Application of Canadian Water Quality Index for Surface Water vulnerability assessment: A Case Study of Water Quality in River Nile

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Abstract: The present work describes the application of Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) to evaluate the Nile River water quality upstream Cairo Drinking Water Plants (CDWPs). The field work was conducted during the period from January to December 2017. In the formulation of CCME WQI, Nine physical, chemical and biological parameters: pH, Dissolved Oxygen (DO), Total Dissolved Salts (TDS), Nitrates, Ammonia, Iron, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Fecal Coliform (FC) are selected according to their relative importance from the point of view of suitability for drinking water purposes. The results of various water quality parameters proved that the water quality at the study area is impacted by a relatively high concentration of COD and FC due to treated or partially treated domestic wastewater and industrial water mixed with agricultural drainage water discharged to the river. Based on water quality parameter assessment and the final results obtained from the CCME WQI, It was noted that Cairo Drinking Water Plants (CDWPs) that takes their raw water source from Nile River need a particular attention and continuous control for their water source quality to prevent health hazards. This work confirms the need to take more integrated action for monitoring the river for proper management.
[Mohamed Ahmed Reda Hamed AbdAllah. **Application of Canadian Water Quality Index for Surface Water vulnerability assessment: A Case Study of Water Quality in River Nile.** *J Am Sci* 2019;15(2):52-59]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). http://www.jofamericanscience.org. 7. doi:10.7537/marsjas150219.07.

Keyword: Assessment, Water Quality Index, CCME WQI, CDWPs.

1. Introduction

The Nile constitutes the essential source of life in Egypt; it provides people with their fresh water needs. It is an essential factor of production and vital for agriculture, transport, tourism and henceforth the socio-economic development of the country. However, the Nile has become, to a great extent, adversely affected by human activities. On the other hand, industrial waste discharge, leakage of sewage by urban agglomeration and agricultural runoff contributes to the Nile contamination (Abd El-Daiem, S., 2011).

Surface water quality deterioration at the intakes of Cairo water treatment plants along River Nile due to increasing level of some pollutants concentration above the guidelines paid the attention of public concern and may cause health hazards. Thus, the need for better management of Cairo treatment plants water sources quality is becoming essential.

One of the simplest methods to assess water quality conditions is by using water quality indices. It is a tool that provides meaningful summaries of water quality data that are useful to technical and non-technical individuals interested in water quality results. The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) was preferred as effective tool for the work due to its simplicity and ability to simplify Drinking Water Quality (DWQ) data without compromising the technical integrity of the data. The Index compares the compliance of the observed data to a water quality standard or objective to give a score ranging from 0, indicating worst quality to 100 signifying the best. The Index is helpful in monitoring water quality change at a specific location over a stated period of time (often a year) and also in comparing directly among stations that employed the same variables and objectives (CCME, 2001).

2. Study area

The Nile River enters Egypt at its southern boundary with Sudan and runs through 1000 km long narrow valley, then divided at a distance of 25 km north of Cairo into two branches (Rosetta and Damietta) forming a delta which ends at the Mediterranean Sea. Cairo, located on the Nile River south of the Mediterranean Sea, just upstream of the point where the river widens into the Delta. Cairo has an area of 353 km2 with an average reach length along the river about 50 km (from Km 900 to km 950 referenced to Aswan High Dam). Figure (1) illustrates the study area layout which covers Cairo governorate along the River Nile, bounded by El Saff town (Giza Governorate) at Km 877.00 from the South and El Kanater town (Qalubia Governorate) at Km 953.00 from the North. The study scope will focus on the upstream of drinking water plants located in Cairo governorate along Nile River (Tibeen, Kafr Elw, North Helwan, Maadi, Fostat, El Roda and Rod Farg) and taking into consideration the effect of pollution sources from Giza governorate drinking water plants which discharge their sludge into the Nile River (Gezeret El Dahab, Giza and Embaba DWPs only).

The study reach pollution sources can be divided to the following main types:-

1) Agricultural drainage water mixed with partially treated or untreated domestic wastewater and industrial wastewater: Massanda, Ghamaza Soghra and Ghamaza Kobra Drain.

