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THE IMPACT of CLIMATE CHANGE on THE SURFACE WATER QUALITY of DRINKING WATER TREATMENT PLANTS

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ABSTRACT

The climate change impacts on the Nile River water quality can be considered as one of the serious water resource management challenges in Egypt. Thus, this study highlights the climate change trends that affect the Nile water quality deterioration upstream of Cairo drinking water treatment plants (WTPs). However, input from Intergovernmental Panel Climate Change (IPCC) greenhouse emission climate data were assessed to determine the extreme future climate change impact scenarios on Nile flow. Consequently, Water Quality Analysis Simulation Program (WASP) was used to evaluate and predict the river hydrodynamics variation trends due to the climate change impacts. Two main water quality indices (WQIs) are involved in river water parameters are assessed to evaluate the current situation. Moreover, the study results revealed that future climate change has a noted effect on the water quality indices upstream Cairo drinking water treatment plants (WTPs). This affirms the need for many coordination and monitoring activities to verify the proper functioning of the waterways.

Keywords: ***Climate Change, Greenhouse Emission, Water Quality Modeling, Water Treatment Plants.***

1. INTRODUCTION

Climate change has serious impacts on Nile water accessibility [1]. Future changes and vulnerabilities within the assignment of Nile water allocation may have noteworthy impacts on agriculture, economic activities, and environmental conservation [2]. Due to these changes, the water treatment plants also can suffer from non-ideal treatment conditions taking place especially in rainy seasons that are anticipated to be prolonged with Climate change [3].

To evaluate the overall quality status, the water quality index can be considered a powerful tool to link the reflection of dominant water quality parameters with one standard number (index) [4]. A water quality index may be a helpful strategy to summarize complex water quality data and encourage its communication to supervisors and a common group of stakeholders.

Moreover, the climate change effect on water quantity takes more attention but a limited degree of certainty is known about its ability to change water quality status [5].

Increasing water temperatures and runoff variability with climate change also have a noted influence on various drinking water purification processes and consequently cause harmful effects on human water use [6].

Water quality analysis and simulation program (WASP) is a two-dimension hydrodynamic and pollutants transport model to simulate different water quality parameters and their interaction with the natural phenomena which supports management decisions [7].

In the framework of this study, the global climate variability effect on distinctive surface water quality indices is investigated to evaluate its impact on the raw water source of seven Cairo WTPs along the Nile River.

2. STUDY AREA

Figure (1) illustrates the locations of Cairo drinking water treatment plants (WTPs) along the Nile River. From which, the scope of this study includes Tibetan, Kafr Elw, North Helwan, Maadi, Fostat, El Roda, and Rod Farg WTPs.

3. MATERIAL and METHOD

In this consider, climate information alter projections and statistic changes were collected. Afterward, the global climate change impacts on two distinctive water quality (WQI, CCME 2001); WQI Weighted Method) for the Nile River fourth reach including the study’s WTPs were developed. Subsequently, future estimation for the water quality indices of Nile River upstream Cairo drinking water treatment plants was developed using a two-dimensional, laterally averaged, finite difference hydrodynamic and water quality module, WASP.

