Water Quality Management in Manzala Lake, Egypt

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ABSTRACT

Lake Manzala, the largest of the northern Delta lakes of Egypt, has a great economic importance as a major natural resource of fish and salt. Unfortunately, the lake is suffering from the high inputs of pollutants from industrial, domestic, and agricultural sources. The present study aims to develop the proposed water quality management scenarios to assess and control lake pollution, the pollution sources as well as the pollution spread from the lake to the connected Mediterranean Sea. To apply study methodology, the work tasks divided into two main parts, the first part involved in modelling the lake environments by using Delft3D-WAQ hydrodynamic and water quality model to study the current status and predict the dynamic state of the Lake. This model was calibrated and validated by using various water quality datasets to simulate different scenarios. In the second part, the required lake water quality improvement scenarios were developed to solve the lake water quality problems.

The study results showed that the first three developed scenarios that focusing on treatment drain effluent using primary, secondary treatment and surface wetland techniques respectively have a limited efficiency on lake water quality improvement. While the fourth scenario that involved on using biological biofilm techniques can improve lake water quality parameters. Moreover, the fifth scenario that proposed adding a new artificial inlet has a limitation due to the noted increases in lake salinity levels. The sixth scenario that proposed a diversion of some drains can improve lake water quality parameters but it can lead to a decrease in Lake water level. From water quality view point, the last scenario that applying a combination biological biofilm activated technique and also adding a new artificial inlet at northern lake region can represent the optimum scenario. Hopefully, this research will preserve the lake environment and contribute to the benefit of the man health as well. This approach could be extended to the hydrodynamic studies in similar large, shallow lakes anywhere in the world.

Keyword: Manzala Lake, Pollution, Water Quality, Hydrodynamic Model, Delft3D-WAQ.

1. Introduction

Manzala Lake lies within the borders of five Egyptian governorates Damietta, Port Said, Ismailia Sharkiya and Dakahliya. The lake annual fish production represents about half of the total fish yield of the northern Delta lakes and about one fifth the (non-marine) fish yield of Egypt. Lake Manzala suffered from a high level of eutrophication, due to the heavy load of nutrients, especially phosphorus and nitrogen compounds due to agricultural runoff, sewage and drains discharges (Saeed and Shaker, 2008).

Delft3D (developed by Delft Hydraulics), provides a sophisticated, 3-dimensional modelling system, is capable of providing three-dimensional flow, surface waves, water quality, ecology, sediment transport and bottom morphology in complicated, coastal areas.

2. Study area

Manzala Lake is located between longitudes 31° 45′ and 32° 22′ E and latitudes 31° 00′ and 31° 35′ N. The lake is bordered by Mediterranean Sea to the North and the North-East, Suez Canal to the East, Dakahlia and Sharkia Provinces to the South and Damietta Branch of the Nile to the West (Hossen et al., 2016). The northern boundary of the lake is the Mediterranean Sea (there are some narrow outlets; the main outlets are El-Gamil outlet and the New El-Gamil Outlet). The lake is also connected to the Suez Canal at El-Qabouti Canal; a few kilometers to the South of Port Said. Enanya Canal connected the lake western boundary to the Nile Damietta Branch, (Sallam and Elsayed, 2015). The Lake received untreated industrial, domestic and agricultural drainage water that discharged to the lake through six main drains (Bahr El Bakar Drain, Ramsis Drain, Hadous Drain, Matariya Drain, El-Serw Drain, and Faraskur Drain).

3. Materials and Methods

3.1 Data Requirements

Surface water samples were collected from (12) sampling locations of Manzala Lake. The analyses of water samples were carried on various water quality parameters according to the standard methods for the examination of water and wastewater (APHA, 2012) during three consequence years (2015, 2016, and 2017) to show the effect of the spatial and temporal variation. Figure (1) illustrates the selected sampling stations for Manzala Lake.

