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Estimating relations between temperature, relative humidity as independed variables and selected water quality parameters in Lake Manzala, Egypt

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Abstract In Egypt, Lake Manzala is the largest and the most productive lake of northern coastal lakes. In this study, the continuous measurements data of the Real Time Water Quality Monitoring stations in Lake Manzala were statistically analyzed to measure the regional and seasonal variations of the selected water quality parameters in relation to the change of air temperature and relative humidity. Simple formulas are elaborated using the DataFit software to predict the selected water quality parameters of the Lake including pH, Dissolved Oxygen (DO), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Turbidity, and Chlorophyll as a function of air temperature, relative humidity and quantities and qualities of the drainage water that discharge into the lake. An empirical positive relation was found between air temperature and the relative humidity and pH, EC and TDS and negative relation with DO. There is no significant effect on the other two parameters of turbidity and chlorophyll.

1. Introduction

Egypt is fairly unique in the distribution of its population, land-use and agriculture, and economic activity which makes it extremely vulnerable to any potential impacts on its water resources and coastal zone. According to Human Development Report of the Initial National Communication (INC) and the United Nations Development Programme [1], Egypt is highly vulnerable to climate change impacts, which may jeopardize the country's development gains.

Lakes are vital component of water resources. Egypt has various inland water resources, all of which are part of the Nile River; these include six northern coastal lagoons opening to the Mediterranean Sea such as Mariout, Edku, Burullus, Manzala, Port Fouad, and Bardawil and two opening to the Suez Canal include Timsah and Bitter Lakes, two closed lakes such as Qarun and Wadi Al Raiyan, and Lake Nasser the large reservoir behind the Aswan High Dam [2]. The population growth and expansion of urbanization in the Nile delta are

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important problems affecting deterioration of water resources. The Northern lakes in Egypt serve as reservoirs for drainage waters, which are contaminated, with anthropogenic materials [3]. Lake Manzala is the largest and the most productive lake of the northern Egyptian coastal lakes. It is an important and valuable natural resource area for fish catch, wildlife, hydrologic and biologic regimes and table salt production. It produces about 50% of the fish catch of the northern lakes and freshwater fisheries. Lake Manzala is characterized by special sensitive environments. Human activities including discharge of sewage and industrial waste and the impact of canal and road networks have a serious impact on the water quality of the lake. Diversion of much of the relative unpolluted freshwater from the drains to El Salam canal in Sinai allowed only the high polluted drainage water into the lake, undermined the water quality of the lake and reduced the lake's productivity of fish catch. The Lake has been gradually transformed from a largely marine or estuarine environment to eutrophic brackish water system [4].

The knowledge of the impact of pollution source on the water resources is essential in environmental water studies as well as for resource management. The Egyptian National Environmental Action Plan of 1992 identified Lake Manzala as among the most heavily polluted water bodies in the country [5]. The effect of pollution is most noticed along the whole lake. Consequently, it is important to assess lake water quality according to its importance as a natural resource and at its socio-economic aspects as a significant source of inexpensive fish for human consumption in Egypt [6].

By the late eighties the problem of climate change and its possible impacts had become an issue of global concern. Egypt's climate is semi-arid and characterized by hot humid summers, moderate winters, and very little rainfall. The climate of Lake Manzala also is described as an arid Mediterranean [7]. The water circulation and consequently the water quality of the lake are affected by climatic variables. The climate change for the Egyptian coastal region of the Nile Delta has direct effects on the hydraulic and biological functioning of the lakes, either as freshwater reservoirs, or as brackish lagoons. The lake and lagoon ecosystems (aquatic vegetation, migrating fish and birds) would be directly affected by this change [8].

Not only great efforts are needed for keeping the purity and healthy of Lake Manzala, but also an additional information is needed to provide a database for water quality status that helps the proper management of the lake. There is also an imperative need for accurate, reliable lake water quality information to measure the impacts of climatic variables change on the Lake Manzala water quality.

The routine water quality monitoring program in Lake Manzala includes monthly in-situ measurements of water quality parameters in drains and canals leading into the lake. But due to the need for information knowledge of spatial and temporal variability of water quality in the lake, an environmental security and water resources management system using Real Time Water Quality (RTWQ) warning and communication was implemented under the Science for Peace initiative of NATO [9].

The recent information knowledge and environmental security system including Remote Sensing and Real Time Water Quality is a suitable technique for large-scale monitoring of inland and coastal water quality and its advantages have long been recognized. RTWQ provides a continuous measurement of different biological, chemical and physical variables. Therefore, recent years have seen increasing interest and research in RTWQ of inland and coastal waters [10].

Real time water monitoring involves continuous measurement of water related parameters in-situ with results provided in real time or near real time. This new integrated water monitoring, warning and reporting system will allow water managers to protect the integrity of Egypt's vital water resources against any natural or anthropogenic threats, take immediate corrective and mitigation measures, and report the suitability of water for designated beneficial water uses. Such a real time water monitoring network will lay the foundation for greater environmental security and water resources management [11].

Therefore, the main objective of this study was to analyze statistically the continuous measurements data of the Real Time Water Quality Monitoring stations in Lake Manzala to measure the regional and seasonal variations of some selected water quality parameters and then to elaborate simple formulas using the DataFit software to predict the selected water quality parameters of the Lake including Power of Hydrogen (pH), Dissolved Oxygen (DO), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Turbidity, and Chlorophyll as a function of air temperature, relative humidity and tide height at port said as co-varying with wind speed and direction in addition to drainage discharge quantities and qualities as the main factors that affect the water quality parameters of the Lake.

2. Study area description

Manzala Lake is located on the northeastern edge of the Nile Delta, separated from the Mediterranean Sea by a sandy beach ridge. It is the largest of the delta lakes and it is bordered by Mediterranean Sea to the north and the north-east, the Suez Canal to the east, Dakahlia and Sharkia Provinces to the south and the Damietta branch of the Nile to the west as shown in Fig. 1. The lake lies within three governorates and the two macroeconomic regions of the Suez Canal and the Delta [6]. Lake Manzala is located between latitudes (31°00′51″) and (31°31′25″) north and longitudes (31°46′10″) and (32°19′17″) east. It extends 64.5 km in its maximum length, 49 km in its maximum width and 239 km in total length of the shoreline. It is shrinking in size; the rate of shrinking of the total area from 1922 to 1995 was estimated, being 5.22 km^2/yr. The greater losses of the lake areas were detectable along the western and southern borders of the lake [12]. In 1900 its area was 1907 km^2, while its area as measured by land sat imagery in 1981 was about 909.85 km^2. As a result of presence of a large number of islets in the lake, the area of open water is only about 700 km^2 [13].

2.1. Hydrological characteristics

The lake is connected to the Mediterranean Sea via three outlets as shown in Fig. 1, and these opened connections allow an exchange of water between the lake and the Sea. These outlets are El-Gamil, El-Boughdady and the new El-Gamil [14]. The lake is also connected to the Suez Canal at El-Qabouti and connected with the Damietta branch of the Nile through the El Inaniya Canal. Therefore, the southwestern corner of the