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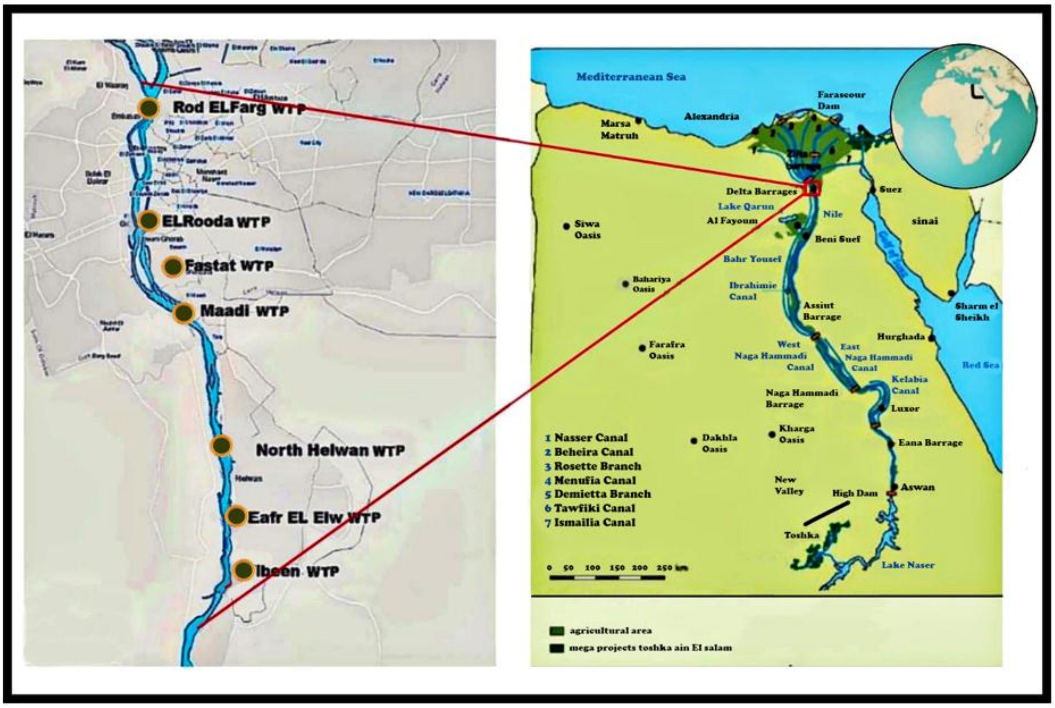

Figure (1) Study Area

3.1 Climate Change Projection

Regarding the IPCC's Special Report on Emissions Scenarios (SRES) [8], new projections of future greenhouse gas emissions are developed. The driven emissions scenarios eventually focused on six SRES scenarios as shown in Figure (2).

It is obvious from Figure (2) that a noted future impact of climate change on Nile stream flow especially of the expected dry climate scenario leads to a gradually decreasing percentage of -15%, -20%, and -31% for 2050,2075, 2100 respectively. This can ensure that the Nile River discharge is also very strongly correlated to temperature changes.

3.2 Water Quality Evaluation

As mentioned above, two water quality indices were developed to evaluate the river water quality state upstream of Cairo's drinking water treatment plants.

A- CCME WQI Method

The technique of CCME WQI method, developed by the Canadian water quality index, (CCME, 2001) is based on three main criteria: scope, frequency, and amplitude.

The field measurements were compared with the corresponding national Egyptian values (law 48/1982), Table (1).

In addition, the corresponding ranks of WQI values are determined as shown in Table (2).

Table (1) Selected Water Quality Variables for CCME Method

Rank	Egyptian National Guidelines, Law48/1982
pH	6.50 - 8.50
DO	$\geq$ 6.00 mg/l
BOD	$\leq$ 6.00 mg/l
TDS	$\leq$ 500 mg/l
NO3	$\leq$ 2.00 mg/l
NH3	$\leq$ 0.50 mg/l
Iron	$\leq$ 0.50 mg/l

Table (2) Water Quality Index Classification, (CCME, 2001)

Rank	WQI Value
Excellent	From 95 up to 100
Good	From80 up to 94
Fair	From 65 up to79
Marginal	From 45up to 64
Poor	From 0 up to 44