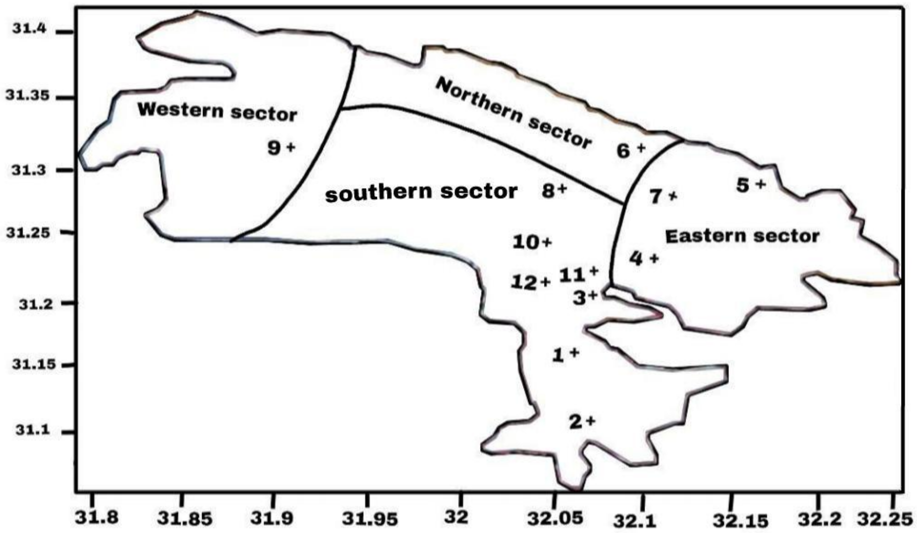


Figure (1) Selected sampling stations of Manzala Lake

3.2 Methods

The methods consisted of three main parts as follows:-

1) Assessment of water quality data
2) Model build
3) Model calibration and statistical analysis
4) Model run
5) Model validations and statistical analysis
6) Develop water quality management scenarios

4. Modeling Framework

Delft3D mathematical model can acquire different numerous hydrodynamics and Morphology lake features which cannot be observed in the field. The flow module and the WAQ module of Delft3D were used for water quality simulation. The main flow equations that be solved by Delft3D model are Continuity equation, Momentum equation and Navier- Stokes equation.

4. Results and Discussion

4.1 Model Calibration and Statistical Analysis

The water quality model calibration was done by using 2015 data set in order to satisfy the target accuracy and stability for the simulated lake water quality variables. The model was spatially calibrated against measured salinity because it is considered a conservative material and it is an excellent water mass tracer. The data sets used for calibration are from a comprehensive field sampling campaign conducted in Manzala Lake during January and July 2015. Figure (2a) illustrates the lake simulated salinity during January 2015, while Figures (2b) show the model the simulated with respect to the observed lake salinity during January 2015.

