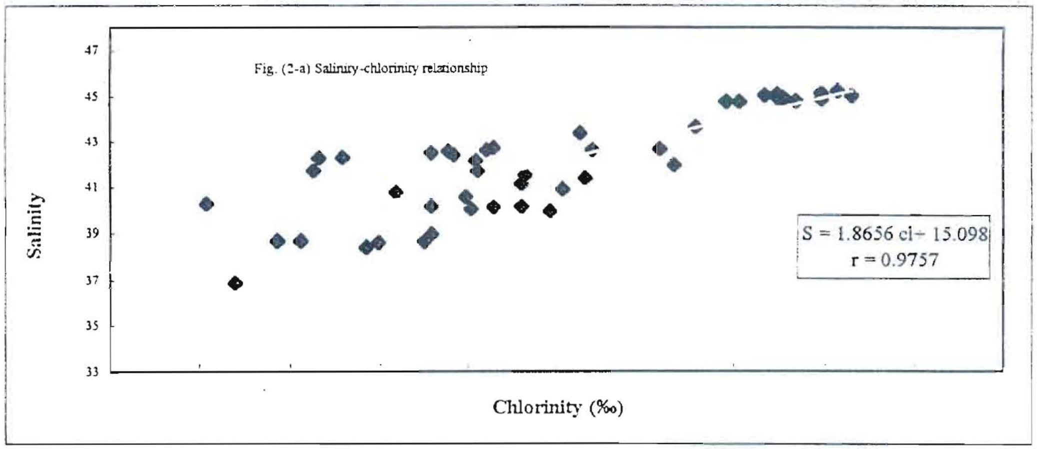


Fig. (2-a) Salinity-chlorinity relationship

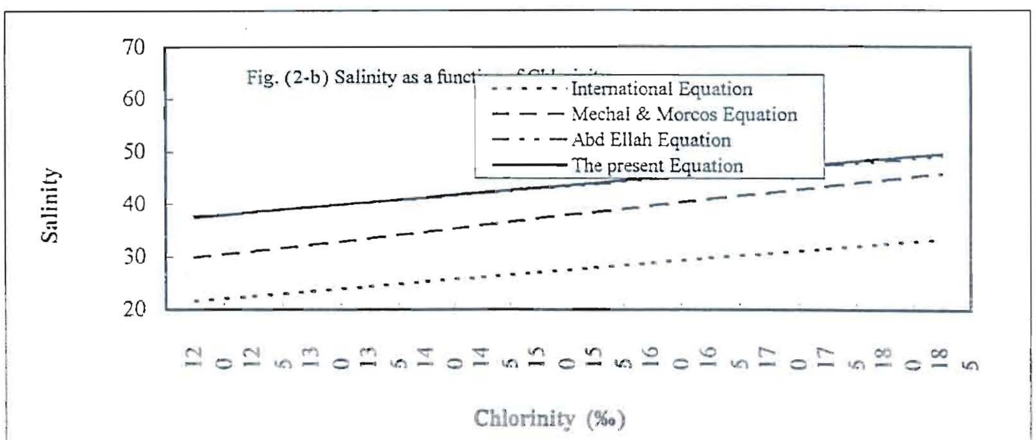


Fig. (2-b) Salinity as a function of Chlorinity

For Lake Qarun ($36.88 \leq S \leq 45.21$ and $0.8660 \leq R_{15} \leq 1.0144$; Fig., 3-a), a fifth order polynomial, giving salinity (S) as a function of the conductivity ratio (R_{15}) was fitted by the least square method (r = 0.9701):

$$S = b_0 + b_1 R_{15} + b_2 R_{15}^{(2)} + b_3 R_{15}^{(3)} + b_4 R_{15}^{(4)} + b_5 R_{15}^{(5)} \quad \text{-------------} \quad [8]$$

The constants of Lake Qarun are the following:

$b_o = +4.513$ $\quad$ $b_1 = +50.003$ $\quad$ $b_2 = -26.407$

$b_3 = +18.552$ $\quad$ $b_4 = -14.629$ $\quad$ $b_5 = +12.274$

The value of (r), between direct gravimetric salinities and those estimated from Equation (8), is 0.973 and (Std. Dev.) is of 2.227. On the other side, the correlation coefficient, between Equations (3&4) and Equation (8), is 0.990 and (Std. Dev.) is of 9.632 (Fig., 3-b).

Meshal &Morcos (1984) established the empirical relationship between salinity and conductivity ratio in the Lake (Fig., 3-b) as:

$$S = C_0 + C_1 R_{15} + C_2 R_{15}^{(2)} + C_3 R_{15}^{(3)} + C_4 R_{15}^{(4)} + C_5 R_{15}^{(5)} \quad \text{----------} \quad [9]$$

Where:

$C_0 = -44.229$ $\quad$ $C_1 = +462.485$ $\quad$ $C_2 = -1626.513$

$C_3 = +2989.965$ $\quad$ $C_4 = -2627.331$ $\quad$ $C_5 = +890.267$

The value of (r), between Equation (8) and Equation (9), is 0.980 and (Std. Dev.) is of 8.626 (Fig., 3-b). The Equation (9) was generally regarded as the best available pointed out that their results contained two errors. One error was caused by their use (R_{15}=1) of the standard seawater (chlorinity = 19.375%) solution. The other was attributed to vary in the recent ions concentration (salt content) comparing with that in another time (1973) in the Lake water.

