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Water quality management of lake Temsah, Egypt using geographical information system (GIS)

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ABSTRACT
The present work is designated to water quality management of lake Temsah through the development of a Geographical Information System (GIS) for the lake. Different Water quality indices were calculated depending on the use of the lake water. The areas suitable for each use were identified on spatial thematic maps within the developed GIS system. The results indicated that the middle area of Lake Temsah is good water quality and suitable for all uses. The (good) water quality for swimming is located in the eastern southern part areas whereas the (bad) quality for the same activity is in the western lagoon and the northern area. The (good) quality for fishing is in the eastern southern part of the lake whereas the (very bad) quality for fishing exists near the eastern part and in the middle of canal area. This water quality classification is designed to assist policy makers to take the suitable measures to restore the lake ecosystem.

1. INTRODUCTION
Contamination of surface water has become a major challenge to environmentalist in the rapid developing countries. By mapping water quality using the decision support system like GIS, it can be useful for taking quick decision based on graphical representation (Marble, 1987; Walsh, 1987). A water quality index provides a single number (like a grade) that expresses overall water quality at a certain location and time based on several water quality parameters. The objective of an index is to turn complex water quality data into information that is understandable and useable by the public. The indices are among the most effective ways that provides the information on water quality trends to the public or to the policy makers and water quality management. It is also defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water. The water quality index (WQI) is considered as one of the simplest methods used in assessing the overall water quality. It is defined as rating reflecting the composite effects of a number of parameters on the overall water quality. The WQI allows the reduction of vast amounts of data obtained from a range of physico-chemical and biological parameters to a single number in a simple reproducible manner. In fact WQI has been used for the assessment of water quality of many water bodies around the world (El-Sherbini. and El-Moattassem, 1994;

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Demuynck *et al.*, 1997; Mohanta, 2000; Bordalo, 2006; Abrahão, 2007; Dwivedi, 2007; Kannel, 2007; Simoes, 2008; Ramakrishnaiah, 2009; Abdul Hameed, 2010 and Sankar, 2011).

Mapping water quality indices within GIS framework will be a useful tool for water quality management of the lake Temsah. Lake Temsah lies between 30°33` and 30° 35`N Latitude and 32° 16` and 32° 19`E Longitude in Egypt (Figure 1).

The region can be distinctly divided into three basins; Lake Temsah, the western lagoon, and the Suez canal pathway. Lake Temsah has a nearly triangular shape with elongated sides extending roughly East-West. The lake is small and shallow. It has a surface area of about 8 square kilometers with an average depth of only 10 meters and containing about 90 million cubic meters of water. The Suez canal pathway is deep, about 23 m depth, but narrows about 200 m wide. Small islands, which partially separate the waterway from Lake Temsah, restrict water circulation and mixing forming two different water quality conditions. The western lagoon is the smallest and the shallowest of the three basins and partially covered with several kinds of vegetation growing in groups. Frequently, Lake Temsah has salinity stratification where it receives brackish water from the western lagoon overtopping its highly saline water. In Ismailia along the shores of lake Temsah, tourism is rapidly developing into one of the major industries in the region. In addition, fishing activities in lake Temsah provides a significant source of food and income generation of local population.