Figure (2a) Simulated salinity during January 2015

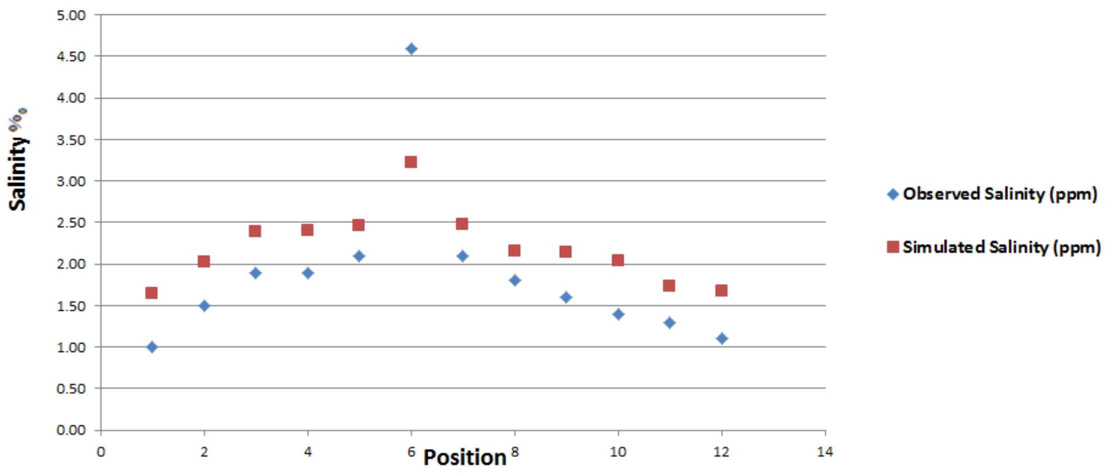


Figure (2b) Observed and simulated salinity during January 2015

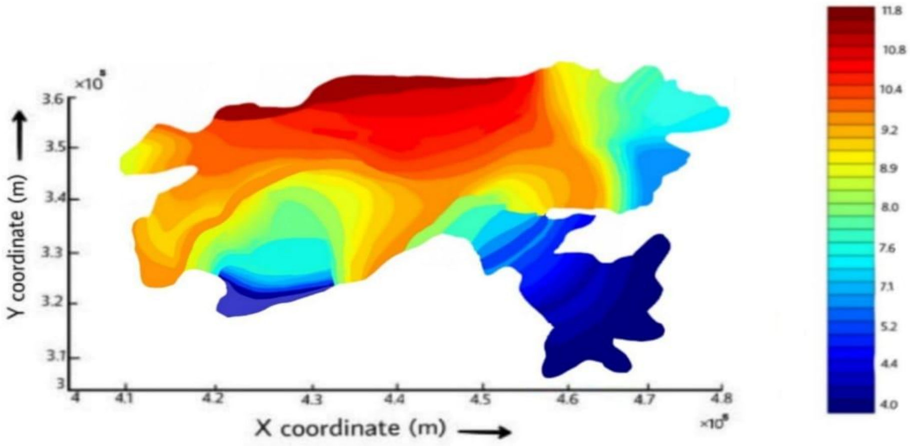
Various statistical measures such as the relative means absolute error and correlation coefficient of determination (R^2) were used for error estimation and to satisfy the calibration accuracy of the model. The errors between observed and simulated data were calculated with the help of these statistical measures**.** The mean absolute error value is very small (0.3) and tends to be equal its optimal statistics value (Zero) for various simulated results. The model accuracy is further confirmed from high values (0.91) of R^2 at the calibration points, so it is obvious that there is an excellent match of observed and modeled results at different sites of the study area.

4.2 Model Run

After calibration of Delft3D mathematical model, the model was successfully executed. The data set used for this model run is water quality data for year 2016.

4.2.1 Modeling of Dissolved Oxygen

A figure (3) illustrates the simulated DO results during January 2016**.**



Figures (3) Simulated DO Spatial Distribution

It can be noted from figure (3) that the DO level in south region of the lake was less than 5.0 mg/l, The DO level in the river reach decreased to lowest levels due to intervention of the different pollution sources in this lake region; however oxygen situation in this lake region is alarming.

4.3 Model Validation and Statistical Analysis

4.3.1 Modeling of BOD

The model was validated by using 2017data set. Figure (4) shows the spatial distribution of BOD during January 2017.

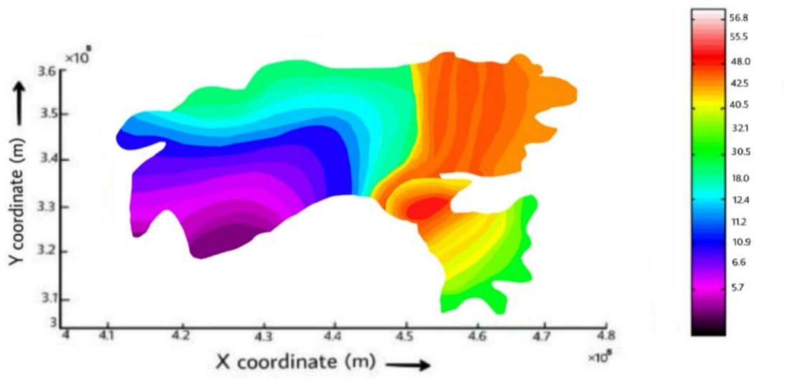


Figure (4) Simulated BOD distribution in Manzala Lake

In different lake sites, the most BOD concentrations were high compared to the adopted limits in Egyptian Governmental Law No. 48/1982 (BOD ≤10.00 mg/l). The high BOD values in the eastern sites of Manzala Lake may suggest an anaerobic decomposition of ammonia and organic materials in industrial and municipal effluents and production of organic material in the lake.

4.4 Management Scenarios

Seven different water quality management scenarios have been simulated to test the lake under different hydrodynamic modes. 3D simulations were done for each scenario to study the water quality pattern in the study area.

Morphological modeling of restoration scenarios was evaluated with a process-based numerical hydrodynamic and morphologic model, Delft3D. The model solves the equations of motion, conservation of water, and conservation of sediment at each time step, which results in a prediction of coastal hydrodynamics and sediment transport (Lesser et al. 2004). Table (1) shows the outlines of the proposed management scenarios to improve Manzala lake water quality.