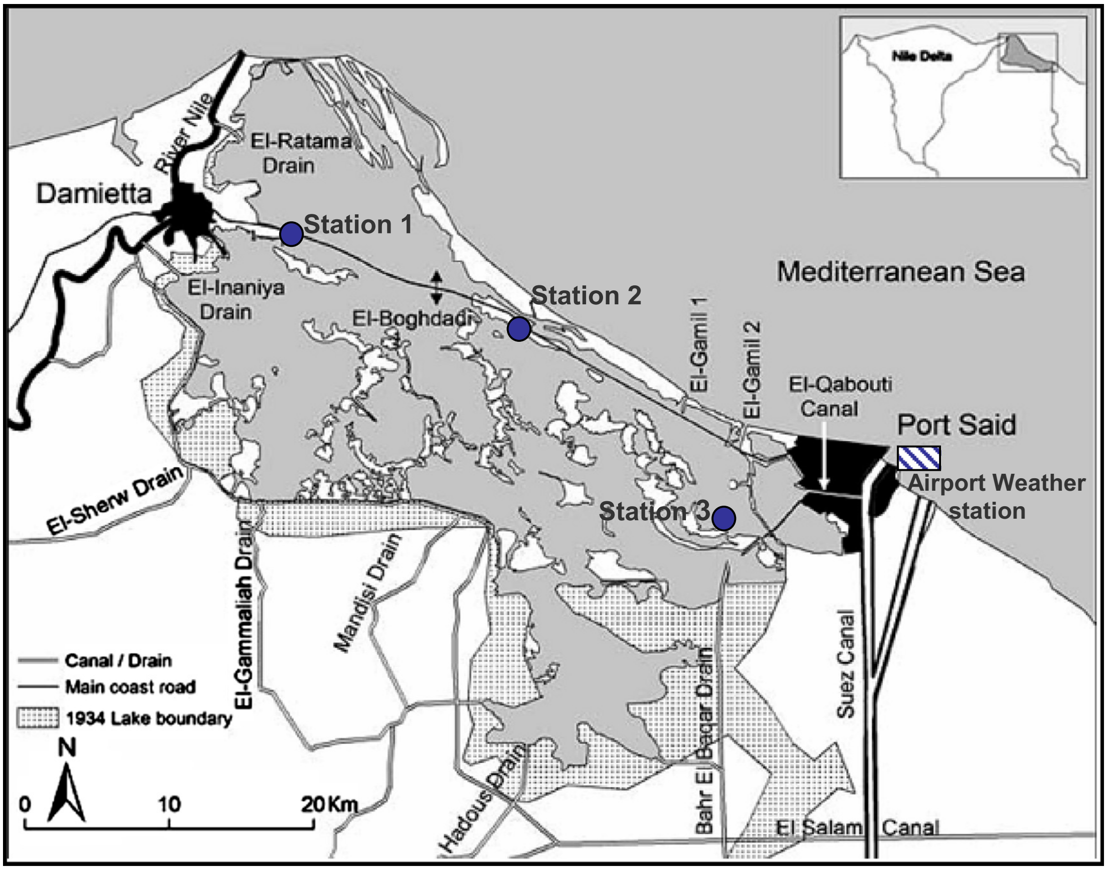

Figure 1 Layout map of Lake Manzala and locations of RTWQ.

lake receives the majority of its freshwater input from the Serw and Faraskur pumping stations, and the Inaniya Canal. The lake is shallow, with an average depth of about 1.25 m [15].

Lake Manzala is a highly dynamic aquatic system that has undergone considerable physical, chemical and biological changes during the past century. This was as a result of different aspects of human impacts, such as the closing and/or opening of straits, establishment of the Aswan High Dam, silting of the lake, continuous drying processes for cultivation purpose and human settlement and pollution with different kinds of water discharge into the lake [16]. Several main agricultural drains used to flow into Lake Manzala and affect its water quality. Drainage water contributes about 98% of the total annual inflow to Lake Manzala. The lake received about 7500 million cubic meters of untreated industrial, domestic and agricultural drainage water, and this amount of water was reduced to about 4000 million cubic meters after construction of El-Salam Canal. This water is discharged annually into the lake through several drains: Bahr El-Baqar Drains (domestic and industrial sewage), Hadous, Ramsis, El-Serw and Faraskur Drains (agricultural effluents) [17].

El-Wakeel and Wahby [18], Akram [9], Flower et al. [19], Barakat et al. [20], and El-Shabrawy and Germoush [21], divided the lake into three zones from the perspective of water quality. The regions are as follows:

- The south eastern region which receives mainly drainage water,
- The north eastern region affected by both seawater and drainage water, and
- The western region affected by drainage water, seawater and freshwater (during flood time only).

2.2. Climate and meteorological information

The climate of El Manzala Lake is described as an arid Mediterranean. The mean annual rainfall over the area is less than 100 mm. Air temperatures do not exceed 35 °C in the summer months. Air pressure has no huge differences during the different seasons of the year [8].

The average surface wind speed at the lake ranges between 17.2 km/h, in the northern border, and 8.1 km/h in the southern region. The wind speed tends to be lower in July and August, increases progressively in November and January and attains its maximum in April. At the southern region the prevailing wind direction is north and northeast, while at the coastal locations the direction is northwest. The net inflow and outflow balance indicates a consistent annual input to the Mediterranean from the Lake. The tide at Port Said headland is estimated as the difference between the mean high water level (50-cm) and the mean low water level (20-cm). The tide happens twice a day and the average depth of the lagoon is less than 2 m; this means that there is about 15–30% per day shift in water level between lagoon and the sea. So the tidal effect could be considered in low inflow months of the lake (winter months) and with the days of intensive storms [22].

The temperature of the water in the lake is highly affected by the air temperature due to water shallowness. The lake is located in the arid and semiarid area, where the temperature is highly varying from summer and winter and from day and night. Air temperature is affected by the geographic location that is close to the Mediterranean Sea. According to the Egyptian Metrological Organization records for the last century, the mean air temperature usually attains its minimum value of about 12.5 during the winter season. It increases gradually through spring, reaching its average maximum values of 30 in summer [17].

The mean monthly relative humidity ranges between 65% and 75% all over the year. The maximum relative humidity (75.6%) is observed in January and it decreases to 60% during April–June. These trends may reflect the origin of the air masses over the region. The low spring values appear to be caused by the dry winds associated with the Khamasin depressions. The winter peak is due to the predominance of winds coming from the sea at the north in this time [8].

3. Water quality

Water quality monitoring is the integrated activity for evaluating the physical, chemical and biological characteristics of water in relation to human health, ecological conditions and designated water uses [23].

The most widely measured parameters in the real time water quality stations are pH, Dissolved Oxygen (DO), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Turbidity, and Chlorophyll [24]. These parameters are the focus of this research.

3.1. pH

The pH value is a very important factor in the study of water chemistry. It is a major factor affecting the availability of nutrients to plants and animals. pH will cycle in the presence of large quantities of algae and macrophytes due to the photosynthetic cycling of CO_2 [25]. The pH test is one of the most common analyses in water testing. An indication of the sample's acidity, pH is actually a measurement of the activity of hydrogen ions in the sample. The pH measurements run on a scale from 0 to 14, with 7.0 considered neutral. Solutions with a pH below 7.0 are considered acids; those between 7.0 and 14.0 are designated as bases. A range of 6.5–8.2 is optimal for most organisms [26].

Typically, pure water (neutral) has pH equals 7. Rainwater is usually slightly acidic (pH 6.5) while seawater is usually slightly basic (pH 8.5). Low pH (0–5 units) can be caused by acidic industrial effluents and fallout from the burning of high sulfur fuels. High pH (9–14 units) can be caused by caustic industrial effluents and return irrigation flows from saline agricultural areas [27].

3.2. Dissolved oxygen

Dissolved oxygen is a measure of the amount of oxygen freely available in water. The concentration of Dissolved Oxygen (DO) gives information on the possibilities for flora and fauna living in the water system. The concentration of DO is controlled by consumption by aerobic organisms, consumption by plants during darkness, production by plants during daylight, exposure (or lack of) by natural reiteration (waterfalls and riffles) and water temperature, flow and depth. The DO for surface water ranges from 0 in extremely poor water conditions to a high of 15 mg/l in very healthy water. However, at temperatures 15–30 °C, 15 mg/l DO is 150–250% supersaturated that means a potential sign of a very unhealthy eutrophication. The oxygen content of natural water varies with temperature, salinity, turbulence, and the photosynthetic activity of algae and plants. In freshwater, concentrations range from 15 mg/l at 0 °C to 8 mg/l at 25 °C [28].

Low dissolved oxygen level (0–8 mg/L) is an indicator of high oxygen demand on the water caused by either high biological or chemical oxygen demand (BOD or COD). High BOD is caused by the decomposition of organic material in industrial and municipal effluents (pulp and paper plants and sewage treatment facilities) and production of organic material in the lagoon itself that can result in fish kills [22]. Any inorganic chemical that consumes oxygen as it degrades causes high COD. High dissolved oxygen levels (12–15 mg/L) can be caused by excessive algal and macrophyte growth and usually due to the photosynthetic cycling. Mid range dissolved oxygen values (8–12 mg/L) are usually an indicator of a healthy system [27].

3.3. Electrical Conductivity (EC)

The common method for evaluating the total salt content in water is by measuring the electrical conductivity of water (EC) at 25 °C. Electrical Conductivity is a measure of the ability of water to pass an electrical current. EC indicates the amount of dissolved substances (salts). Electrical conductivity is expressed in mmhoS/cm (mS/cm). There is a relation between the electrical conductivity and the concentration of salts in milliequivalents per liter. Every 10 meq/liter of salts (cation concentration) creates 1 mS/cm EC. The sum of cations should equal the sum of anions. The accuracy of the chemical water analyses should be checked on the basis of this relationship [29].

Low electrical conductivity is an indicator of pristine or background conditions but in the presence of low pH can indicate the removal of most salts. High conductivity (1000–10,000 mS/cm) is an indicator of saline conditions caused by high evaporation, saline irrigation returns or runoff and caustic or alkaline industrial processes [27].