2) Industrial wastewater effluent: Tibeen Power Station, El Nasser Glass and Delta Cotton Kanater.

3) Wastewater from drinking water plants sludge disposal: Tibeen, Kafr El Elw, North Helwan, Maadi, Fostat, Gezeret El Dahab, El Roda, Giza, and Embaba Rod El Farag DWPs.

4) Mixed Waste: Khour Sail El Tibeen.

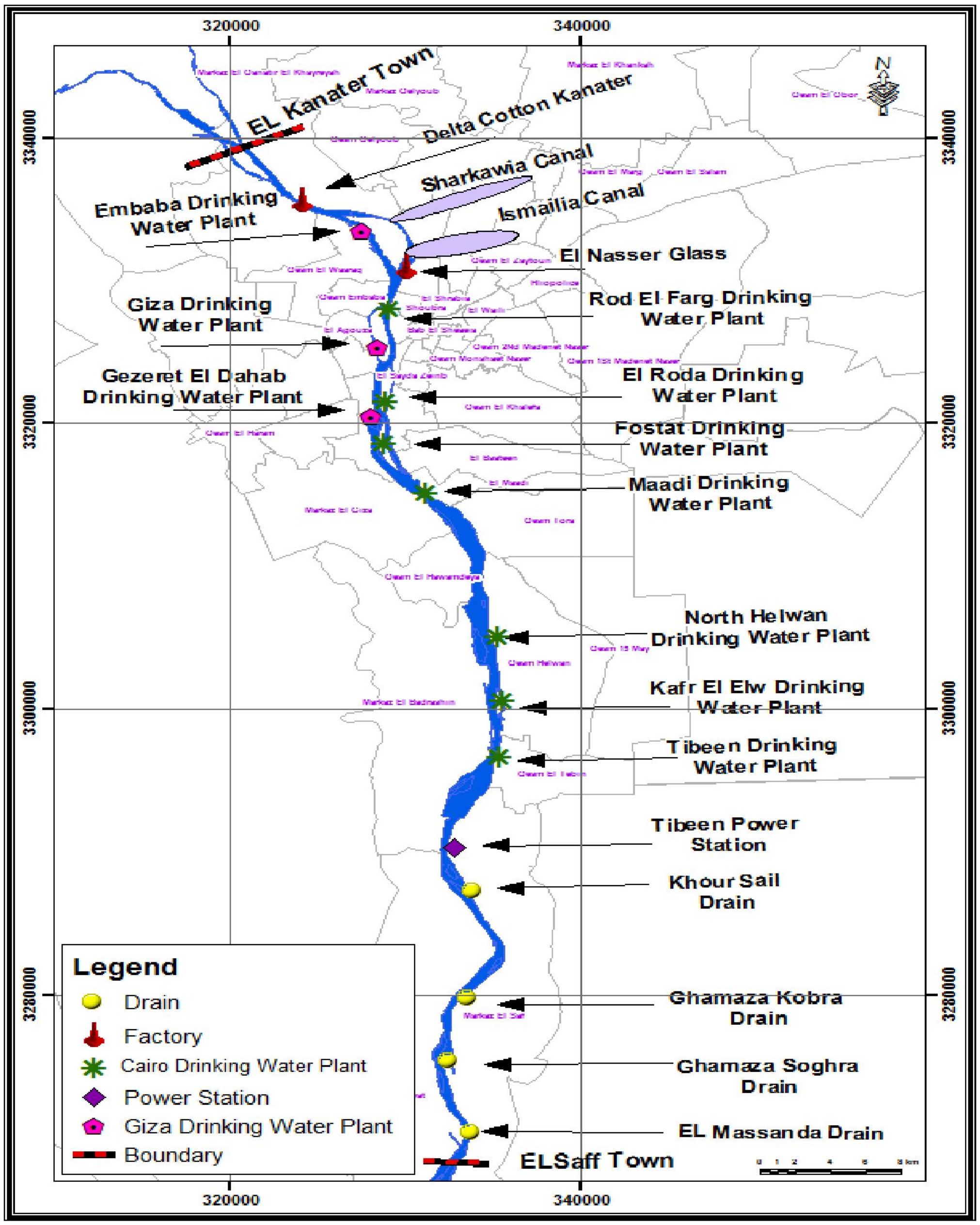

Figure (1) Study Area Layout

3. Materials and Methods

Surface Water samples were collected from various sampling locations of rivers, canal, drains and industrial pollution sources of the study area. The water samples were collected from 57 locations including 4 locations for drains, 3 locations for industrial pollution sources and 10 locations for wastewater from drinking water plants sludge disposal. Generally, the determination of sampling sites locations is mainly based on taking three sample at each pollution source location: the first, along the river and just before pollution source, the second at the end of pollution source before discharging into river to determine its effluent characteristics, the third, along the river at 200 meter after the pollution source to ensure a complete mixing of pollution water source discharge with river water, (Fischer, et al., 1979). Figure (2) illustrates the location of various water samples.

The analyses of water samples were carried according to the standard methods for the examination of water and wastewater (APHA, 2012) for twelve consequence months during year 2017 to show the effect of the spatial and temporal variation.

The methodology of CCME WQI determination is based on three measures of variance from selected water quality objectives (Scope; Frequency; Amplitude).

The CCME WQI values are then converted into rankings by using an index categorization schema that can be customized to reflect expert opinion by users. The detailed formulation of the WQI is described in the Canadian water quality index, (CCME, 2001). The observed values of samples were compared with standard values recommended by Egyptian National water quality standards (objectives), Law 48/1982 regarding the protection of the River Nile and waterways from pollution.

Based on the collected water quality data, CCME WQI values is calculated and then rated according to their corresponding ranks (excellent, good, fair, marginal and poor) as shown in table (1).