Table (1) Water Quality Management Scenarios Description

Scenario	Description
Base Condition	Pre-simulated model with 2016 water quality dataset
Scenario (1)	Primary treatment of six polluted drains
Scenario (2)	Secondary treatment of the mentioned polluted drains
Scenario (3)	Using surface flow wetland
Scenario (4)	Biological biofilm activated with aerator
Scenario (5)	Adding a new artificial inlet
Scenario (6)	Diversion of some polluted drains
Scenario (7)	A combination of scenario (4) and scenario (5)

Figure (5), (6), (7), and (8) illustrates the comparison between the seven scenarios with Respect to their effect on the previous selected lake parameters: DO, BOD, NH4, and PO4 concentration respectively.

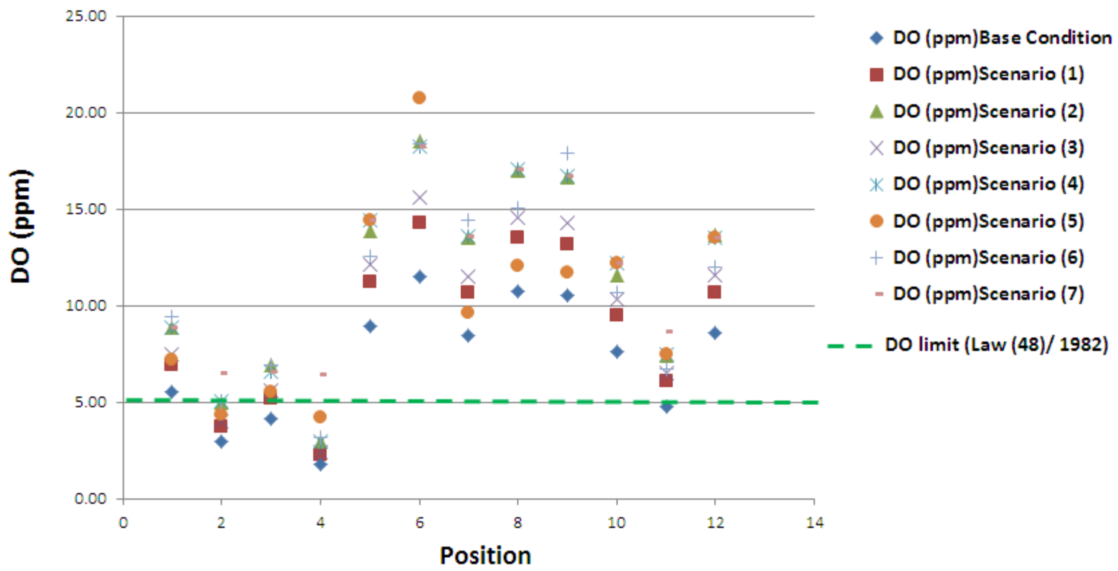


Figure (5) DO Scenarios Comparisons

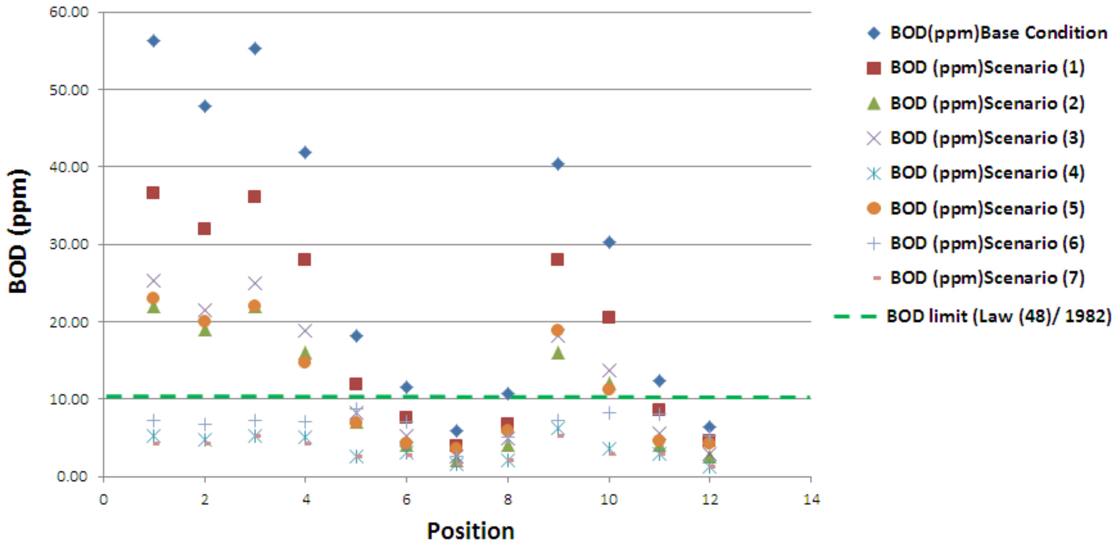


Figure (6) BOD Scenarios Comparison

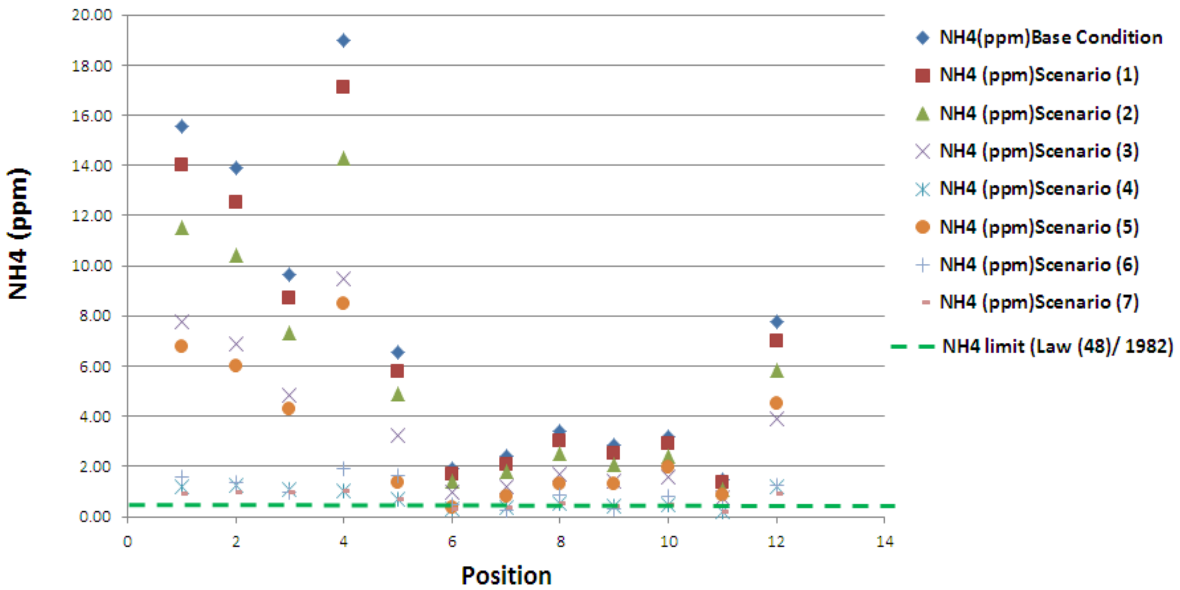


Figure (7) NH_4 Scenarios Comparison

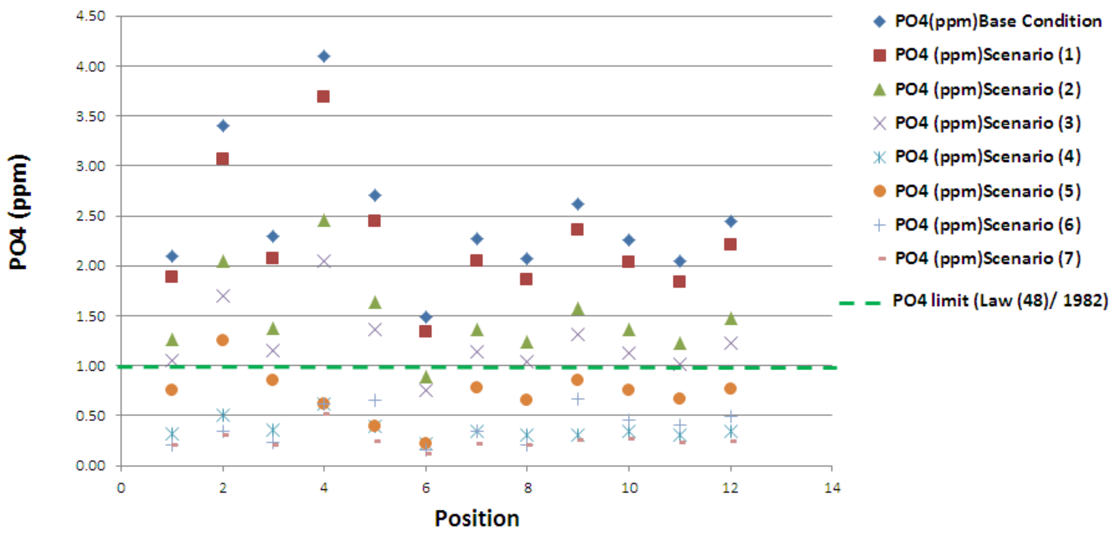


Figure (8) PO_4 Scenarios Comparison

it can be noted that from Figures (5), (6), (7), and (8):-

- In the first scenario, an increasing in the DO values from 24% to 27%. However, most of sampling DO results satisfy the permissible limits of the Egyptian national guidelines (law 48/1982) except for the two samples no (2) and no(4) at south and east region respectively can't satisfy the limits but this scenarios can't satisfy the mentioned required limit for BOD, NH_4, and PO_4 concentration.

- By applying secondary treatment scenario, an increasing in the DO values from 48% to 70% that satisfy the permissible limits of the Egyptian national guidelines (law 48/1982) at all location except for sample no(4) at eastern region but this scenario also can't satisfy the mentioned required limit for BOD, NH_4, and PO_4 concentrations.

