
# Impact of global warming on dissolved oxygen concentrations in rivers and on the waste load allocation plan of rivers; Case Study: River Nile, Egypt

**By**

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# Presentation Outline

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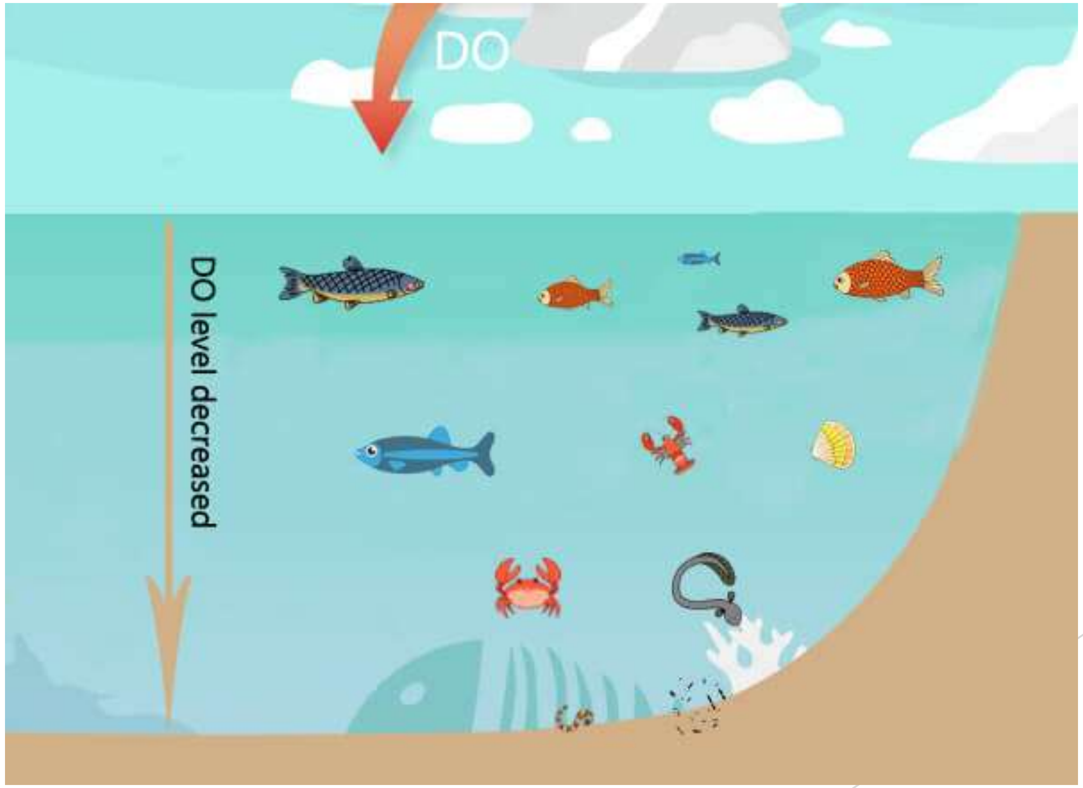
# Objective of the Research Study

The aim of this research is to predict the critical Dissolved Oxygen (DO) concentration values in the Nile River as a result of the global warming effects. This is over 23 years during the period from 1990 till 2012. Another aim of this research is to monitor and predict the DO concentration values in Nile River from 2013 up to 2030 as a result of global warming effects. This is important to study, because it will affect the waste load allocation plan of rivers and the location of water treatment plants on rivers

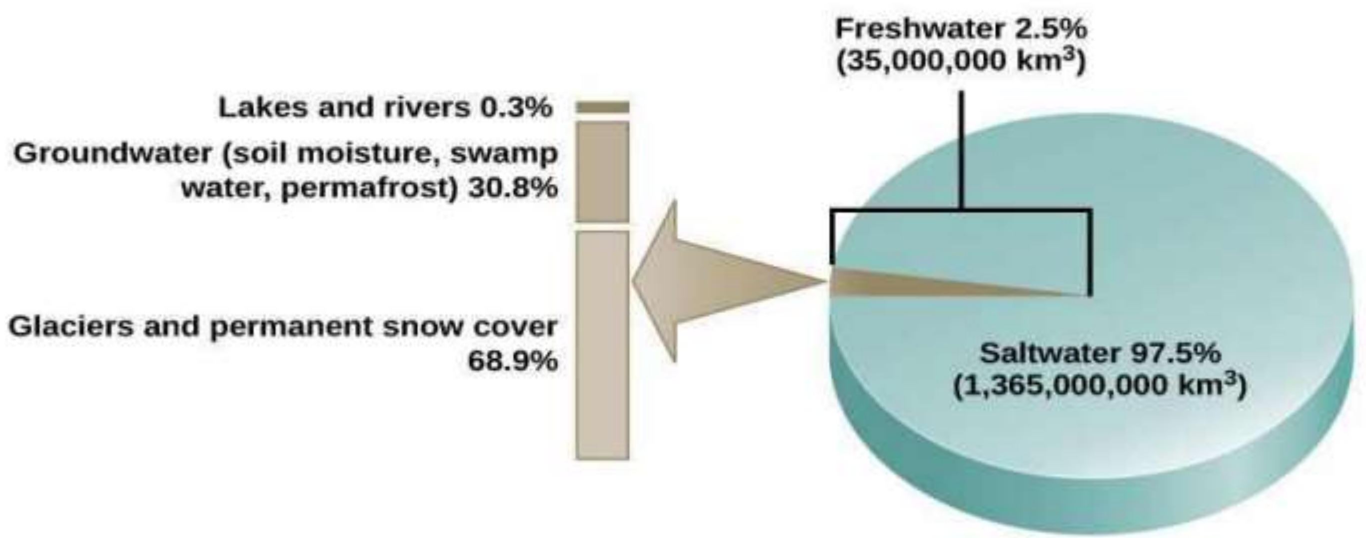


# Water Quality and Water resources distribution

- Water is the hub of life and driver of nature.
- Water quality is one of the most important concerns nowadays all over the world.
- Monitoring and improving water quality is considered as one of the key factors in the water quality management strategies.
- Water quality is extremely important to all countries and particularly in regions that depend mainly on water as a main source of life, like Egypt.
- What water quality parameters?
  - Chemical
  - Physical
  - Biological
- Why is water quality important to study, predict and monitor?