3.4. Total Dissolved Solids (TDS)

Total Dissolved Solid (TDS) is a water quality parameter defining the concentration of dissolved organic and inorganic chemicals in water. It is used to evaluate the quality of freshwater systems. TDS is an indication of the potential buffering capacity of water and water hardness. TDS concentrations are equal to the sum of positively charged ions (cations) and negatively charged ions (anions) in the water. Water is tested for TDS because excessive amounts may be unsuitable for aquatic river life, it can affect the buoyancy of fish eggs and other organisms, and because of poor crop irrigation, in addition to being unsuited for drinking water [27].

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Primary sources for TDS in receiving waters are agricultural runoff, leaching of soil contamination and point source water pollution discharge from industrial or sewage treatment plants. Table 1 shows the water classification by salinity according to Phocaides [29].

3.5. Turbidity

Turbidity is a principal physical characteristic of water and is an expression of the optical property that causes light to be scattered and absorbed by particles and molecules rather than transmitted in straight lines through a water sample. It is a measure of the translucence of water and the amount of suspended material in water at any one particular time. It is caused by suspended matter or impurities that interfere with the clarity of the water. These impurities may include clay, silt, finely divided inorganic and organic matter, soluble colored organic compounds, and plankton and other microscopic organisms [28].

In most equipments, turbidity is measured by emitting infrared light from a known source and measuring the amount of backscatter from suspended particles. The greater the backscatter, the higher the turbidity, measured in NTUs (nephelometric turbidity units). High levels of turbidity can change the diversity of aquatic systems and can shade out aquatic plants and other fauna. Increased turbidity can also affect water temperature and distribution of heat through the water column. Surface water can become warmer and subsurface water may become cooler due to the shading action [27].

3.6. Chlorophyll

Chlorophyll gives plants their green color and is produced by microscopic plants called algae in lakes and rivers. There are many human activities that affect chlorophyll in water, such as sewage inputs and destruction of lake and river shorelines. More chlorophyll indicates more algae, and algae are very important because they form the base of the food chain. If conditions are suitable in the water, algae can grow and cover lakes with green scum or make the water look greener than normal. Algae blooms may be dangerous for fish because when algae die, bacteria decompose them and use up oxygen in the water. When oxygen levels decrease, fish can suffocate and die. This happens in areas where human activities have caused algae to grow much more quickly than normal [30].

This means that a medium level of algae is needed to be enough to feed the food chain – but not so much that bacteria go crazy decomposing and use up all the oxygen. Table 2 indicates how chlorophyll is translated into productivity.

Table 1 Water classification by salinity.

Water classification	EC (mS/cm)	TDS (mg/L)
Non-saline water	< 0.7	< 500
Saline water	0.7–42	500–30,000
Slightly saline	0.7–3.0	500–2000
Medium saline	3.0–6.0	2000–4000
Highly saline	> 6.0	> 4000
Very saline	> 14.0	> 9000
Brine	> 42	> 30,000

Table 2 Relation between chlorophyll concentration and productivity.

Productivity/ Trophic Status	Water look	Chlorophyll concentration (μg/L)
Oligotrophic	Clear	Less than 8
Oligo-mesotrophic	Usually clear	Occasionally over 8
Mesotrophic	Sometimes green	8–25
Eutrophic	Green most of summer	26–75
Hyper-eutrophic	Frequent dense algal blooms	Over 75

4. Materials and methods

The methods used to perform Water Quality Monitoring (WQM) have changed dramatically over the last 10 years resulting in improving knowledge and understanding of the relation between water quality and changes in hydrology, geology, and climate. Technological advances in water-quality sampling and recording instruments allow for an almost continuous record of the concentrations of water-quality variables in streams and rivers. A device that measures water quality in this way is called Real Time Water Quality (RTWQ) monitor. These monitors have sensors and recording systems to measure physical and chemical water-quality field parameters at discrete time intervals at point locations [31].

However, the data collected are only as good as the quality assurance and quality control procedures, and the quality assessment measures incorporated into the sampling program. In-stream water-quality sensors provide continuous measurements (typically, every 5–60 min) of water-quality conditions that may vary widely over short periods of time due to any natural or anthropogenic threats. Communication and data retrieval can be done on-site with a laptop or hand-held display or remotely in real-time via a phone or satellite. When water management officials notified of these changes, they are able to respond by altering treatment [11].

4.1. Data collection

The National Water Research Center of Egypt recently initiated applying the new Water Quality Monitoring technique using RTWQ instruments for some strategic points in the Water resources system of Egypt including Lake Manzala. This advanced technique for water quality sampling allows for real-time (continuous) records of concentrations of water-quality variables in water streams.

The water monitoring system implemented in Lake Manzala comprised of three real-time water monitoring stations and setup of a data collection and reporting command center. The stations locations were selected to cover different regional zones in the lake. As shown in Fig. 1, station 1 is located in the West side of the lake, station 2 located at the North east side and finally station 3 located at the South east side. The meteorological data were collected from the nearest weather station to the study area which is Port Said Airport station (http://www.wunderground.com/weather-forecast/EG/Port_Said_Airport.html) [32]. The location of this station is

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also shown in Fig. 1 (Longitude: 32°14.4′E and Latitude: 31°16.764′N).

As the main objective of this study was to assess the impact of the change of air temperature, relative humidity and tide height at port said during the day and night of the summer and winter seasons in addition to drainage discharge quantities and qualities on the water quality parameters of the Lake Manzala, the continuous measurements data of the Real Time Water Quality stations in the Lake were used. The water quality parameters are measured in real time using a HACH Hydro-laboratory multi-parameter probe. The real-time network in the monitoring sites was provided with sensors to measure pH, DO, EC, TDS, Turbidity, and Chlorophyll. The data are recorded in a data-logger at the data collection platform every 15 min and are adjusted to take its average; through which an average is calculated in order to get an hourly record. The study period started at 27 July 2009 till 20 May 2010 to include water quality measurements and meteorological data during different seasons to achieve the main objective of the study. The tide height was collected from the following site: http://www.mobilegeographics.com/.

4.2. Statistical analysis

To achieve the purpose of this study, the data were statistically analyzed by using the box-and-whisker plot to measure the regional and seasonal variations of the selected water quality parameters. Box and whisker plots are uniform in their use of the box [33]. In descriptive statistics, a box-and-whisker plot is a convenient way of graphically depicting groups of numerical data through their five-number summaries: the smallest observation (sample minimum), the bottom of the box is always the 25th percentile or lower quartile (lower quartile value is the median of the lower half of the data), median, the top of the box is the 75th percentile or upper quartile (upper quartile value is the median of the upper half of the data), and largest observation (sample maximum).

Secondly, Data-Fit software as a science and engineering tool that simplifies the tasks of data plotting, regression analysis (curve fitting) and statistical analysis was used to elaborate simple formulae that can help in predicting the water quality parameters of Lake Manzala including pH, DO, EC, TDS, Turbidity, and Chlorophyll as a function of air temperature and relative humidity and measure the impact of these climatic variables change on the water quality parameters. Oakdale Engineering develops Data-Fit curve fitting (nonlinear regression) and data plotting software was used. Curve fitting refers to fitting curved lines to data. These curved lines come from regression techniques or interpolation. The main objective of curve fitting is to gain insight into the data set. This will lead to improve data acquisition techniques for future experiments, extract physical meaning from fitted coefficients, and draw conclusions about the data's parent population [34].

The fitting curve process was carried out using the collected data from 27 July 2009 till 20 May 2010. The regression models were developed for each water quality parameters in relation to the air temperature and relative humidity, and then sorted according to the goodness of fit criteria (Residual Sum of Squares and Relative Mean Error). In all cases, the formula that has higher coefficient of determination (R^2) and less Relative Mean Error (RME) was selected as a best fitted formula. Fortunately, the square of the correlation coefficient provides exactly the value of coefficient of determination.

5. Results and discussion

The continuous measurements data of the Real Time Water Quality Monitoring stations in Lake Manzala, from 27 July 2009 till 20 May 2010, were statistically analyzed by using the box-and-whisker plot method to measure the regional and seasonal variations of the selected water quality parameters in relation to air temperature and relative humidity. The Data-Fit software was used to elaborate empirical relations between air temperature and the relative humidity and pH, DO, EC, TDS, Turbidity, and Chlorophyll.