- Surface flow wetland treatment scenario can realize an increasing in the DO values from 34% to 36% but this increasing not satisfies the permissible limits of the Egyptian national guidelines (law 48/1982) but the final BOD, NH_4, and PO_4 concentrations still exceed the allowable mentioned limits

- Applying biological biofilm scenario can satisfy the permissible limits of the Egyptian national guidelines (law 48/1982) except for the sample location no (4) at lake eastern region. This scenario can solve the current BOD concentration exceedance and satisfy the required limit. Except for some locations in south and east lake regions, applying Biological biofilm technique can satisfy the allowable NH_4 concentration limits. Moreover, this scenario can also solve the lake phosphate concentration problem with a relatively slight exceedance at some south and east lake regions.
- It is obviously that adding a new artificial inlet can improve the lake water parameters but not satisfy the permissible limits but this scenario can increase lake salinity concentration

- The sixth scenario involves in diverting some drains from discharging into the lake to the west branch of the Nile in order to control lake pollution and at the same time address the problem of sediment accumulation at the Rosetta mouth of the Nile can relatively satisfy the allowable DO, BOD, NH_4 and PO_4 concentration limits in most lake's regions.

- In the seventh scenario, with a proposed combination of both using biological biofilm activated scenario and adding a new artificial inlet scenario, an obvious improvement in the lake water quality and complying with the target limits is noted.

6. Conclusions

In this study an assessment for Lake Manzala and its drainage system were carried out and proposed scenarios to solve the contaminated drains problems, the results of this work lead to these conclusions :-