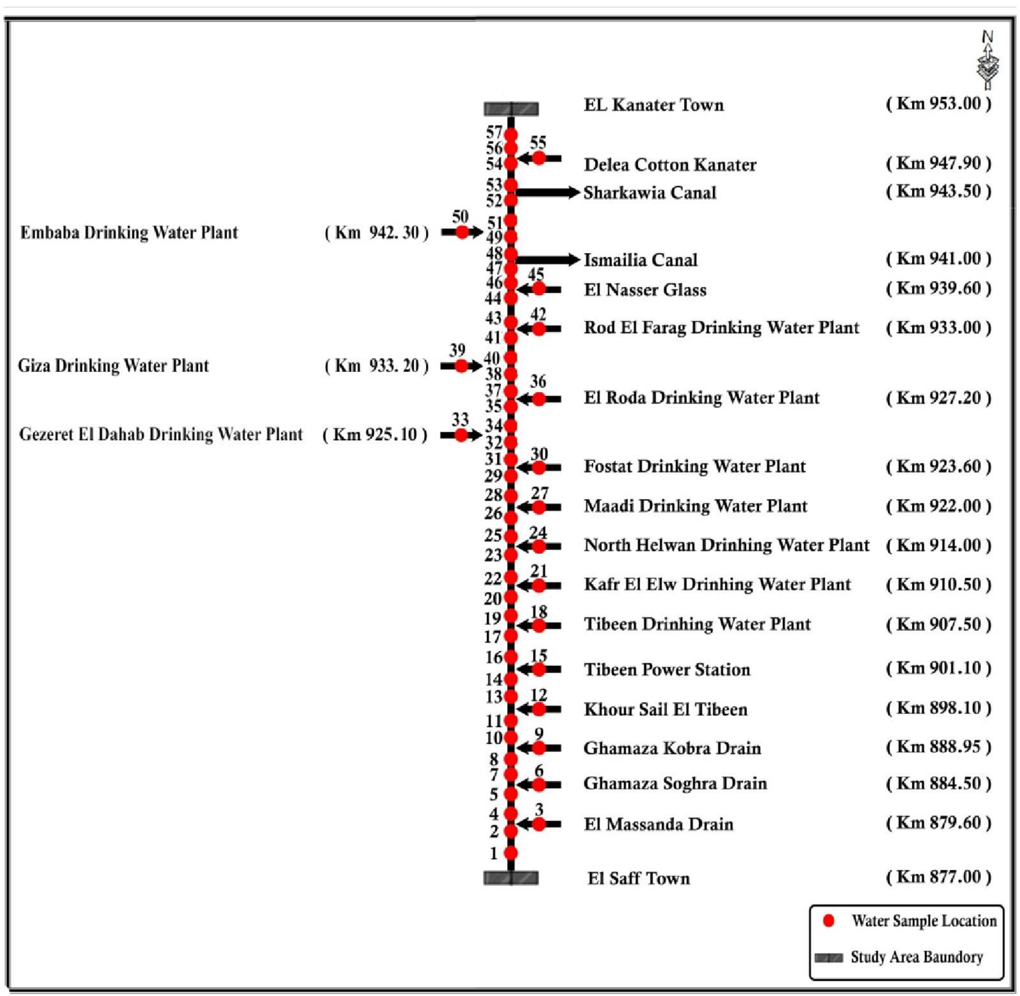

Figure (2) Study Area Water Samples

Table (1) Water Quality Index Classification, (CCME, 2001)

Rank	WQI Value	Description
Excellent	95-100	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels; these index values can only be obtained if all measurements are virtually within objectives all of the time.
Good	80-94	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
Fair	65-79	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable. Levels.
Marginal	45-64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Poor	0-44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

4. Analysis and Results

Figure (3a, b, c, d, e, f, g, h, I, j) focuses on River Nile water sample results upstream Cairo drinking water plants to illustrate the spatial variation of mean annual pH, DO, TDS, Nitrate, Ammonia, Iron, BOD, COD, FC, and CCME WQI respectively.

The seasonal variation of Nile River water quality upstream Cairo drinking water plants was assessed and the river water quality status was evaluated using CCME water quality Index. The result illustrated in figure (3a, b, c, d, e, f, g, h, I, j) of study revealed that:-

- The mean annual study area pH value is 7.97±0.24. This value is within the permissible limits (6.5-8.5) of the national guidelines (law 48/1982).
- The mean annual study area DO value is 7.89±0.31 mg/l. This value is within the permissible limits (minimum permissible 6mg/l) of the national standard. After different pollution source locations (drains, factories and DWPs wastewater), a relative decrease of dissolved oxygen concentrations can be noted. This may be related to pollutants discharges which contain high amount of organic matter.
- The mean annual study area TDS concentration is 294.04±41.5 mg/l. This value is within the permissible limits (maximum permissible 500 mg/l) of national guidelines (law 48/1982).