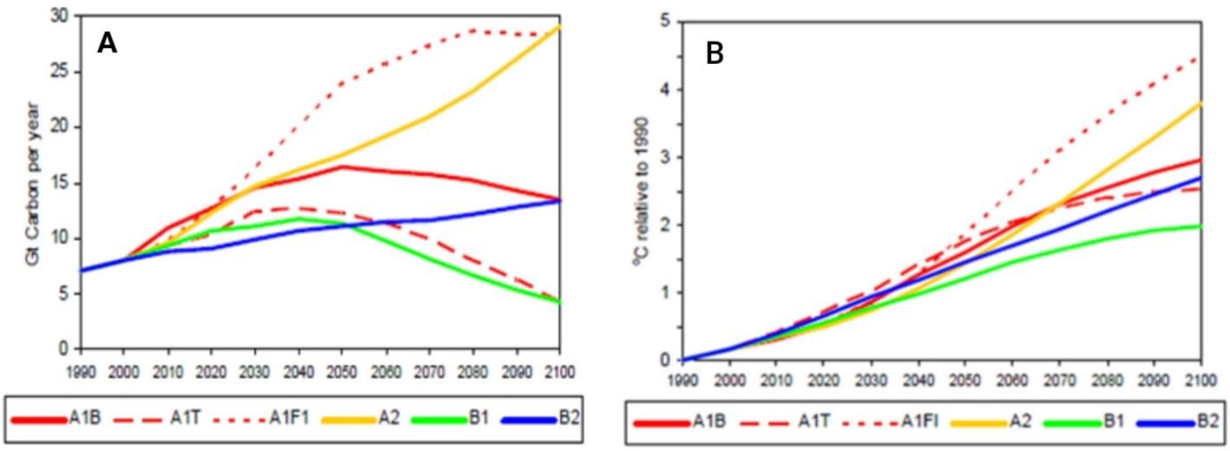

Figure (2) IPCC SRES scenarios of A: Carbon emissions and B: Temperature change

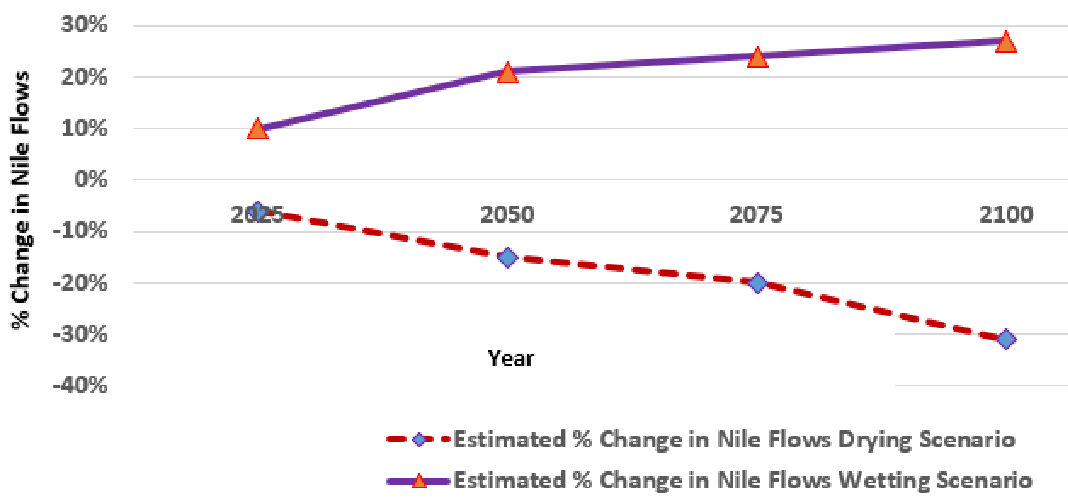

Figure (3) Climate Changes Scenarios Summary

A- WQI Weighted Method

This method is a broadly utilized strategy, the WQI is determined as the weighted of different sub-record scores [10]. Parameter scores are amassed into one evaluating number (between and 100).

The selected water quality parameters are: DO, Conductivity, pH, BOD, water temperature (Tw), NH3, NO, Turbidity (T), Fecal Coliform (FC). The weighted WQI is calculated according to Eq.(1).

$$\mathrm{WQI} = \frac{\sum_i C_i P_i}{\sum_i P_i} \qquad (1)$$

Where: Pi and Ci are the relative weights and normalized values of the selected water quality sub-index.

3.3 Mathematical Modeling

The water quality model (WASP 7.5) was used hydrodynamic for simulation river water quality characteristics upstream Cairo drinking water treatment plants. In addition, the formation of WASP mathematical modeling is mainly based on finite difference as shown in equation (2), [11, and 12]:

$$\frac{\partial}{\partial t}(AC)\ \frac{\partial}{\partial x}\left((U_x AC| + E_x A\frac{\partial C}{\partial x}\right) + A(S_L + S_B) + AS_K \qquad (2)$$

Where A = cross-sectional area (m2). The three major classes of water quality processes of transport (term 1), loading (term 2), and transformation (term 3) are all represented in Eq. (3).