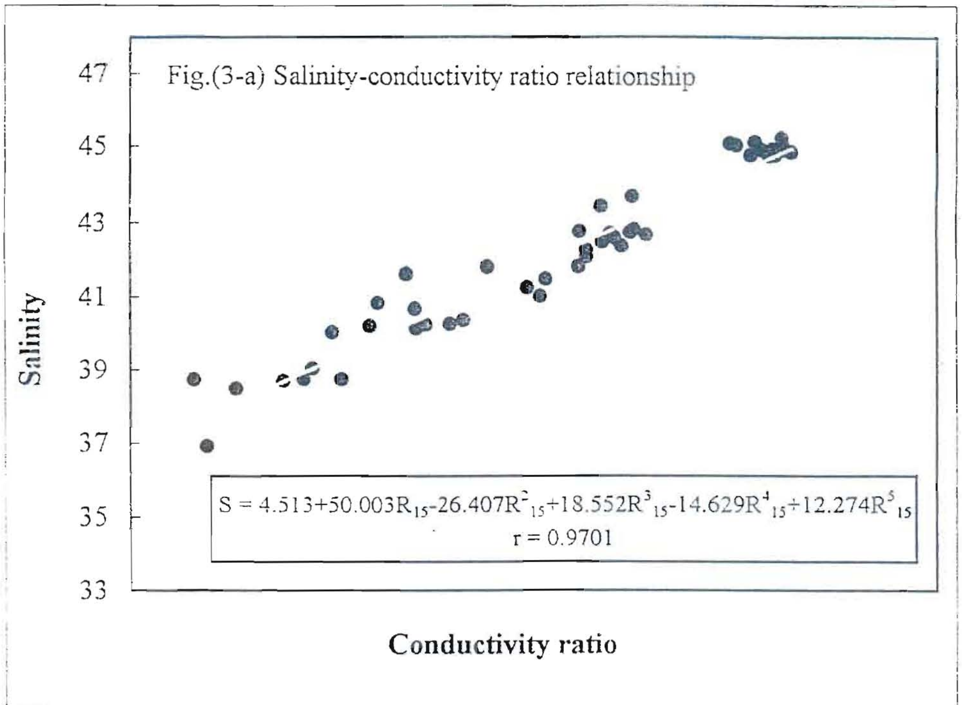
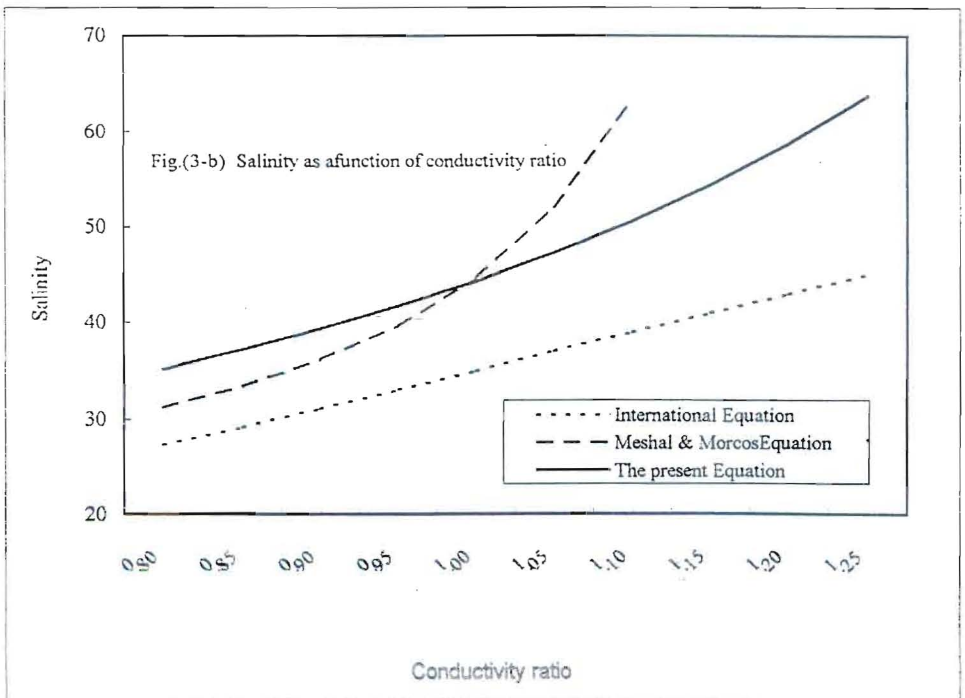


Fig.(3-a) Salinity-conductivity ratio relationship
47
45
43
41
39
37
35
33
Salinity
S = 4.513+50.003R15-26.407R²15+18.552R³15-14.629R⁴15+12.274R⁵15
r = 0.9701
Conductivity ratio


70
60
50
40
30
20
Salinity
Fig.(3-b) Salinity as afunction of conductivity ratio
International Equation
Meshal & MorcosEquation
The present Equation
0.80
0.85
0.90
0.95
1.00
1.05
1.10
1.15
1.20
1.25
Conductivity ratio

CONCLUSIONS

- The application of International Oceanographic Equations, for salinity, on Lake Qarun waters lead to erroneous results. The difference ionic composition in the Lake in comparison with seawater might be reason.

- Three Equations (E_2), (E_6) and (E_7) gave salinities which are the averages of 62.15%, 85.41% and 99.79% in the Lake.

- Equations (E_3) and (E_4) give salinity which is the average 78.39%.

- Equation (E_9) give salinity with the averages of 91.63% ($0.95 \geq R_{15}$) and 112.48% ($0.95 < R_{15}$).

- The new empirical Equations (E_5) and (E_8) prove to be reliable and give accurate estimation of salinity in Lake Qarun.

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