# Water Resources Distribution

Water is one of the main sources of Life on earth, all life aspects are mainly depending on water. But just how much water exists on, in, and above our planet? About **71 percent of the Earth's surface is water-covered** The majority of water on the Earth's surface around **96 % is saline water** in the oceans. And **only 3 % is fresh water .**This small percentage of fresh water increases the importance of water and water quality management systems



# Global Warming and its Cause?


Global warming is the long-term heating of Earth's surface observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere. This term is not interchangeable with the term "climate change."

# Climate Change

Climate change refers to long-term shifts in temperatures and weather patterns due to global warming. So Climate change is an effect of global warming

# Amount of Temperature Rise of Earth


According to NOAA's (National Oceanic and Atmospheric Administration) 2021 Annual Climate Report the combined land and ocean temperature has increased at an average rate of 0.14 degrees Fahrenheit ( 0.08 degrees Celsius) per decade since 1880; however, the average rate of increase since 1981 has been more than twice as fast: 0.32 ˚F (0.18 ˚C) per decade.

# Main Effects of Global Warming and Climate Change

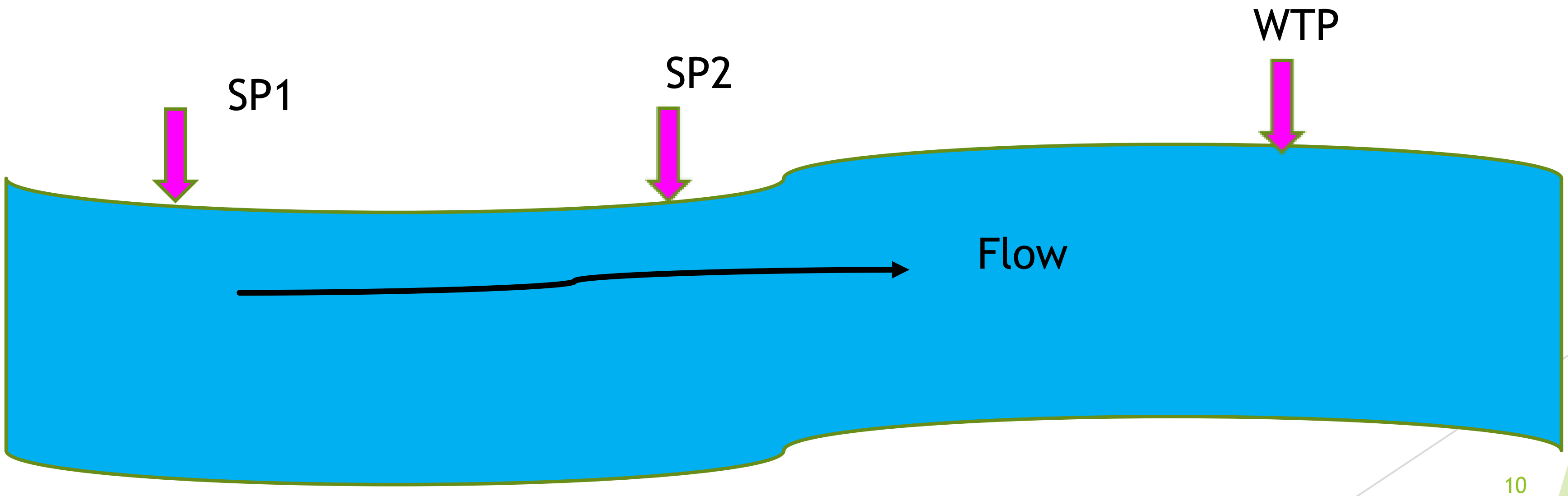
**Drought**

**Flooding**

*Sea rise
*Change of coastal shoreline
*Sinking of deltas

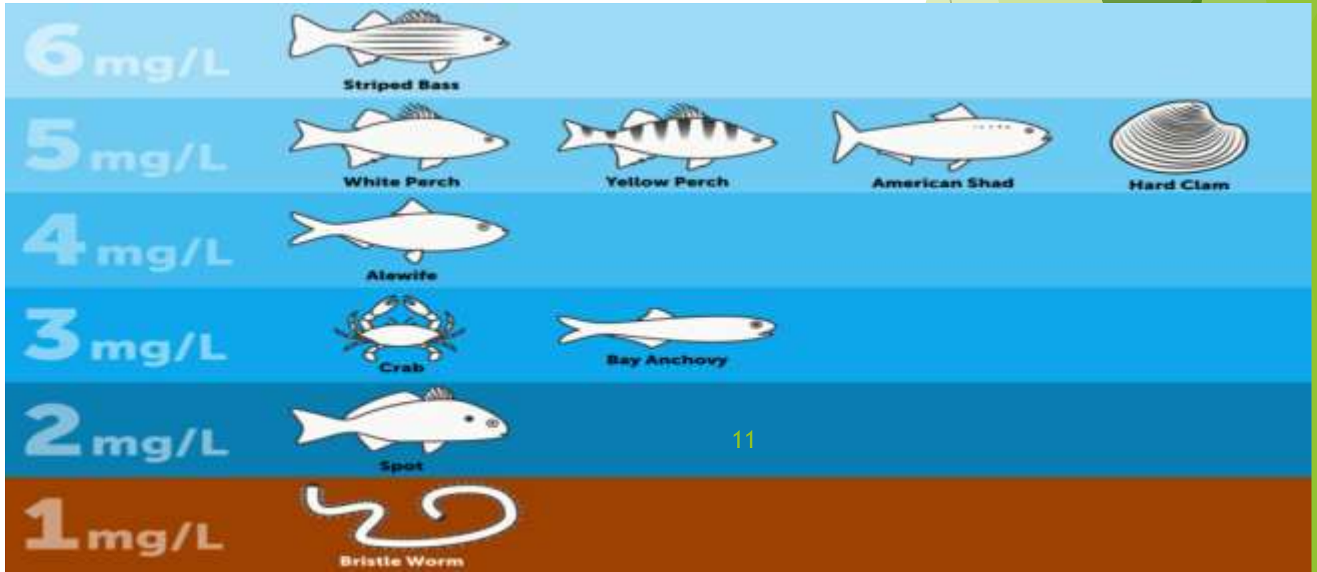
# Waste Load Allocation Plan of rivers

- **River waste load allocation plan**



# Dissolved oxygen (DO) concentration

- DO is one of the major parameters that are considered an essential indicator of the quality of water used by humans ;as well as, aquatic flora and fauna.
- The presence of DO is very essential for maintaining the aquatic life. It is maintained by many natural chemical and biological processes that either increase or decrease local oxygen concentrations
- One of the major factors affecting dissolved oxygen in streams is temperature. An increase in temperature reduces solubility of oxygen in water and consequently reduces the dissolved oxygen level in water.
- Different DO standards for different water usages and for different species in water
  - River water not less than 5 mg/l
  - Potable water from 7 mg/l to 9 mg/l
  - Irrigation water around 4 mg/l