- The mean annual Nitrate concentration for the study is 0.37±0.08 mg/l. This mean value is within the permissible limits (maximum permissible 2.00 mg/l) of the national guidelines (law 48/1982).
- The mean annual Ammonia concentration for the study area is 0.25±0.05 mg/l. This value is within the permissible limits (maximum permissible 0.50 mg/l) the national guidelines (law 48/1982).
- The mean annual Iron concentration for the study area is 0.32±.10 mg/l. This value is within the permissible limits (maximum permissible 1mg/l) of the national guidelines (law 48/1982).
- The mean annual BOD concentration for the study area is 5.33±0.29 mg/l. This value is within the permissible limits (maximum permissible 6mg/l) of the national guidelines (law 48/1982).
- The study area's COD values showed slight and steady increase from South to North. The mean annual COD concentrations vary from 17.81±0.19 to 18.22±0.23 mg/l. The mean COD value of overall study area is 17.92±1.47 which violate the permissible limits (maximum 10 mg/l) of the national guidelines (law 48/1982). This increase in COD values may be due to the discharge of industrial effluents and other wastes into the Nile by some factories.
- The national guidelines have not set a standard value for fecal coliform (FC) counts for the ambient water quality of the Nile River. Therefore, the value given by the WHO (1989) as a guideline for use of water for unrestricted irrigation (FC≤1000MPN/100ml) has been taken as a guide for the evaluation of the water quality in this study. The mean annual FC values for the study area vary from 1370±15 to 1399±22 MPN/100ml. The high mean values of FC may be related to the domestic wastewater discharge into the River Nile.
- According to CCME – WQI, study reach water quality can be categorized into two types "Good" and "excellent ". The mean annual WQI values varied from 90.12±1.53 to 97.36±2.09. A relative decreasing of River Nile water quality status expressed by WQI after pollution sources (drains, factories, wastewater from DWPs) locations.