5.1. The regional variations of the selected water quality parameters

Fig. 2 shows the results of the statistical analysis of the collected data of the three RTWQ stations by using box and whisker analysis to measure the regional variations of the selected water quality parameters in Lake Manzala. The pH measurements in Lake Manzala show that pH values in the lake were alkaline and have a slight regional variation. The pH values were fluctuated from 7.52 to 9.48. As shown in Fig. 2a, the fluctuation of pH values is decreased from the east to the west so the fluctuation of measurements in station 3 is more than in the other two stations. So it is clear that, in the western region of the lake (station 1), the pH values lie in the alkaline side and mostly above 8.0. Moreover, the pH values in the North eastern region (station 2) are slightly higher than those of the South eastern region (station 3). This result is in agreement with the previous results of El-Wakeel and Wahby [18] and Ali [13]. They reported that the pH values of Lake Manzala were fluctuated from 7.45 to 8.90 with slight regional and seasonal variations. These results are also in agreement with those obtained by Fathi and Abdelzahar [35] who reported that the change in pH value was always in the alkaline side and ranged between 7.7 and 9.0.

It is also clear that the pH values near the drains (El-Gammaliah drain, El-Serw drain and Inaniya drain in front of station 1 and Bahr El-Baqar drain in front of station 3) are lower than the other areas of the lake. This could be explained on the basis of the fermentation of the organic matter and liberation of hydrogen sulfide and methane gases which lead to lowering pH values. These results are in agreement with the previous results that obtained by El-Wakeel and Wahby [18] and Ali [13].

The recorded measurements of Electrical Conductivity (EC) clear that the lake is brackish. These measurements are in agreement with the previous observations of Elewa et al. [36] and Fishar [37]. Elewa et al. [36] mentioned, the variations in the water conductivity were relatively limited, and characteristic for brackish water is observed at most locations, except the area that is related to the Sea–Lake connection through El-Gamil outlet which has high EC value. Fishar [37] indicated that the lake is brackish and the northern portion of the Lake has high salinities ranging from 3000 mg/L to 35,000 mg/L due to the influence of the Mediterranean Sea. Historically the salinity of the lake was higher [7]. Fishar [37] also mentioned that the implementation of the El Salam Canal project will

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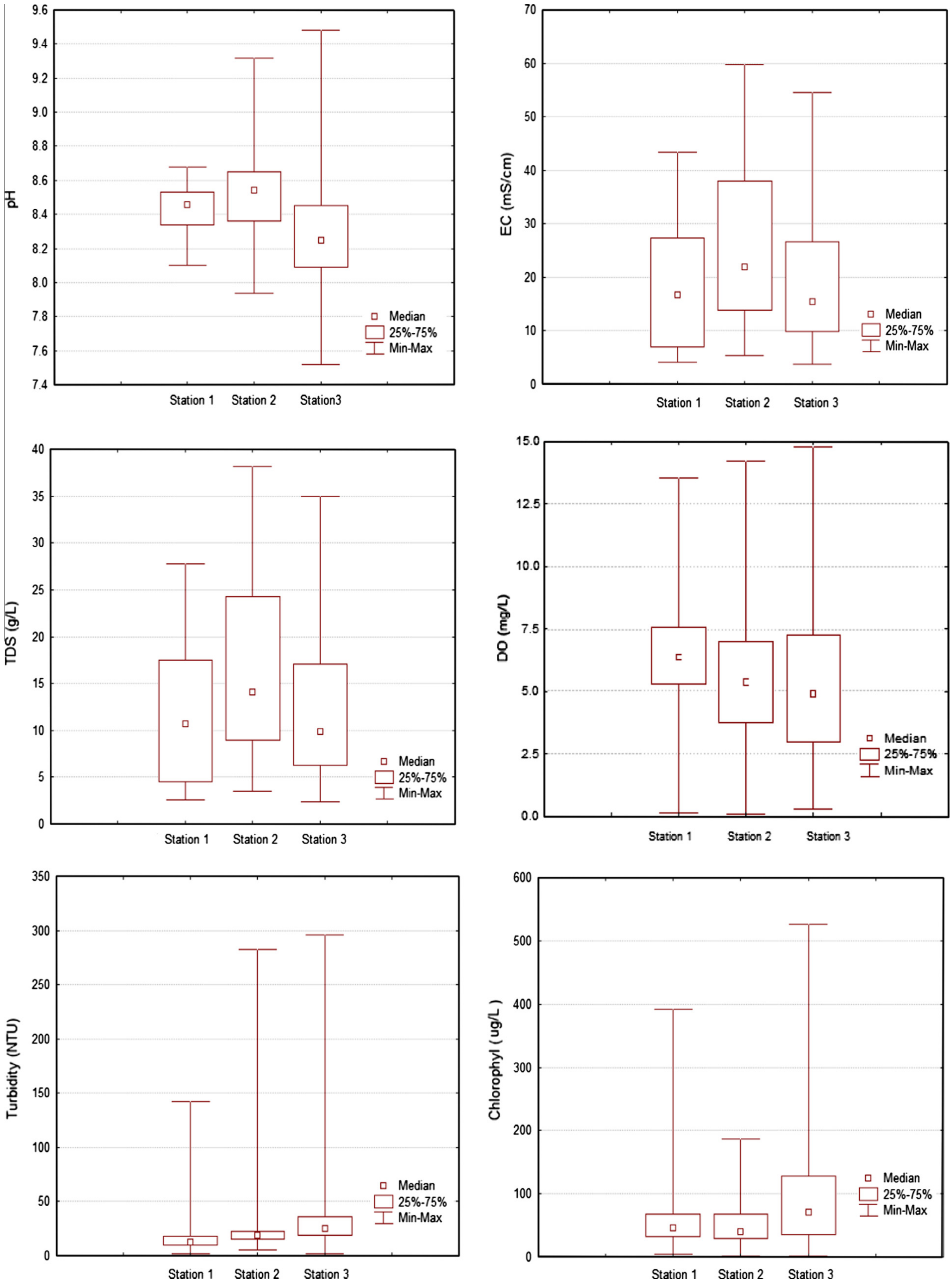

Figure 2 The regional variations of the water quality parameters in Lake Manzala.

require the diversion of water from the delta. This is expected to significantly increase salinity in the lake to 8000 mg/L from the present 3000 mg/L.

Ali [13] also recorded that, both electrical conductivity and salinity values are distributed in Lake Manzala in a similar trend. Their values increased in the north eastern area near to Boughaz El-Gamil recording the maximal values of 43.8 mS/cm and 22.5% respectively. He mentioned that, these results are in agreement with those obtained by Khalil and Bayoumi [38] and Abdel-Satar [39].

Fig. 2b shows that the northern region of the Lake at station 2 has the highest salinities due to its location in the North eastern region in between the outlets that connected the lake to the Mediterranean Sea (El-Boughdady and El-Gamil) as mentioned before by Fishar [37]. The salinity values at station 2 range from 5.47 mS/cm to 59.7 mS/cm with a median equal to 22 mS/cm. However, the values of EC in the other two stations which are near the drains and strongly affected by drain effluents are slightly lower and nearly varied and distributed in a similar trend. Station 1 records vary from 4.06 mS/cm to 43.4 mS/cm with a median value equal to 16.7 mS/cm. On the other hand, the records in station 3 vary from 3.73 mS/cm to 54.6 mS/cm with a median value equal to 15.5 mS/cm. On the other hand, the total dissolved solid values have the same trend as the salinities measurements. The highest values are found in station 2 records which impacted by saltwater of the Mediterranean Sea. Fig. 2c shows that there is a big fluctuation in the measurements of the three stations.

As mentioned before by El-Wakeel and Wahby [18], the RTWQ measurements indicated that the water of Lake Manzala is moderately oxygenated and showed no signs of oxygen depletion in the different regions except in station 3 which is strongly affected by Bahr El-Baqar drain effluents as indicated by Elewa et al. [36]. There is a limited regional variation in the measurements as shown in Fig. 2d. Fig. 2e and f shows the statistical analysis of the turbidity and chlorophyll measurements. The results indicated that in station 1, there is a high concentration of chlorophyll affected by agricultural runoff. However, in station 2 there is low chlorophyll and high turbidity due to re-suspension caused by waves because it is impacted by seawater. For station 3, it was found that there is high concentration of chlorophyll and high turbidity due to current or discharge of polluted water of Bahr El-Baqar Drain.

5.2. The seasonal variations of the selected water quality parameters

To define the quantitative impacts of the seasonal change of the air temperature and relative humidity on the catchment area of the lake, the water balance of the lake should be detected. The water balance of any hydrologic system is the relationship between gains and losses. The major inflows and losses from the lake Manzala are drainage inflow, rainfall, evaporation and tidal effect.