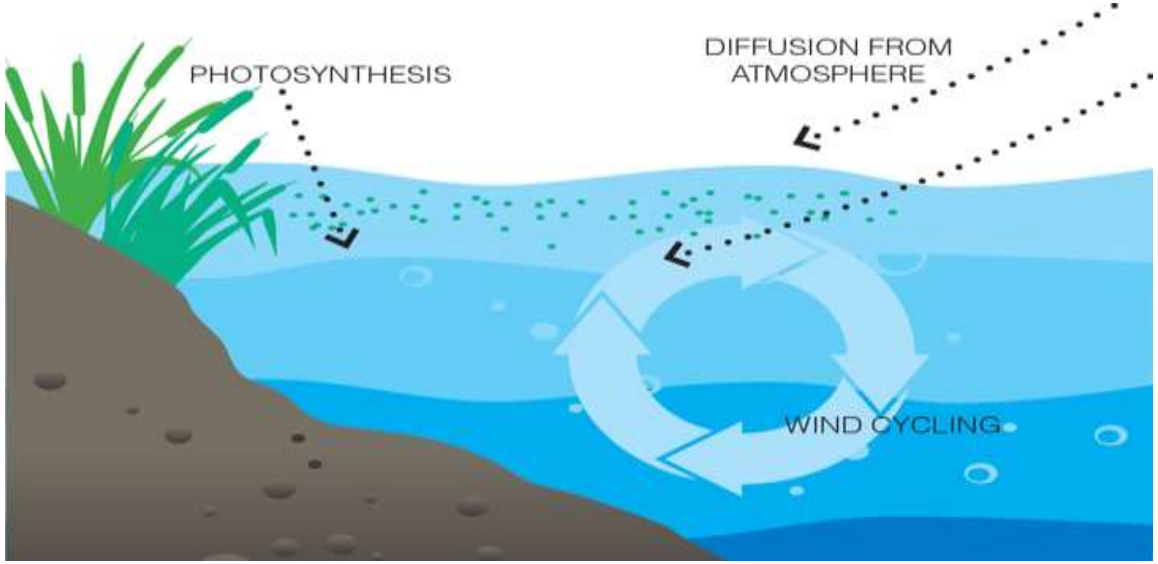


# Dissolved oxygen (DO) concentration

## Mass Balance Equation

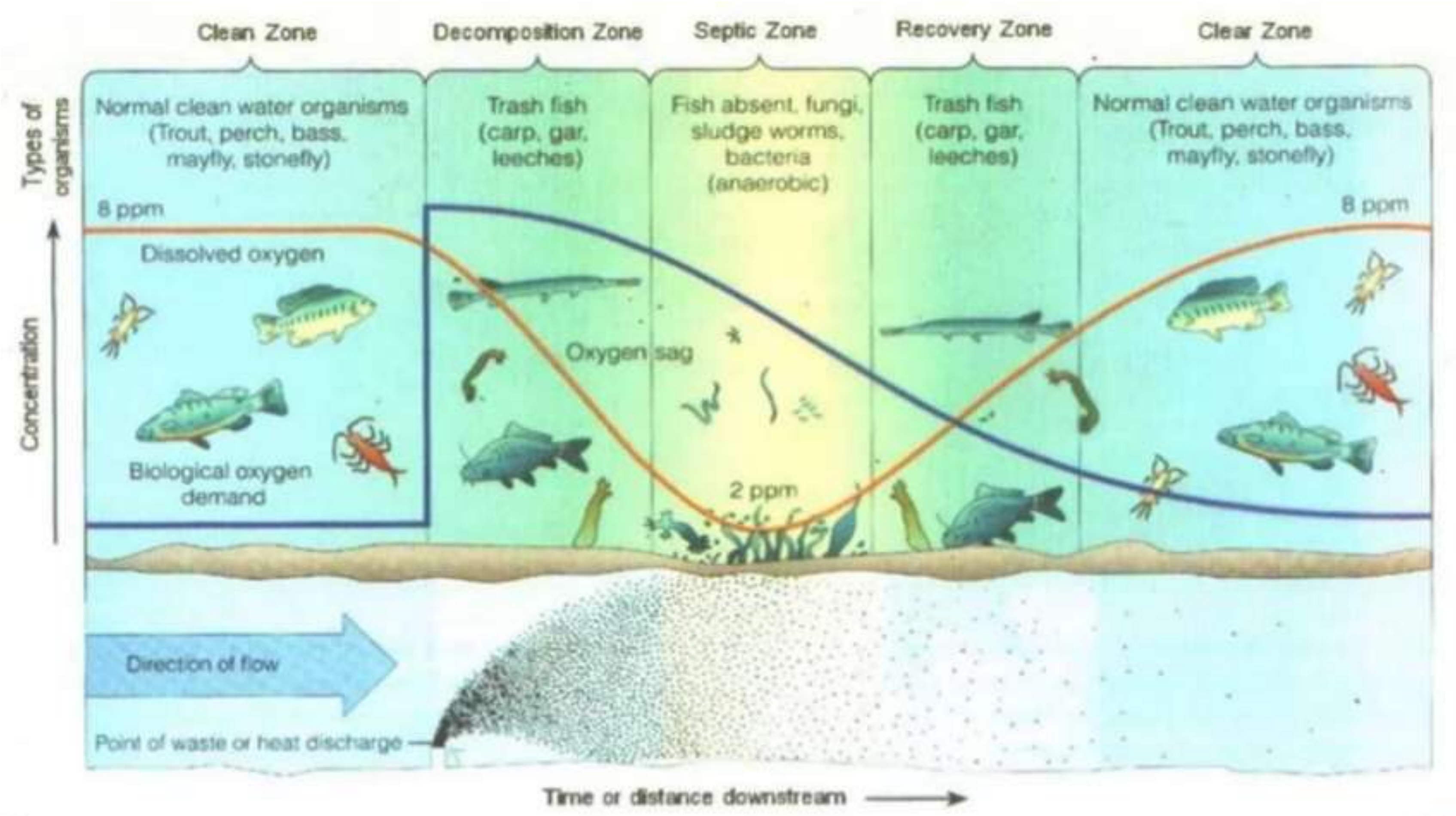
**Outflow = Inflow + change over control volume**

Inflow concentration → BOD, Photosynthesis, Respiration, Reaeration → Outflow concentration



# Water Quality Modelling

## Dissolved oxygen (DO) concentration and Sag Curve



## Impact of Global Warming on DO Concentrations in rivers; Case study: Nile River, Egypt

## Problem Statement

- Egypt is one of the most vulnerable countries to the potential impacts and risks of climate change, even though it produces less than 1 % of the world total emissions of greenhouse gases. Numerous studies showed that River Nile is very sensitive to temperature and precipitation changes.

- Although several studies were conducted on River Nile in different fields, there is lack of researches concerning the effect of global warming on the quality of the River Nile, in particular dissolved oxygen levels.

- Global warming might increase the stress on Rosetta Branch of the River Nile and decline its water quality since higher water temperatures reduce dissolved oxygen levels, especially for low concentrations

# Impact of Global Warming on DO Concentrations in rivers; Case study: Nile River, Egypt

## Methodology

- This paper studies the effect of global warming on dissolved oxygen critical concentrations and thus the sag curve for the River Nile.

- This study aims to investigate the effect of global warming on rivers' water quality. The effect of global warming during years 1990 to 2012 on dissolved oxygen (DO) critical concentrations and hence on its sag curve is investigated. The study is done on the Nile River in Egypt at two