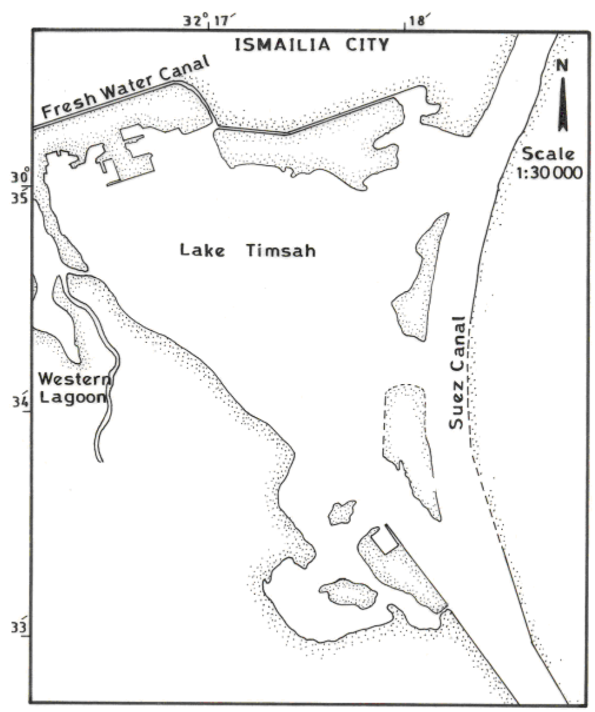


Fig. 1: Map of study area showing temsah lake

Unfortunately however, the lake waters receive a great deal of untreated domestic and industrial waste discharges and agricultural drainage return flows. The discharge of wastes adds a large range of products, nutrients, heavy metals, toxic organic, and others which are toxic to both aquatic biota and humans. Consequently, the lake and its beaches exhibit serious water quality problems in many locations. The water quality problems were reported to affect the people living around the lake and the health of the inhabitants in the area. In addition, the massive amounts of sediment loads, which enter the lake, produce higher accretion rates and seriously interfere with lake transport. Many researches were conducted to investigate the water quality of temsah lake (AWRC, 1994), (SLTDS, 1994), (ETPS, 1996) and (Donia, 2005). The results indicated that lake Temsah is currently suffering from increasing pollution levels which are essentially caused by untreated domestic and industrial wastewater in addition to contaminated drainage water. Previous studies reflected the fact that the deterioration of the lake has extended to a serious level where urgent action is required immediately to restore the lake ecosystem.

Since lake water quality is affected by a variety of natural and anthropogenic factors and as the data are very diverse, the spatial analysis of these data and other factors is a time consuming and complicated task when performed manually. The computer based geographic information system will facilitate the analysis of all various types of data. Since GIS are capable of combining large volumes of data from a variety of sources, they are useful tool for many aspects of water quality investigation. Therefore, the main objective of the research is to manage the water quality of the lake through calculating several water quality indices of the lake for several uses within a GIS based framework. This will help the decision makers to identify the spatial extent and causes of water quality problems, such as the effects of land-use practices on the water body of the lake.

2. METHODOLOGY

2.1 Field Measurements

Recently, a monitoring program was established. Water samples were collected monthly from 12 stations covering different areas around the lake. Samples (3, 4 and 9) from Suez canal pathway, samples (1 and 11) near the industrial workshops for shipyards. Samples (2 and 10) from the recreational beaches along the lake shore, sample 5 from the middle of the lake as reference of the lake, samples (8 and 12) near the agricultural and domestic wastewater discharge, samples (6 and 7) near the domestic outfall areas. The GIS database includes the water quality analysis for the 12 points along Temsah lake and the collected samples were analyzed according to (APHA, 2005). Twelve physico-chemical parameters namely pH, Conductivity, Turbidity, Total hardness, Mg hardness, Ca, hardness, Total Dissolved Solids (TDS), Chlorides, Alkalinity, Sulphate, Nitrates, Iron, Dissolved Oxygen, Phosphates, Total Petroleum Hydrocarbons, salinity and Total dissolved solids were used to calculate the water quality index (WQI).

2.2. Design of the Geographic Information System (GIS)

The software integrated land and water information systems (ILWIS) developed and marketed by the international institute for Aerospace Survey and earth Sciences (ITC, 1998) has been used for the development of the GIS of Temsah lake. The base map of the study area consists of three layers:

- A point map that includes all monitored data in the specified sampling locations.
- Polygon map that includes the body of Temsah lake digitized and georeferenced.
- Pollution source map including the drains discharging into the area.

First, the spatial Variability of water quality parameters in Lake Temsah are distributed over the constructed basemap in figures (2, 3, 4, 5, 6). Second, the spatial assessment of water quality of lake Temsah were carried for the estimation of unknown values using moving average method. The ILWIS point estimations methods were used instead of ordinary kriging (in spite of the latter's advantages) for reasons of efficiency. Also the results of ordinary kriging depend heavily on assumptions of the model, which are difficult to verify. The deterministic method of interpolation was chosen also because the final goal of estimation is contouring and representing the gathered data in a qualitatively demonstrative way. To estimate unknown values, the weighted linear combinations were used where the weights account for the distance to the nearby samples by using the inverse distance method. This method relies on the idea that the data are more likely to be useful if they are measured near the point of interpolation. Therefore, more weight is given to the closest samples and less to those furthest away. The value of intermediate point is thus calculated from the summation of the product of the observation values v_i and weights, divided by the summation of weights. The inverse distance algorithm used is by making the weights inversely proportional to any power of the distance according to the following equation:

$$v1= \frac{\sum_{i=1}^{p} \frac{1}{d_i^n} v_i}{\sum_{i=1}^{p} \frac{1}{d_i^n}}$$

Where v are the sample values, d are the distances from the p Sample (4)

As n decreases, the weights given to the samples become more similar. For progressively larger values of n, the closest samples receive a progressively larger percentage of the total weight. The (IDW) interpolation method has been widely used on many data types because of its simplicity, speed in calculation, easiness in programming, and credibility in interpolating surfaces (ESRI, 1994).