4. RESULTS AND DISCUSSION

4.1 Current Water Quality Indicators

At the initiation phase of the study, an assessment of the current surface water characteristics is implemented. Figure (4) illustrates the annual results of surface water samples that were taken upstream of the studied WTPs within various seasons of the year 2020.

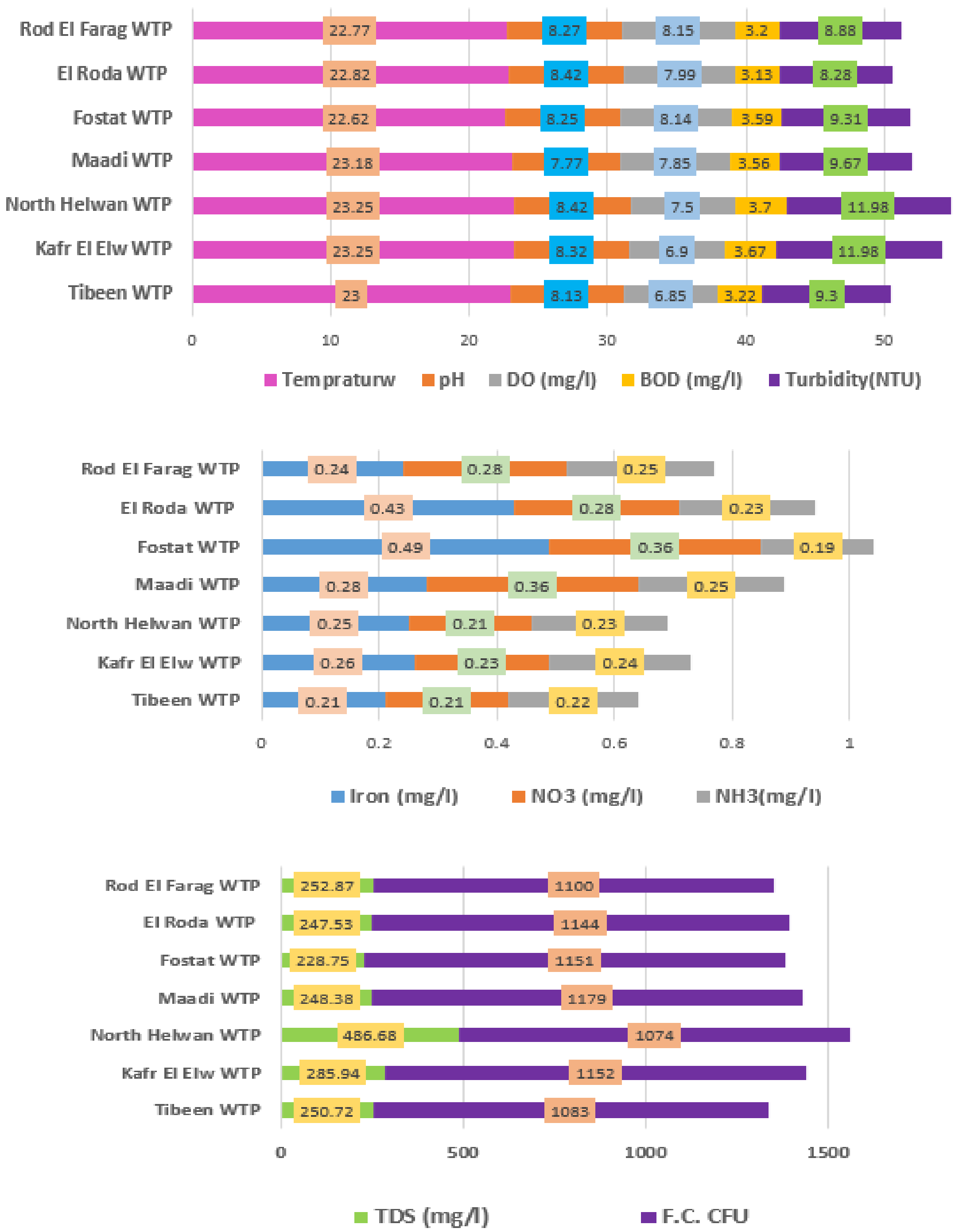

Figure (4) Current Water Quality Indicators

It can be noted that most surface water quality indicators comply with the Egyptian national guidelines. In addition, the mean annual fecal coliform (FC) values of collected surface water samples were then compared with WHO (1989) as a guideline for use of water for unrestricted irrigation (FC≤1000MPN/100ml). Thus, the high mean values of FC exceed the mentioned guidelines. After that, a baseline for current surface water quality status was implemented through two different methods for water quality indices. Figure (5) shows the overall WQI upstream study's WTPs based on both of CCME method and the WQI weighted method.