monitoring stations; namely at Luxor governorate (upstream the Nile River) and at Alexandria governorate (downstream the River). A mathematical model is constructed to simulate the DO critical values and the DO sag curves at different water temperatures. The study is investigating two scenarios; namely it simulates the critical DO concentration in summer (month August) where the Nile reaches its peak discharge in Egypt. Also it simulates the critical DO values in winter (month February) where the lowest discharge in the Nile in Egypt is reached. The study used air temperatures of years 1990 to 2012 to predict the Nile River water temperatures at the two above mentioned stations.

- Also in this research a mathematical model was developed to predict air temperatures from 2013 till 2030 and hence predict the values of water temperatures and DO concentrations for the same period of years (2013-2030). This is through using previous information and establishing a trend line and thus an equation that predicts air temperatures, water temperatures and DO concentrations for future

# Impact of Global Warming on DO Concentrations in rivers; Case study: Nile River, Egypt

## Methodology

- Mathematical modeling on Excel spreadsheet
- The different components of the model could be described as follows:

- Predicting water temperatures from given air temperatures. Air temperatures of 13 successive years (from 1990 to 2012) were used to predict water temperatures. The values for the air temperatures used were those of the month of February and the month of August (meaning the average temperature of all temperatures through the month of August was taken for each year from 1990 to 2012). Same was done for the month of February.