It should be emphasized that the drainage inflow to the Lake represents the continuous inflow either by free discharges or by pumping to the lake. The drainage system provided the lake with about 2898 million cubic meters in year 2009–2010 from five main sources (Bahr El-Baqar drain, Hadus drain, El-Serw pump station, Farasqur pump station and Mataria pump station). The monthly inflows of the drainage system to the lake are presented in Table 3. The maximum rate of water discharged to the lake takes place in summer months. Bahr El-Baqar drain discharges the maximum amount, which is about 38% of the total volume while Bahr Hadus drain discharges about 30% of the total volume and Mataria pump station discharges about 20%. The rainfall data recorded at Port Said station indicated that the mean annual rainfall over the area is about 78.35 mm. This precipitation provides the lake with mean annual volume of about 58.76 million cubic meters. Analysis also demonstrates that the most rainfall takes place during winter season (October–March). The area does not receive any rainfall in the summer months. The maximum precipitation is received in December and January. On the other hand, the evaporation measurements at Port Said Airport station have been collected. The monthly values of evaporation have been transformed to volumes of water losses from the lake by considering the surface area of the lake. The annual evaporation losses consume about 1277 million cubic meters. The peak evaporation occurs late in spring and in early

Table 3 Monthly Drainage Inflows to Lake Manzala (August, 2009–July, 2010).

Month	Bahr El-Baqar drain *Q* (MCM/month)	Farasqur pump station *Q* (MCM/month)	Mataria pump station *Q* (MCM/month)	Lower Serw pump station *Q* (MCM/month)	Bahr Hadus drain *Q* (MCM/month)	Total *Q* (MCM/month)
August	101.61	49.29	122.74	0.00	95.33	369
September	89.05	36.41	84.49	17.40	70.86	298
October	102.65	21.58	57.58	12.08	50.15	244
November	102.69	22.30	58.51	22.26	72.75	279
December	103.48	16.16	22.10	0.00	86.27	228
January	99.07	19.83	56.61	0.00	59.13	235
February	93.74	21.67	30.52	0.00	66.05	212
March	103.74	27.25	23.77	0.00	61.78	217
April	79.33	21.87	39.69	0.00	49.42	190
May	76.05	27.10	30.23	0.00	45.08	178
June	71.80	27.37	44.48	0.00	83.05	227
July	84.66	18.51	30.23	0.00	87.81	221
Total	1107.87	309.34	600.95	51.74	827.68	2898

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summer with an average of 5 mm/day [22,40]. The data of agricultural drainage discharges in the Lake indicated that the quantities of drainage water in winter are less than in summer and this may cause the seawater to enter the lake in winter season due to tidal effect.

The collected data of station No. 1 were used to measure the seasonal variation of the water quality parameters. Fig. 3 shows the results of the collected data from 27 July 2009 till 20 May 2010. The data were divided into four categories to measure the seasonal and climatic variations of the selected water quality parameters in Lake Manzala. The measurements of the summer season (from 27 July to 31 October) were divided into two categories including the measurements of the day hours from 4 a.m. to 6 p.m. and the measurements of the night hours from 7 p.m. to 3 a.m. The measurements of the winter season (from 1st November to 20 May) were also divided into two categories including the day hours and night hours.

The seasonal analysis of the station 1 data revealed that the lake water has a slight seasonal variation in the pH values. The pH values fluctuated from 8.36 to 8.68 in the summer season and fluctuated from 8.1 to 8.41 in the winter season. So, it is clear that the pH values in summer season are slightly higher than in winter season and this may be attributed to the photosynthesis activity as mentioned by Elewa et al. [36]. There is no variation between day and night observations in both summer and winter seasons as shown in Fig. 3a.

Fig. 3b shows that the Electrical Conductivity (EC) values in summer season are higher than in winter season. This may be attributed to the increasing flux of high saline water from

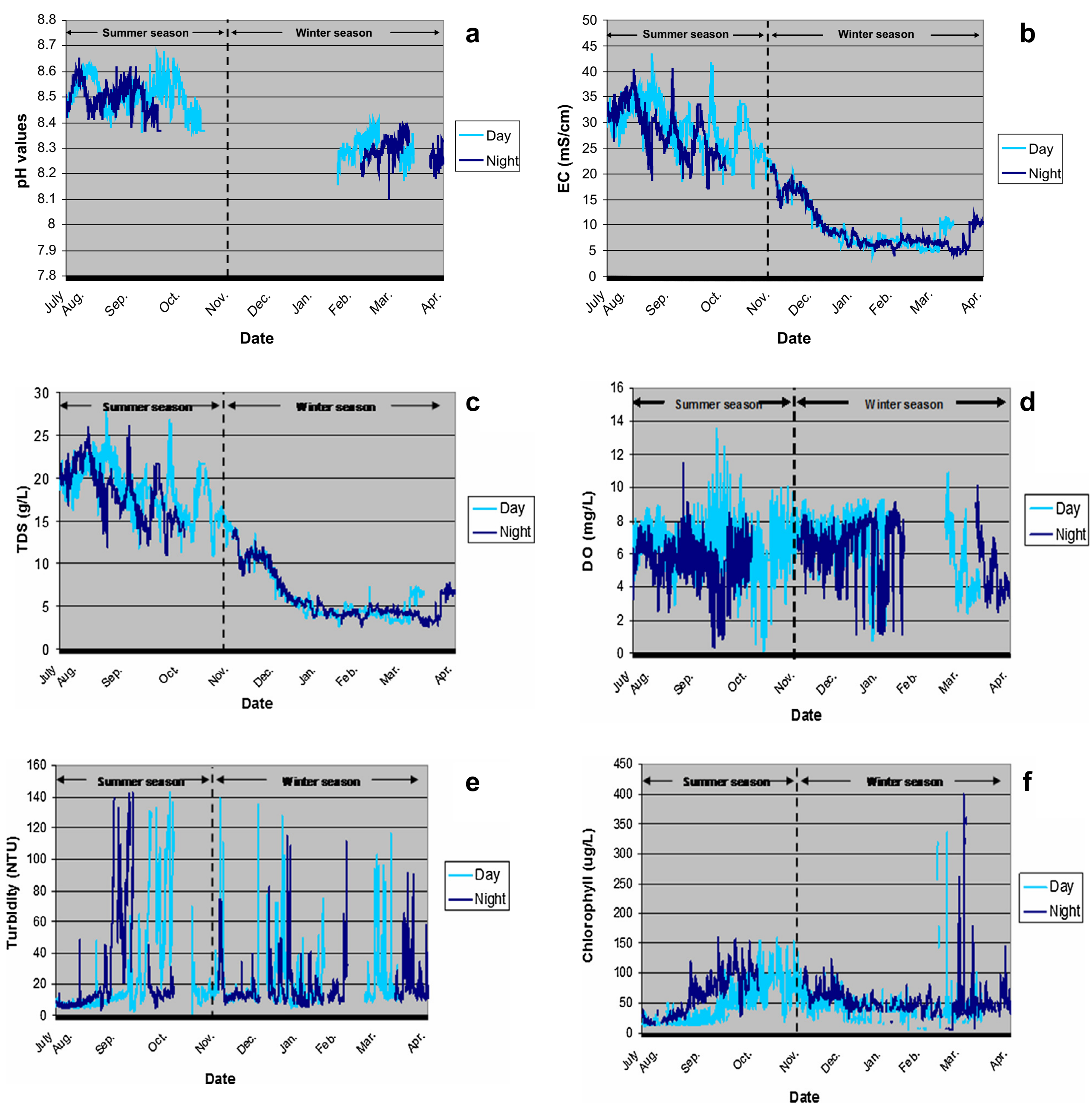

Figure 3 The seasonal variations of the water quality parameters in station No. 1 in Lake Manzala.

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the sea into the lagoon where the salinity in summer is lower in the eastern part of the lagoon close to the entrances of the sea. The influx is caused by the NW wind during summer month (from April to October) that elevating the seawater level about 10 cm at Port Said on top of the tidal wave that equals to about 15–30 cm twice a day. This influx of high saline bottom water is mixed by wind in the lagoon and causes increase in water salinity. Moreover, the EC values of drainage water in summer are higher than in winter. It was also observed that the variations in the water conductivity during day and night hours of the two seasons are relatively limited. On the other hand, Fig. 3c shows that the total dissolved solid values in summer season are higher than in winter season. This is attributed to the fact that the primary sources of TDS in receiving waters are agricultural runoff drainage and the inflow to the lake in summer season is more than in winter season as shown in Table 3.

As mentioned before, the water of Lake Manzala is moderately oxygenated. There is a limited seasonal variation in the measurements as shown in Fig. 3d. It is clear that, the values of DO in winter are higher than in summer and it is also higher during the day hours than in the night hours in the two seasons. The lower values in summer are related to the increasing flow of drainage water with low DO to the lake as shown in

Table 4 DataFit Results of Water Quality Parameters as a Function of Air temperature and Relative Humidity.