According to both of CCME and Weighted WQIs results, it can be noted that the surface water quality upstream Cairo WTPs can be classified into two main categories "Good" and "excellent ".

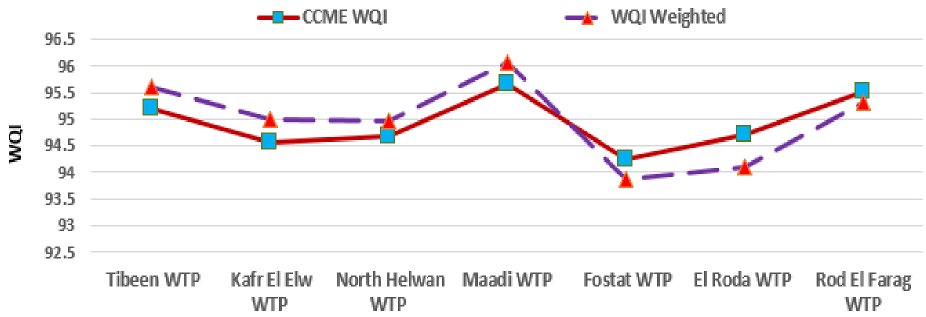

Figure (4) CCME and Weighted WQIs

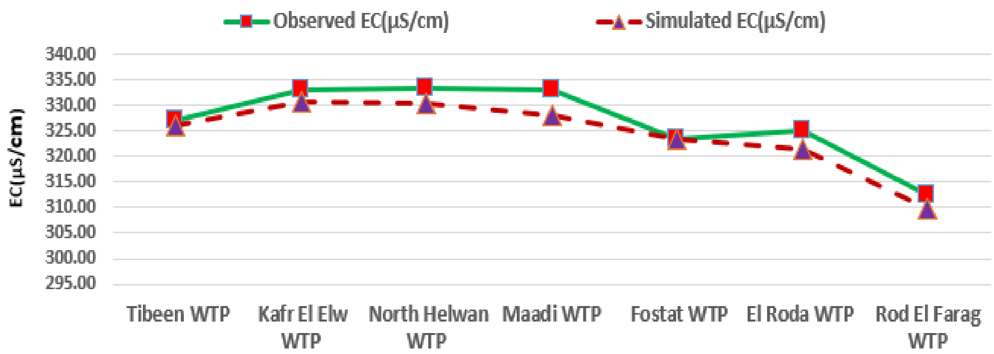

Figure (5) Observed and Simulated EC (µS/cm)

4.2 Hydrodynamic Modeling

The WASP model network is consisting of several segments; which together represent the water body. surface water, and subsurface. In this study, the boundary conditions included 26 segments to represent various hydrodynamic conditions upstream Cairo WTPs along the Nile. Before running the WASP with a water quality sub-model (Euro Sub-model), a model calibration was implemented by using electric conductivity to check the flow as it is considered as an excellent conservative substance and as a water mass tracer. The quantitative measures of the climate impact on water quality upstream Cairo WTPs will be measured through two water quality indices CCME The network was constructed in a 2-D direction, segments in WASP were classified into four categories:

The calibration runs were carried out for a set of data for the year 2019. Before initiating the WASP run, the TOXI sub-model is used to simulate the electric conductivity. Figure (5) shows the observed and simulated EC (µS/cm) values upstream WTPs. It is obvious that a good matching between observed field measurements and modeled EC results (Correlation coefficients = 0.83).

4. 3 Climate Change Impact Estimates

WQI and Weighted WQI. Thus, the effect of climate change on the mentioned indices was calculated relative to the base year results (2020) with the aid of WASP simulated results. In doing so, four main time phases (2025, 2050, 2075, and 2100) for each of the two main scenarios were considered in developing the future climate change impact on the Nile river and subsequently, the water quality indices change upstream Cairo WTPs. Figures (6) illustrate the impact of both wet and dry climate changes scenarios on CCME WQI and Weighted WQI, respectively.