2.3 WQI Calculation

A WQI is a mathematical way of summarizing multiple properties into a single value. Typically, a WQI ranges between 0 and 100, with higher numbers indicating lower quality water. A WQI is useful for comparing differences in water quality across a region, or for monitoring changes in water quality over time. In this research, the water quality index is calculated using the equation developed by (Tiwari and Manzoor, 1988). The quality rating q_i, for the i^{th} water quality parameter can be obtained by the following relation:

$$q_i = 100\left(\frac{V_i}{S_i}\right) \qquad (1)$$

Where V_i = observed value of the i^{th} parameter at a given sampling site and Si = stream water quality standard. Equation (1) ensures that q_i = 100 if the observed value is just equal to its standard value. Thus, the larger the value of q_i, the more polluted the water is, with respect to the corresponding pollutant value (mg/L). Thus q_i = 0, when VDO = Saturation level (in mg/L) and qi = 100, when VDO = 5 mg/L; for simplicity, VDO will be taken as saturated whenever exceeds the saturation level. To calculate the water quality index, the quality rating qi corresponding to the ith parameter can be determined using the Equation (1). The overall water quality index was calculated by aggregating these quality ratings linearly as follows:

$$WQI = \sum_{i=1}^{n} q_i \qquad (2)$$

Where n = number of parameters. The average water quality index (AWQI) for n parameters was calculated using this equation:

$$AWQI = \frac{\sum_{i=1}^{n} q_i}{n} \qquad (3)$$

Where n = number of parameters. The AWQI was classified into 4 categories: (good) 0-100, (medium) 100-150, (bad) 150-200 and (very bad) over 200.

3. RESULTS AND DISCUSSION

Many thematic maps were created sowing the spatial variability of different water quality parameters as shown in figures (2, 3, 4, 5, 6 and 7). DO fluctuated between 5 at tawen club and 6.3 in the middle of the lake because tawen areas is subjected to substantial dumping or leakage of industrial wastes from ships passing through the lake as well as disposal of domestic water from clubs along the shore. The highest salinity (31.8 mg/L) exists whereas the highest salinity was recorded in the eastern site whereas the lowest salinity (1.1 mg/L) exists in the western site due to freshwater discharged from sewage treatment systems, untreated source and nonpoint source runoff. High level of nitrate and phosphate are in the western site due to eutrophication caused by irrigation drainage water into the lake. TDS values are very high near the southern western side due to outfall of domestic and industrial wastewater. TPH values are high near the northern part.