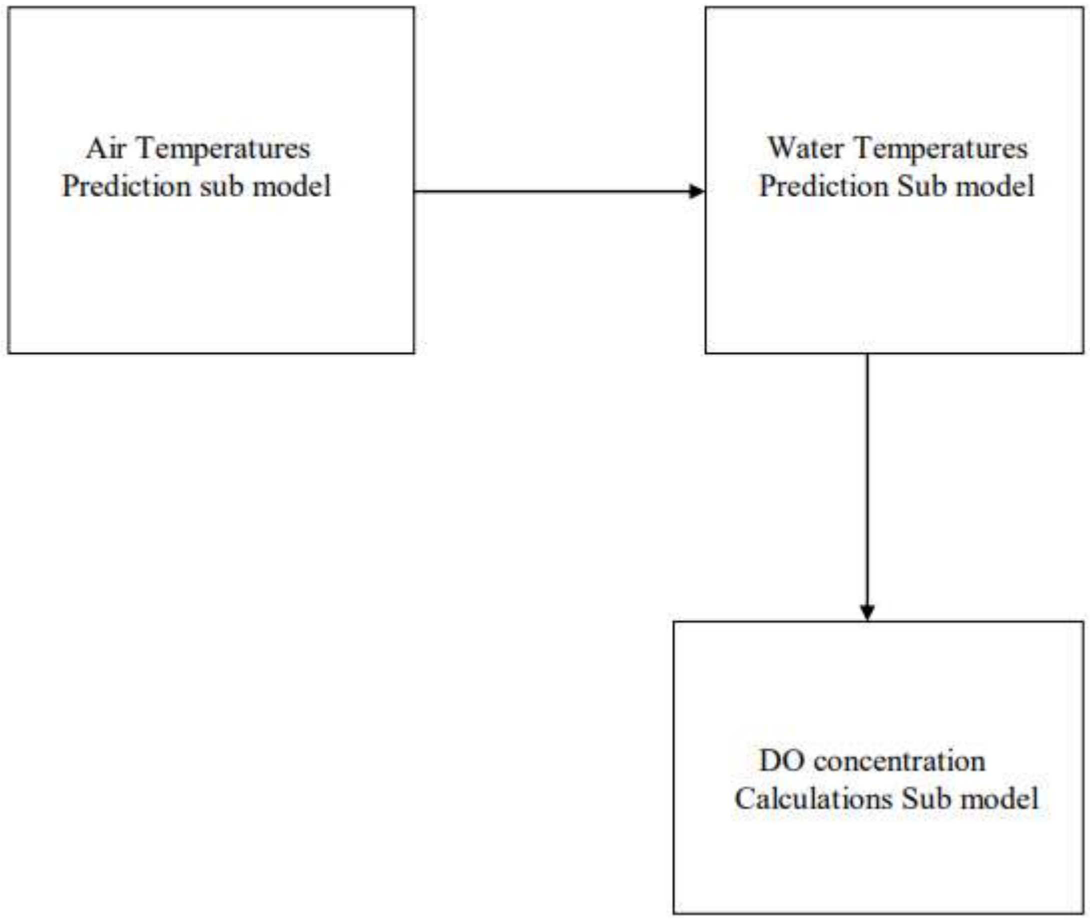
- In order to predict water temperatures from air temperatures the equation of Heinz [6] which takes into consideration the lag time between air and water temperature was used.

- The simulated water temperatures of the Nile River were used to calculate the critical DO concentrations via the Streeter-Phelps equation

- February is the month in the winter at which the River Nile (in Egypt) reaches its lowest discharge. August it is the month in the summer at which the Nile reaches its peak discharge

# Impact of Global Warming on DO Concentrations in rivers; Case study: Nile River, Egypt

## Methodology



# Impact of Global Warming on DO Concentrations in rivers; Case study: Nile River, Egypt

## Methodology

The water temperature and DO critical concentrations were calculated at two gage station on the Nile River in Egypt namely; the first station is at Luxor which is at the upstream end of the Nile River and the second station at Alexandria which is at the downstream end of the river as in the figure

# Mathematical Model Formulation

## Air and water temperature calculations:

$$Tw(t) = A + \frac{\Delta Tw}{\Delta Ta} * Ta(t - \delta)$$

$$\delta = \frac{\tau}{2\pi} * \tan^{-1}\left(\frac{2\pi * depth}{\tau * \alpha}\right)$$

$$\alpha = \frac{K}{C_p * \rho}$$

$$\frac{\Delta Twater}{\Delta Tair} = \frac{1}{\sqrt{1 + \left(\frac{2 * \pi * depth}{\tau * \alpha}\right)^2}}$$

## Dissolved Oxygen calculations:

$$D_t = \frac{K_1 L_0}{K_2 - K_1}(e^{-K_1 t} - e^{-k_2 t}) + D_0 e^{-K_2 t}$$

$$t_c = \frac{1}{K_2 - K_1} \ln[\frac{K_2}{K_1}(1 - D_0 \frac{K_2 - K_1}{K_1 L_0})]$$