Parameters	Curve fitting formula	Standard error	R^2	MPRE
pH	$Y = a\,\text{RH} + b\,T + (c\,Q_b + d\,\text{pH}_b) + (e\,Q_f + f\,\text{pH}_f) + (g\,Q_m + h\,\text{pH}_m) + (i\,Q_s + j\,\text{pH}_s) + (k\,Q_h + l\,\text{pH}_h) + m\,\text{TH}$	0.11	0.86	−0.01
EC	$Y = a\,\text{RH} + b\,T + (c\,Q_b + d\,\text{EC}_b) + (e\,Q_f + f\,\text{EC}_f) + (g\,Q_m + h\,\text{EC}_m) + (i\,Q_s + j\,\text{EC}_s) + (k\,Q_h + l\,\text{EC}_h) + m\,\text{TH}$	3.49	0.89	−7.34
TDS	$Y = a\,\text{RH} + b\,T + (c\,Q_b + d\,\text{TDS}_b) + (e\,Q_f + f\,\text{TDS}_f) + (g\,Q_m + h\,\text{TDS}_m) + (i\,Qs + j\,\text{TDS}_s) + (k\,Q_h + l\,\text{TDS}_h) + m\,\text{TH}$	2.18	0.89	−6.60
DO	$Y = a\,\text{RH} + b\,T + (c\,Q_b + d\,\text{DO}_b) + (e\,Q_f + f\,\text{DO}_f) + (g\,Q_m + h\,\text{DO}_m) + (i\,\text{Qs} + j\,\text{DO}_s) + (k\,Q_h + l\,\text{DO}_h) + m\,\text{TH}$	1.45	0.80	−6.69
Turbidity	$Y = a\,\text{RH} + b\,T + (c\,Q_b + d\,\text{Turbidity}_b) + (e\,Q_f + f\,\text{Turbidity}_f) + (g\,Q_m + h\,\text{Turbidity}_m) + (i\,Q_s + j\,\text{Turbidity}_s) + (k\,Q_h + l\,\text{Turbidity}_h) + m\,\text{TH}$	19.00	0.24	−40.18
Chlorophyll	$Y = a\,\text{RH} + b\,T + (c\,Q_b + d\,\text{Chlorophyll}_b) + (e\,Q_f + f\,\text{Chlorophyll}_f) + (g\,Q_m + h\,\text{Chlorophyll}_m) + (i\,Q_s + j\,\text{Chlorophyll}_s) + (k\,Q_h + l\,\text{Chlorophyll}_h) + m\,\text{TH}$	28.31	0.31	−27.42

In which:
Y value of water quality parameter at Lake Manzala.
RH Relative Humidity (%).
T air temperature in Celsius.
TH Tide Height (m).
Q drainage discharge to the Lake (m^3/s).
Symbol $_b$ Indicated for Bahr El-Baqar drain,
Symbol $_f$ Indicated for Farasqur drain.
Symbol $_m$ Indicated for Mataria drain.
Symbol $_s$ Indicated for Lower Serw drain.
Symbol $_h$ Indicated for Bahr Hadus drain.

Table 5 Regression variable results for the water quality parameters.

Variable	Value					
	pH	EC	TDS	DO	Turbidity	Chlorophyll
a	0.1354418	−0.6824333	0.4951776	−3.8967745	−33.1182041	4.3551157
b	0.0120662	0.3912431	0.2464844	−0.0123427	−1.2056819	0.2389734
c	−0.005695	−0.101227	−0.105267	0.0953	83897755253.6685	128051766417.3260
d	0.227113	−2.730906	−5.821874	−2.9578	−94438380632.4766	−161913793836.7650
e	−0.002084	0.558166	0.571043	−0.1862	112528842065.9600	−122826103539.3790
f	0.853044	−2.921978	2.156014	0.5878	−91429209148.7359	−186952722790.7160
g	−0.006621	0.085656	−0.003229	0.1065	16146990316.0311	61911069549.3874
h	0.347613	−1.015365	2.258945	−0.0343	35104171069.3524	−2585826502540.59
i	0.016741	−0.595924	−0.384642	−0.2518	−113764012681.8710	195678699525.5920
j	−0.024836	−6.343165	−7.620888	1.4644	158403231983.2600	3770096570119.0000
k	−0.013357	−0.084630	−0.055895	0.2562	26888717400.1894	41328104017.2202
l	−0.338071	1.536349	−0.000818	−0.5766	−231657823984.2430	−69584145294.3440
m	1.2425148	64.863265	49.3144561	−1.25164715	2.667814091	−50.4238548

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Table 3. Besides that, the increasing flow of drainage water increases the productivity of floating algae in the lake which consume oxygen and decrease its levels. This agrees with Ali [13] who mentioned that the water of Lake Manzala is well oxygenated during different time intervals except the inlet of Bahr El-Baqar region which suffered from complete depletion of dissolved oxygen around the year especially during hot months as a result of decomposition of organic matter and materials consumed the dissolved oxygen. However, the maximum value of DO (10.2 mg/l) was recorded during December due to decrease of temperature and to the prevailing winds which permit to increase the solubility of atmospheric oxygen. But he only has measured during daytime where the plankton primary production supersaturates the water with DO.

Fig. 3d shows that there is DO depletion during night below 2 mg/l just before dawn. It is an effect of eutrophication because during day the photosynthesis supersaturates the water with DO and after sunset the high concentration of plankton and organic debris respires the DO to low values. Any plans of fish farming under these DO conditions are unlikely to be successful. The values of DO in the summer days vary from 0.12 mg/l to 13.52 mg/l with a median value equal to 6.47 mg/l and in the summer nights vary from 0.32 mg/l to 11.54 mg/l with a median value equal to 5.59 mg/l. On the other hand, the values of DO in the winter days vary from 0.74 mg/l to 10.91 mg/l with a median value equal to 7.23 mg/l and in the winter nights vary from 0.14 mg/l to 10.12 mg/l with a median value equal to 6.4 mg/l. These results are in agreement with Elewa et al. [36] who found that the values of DO fluctuated between 3.0 and 8.4 mg/1 and the highest values were recorded during the cold period (autumn and winter), while the lowest values were observed during the hot period (spring and summer) as a result of temperature elevation. Fishar [37] also noted that dissolved oxygen values were high in winter.

El-Wakeel and Wahby [18] observed that the DO values show wide variation on a spatial basis. The fluctuation is particularly in regions of the lake with water plants. In these regions, the dissolved oxygen values are lowest in the winter months due to the consumption of oxygen due to the fermentation of water plants and reduced sunshine in winter months. In other regions of the lake that are devoid of plants the winter dissolved oxygen values are on an average higher than summer values.

Fig. 3e shows that there is a limited fluctuation in the turbidity measurements in both winter and summer seasons. For chlorophyll measurements there is more fluctuation in measurements in summer season than in winter season. As chlorophyll is produced by the phytoplankton, the amount of chlorophyll in water is usually highest in summer and lowest in winter because it is not easy for plants to grow in winter and as mentioned before the increasing flow of drainage water in summer increases the productivity of floating algae. For that, the chlorophyll values in summer season are slightly higher than in winter season in Lake Manzala. There is some variation between day and night observations in both summer and winter as shown in Fig. 3f. It is clear that the chlorophyll values in night hours are slightly higher than in day hours.

5.3. Data-Fit results

Secondly, Data-Fit software as a science and engineering tool that simplifies the tasks of data plotting, regression analysis (curve fitting) and statistical analysis was used to elaborate

Table 6 Drainage discharge quantity and quality used to measure the accuracy of predicted equations.