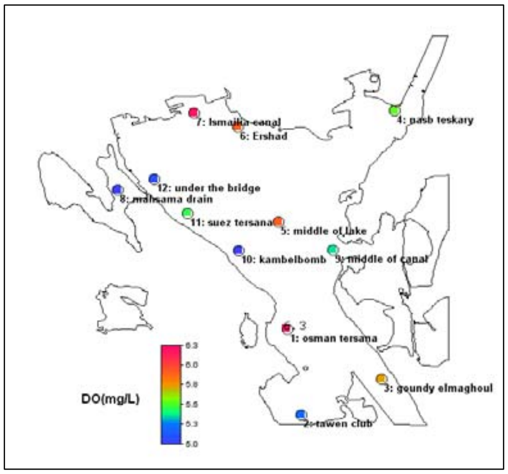


Fig. 2: Variability of DO in Lake Temsah

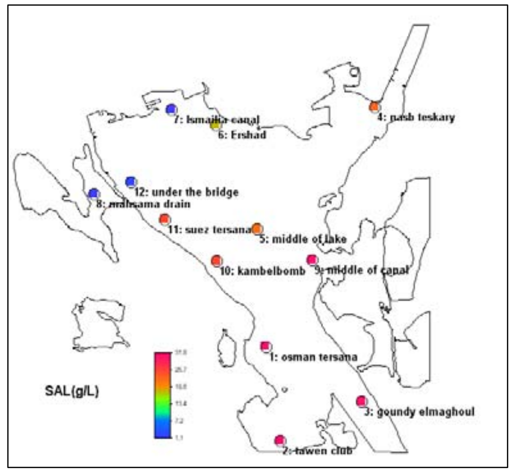


Fig. 3: Variability of Salinity in Lake Temsah

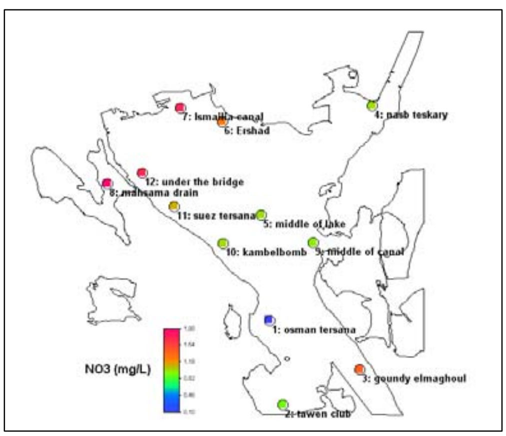


Fig. 4: Variability of NO3 in Lake Temsah

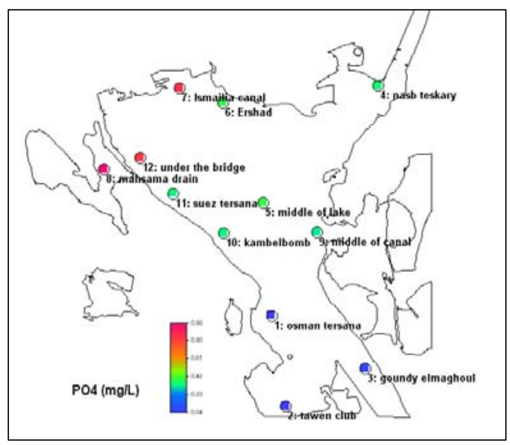
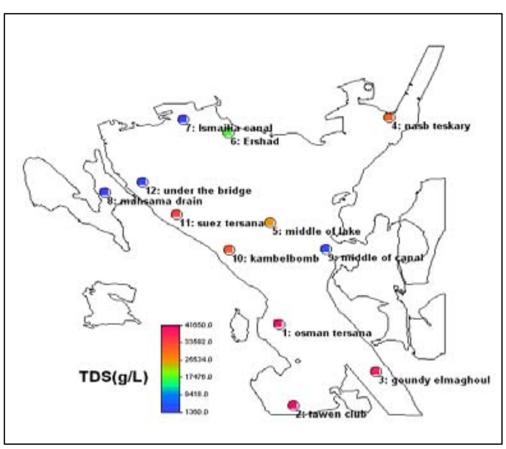


Fig. 5: Variability of PO4 in Lake Temsah



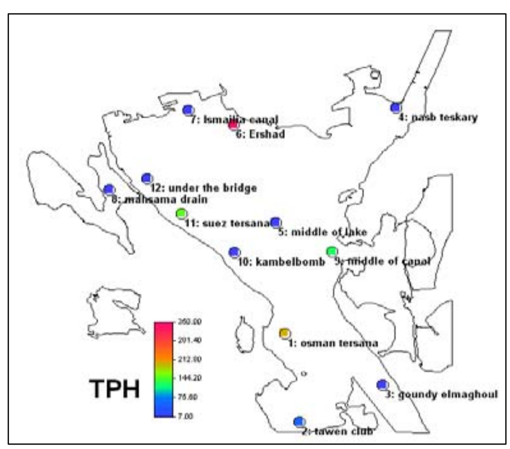


Fig. 6: Variability of TDS in Lake Temsah

Fig. 7: Variability of TPH in Lake Temsah

After aggregation of all water quality maps of all measured parameters, different water quality indices maps were created.

Figure 8 shows the water quality index (AWQI) calculated if the Egyptian standards are considered (EEAA, 1994). It shows that that the overall (good) water quality is located in the middle of the lake and in Kamb Elbomb areas, the (medium) quality is in near the outfall of Elmahsama drain and in the western lagoon and under the bridge area. The (bad) water quality exists near the outfall of Suez Tersana, Taawen club and the middle of canal. The (very bad) quality exists in the outfall of Osman Tersana and outfall of Elershad residential area.

Figure 9 shows the calculated water quality index if the European standards for swimming and recreational activities are used (AWQIM) that the (good) quality is located in the middle of the lake and in Elgondy Elmaghoul areas, the (medium) quality for swimming exists near the north shore of the lake and in kambElbomb area. The (bad) quality for swimming is in near the outfall of Elmahsama drain and in the western lagoon under the bridge area. The (very bad) water quality for swimming exists near the outfall of Suez and Osman Tersana companies.