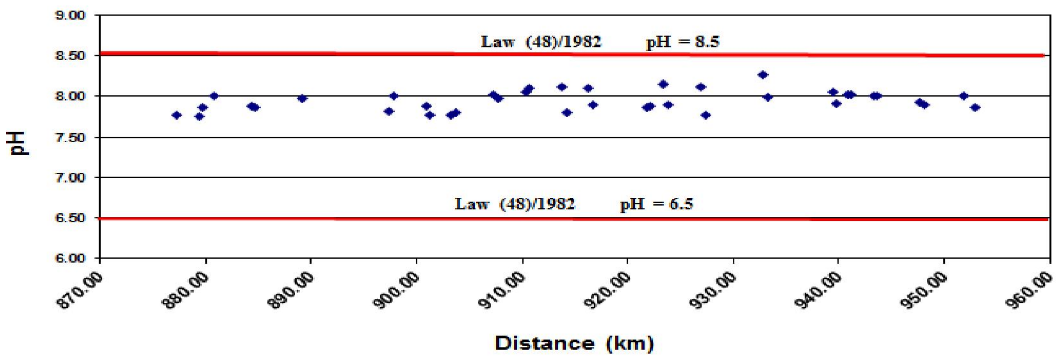

Figure (3a) pH Measured Values in the River Nile

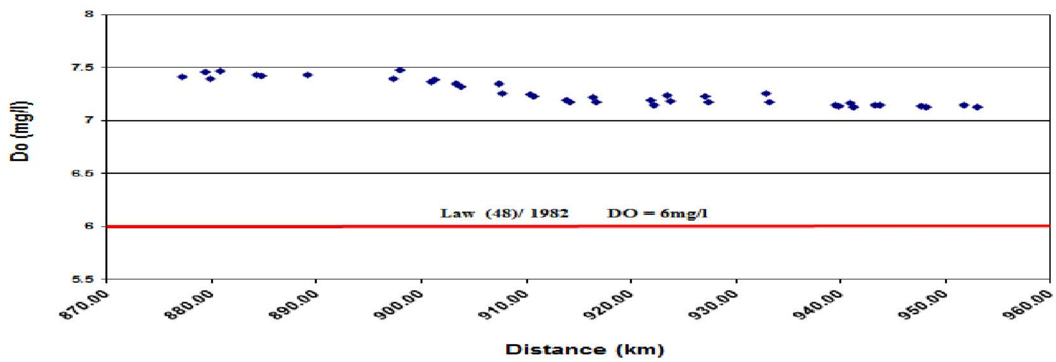

Figure (3b) Do Measured Values in the River Nile

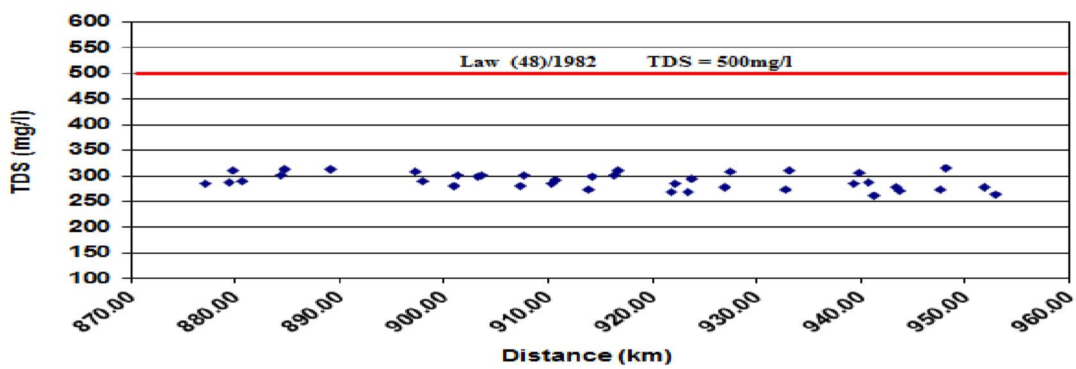

Figure (3c) TDS Measured Values in the River Nile

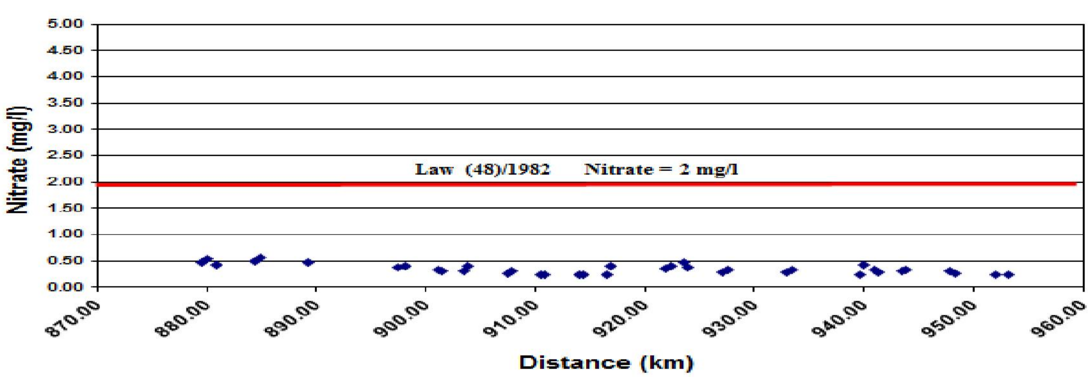

Figure (3d) Nitrate Measured Values in the River Nile

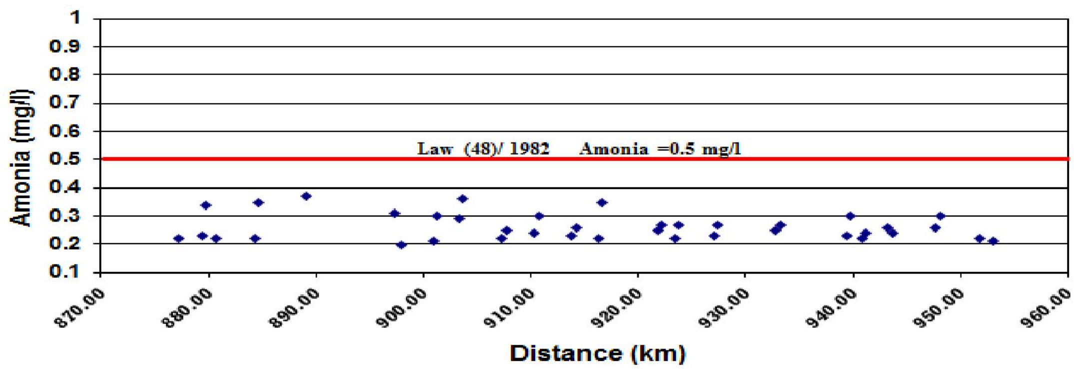

Figure (3e) Amonia Measured Values in the River Nile

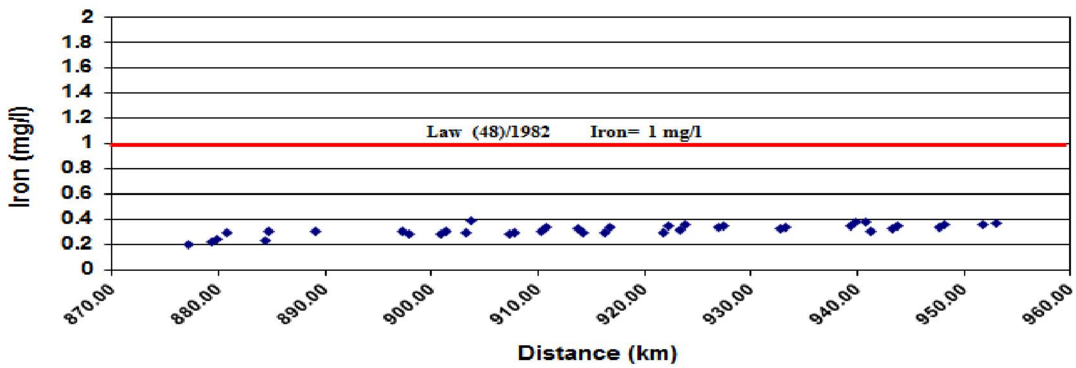

Figure (3f) Iron Measured Values in the River Nile

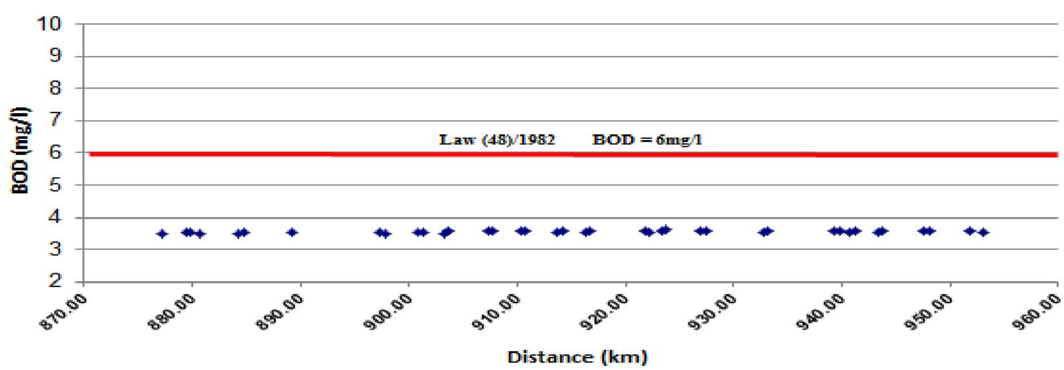

Figure (3g) BOD Measured Values in the River Nile