Date of in-situ sampling	Bahr El-Baqar drain				Farasqur Pump Station				Mataria Pump Station				Lower Serw Pump Station				Bahr Hadus Drain			
	Q (m^3/s)	EC	pH	DO	Q (m^3/s)	EC	pH	DO	Q (m^3/s)	EC	pH	DO	Q (m^3/s)	EC	pH	DO	Q (m^3/s)	EC	pH	DO
August 2010	84.01	4.4	7.47	1.10	23.21	1.35	7.80	4.30	34.36	2.52	7.76	1.50	00.00	1.77	7.90	1.00	0.53	2.52	7.66	1.70
November 2010	92.90	3.81	7.12	1.25	11.81	1.57	7.71	4.20	19.30	2.30	7.70	1.71	00.00	1.41	7.62	0.80	5.53	3.56	7.80	1.53
February 2011	82.39	3.81	7.29	1.21	9.61	1.57	7.80	4.70	16.83	2.36	7.70	2.06	00.00	1.41	7.70	1.13	22.50	3.55	7.80	1.80
May 2011	78.73	3.30	7.48	1.02	13.15	0.89	7.70	4.40	20.64	1.49	7.64	1.60	00.00	0.81	7.71	0.80	15.23	2.10	7.76	1.70
August 2011	81.35	4.50	7.63	1.32	25.64	1.16	7.48	4.50	33.64	0.32	7.88	1.80	00.00	1.60	8.61	1.00	1.26	1.24	7.56	1.64
November 2011	91.14	3.99	7.56	2.11	11.95	1.65	7.82	3.90	22.20	2.43	7.60	1.80	00.00	1.65	7.56	2.00	21.88	1.63	7.49	4.20
February 2012	71.16	3.61	7.71	1.89	11.19	1.59	7.70	4.80	20.51	1.53	8.01	1.90	00.00	1.08	7.82	1.00	41.03	2.61	7.97	1.70
May 2012	82.53	3.82	7.60	1.41	14.18	1.16	7.81	4.00	22.46	2.40	7.81	2.00	00.00	1.68	7.59	1.60	14.40	2.42	7.84	2.00
November 2012	89.98	3.37	7.85	1.56	6.64	1.66	7.88	4.10	25.02	2.53	7.69	1.90	9.55	1.57	7.86	0.90	12.45	1.66	7.94	1.70
February 2013	66.62	2.97	7.69	1.98	5.68	0.77	7.59	3.90	19.82	2.23	7.86	1.70	7.30	0.99	7.86	1.00	26.25	1.22	7.86	1.70

Table 7 Predicted and measured in-situ water quality.

Date of in-situ sampling	Relative humidity (%)	Air Temperature	Tide Height (m)	Avg. Actual EC	Predicted EC	Avg. Actual pH	Predicted pH	Avg. Actual DO	Predicted DO
August 2010	78	29	0.55	28.17	27.96	8.29	8.64	5.11	3.10
November 2010	74.6	23	0.52	14.6	17.29	8.21	8.31	5.26	5.29
February 2011	72	16.5	0.35	8.8	4.35	8.43	7.99	7.37	9.90
May 2011	73	22	0.39	14.88	18.22	8.43	8.14	5.01	7.26
August 2011	74	28	0.55	26.48	27.59	8.56	8.45	2.73	2.17
November 2011	70	19	0.52	9.2	12.03	8.35	8.30	6.17	7.31
February 2012	75	14	0.35	5.35	6.1	7.46	7.81	15.7	11.51
May 2012	73.96	22.6	0.39	21.33	19	8.4	8.28	8.33	6.96
November 2012	75	22	0.52	7.93	7.79	8.4	8.61	5.81	5.01
February 2013	74	16.5	0.35	8.48	3.17	8.07	8.08	4.37	5.63

simple formulae that can help in predicting the water quality parameters of Lake Manzala including pH, DO, EC, TDS, Turbidity, and Chlorophyll as a function of air temperature, relative humidity and tide height at port said as co-varying with wind speed and direction in addition to drainage discharge quantities and qualities as the main factors that affect the water quality parameters of the Lake. The fitting curve process was carried out using the collected data of station No. 1 and the measured data of the drainage water quantity and quality that was taken by Drainage Research Institute in the same period from July 2009 till May 2010. The regression models (formulae) were developed for each water quality parameter, and then sorted according to the goodness of fit criteria (Residual Sum of Squares and Mean Percentage Relative Error). In all cases, the formula that has higher coefficient of determination (R^2) and less Mean Percentage Relative Error (MPRE) was selected as a best fitted formula. The Mean Percentage Relative Error was calculated as follows:

$$\text{MPRE} = \sum\{[(\text{Model result} - \text{Field measurement})/\text{Field measurement}] \times 100\}/\text{Number of results}$$

Tables 4 and 5 show the statistical results and the regression variables of Data-Fit. The values of R^2 of the curve fitting formulae for pH, EC, TDS, DO, turbidity and chlorophyll are 0.86, 0.89, 0.89, 0.80, 0.24 and 0.31 respectively. On the other hand, the values of MPRE of the curve fitting formulae for pH, EC, TDS, DO, turbidity and chlorophyll are 0.01%, 7.34%, 6.6%, 6.69%, 40.18% and 27.42% respectively. The high values of R^2 and low values of MPRE for pH, EC, TDS and DO indicate significant correlation coefficients. Thus, these formulae proved to perform well in predicting these water quality parameters in relation to the air temperature and relative humidity. Moreover, the low values of R^2 and high values of MPRE for turbidity and chlorophyll mean that there is no empirical relation between air temperature and relative humidity and these two parameters.

The predicted formulae were tested using the in-situ measurement data of water quality of Lake Manzala that was carried out monthly by the Egyptian Environmental Affairs Agency (EEAA) through ten stations which covered the whole area of the lake from August 2010 to February 2013. The developed equations were used to predict the pH, EC and DO parameters using the measured data of drainage water quantity and quality that discharge into Lake Manzala as shown in Table 6 and the air temperature and relative humidity of the Port Said Airport weather station. The predicted data and the actual in-situ measurements as an average for the ten stations were compared together as shown in Table 7.

The percentage of the errors between the actual measured water quality data (AWQ) and the predicted water quality (PWQ) was carried out to check the accuracy of the predicted equations as follows:

$$\text{Diff} = \text{PWQ} - \text{AWQ}$$

$$\text{Error\%} = \left(\frac{\sqrt{\sum(\text{Diff.})^2}}{n}\right)/\text{avg.AWQ}$$

It was found that, the error percentage for pH values is equal to 0.94%. On the other hand for EC values, it was equal to 6% and for DO it was equal to 9%. The error percentages for the different parameters are less than 10% which could be considered as minor error and the predicted equations could be accepted as empirical relation between air temperature and humidity and water quality parameters

6. Conclusions

Lake Manzala is the largest and the most productive lake of the northern Egyptian coastal lakes. Due to the special sensitive environments of the lake, the water circulation and consequently the water quality of the lake are affected by climatic variables. Therefore, it was important to measure the regional and seasonal variations of some selected water quality parameters of the Lake in relation to the change of two climatic variables which are air temperature and relative humidity during the day and night of the summer and winter seasons using the continuous measurements data of the Real Time Water Quality monitoring stations in the Lake. The collected data were used to elaborate an empirical relation between air temperature and relative humidity and pH, DO, EC, TDS, Turbidity, and Chlorophyll.

For the regional variations, the recorded measurements clear that the lake is, in general, brackish. The Lake has high salinities in the northern region of the Lake which is impacted by saltwater. The salinities are slightly lower in the other regions which are strongly affected by drain effluents. The total dissolved solid values have the same trend as the salinities measurements. It was found that the pH values in the lake are alkaline and have a slight regional variation. The pH values near the drains are lower than the other areas of the lake. In the regions that affected by drain effluents there is high concentration of chlorophyll and high turbidity while in the other regions which are impacted by seawater there is also high turbidity but low chlorophyll. It was clear that there is a slight seasonal variation in the pH values. The salinities values in the summer season are higher than in the winter season. It was also observed that the variations in the water salinities during day and night hours of the two seasons are relatively limited. The total dissolved salt values have the same trend as the salinities measurements. The values of DO in winter are higher than in summer and it is also higher during the day hours than the night hours in the two seasons. There is DO depletion during night as an effect of eutrophication so any plans of fish farming under these DO conditions are unlikely to be successful. There is a limited fluctuation in the turbidity measurements in both winter and summer seasons. For chlorophyll measurements there is more fluctuation in measurements in summer season than in winter season.

The statistical results of Data-Fit showed that the values of R^2 of the curve fitting formulae for pH, EC, TDS, DO, turbidity and chlorophyll are 0.86, 0.89, 0.89, 0.80, 0.24 and 0.31 respectively. The low values of R^2 for turbidity and chlorophyll mean that there is no empirical relation between air temperature and relative humidity and these two parameters. The percentage of the errors between the actual measured water quality data (AWQ) and the predicted water quality (PWQ) were equal to 0.94%, 6% and 9% for pH, EC and DO respectively which could be considered as minor error and the predicted equations could be accepted.

References

[1] UNDP. Human development report. Report of United Nations Development Program; 2006. <http://hdr.undp.org/en/>; (04/01/2013).

[2] GEF, GEF Country Portfolio Evaluation: Egypt (1991–2008). Report of global environment facility evaluation office No. 51. Editing and design: Nita congress, Global Environment Facility Evaluation Office, 1818 H Street, NW, Washington, DC 20433 USA; 2009. 163 p. Internet: <www.gefeo.org>; DC 20433.