Figure 10 shows the calculated water quality index if the European standards for coarse (AWQIF) and shell fishing (AWQIS) are used (Tebbut, 2002). It shows that the (good) quality for fishing in the eastern southern part of the lake in Elgoundy Elmaghoul area. The medium quality is in near the outfall of Elmahsama drain and in the western lagoon and under the bridge area.

The (very bad) quality for fishing exist near the outfall of Suez and Osman Tersana companies and in the middle of canal area. All other locations for lake are considered as (bad) quality for fishing.

Figure 11 shows the calculated water quality index if the European standards for shell fishing (AWQIS) are used (Tebbut, 2002). It shows that almost all the lake water quality is considered (very bad) for shellfishing except the southern region of the lake at Elgondy Elmaghoul and near Tawen club that are considered better quality but still (bad) for shellfishing.

4. CONCLUSIONS

A geographical information system is developed for lake Temsah. Also, the classification of lake water quality and its suitability for the designated uses are determined using the developed system.

Different WQI's are calculated depending on the use of the lake water. The areas suitable for each use were identified on spatial thematic maps within the developed GIS system. The results indicated that Lake Temsah is currently suffering from increasing pollution levels which are essentially caused by untreated domestic and industrial wastewater in addition to contaminated drainage water.

This geographical information system appears to have immediate potential for operational use as a decision support tool for water management in the area. The developed system is expected to help the decision maker to take the appropriate actions to improve the lake water quality and therefore the conservation of the lake ecosystem.

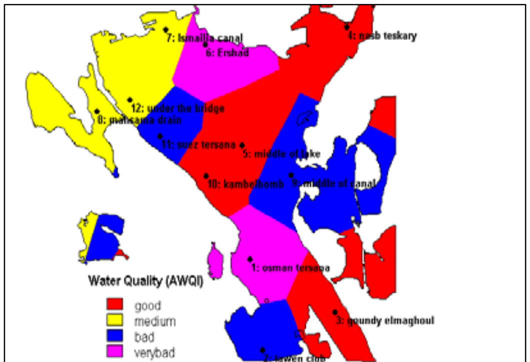


Fig. 8: AWQI For Temsah Lake

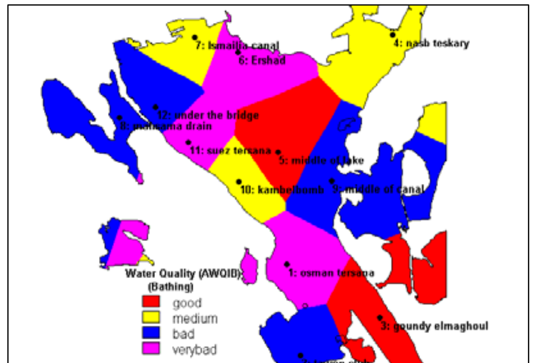
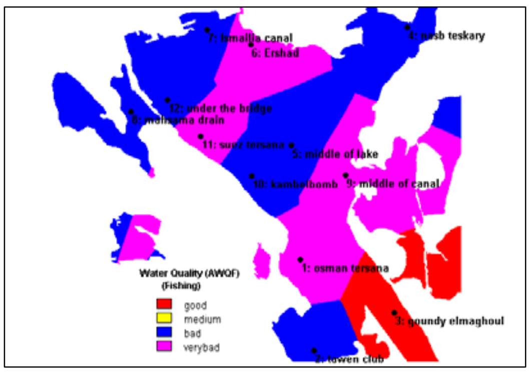


Fig. 9: AWQI For Swimming



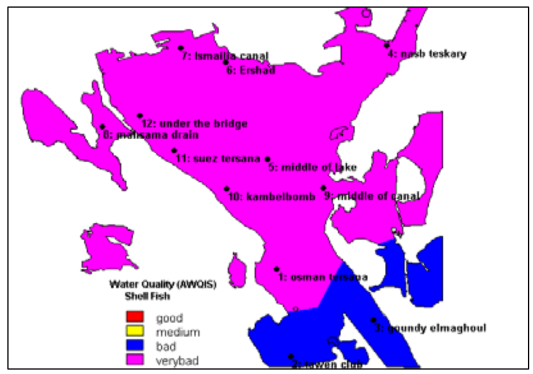


Fig. 10: AWQI For Coarse Fishing

Fig. 11: AWQI For Shell Fishing

5. REFERENCES

Abdul Hameed M. Jawad Alobaidy, Haider S. Abid, Bahram K. Maulood, (2010). Application of Water Quality Index for assessment of Dokan Lake ecosystem, KurdistanRegion,JWARP,scientific Research Publishing, ISSN: 1945-3094

