Original Articles

Assessment of Surface Water Quality in Egypt

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Abstract

The population growth, economic development, with the consequent anthropogenic activities in Egypt and global climate change pose to reduce the quality trends of surface water resources. This study was aimed at the assessment of some water quality indicators through the period of years from 2002 to 2009 in the main River Nile, Rosseta and Damietta branches, El-Ismailia, El-Mahmodia and El-Ibrahimia canals, and Bahar Yousef in twelve governorates of Egypt. The water quality indices are an attempt to represent overall quality of water. The method carried out for calculation of Statistical Water Quality Index (SWQI) depends on using four parameters; dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total dissolved solid (TDS). Annual mean data for these water quality parameters were obtained from the website of central agency for public mobilization and statistical. SWQI is the summation of four sub-indices which are the multiplying of concentration and weight for each water quality parameters. The weight is given to the parameters according to the concentrations available data by using SPSS® statistical program. Spatial and temporal variations for water quality parameters also carried out. Finally, a statistical analysis of the four sub-indices constituted SWQI was performed in order to evaluate the relative importance for each one on SWQI. The results of SWQI for the selected governorates indicated that Aswan governorate is less vulnerable to surface water quality deterioration, while Damietta governorate is high vulnerable. The results of spatial and temporal variations as well as SWQI illustrated a deterioration of water quality northward while water quality improved with time. Statistical analysis of sub-indices of SWQI indicated that BOD is the most effective on SWQI value.

Keywords: Statistical WQI, Surface Water Quality, Governorate.

Introduction

Environmental pollution problems are one of the most serious national problems which requires great efforts at all levels; individual, group, national and international. This is especially true with respect to pollution of rivers because they serve as the recipient of urban and rural wastewater. Water quality issues have become of major concern to all agencies dealing with water resources management and planning. This requires data collection, analysis, and interpretation. One major goal of surface water quality data collection may be the estimation of magnitude of changes in the concentration of various constituents (Yehia et al., 2011). This paper presented water quality aspects for surface water in twelve governorates (Cairo, Giza, Qalyobyah-Greater Cairo-Aswan, Suhag, Assuit, El-Menia, Beni-Suef, Gharbia, Dakahlia, Damietta, and Alexandria). Out of large number of chemical parameters linked with water quality status, data of some significant contaminating indicators, namely, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total dissolved solid (TDS) are collected. The objective of this paper firstly is to study offered comprehensive water quality information of some deltaic and sub-delatic governorates for surface water, Egypt. Secondly statistical water quality index is an attempt to represent overall surface water quality in the studying governorates.

Materials and Methods

Recently, one of the simplest and understandable methods used in assessing the overall water quality is by calculating an index for a group of parameters, known as the water quality index (WQI). The WQI is allows the reduction of vast amounts of data on a range of parameters to a single number in a simple reproducible manner. In Egypt, the Central Agency for Public Mobilization and Statistical (CAPMAS) represents the official authority for national data collection for the country. Its website offers information and data concerning various environment and development indicators (Egypt Second National Communication, 2010). Annual mean data for

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four water quality parameters, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total dissolved solid (TDS) in the period from 2002 to 2009 were obtained from the website of central agency for public mobilization and statistical, "http://www.capmas.gov.eg". The mother source of these data is environmental observatory center- Ministry of Health and Population, according to table (1). These parameters were used for calculation of statistical water quality index (SWQI) for each governorate by aiding of SPSS® statistical program software version 18. Statistical program used to calculated weight value for each parameter through neural networks analysis. Then the SWQI is calculated by using the following linear transformation equations which used to simplify and analyze multivariate variables:

\[
SWQI = \sum_{i=1}^{n} (\text{sub} - \text{index})_i,
\]

\[
\text{sub} - \text{index} = (C \times W)_i,
\]

Where:

C and W are the concentration and the weight value, respectively for the ith water quality parameter. While n is the number of parameters (n=4). The multiplying value for concentration and weight for each parameter is called sub-index. Then, according to the average statistical water quality index (ASWQI) for each governorate in the study period from the years 2002 to 2009 the governorates are ranked. The increasing in the value of SWQI indicated that the water quality will be more deteriorates.