$$(K_1)_T = (K_1)_{20} 1.047^{T-20}$$

$$(K_2)_T = (K_2)_{20} 1.024^{T-20}$$

$$D_c = C_s - C_c$$

# Results

DO CRITICAL CONCENTRATIONS VS. STATION AND MONTH

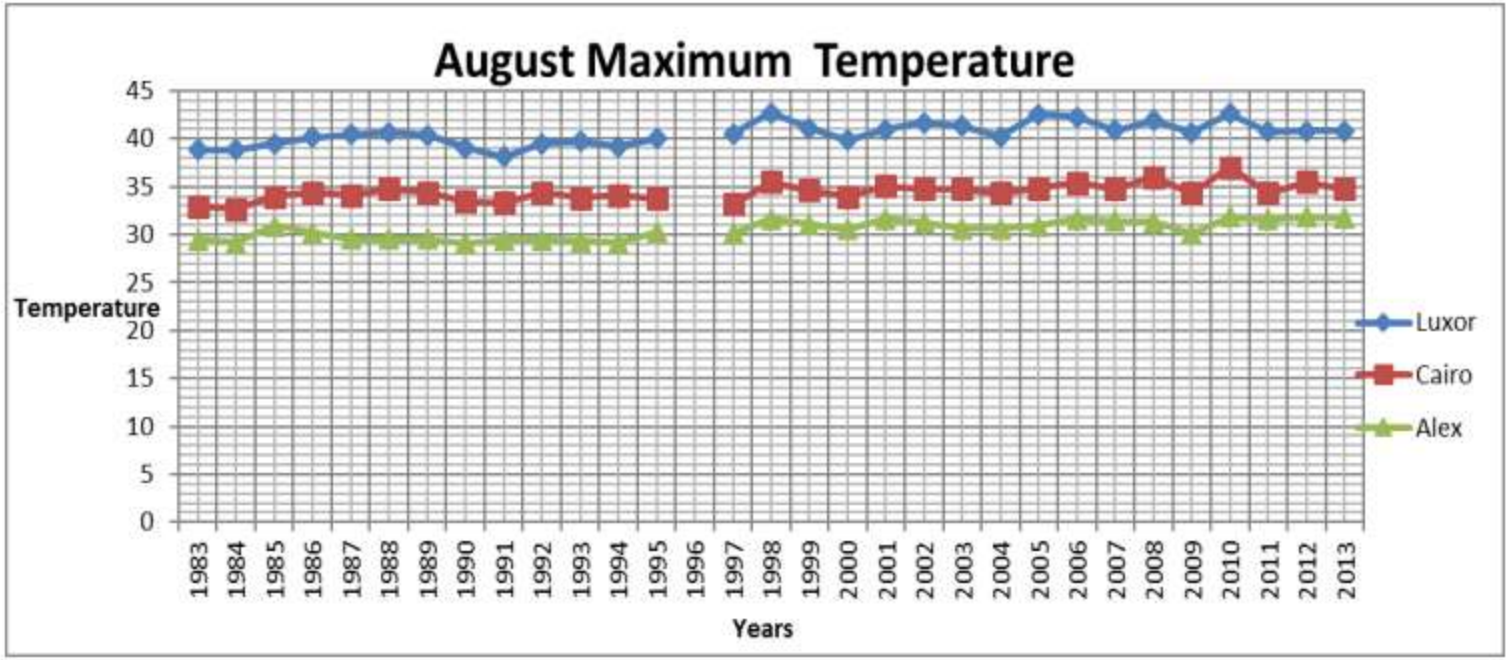
| | Water T.; °C | Lo; mg/L | Dc ;mg/L | Cs; mg/L | Cc; mg/L | % dec. in Cs |
|---|---|---|---|---|---|---|
| **Luxor February** | 19 | 6 | 2.81 | 9.26 | 6.45 | 3.8 |
| | 21 | 6 | 2.70 | 8.90 | 6.20 | |
| **Luxor August** | 24 | 6 | 2.56 | 8.40 | 5.84 | 4.0 |
| | 26 | 6 | 2.48 | 8.09 | 5.61 | |
| **Alexandria February** | 17 | 3.7 | 2.14 | 9.65 | 7.51 | 1.4 |
| | 18 | 3.7 | 2.04 | 9.45 | 7.41 | |
| **Alexandria August** | 20 | 3 | 1.63 | 9.07 | 7.44 | 5.4 |
| | 24 | 3 | 1.37 | 8.4 | 7.03 | |

# Mathematical Model Calibration

MODEL SIMULATED DO CRITICAL CONCENTRATIONS VS. REAL LIFE DO CONCENTRATIONS

| | Water Temp.; °C | Cc; mg/L | Avg. Cc;mg/L | Actual DO; mg/L | % error |
|---|---|---|---|---|---|
| **Luxor February** | 19 | 6.45 | 6.33 | 5.96 | 5.7 |
| | 21 | 6.20 | | | |
| **Luxor August** | 24 | 5.84 | 5.72 | 6.09 | 6.3 |
| | 26 | 5.61 | | | |
| **Alexandria February** | 17 | 7.51 | 7.46 | 7.43 | 0.4 |
| | 18 | 7.41 | | | |
| **Alexandria August** | 20 | 7.44 | 7.24 | 6.68 | 7.7 |
| | 24 | 7.03 | | | |

# Air Temperatures for Cairo, Alexandria and Luxor 1983 till 2013



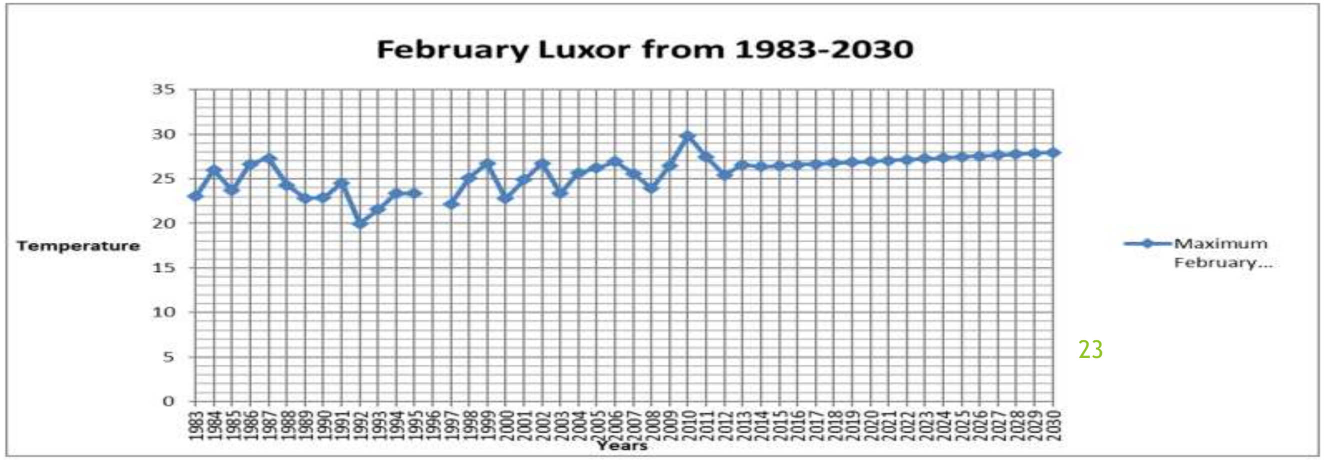

From the figure, it can be concluded that air temperatures curves for the 3 cities in February and August during the 30 years from 1983 till 2013 has always been in a rising trend. The average of increasing through the whole time length is from (1.7- 2.5) degree Celsius.