Abrahão R.; M. Carvalho, W. R. da Silva Jǘnior, T. T. V.Machado, C. L. M. Gadelha and M. I. M. Hernandez, (2007). Use of Index Analysis to Evaluate the Water Quality of Stream Receiving Industrial Effluents, Vol. 33, No. 4, pp. 459-465.

APHA, American Public Health Association, (2005). Standard Methods for Examination of Water and Wastewater 21st Edition, American Public Health Association, Washington DC,.

AWRC, (1994). Monitoring program established by Abu Attwa Water Reuse Center and Suez Canal University, Ismailia, Egypt

Bordalo A. A., R. Teixeira and W. J. Wiebe, (2006). A Water Quality Index Applied to an International Shared River Basin: The Case of Douro River. Environmental Management, Vol. 38, No. 6, pp. 910-920.

Demuynck-C.; Bawens-W.; Pauw-N-de, Dobbel aere-I, Poelman-E and De-Pauw-N, (1997). Evaluation of Pollution Reduction Scenarios in a River Basin. Water Science and Technology, 35:65-75.

Donia N. S. (2005). Water Quality Assessment of Temsah Lake, AUEJ, 8(1): 54-64.

Dwivedi S. L. and V. Pathak, (2007). A Preliminary Assignment of Water Quality Index to Mandakini River, Chitrakoot, Indian Journal of Environmental Protection, Vol. 27, No. 11, pp. 1036-1038.

EEAA, Egyptian fourth law of environment (1994). Egyptian environmental agency.

El-Sherbini A. and El-Moattassem M. (1994). River Nile Water Quality Index during High and LowFlow Conditions. National Conference on the River Nile, Assiut Center for Environmental Studies

ESRI (1994). Cell based modeling with grid. Environmental Systems Research Institute Inc., USA.

ETPS (1995). Environmental testing of pollution status in lake Temsah, Abu Attwa water reuse center research and training, Ismailia, Egypt, 356 pp.

ITC, (1998). Ilwis 2.1 for windows, Reference guide, International institute for Aerospace Survey & Earth Sciences.

Kannel P. R, S. Lee, Y. Lee, S. R. Kanel and S. P. Khan, (2007). Application of Water Quality Indices and Dissolved Oxygen as Indicators for River Water Classification and Urban Impact Assessment," Environmental Monitoring and Assessment, Vol. 132, No. 1-3, pp. 93-110.

Marble, D. F. (1987). Geographic Information Systems: An Overview, American Society for Photogrammetry and Remote Sensing, Falls Chuerch, Virginia, 288 pp.

Mohanta, B.K. and A.K. Patra. (2000). Studies on the water quality index of river Sanmachhakandana at Keonjhar Garh, Orissa. Poll. Res. 19 :3, 377-385.

Ramakrishnaiah C. R., C. Sadashivaiah and G. Ranganna, (2009). Assessment of Water Quality Index for the Ground Water in Tumkur Taluk, E-Journal of Chemistry, Vol. 6, No.2, pp. 523-530.

Sankar Narayan Sinha and Mrinal Biswas, (2011) Analysis of Physico-Chemical Characteristics to Study the Water Quality of a Lake in Kalyani,West Bengal. asian j. exp. biol. sci. vol 2(1): 18-22.

SLTDS, (1994). Summary of Sustainable lake Temsah Development Strategy. Lake Temsah Development, Chemonics Egypt.

Simoes F. S., A. B. Moreira, M. C. Bisinoti, S. M. N. Gimenez and M. J. S. Yabe, (2008). Water Quality Index as a Simple Indicator of Aquaculture Effects on Aquatic Bodies, Ecological Indicators, Vol. 8, No. 5, pp. 476-484.

Tiwari, T.N. and Manzoor Ali. (1988). Water quality index for Indian rivers. In:Ecology and Pollution of Indian rivers.pp:271–286. Ashish Publishing House, New Delhi.

Walsh S. J. (1987). Geographic Information Systems for Resource Management. American Society for Photogrammetry and Remote Sensing, Falls Chuerch, Virginia, 288 pp.