Moreover, there is an upgrade of both water quality evaluation indices state from “Good” to “Excellent” classification through applying wet scenarios. While it is clear that there is a significant decrease in the two evaluating water quality indices relative to the base scenarios due to applying dry scenarios.

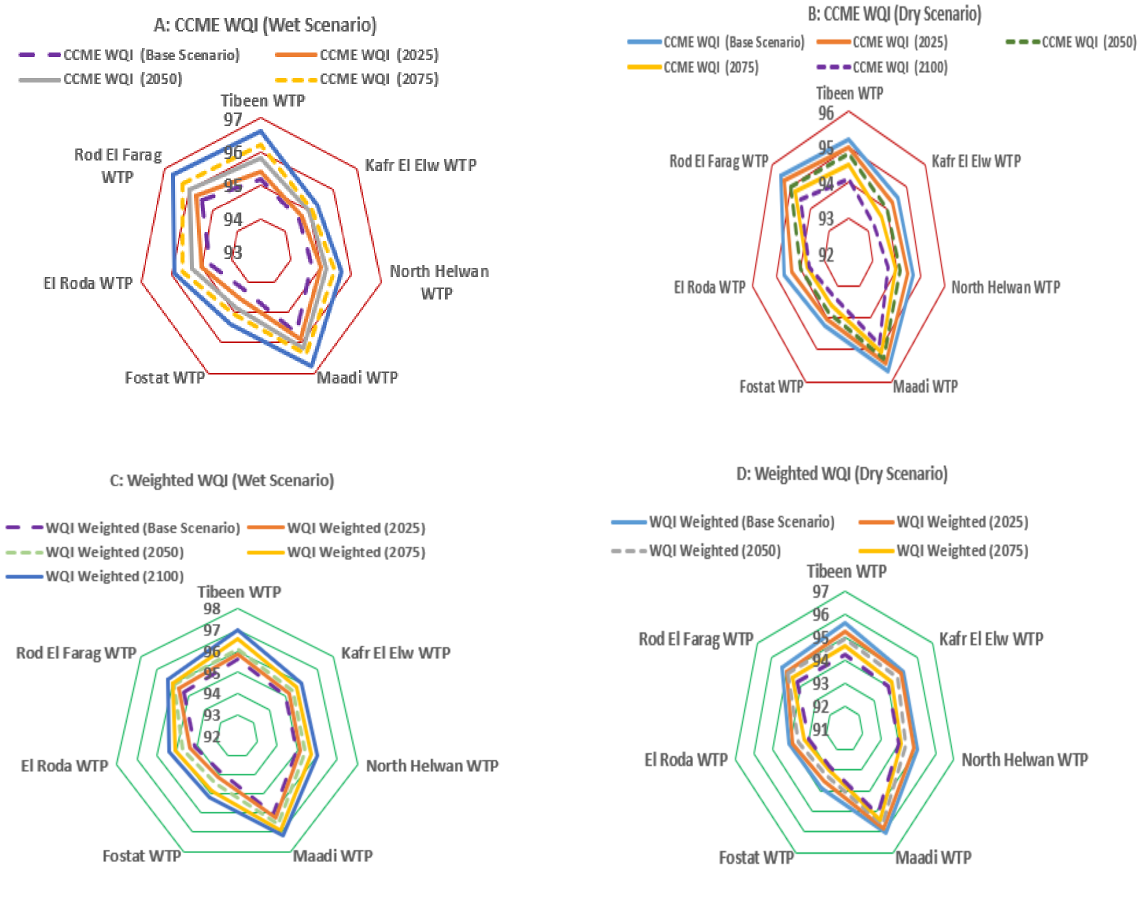

Figure (6) Climate Changes Impact scenarios on Water Quality Indices

5. CONCLUSIONS

The study results show that future climate change has a relative effect on the investigated indices. Climate change will decrease the two water quality indices of surface water upstream Cairo WTPs in the case of a dry scenario. However, it is highly recommended to continue monitoring intakes water quality indicators to ensure their compliance with national waterways guidelines.

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