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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

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