[3] El-Sammak AA, El-Sabrouti MA. Organic carbon distribution and preservation in sediments of Lake Burullus, S.E. Mediterranean, Egypt. Fresenius Environ Bull 1995;4:457–62.

[4] Thompson JR, Flower RJ, Ramdani M, Ayache F, Ahmed MH, Rasmussen EK, Petersen OS. Hydrological characteristics of three North African coastal lagoons: insights from the MELMARINA project. J Hydrobiol 2009;622(1):45–84. http://dx.doi.org/10.1007/s10750-008-9680-x.

[5] Abdel-Gawad ST, El-Sayed A. An approach to identify the pollution field in Lake Manzala. In: Conf on coping with water scarcity, Hurghada, Egypt, 28 August; 1998. p. 1–10.

[6] Mageed Adel Ali A. Distribution and long-term historical changes of zooplankton assemblages in Lake Manzala (south Mediterranean Sea, Egypt). Egypt J Aquat Res 2007;33(1):183–92.

[7] UNDA, project document Lake Manzala engineered wetland prepared for: United Nations Development Agency. One United Nations Plaza, New York, United States 10017. Prepared by: Tennessee Valley Authority 400 W. Summit Hill Drive: United Nations Development Agency; 1997. 185 p.

[8] Abdel Ghaffer E. Impact of climate change on the hydrology of Lake Manzala. In: First inter conf on environmental change of Lakes, Lagoons and Wetlands of the Southern Mediterranean Region, 3–7 January, 06, Cairo, Egypt. ECOLLAW; 2006. p. 12–29.

[9] Akram Mohamed ElGanzori. Satellite monitoring of water quality in Lake Manzalah, Egypt. In: Proceeding of TIGER workshop, Cape Town, South Africa; November 20–21 2006. p. 60–75.

[10] Farag HA. Using earth observation (EO) technique for monitoring water quality in Lake Burullus. Nile Basin Water Sci Eng J 2011;4(2):37–46.

[11] Khan H, Abdel-Gawad S, Dawe P, Khan AA. Environmental security and water resources management system using real time water quality warning and communication. In: Conference of water observation and information system for Balkan Countries (BALWOIS), Ohrid, Republic of Macedonia; 25–29 May, 2010. <http://balwois.com/balwois/info_sys/publication2010.php> paper 573.

[12] Frihy O, Dewidar K, Nasr S, El Raey M. Change detection of the northern Nile delta of Egypt: shoreline changes, spit evolution, margin changes of Manzala lagoon and its islands. Int J Remote Sens 1998;19:1901–12.

[13] Ali Mohamed HH. Assessment of some water quality characteristics and determination of some heavy metals in Lake Manzala, Egypt. Egypt J Aquat Biol Fish 2008;12(2):133–54.

[14] Elewa AA, Saad EA, Shehata MB, Ghallab MH. Studies on the effect of drain effluents on the water quality of Lake Manzala, Egypt. J Aquat Biol Fish 2007;11(2):65–78.

[15] Dowidar NM, Abdel-Moati AR. Distribution of nutrient salts in Lake Manzalah (Egypt). Rapp Comm Int Mer Medit 1983;28(6):185–8.

[16] Ahmed Mahmoud H, Donia Noha, Fahmy Mamdouh A. Eutrophication assessment of Lake Manzala, Egypt using geographical information systems (GIS) techniques. J Hydroinform 2006;8(2):101–9, IWA publication 2006. Available at: http://www.iwaponline.com/jh/008/jh0080101.htm.

[17] Ahmed MH, El Leithy BM, Thompson JR, Flower RJ, Ramdani M, Ayache F, Hassan SM. Application of remote sensing to site characterization and environmental change analysis of North African coastal lagoons. Hydrobiologia 2009;622:147–71.

[18] El-Wakeel SK, Wahby SD. Hydrography and chemistry of Lake Manzalah, Egypt. Arch Hydrobiol 1970;67(2):173–200.

[19] Flower RJ, Appleby PG, Thompson JR, Ahmed MH, Ramdani M, Chouba L, Rose N, Rochester R, Ayache F, Kraiem MM. Sediment distribution and accumulation in lagoons of the Southern Mediterranean Region (the MELMARINA Project) with special reference to environmental change and aquatic ecosystems. J Hydrobiol 2009;622(1):85–112.

[20] Barakat Assem O, Mostafa Alaa, Wade Terry L, Sweet Stephen T, El Sayed Nadia B. Assessment of persistent organochlorine pollutants in sediments from Lake Manzala, Egypt. Mar Pollut Bull 2012;64(8):1713–20.

[21] El-Shabrawy Gamal M, Germoush Mousa OA. Seasonal changes and abundance of rotifers in a shallow Manzalah lake (Egypt). J Ecohydrol Hydrobiol 2014;14(3):243–52.

[22] Kock Rasmussen E, Svenstrup Petersen O, Thompson JR, Flower RJ, Ahmed MH. Hydrodynamic-ecological model analyses of the water quality of Lake Manzala (Nile Delta, Northern Egypt). J Hydrobiol 2009;622(1):195–220.

[23] United States Geological Survey (USGS). The nationwide strategy for improving water quality monitoring in the United States. Intergovernmental task force on monitoring water quality, Washington, D.C.; 1995.

[24] Wagner RJ, Boulger Jr RW, Oblinger CJ, Smith BA. Guidelines and standard procedures for continuous water-quality monitors—station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; 2006. Available at <http://pubs.water.usgs.gov/tm1>; (accessed April 10, 2006).

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[25] APHA. Standard methods of the examination of water and wastewater. New York: American Public Health Association Publishing; 1995, 1193 p.
[26] Campbell G, Wildberger S. The monitor's handbook. Chestertown, MD: LaMotte Company; 1992, p. 30–2, 36–9.
[27] DRI. Real-time water quality monitoring along the Nile River. Technical report of project of an environmental security and water resources management system using real-time water quality warning. El Kanater, Egypt: Drainage Research Institute; 2010. 96 pp.
[28] EPA. Guidance manual for compliance with the interim enhanced surface water treatment rule. United States, Environmental Protection Agency, Office of Water (4607) publishing, EPA-815-R-99-010; April 1999. 201p.
[29] Phocaides A. Water quality for irrigation, "in Technical Handbook on Pressurized Irrigation Techniques". Ch. 7. Rome: FAO; 2000. p. 79–97.
[30] Horne AJ, Goldman CR. Limnology. 2nd ed. McGraw-Hill, Inc.; 1994, 576 p.
[31] Habash A, El-Sadek A, Shaban M, Using real-time telemetry system for assessing water quality and improving routine monitoring. In: Proceeding of the 10th Gulf water conference, Doha – Qatar; 22–24 April 2012. p. 369–82.
[32] <http://www.wunderground.com/weather-forecast/EG/Port_Said_Airport.html>.
[33] Friedman Jerome H, Stuetzle Werner. John W. Tukey's work on interactive graphics. The annals of statistics, vol. 30, no. 6. Institute of Mathematical Statistics; 2002. p. 1629–39.
[34] Shaban M, Elsayed EA. Regression based modeling and numerical simulations for the assessment of water management practices for El-Salam Canal Project, Egypt. Nile Basin Water Sci Eng J 2012;5(1):1–13.
[35] Fathi AA, Abdelzahar HMA. Limnological studies on the wetland Lake El-Manzala, Egypt. Bull Fac Sci Assiut Univ 2003;32(2-D):215–33.
[36] Elewa Abdel-Samei A, Saad Ebtisam A, Shehata Mohamed B, Ghallab Mohamed H. Studies on the effect of drain effluents on the water quality of Lake Manzala, Egypt. Egypt J Aquat Biol Fish 2007;11(2):65–78.
[37] Fishar MRA. Distribution and abundance of benthic assemblages in El-Gamil basin (Lake Manzalah, Egypt). Bull Natl Inst Oceanogr Fish (Egypt) 1999;25:151–66.
[38] Khalil MT, Bayoumi AR. Fishery assessment survey of Lake Manzala, Egypt. Bull Nat Inst Oceanogr Fish ARE 1988;14(3):139–54.
[39] Abdel-Satar AM. Environmental studies on the impact of the drains effluent upon the southern sector of Lake Manzala, Egypt. Egypt J Aquat Biol Fish 2001;5(3):17–30.
[40] Abdallah AS. Water body change detection using remote sensing applications in Coastal Lagoons of North Africa (a case study of Lake Manzala in Egypt). MSc thesis. Japan: Graduate School of Tottori University; 2010. p. 106.

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