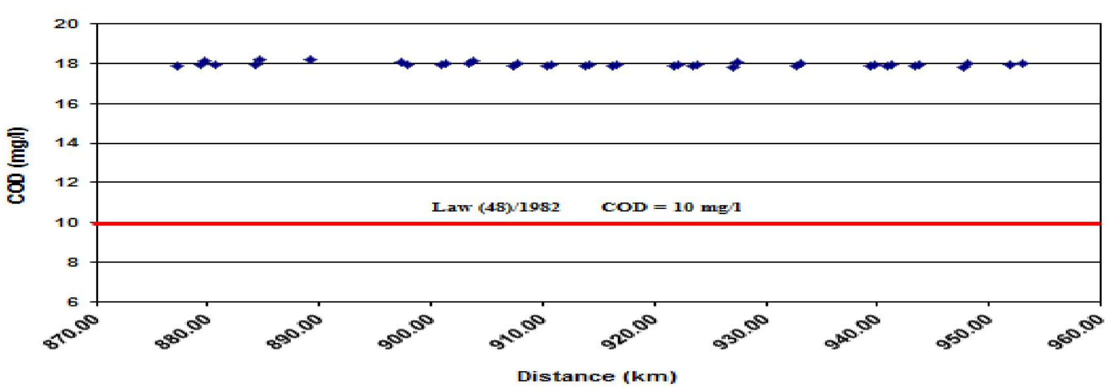

Figure (3h) COD Measured Values in the River Nile

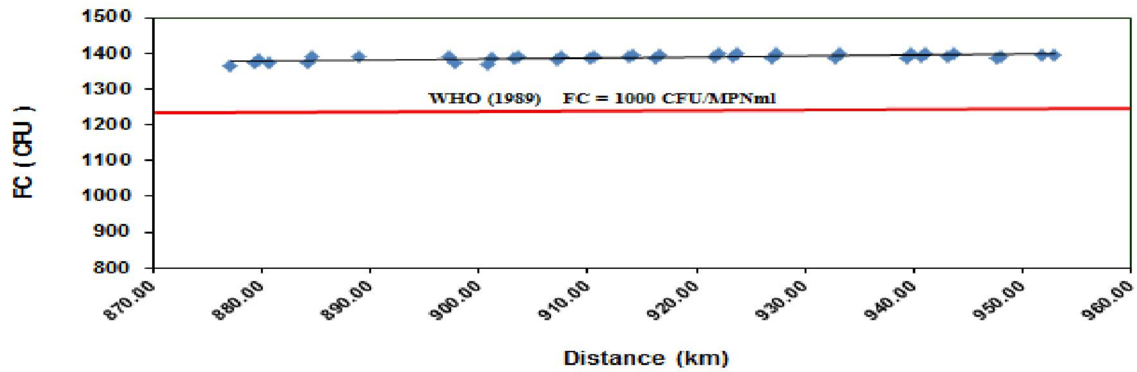

Figure (3i) BOD Measured Values in the River Nile

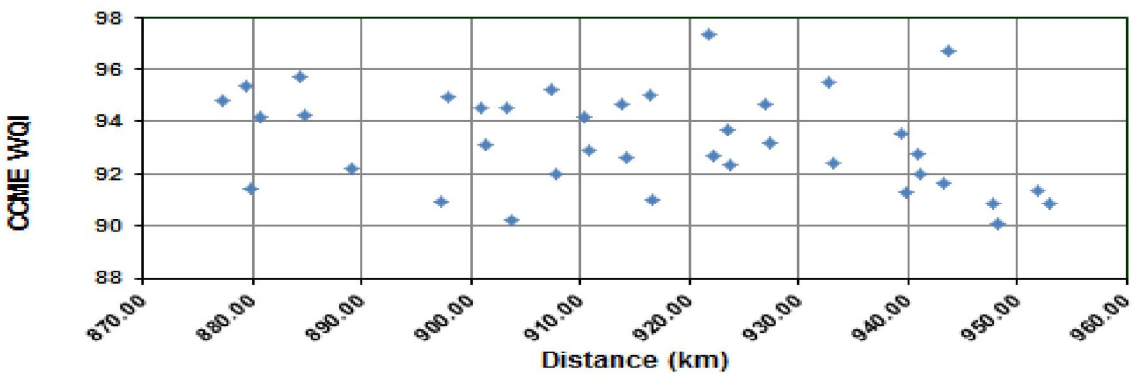

Figure (3j) Variation of CCME WQI

4. Conclusions

In this study, the water quality assessment was constructed to facilitate estimating WQI in various river locations. Based on CCME WQI, the water quality in Cairo reach was ranged from good to excellent. However, the CCME WQI study on this reach shows that the water can be used for drinking and different other purposes.

- The results of various water quality parameters proved that the water quality at the study area is impacted by a relatively high concentration of COD and FC due to treated or partially treated domestic wastewater and industrial wastewater mixed with agricultural drainage water discharged to the river.

From the study results, it has shown that the agricultural drain, industrial effluents and the DWPs sludge disposal have negative impacts on the water quality of the River Nile. This is explained by the increasing in concentration of the water quality parameters analyzed downstream after each discharge point as compared to upstream sites. Even though, some of the parameters measured during the study were within the acceptable guideline values recommended by Egyptian National water quality standards, Law 48/1982 regarding the protection of the River Nile and waterways from pollution.

It is high preferred to modify Egyptian National water quality standards, Law 48/1982 regarding the protection of the River Nile and waterways from pollution to state much effective restriction on different agricultural, industrial and domestic discharge disposal into the Nile River to ensure a sustainable water quality control.

-The required modification must set different allowable pollution discharge into the river as a hydraulic loads base instead of concentration base.

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2/18/2019