- Lake Manzala receives water from six drains and can't meet the required Egyptian standard limit for law 48 so the influent drains considered as the main source in the Lake pollution.

- The southern and eastern regions of the lake are more contaminated than the northern and western regions. However many scenarios have been conducted to improve the water quality in the lake and to assess the spreading and mixing of the drains discharge effluents and its impact on the lake.

- According to the proposed water quality management results, the first three proposed scenarios that based on applying primary treatment, secondary treatment and surface flow wetland respectively for treatment study area drains have a relatively limited effect on water quality improvement. However, with applying these scenarios, a noted residual exceedance in final water parameters concentrations compared with the target Egyptian national guidelines (law 48/1982).

-By applying the fourth scenario that involved on using biological biofilm techniques, an improve lake water quality parameters which made the DO, BOD, NH_4 and PO_4 satisfy the required limits in most lake various locations. Moreover, the fifth scenario that proposed adding a new artificial inlet has a limitation due to the noted increases in lake salinity levels.

-The sixth scenario that proposed a diversion of some drains has a reasonably effect on lake water quality parameters improvement but it can lead to a decrease lake water level.

The last scenario that applying a combination biological biofilm activated technique and also adding a new artificial inlet at northern lake region can satisfy the mentioned Egyptian national guidelines (law 48/1982) standard limits. However this scenario has a high efficiency to solve the lake water quality problems.

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9. Conflict of Interest: The authors declare that they have no conflict of interest.

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