# Results for predicting till 2030 for Cairo, Alexandria and Luxor

Following figures use the data of air temperature from 1983 till 2013 (shown in previous figure as an example) and then draw a trend line, get its equation, then predict temperatures till 2030.

Kindly note this is an example for Luxor in the month of February

Results: total average increase from 1983- 2030 is between 3-4 degree Celsius

# Results for predicting till 2030 for Cairo, Alexandria and Luxor

**Air temperature predicted till 2030 for Luxor in February**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Temperature | . | | | | | | | | |
| February | | | | | | | | | |
| Luxor | | | | | | | | | |
| Year | Average | Year | Average | Year | Average | Year | Average | Year | Average |
| 1983 | 23.0 | 1993 | 21.5 | 2003 | 23.3 | 2013 | 26.5 | 2023 | 27.2 |
| 1984 | 26 | 1994 | 23.3 | 2004 | 25.6 | 2014 | 26.3 | 2024 | 27.3 |
| 1985 | 23.6 | 1995 | 23.3 | 2005 | 26.1 | 2015 | 26.4 | 2025 | 27.4 |
| 1986 | 26.6 | 1996 | | 2006 | 26.9 | 2016 | 26.5 | 2026 | 27.5 |
| 1987 | 27.2 | 1997 | 22.1 | 2007 | 25.5 | 2017 | 26.6 | 2027 | 27.6 |
| 1988 | 24.2 | 1998 | 25.0 | 2008 | 23.9 | 2018 | 26.7 | 2028 | 27.7 |
| 1989 | 22.8 | 1999 | 26.7 | 209 | 26.4 | 2019 | 26.8 | 2029 | 27.8 |
| 1990 | 22.8 | 2000 | 22.7 | 2010 | 29.8 | 2020 | 26.9 | 2030 | 27.9 |
| 1991 | 24.5 | 2001 | 24.8 | 2011 | 27.4 | 2021 | 27.0 | | |
| 1992 | 19.9 | 2002 | 26.7 | 2012 | 25.4 | 2022 | 27.1 | | |
| | | | | | | | | | |

**Water temperature is calculated using Heins equation with all the previous mentioned parameter and the air temperatures.**

| | | | |
|---|---|---|---|
| Luxor Feb. water data | | | |
| B | 0.89 | | |
| s | 0.085625 | | |
| A | 2 | | |
| Year | Temperature | Year | Temperature |
| 2009 | 19.53 | 2020 | 21.93 |
| 2010 | 19.56 | 2021 | 21.94 |
| 2011 | 19.67 | 2022 | 21.97 |
| 2012 | 19.7 | 2023 | 21.99 |
| 2013 | 19.71 | 2024 | 22 |
| 2014 | 21.44 | 2025 | 22.9 |
| 2015 | 21.52 | 2026 | 23.5 |
| 2016 | 21.6 | 2027 | 24.5 |
| 2017 | 21.68 | 2028 | 24.5 |
| 2018 | 21.77 | 2029 | 24.6 |
| 2019 | 21.85 | 2030 | 24.7 |

# Critical DO (Cs) Predictions for Cairo, Alexandria and Luxor

| | Water Temperature ( degree Celsius) | BOD (mg/l) | Dc (mg/l) | Cs mg/l | Cc mg/l | % decrease in Cs |
|---|---|---|---|---|---|---|
| Luxor February | 19 | 6 | 2.75 | 9.26 | 6.51 | 3.99 |
| | 21 | 6 | 2.65 | 8.9 | 6.25 | |
| | | | | | | |
| Luxor August | 24 | 6 | 2.54 | 8.4 | 5.86 | 4.26 |
| | 26 | 6 | 2.48 | 8.09 | 5.61 | |
| | | | | | | |
| Cairo February | 18 | 3 | 2.47 | 9.65 | 7.18 | 4.038 |
| | 19 | 3 | 2.37 | 9.26 | 6.89 | |
| | | | | | | |
| Cairo August | 22 | 2.3 | 2.09 | 8.72 | 6.63 | 4.82 |
| | 25 | 2.3 | 1.93 | 8.24 | 6.31 | |
| | | | | | | |
| Alexandria February | 17 | 3.7 | 2.24 | 9.65 | 7.41 | 1.34 |
| | 18 | 3.7 | 2.14 | 9.45 | 7.31 | |
| | | | | | | |
| Alexandria August | 20 | 3 | 1.573 | 9.07 | 7.497 | 5.16 |
| | 24 | 3 | 1.29 | 8.4 | 7.11 | |

Results for the 3 cities showed: Each city for each month has two different temperatures these are the lowest and highest water temperature occurred more than once in the water temperature calculations tables and accordingly the Cs was calculated between these 2 temperatures

# Model Calibration

## Max Air temperature calibration for Luxor in August

| Year | Extracted from website | Error % |
|---|---|---|
| 2000 | 40.59 | -1.85 |
| 2001 | 40.68 | 0.59 |
| 2002 | 40.76 | 2.199 |
| 2003 | 40.84 | 1.085 |
| 2004 | 40.92 | -1.79 |
| 2005 | 41.00 | 3.64 |
| 2006 | 41.09 | 2.70 |
| 2007 | 41.17 | -0.755 |
| 2008 | 41.25 | 1.59 |
| 2009 | 41.33 | -1.57 |
| 2010 | 41.42 | 2.84 |
| 2011 | 41.50 | -1.84 |
| 2012 | 41.58 | -1.84 |
| 2013 | 41.66 | -2.06 |

Accepted error range: That % of errors could be due to inaccuracy of real life measurements also the temperatures calculated are approximated to whole numbers although this won't affect the model as the % of error is minor and in the accepted range.