### Table 1: Number of monitoring point in the governorates surface water.

<table>
<thead>
<tr>
<th>Governorates</th>
<th>Total</th>
<th>River Nile</th>
<th>Rosetta branch</th>
<th>Damietta branch</th>
<th>Ismailia canal</th>
<th>El-Mahmoudia canal</th>
<th>Bahar Yousef</th>
<th>Ibrahimia canal</th>
<th>Lake Nasser</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aswan</td>
<td>20</td>
<td>19</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>1</td>
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<tr>
<td>Suhag</td>
<td>17</td>
<td>17</td>
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<tr>
<td>Assuit</td>
<td>20</td>
<td>15</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>5</td>
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<tr>
<td>Menia</td>
<td>13</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
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<tr>
<td>Beni-Suef</td>
<td>11</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Greater Cairo</td>
<td>18</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Gharbia</td>
<td>24</td>
<td>19</td>
<td>3</td>
<td>2</td>
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<tr>
<td>Dakahlia</td>
<td>8</td>
<td>8</td>
<td></td>
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<tr>
<td>Alexandria</td>
<td>7</td>
<td>7</td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Damietta</td>
<td>7</td>
<td>7</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>144</td>
<td>97</td>
<td>4</td>
<td>18</td>
<td>4</td>
<td>7</td>
<td>2</td>
<td>12</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: CAPMAS website according to Environmental Observatory Center - Ministry of Health and Population.

**Background On Water Quality Status:**

The water quality of Lake Nasser and the main stream of the River Nile from Aswan to Cairo are good and traces of pollutants. However, water quality in the irrigation and drainage canals deteriorates downstream and reaches alarming levels in the Delta (Abd El-Daiem, 2011). As the River Nile flows downstream from High Aswan Dam (HAD), the total salt load increase while the volume of water decreases because of additional drainage water and the continuous abstraction of water used for different purposes (El-Kady, 1997). El-Sherbini et al., (1992) and El-Motassem et al., (1996) pointed out that the River Nile is polluted northward in some locations, where it is used as disposal pathway for different types of wastes. The situation is probably getting worse with time, as the discharge of wastes is increasing. Kees (1996) stated that the Nile in Egypt can be characterized as a moderately polluted are in general terms. Also, the canals have water quality similar to that at point of diversion from the Nile (Hussien, 1998). Ismailia canal transports fresh water from the River Nile at north of Cairo at El-Mazalet region to Ismailia, Port Said and Suez governorates (Abdo, et. al., 2010). El-Mahmoudia canal represents the main freshwater resources to Alexandria. The Ibrahimia canal is the longest canal in the country and it irrigates about one forth of the cultivated lands in Egypt (Morsy et al., 2002). Bahar Yousef canal fed Fayoum governorate by Nile water (MWRI/ USAID, 2003b). El-Gohery, 1983 reported that the River Nile receives considerable amounts of untreated effluents rich in organic matter. However, Abd El-Hamid, 1992 may suggest that the River Nile has an intensive self-purification capacity. He may also indirectly support this suggestion by referring to the analysis of BOD. The same parameter has been recommended by Stachowicz 1983 as a sensitive measure of stream self-purification capacity. The self-purification capacity of the River Nile is supposed to be high. The characteristics of the Nile ecosystem clearly reflect the impact of river flow control. The water quality in the Nile downstream from Aswan has changed dramatically as the Nile water became silt-free, less turbid and with considerably less velocity (Saad and Goma, 1994). According to the
National Water Research Center (NWRC, 2000), the River Nile from Aswan to Delta barrage receives wastewater discharge from 124 point sources, of which 67 are agricultural drains and the remainders are industrial sources. Now, the changes in water quality are primarily due to a combination of land and water use, as well as water management interventions such as: (a) different hydrodynamic regimes regulated by the Nile barrages, (b) agricultural return flows, and (c) domestic and industrial waste discharges including oil and wastes from passenger and riverboats. These changes are more pronounced as the river flows through the densely populated urban and industrial centers of Cairo and the Delta region (Agricultural Policy Reform Program, 2002). The severity of water quality problems in Egypt vary among various water bodies depending on: flow amount, pattern of use, population density, extent of industrialization, availability of sanitation systems and the social and economic conditions. Water quality shows more deterioration signs near big cities and industrial areas. However, rural areas which mostly lack proper sanitation are major sources of water pollution (Abd El-Daiem, 2011). The water quality released from the HAD shows little degradation. It remains remarkably clean areas. However, rural areas which mostly lack proper sanitation are major sources of water pollution (Abd El-

Results and Discussion

The results of this paper discussed the variation of annual mean values for surface water quality data in twelve governorates of Egypt as well as studied their SWQI in the period from 2002 to 2009.