# Model Calibration

The mathematical model is also calibrated for the calculation of the water temperature for the three cities. This was done through comparing the values calculated against real life measurement. It wasn't available to get real life measurements for water temperatures except for years 2009 and 2010, so Calibration was done through these years

## Water temperature calibration:

| | Water Temperature Calculated | Water Temperature from real life | %Error |
|---|---|---|---|
| Luxor February | | | |
| 2009 | 19 | 20 | 5 |
| 2010 | 19.7 | 20.5 | 3.9 |
| Luxor August | | | |
| 2009 | 23.9 | 24.5 | 2.4 |
| 2010 | 25.7 | 25 | 2.8 |
| Cairo February | | | |
| 2009 | 17.7 | 17 | 4.1 |
| 2010 | 18 | 17.7 | 1.6 |
| Cairo August | | | |
| 2009 | 21.5 | 21.9 | 1.8 |
| 2010 | 21.9 | 22.5 | 2.6 |
| Alexandria February | | | |
| 2009 | 16.5 | 16 | 3 |
| 2010 | 16.7 | 16.4 | 1.8 |
| Alexandria August | | | |
| 2009 | 15 | 15.5 | 3.2 |
| 2010 | 15.7 | 15.9 | 1.25 |

It could be concluded that % of error between water temperatures calculated and that measured in real life for Luxor, Cairo and Alexandria for years 2009 and 2010 didn't exceed the 5 % which makes the mathematical model credible and the results obtained reliable.

# Model Calibration

As For the DO calibration model it faced the same problem as water calibration model which is the lack of real life measurements, DO values was only available for years 2009 and 2010 (19)so the calibration was done using the data for these 2 years as shown in the following table:

## DO concentrations calibration:

| | Water Temperature ( degree Celsius) | Cc mg/l | Average Cc mg/l | Real life DO values mg/l | % of Error |
|---|---|---|---|---|---|
| Luxor February | 19 | 6.51 | 6.38 | 6 | 6.3 |
| | 21 | 6.25 | | | |
| | | | | | |
| Luxor August | 24 | 5.86 | 5.735 | 6.1 | 5.8 |
| | 26 | 5.61 | | | |
| | | | | | |
| Cairo February | 18 | 7.18 | 7 | 6.7 | 5 |
| | 19 | 6.89 | | | |
| | | | | | |
| Cairo August | 22 | 6.63 | 6.47 | 6.45 | 0.3 |
| | 25 | 6.31 | | | |
| | | | | | |
| Alexandria February | 17 | 7.41 | 7.3 | 7.46 | 1.3 |
| | 18 | 7.31 | | | |
| | | | | | |
| Alexandria August | 20 | 7.497 | 7.4 | 6.8 | 7.35 |
| | 24 | 7.11 | | | |

# Waste  Load Allocation Plan for Rivers

- By calculating the critical time at which DO reaches its critical values for Luxor, Cairo and Alexandria during the highest discharge of the Nile (August months) and the lowest discharge of the Nile (February months) it is possible to know when and where the critical DO concentrations (Cc) will occur for each city during each year for the upcoming years. The Critical dissolved Oxygen concentrations is very dangerous for Mankind and aquatic life in the river, the minimum value for DO in river is 5 mg/l.

- Alert : Scientists for should look into and simulate the effect of global warming on DO concentrations in rivers when designing the waste load allocation plan in order to select the optimum location for point source pollutants and for water treatment plants in a way to avoid deteriorated water quality.

# Conclusion

- Air temperatures from 2013 till 2030 showed an average increase by 2.5- 3 degree Celsius and this showed the high impact of global warming and climate change that the world is facing.
- The calculated water temperature showed an average rise in temperature through the period of study from 3- 5 degrees Celsius.
- The decrease in critical DO concentrations was around 4% ( in both cases from 1990 till 2012 and from 2013 till 2030: values for both cases were slightly different) This is going to affect all values of DO concentration and thus the time needed for DO recovery in rivers is going to increase which will make the water quality of a poor condition for long periods of time and hence negatively affect the fauna and flora in rivers and also it will affect the waste allocation management plan on that river.
- A great effect is on the water treatment plants if the global warming factor is not considered in the future.
- Poor treated water quality, expensive treatment, much chemicals to treat water –> negatively affect human health

# Correlation between space technology and water quality

- I strongly rely on meteorological data to mathematically model or simulate water quality parameters as well as on satellite data from Landsat-8 OLI L1 and L2 (for data on surface temperature) and Sentinel-2 (2A and 2B) for monitoring certain water quality parameters. Not all relevant water quality parameters can be mapped via optical satellites.
- I mostly rely on data by meteorological satellites (such INSAT-3D and INSAT-3DR) and use parameters, such as air temperature, precipitation, and humidity in my mathematical modeling simulations to calculate water quality parameters dissolved oxygen concentration in water, total dissolved solids, turbidity, algae counts, pH, salinity, alkalinity, etc.
- Using Landsat-8's surface temperature measurements I calculate the effect of surface temperature– on water quality parameters through modeled equations. For example, when temperature rises, the dissolved oxygen concentration in water decreases, which is not good for the fauna and flora in the water and for the surface water quality in general. Without satellite data, my work would be very difficult, as I would need to rely on gauging stations data which is tedious and hard to find. On the contrary, satellite data are often available free of charge online.
- The Sentinel-2 Water Quality Script (Se2WaQ) uses Sentinel-2 products (L1C & L2A) to display the spatial distribution of six relevant indicators of water quality in surface water bodies overall:

- the concentration of chlorophyll-a,
- the density of cyanobacteria,
- turbidity,
- colored dissolved organic matter,
- dissolved organic carbon, and
- water color.



- So in this research I relied on metrological data which I used in calculating water temperature and DO concentration in water, because there is no satellite found that measures DO concentration in water