- **Spatial and Temporal Variation for Water Quality Parameters:**

  Water quality parameters such as DO, BOD, COD, and TDS have been considered for studying spatial and temporal variation along twelve governorate in the period of study from 2002 to 2009. The spatial variation for the average values of water quality parameters are shown in figures (1-A, B, C, and D). These figures illustrated a decreasing trend for DO and an increasing trend for BOD, COD, and TDS northward from Aswan to Damietta governorates. Each parameter fluctuates between the years at each governorate. The water quality parameters trend attributed to the urbanization increase and so increasing wastewater with decreasing water flow and discharge in surface water bodies. This came in accordance with the (AWC, Arab Water Council, 2009) which proved that decline in water quality has, in part, been caused by problems related to the fast growth of urbanization in the region, insufficient and inefficient municipal and industrial wastewater treatment facilities, and disposal and reuse of agricultural drainage water. The work presented in report of MWRI/ USAID (2003a) included that the major sources of pollution directly to the Nile from Aswan to Delta barrage are the drains of Khour El-Sail Aswan, El-Berba drain, Kom-Ombo drain, and Etsa drain, which receive contaminated loading from agricultural lands and industries. In addition, numerous sugar factories in Upper Egypt and Giza, oil & soap factories in Sohag, and other manufacturing plants discharge wastewater with little or no treatment directly into the Nile. Although the impact of discharges of these wastes on ambient water quality of the Nile has not been significant due to high dilution and the high self assimilation capacity of the Nile water. The assessment of the water quality data during the whole period of the National Water Quality and Availability Management Project (NAWQAM) project (1999 – 2007) indicated that Lake Nasser exhibits excellent water condition in the River Nile from Aswan to Delta barrage remains healthy and suitable for the present beneficial uses. In addition water quality analysis provides an indication of the high organic contamination and deficiency of dissolved oxygen in the water of both Damietta and Rosetta branches. The average concentrations of water quality parameters in the two branches of the Nile are always higher than in the main river. Spatial distribution of water quality parameters varies downstream the HAD due to discharges of return flows from agricultural, domestic and industrial uses (Abd El-Daiem, 2011). In this study the temporal variation of water quality parameters illustrated in figures (2-E, F, G, and H). These figures showed that the DO trend increasing with time, while BOD, COD, and TDS decreasing with time, on the other hand there is fluctuations between the surface water quality in each governorate. The temporal trend illustrated improving for water quality parameters with time, this attributed to the enforcement for environmental law No. 4/1994 for treatment of wastewaters before their discharges into surface water body.
Fig. 1: Spatial variation of water quality parameters.

- Statistical Water Quality Index (SWQI):

The available data showed that SWQI, figure (3), varied widely from governorate to another according to the concentration of various water quality parameters (BOD, COD, DO, TDS) and to their specific contribution to the index calculation for surface water in the investigated governorates. These variations represented that surface water suffering from different human activities and different maintenance level.

From figure (3), firstly, it is noticed that the ASWQI for surface water in all governorates along the period of study from 2002 to 2009 ranged from 114.74 in Aswan governorate to 215.38 in Damietta governorate. Figure (3) also illustrated that the trend of ASWQI increased northward. Secondly, the rank of studying twelve governorates according to their ASWQI in ascending order is Aswan, El-Menia, Suhag, Assuit, Greater Cairo, Beni-suif, Dakahlia, Alexandria, Gharbia, Damietta. This order is represented in ASWQI-rank map as in figure (4). On the other hand the percentage contribution for each governorate according to ASWQI is shown in figure (5). This figure showed that Aswan governorate represented the least contribution by its surface water quality to pollution in Egypt for the studying governorates in the period from 2002 to 2009. The highest contributions are found in Gharbia and Damietta governorates. This deterioration in water quality in Gharbia governorate due to point sources of pollution is pronounced at Rosseta branch at kafir-Ezzyat city. At this city the River Nile received considerable amounts of untreated industrial effluents (Abd El-Hamid, 1992). On the other hand and according to Ministry of Water Resources and Irrigation (MWRI) 2005 water quality survey carried out along the River Nile showed that the distribution of the values of quality parameters is nearly uniform from Aswan to Cairo. In the Nile branches, the water quality deterioration in a northward direction due to disposal of municipal and industrial effluent and agricultural drainage as well as decreasing flow. Rossetta branch receive a discharge from a part of the wastewater of greater Cairo through the Muheet/Rahawy drain as well as discharges of pesticides and toxic chemicals from other sources. Dammita branch receive discharge from the Talkha fertilizer industry and drainage of herbicides and pesticides from agricultural drains. Mahmoodia and Ismailia canals are suffering from wastewater input from agricultural, industrial and domestic wastes from canal banks and reuse pump stations. On the hand the temporal distribution of ASWQI shows that the surface water quality improved with time as shown in figure (6). The improving of water quality for surface water with time is attributed to the decided of Ministry of State for Environment Affairs in July 1997 for prevention of industrial pollution to the Nile through Nile pollution prevention program (NPPP) which launched at the top of the 1998 environmental agenda (Ebeid et al., 1999).
Statistical Analysis Of Results:

The statistical analysis carried out by calculated of minimum, maximum, mean, standard deviation, and coefficient of variations (CV%) for temporal, spatial variation of water quality parameters and for SWQI. The statistical summary of temporal variation for the studied water quality parameters showed that the minimum value of DO (4.6 mg/l) found in the year of 2005 which violating the allowable value (≥ 5mg/l) in law of MWRI No. 48/1982 for the protection of the River Nile against pollution. The maximum value of BOD (17.81 mg/l) and COD (25.83 mg/l), are found in the year 2002 which exceeding the allowable value for (BOD ≤ 6 mg/l) and (COD ≤ 10 mg/l) in law 48/1982. The mean value for BOD is not exceeding the law in all year, while for COD is exceeding the law in all year except for the year 2008. The maximum value of TDS (382 mg/l) is found in the year 2004 which not exceeding the allowable value (TDS ≤ 500 mg/l) in law 48/1982. The statistical values for spatial variation along twelve governorates showed that the minimum value of DO is found in surface water body at Alexandria governorate and this value is exceeding the law 48/1982. The maximum values for BOD and COD are found in Gharbia governorate. The statistical summaries of SWQI for the twelve studying governorates along the period of study from 2002 to 2009 showed that, Aswan governorate had values ranging...
from 99.9 to 127.81, as compared to Damietta governorate which registered SWQI values ranging from 166.97 to 273.2. The highest values in Damietta governorate suggest quality deterioration of its surface water. Surface water quality at Aswan showed less variation in SWQI than Damietta, as indicated by their standard deviation and coefficient of variations. By regarding to the contribution of sub-index for the four parameters incorporated to the variation of the SWQI; a small variation for sub-index of BOD would greatly affect the values of the index. This was exhibited by high coefficient of variation value (88.64%) associated to this parameter. Changes in (CV%) for COD (47.03%) and DO (31.57%) sub-indices, would have moderate impact whereas variation in TDS sub-index would low impact the deterioration of water quality, where its CV% equal 23.91%.

Fig. 4: ASWQI-rank map along the studying governorates.

Fig. 5: Percentage contribution for each governorate (ASWQI%).
**Fig. 6:** Temporal distribution of ASWQI.

**Conclusions:**

Water quality parameters data for DO, BOD, COD, and TDS in surface water (the main River Nile, Rosetta and Damietta branches, El-Ismailia, El-Mahmodia and El-Ibrahimia canals, and Bahar Yousef) of twelve governorates are collected from website of CAPMAS. SWQI is a simple tool enabled us to integrate the results of the eight years of study from 2002 to 2009 in twelve deltaic and sub-deltaic governorates in Egypt for their surface water resources. The trend for spatial and temporal variations for water quality parameters as well as SWQI illustrated a deterioration of water quality northward while water quality improved with time. The trend of water quality deterioration for governorate is northward as the anthropogenic activities and waste disposal problems increases. The governorates rank according to ascending order for deterioration of their surface water as follow: Aswan, El-Menia, Suhag, Assaut, Greater Cairo, Beni-Suef, Dakahlia, Alexandria, Gharbia, and Damietta. The improved in temporal variations is attributed to the enforcement for environmental law No. 4/1994 for treatment of wastewaters before their discharges into surface water body. Statistical analysis of sub-indices of SWQI indicated that BOD sub-index is the most effect on SWQI value, which illustrated by the high coefficient of variation value associated to this parameter.

**References**


