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RESEARCH ARTICLE

Evaluation of The River Nile Water Quality Around The New Assiut Barrage and Its Hydropower Plant

¹Mohamed M. Shahata and ²Thabet A. Mohamed

1. Environmental affairs Department, Assiut University Hospitals, Assiut University, Assiut, Egypt.

2. ph.D. Environmental Engineering, STRI, Assiut University- Assiut- Egypt.

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*Corresponding Author

Mohamed M. Shahata

Abstract

The New Assiut Barrage and its Hydropower Plant in Egypt was initiated at May, 2012 and it is suggested to end in December, 2017. The project is considered one of the most important industrial projects that established to enhance economy and development. The project energy of about 32 MW may contribute in the main electric grid for population and developmental approaches. Surface water samples from the River Nile, around the proposed project were collected and analyzed according to EPA Method- 1669. The measured values of pH, TDS, EC, DO, COD, Total hardness, and Temperature were recorded and reached 8.3, 183.5, 317.3, 7.7, 19.5, 135, and 25.7 °C respectively and were compared with guidelines stated by the Egyptian law 48/ 1982 concerned with protection of River Nile from pollution . Biological properties were obtained and statistically analyzed and their sample locations were determined by Global Positioning System (GPS). The study helps the Environmental Impact Assessment in the stage of the operation of the hydroelectric power station.

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INTRODUCTION

The Assiut Barrage was constructed between 1892 and 1902 to sustain a water level difference of about 4 m in order to feed the Ibrahimia canal (length about 350 km) which irrigates an area of almost 600,000 ha. The barrage was remodeled by 1930 to increase the permissible head pond level difference to 4.2 m and thereby increasing the capacity of the Ibrahimia canal. The civil works have been affected by age and also by tail water erosion as a consequence of a modified river regime after the construction of the Aswan High Dam.

The government of Egypt intends to replace the existing barrage with a new structure incorporating a hydropower plant. After studying various alternatives, the Egyptian government decided to construct a multipurpose barrage to guarantee the supply of irrigation, to generate hydropower, and to increase navigation capacity for river traffic. It consists of a sluiceway to evacuate emergency flood release, a hydropower plant, a double navigation lock and a road bridge.

The project scope of works: the construction of 2 navigation locks of 150x 17 m according to the latest international technologies to accommodate the increase in the river and tourism transport units; the construction of a 4- lanes upper bridge over the new barrage with capacity 70 tons to link the East and West banks of the River Nile in Assiut. The barrage project components are: Sluiceway with 8 radial gates 17 m wide and Road Bridge; Hydropower plant: Low-head hydropower plant with 4 bulb units of 8 MW, total capacity 32 MW; new navigation lock: 120x17 m chamber in addition to the refurbished 80 x 16 m high; Rehabilitation of the existing navigation lock: Replacement and Rehabilitation of the existing Ibrahimia canal head regulator: and Transmission line. The project of New Assiut Barrage and its Hydropower Plant has very promising positive aspects in relation to sustainable development, poverty alleviation, social and economic development in Egypt (Batisha (2007).

The impact of hydroelectric power plant on the environment is varied and depends upon the size and the type of the project. Although hydropower generation does not burn any fuel to produce power and hence does not emit

greenhouse gases, there are definite negative effects that arise from the creation of the reservoir and alteration of natural water flow. It is a fact that dams, inter-basin transfers and diversion of water for irrigation purposes have resulted in the fragmentation of 60 % of the world's rivers (Alobeidy et al., 2010).

The sediment in the reservoir in the front of the hydropower station plays an important role in degradation of water quality. Sediment diagenesis may reduce the organic matter content by bacterial degradation linked to methanogenesis, oxidation and CO₂- production, and other processes (Bhatt et al., 2011). Sediment erosion within the reservoir depends on hydrodynamics, mainly on stream velocity in river reservoir and thus on the river load. (Chindeu et al., 2011) reported that remobilization of contaminants from sediments and their return to the trophic chain, either by sediment erosion, by uptake by organisms (fish, plants and sediment dwellers), or by infiltration of interstitial water from the sediment to the ground water. Also Jena et al., 2013, showed that reduction of nutrients inputs to coastal areas of oceans and seas, resulting in reduced primary production in offshore areas. This may affect the marine carbon balance through limitation of production, and therefore climate change. Oxygen depletion by the oxidation of particulate and dissolved organic carbon may lead to deoxygenated or even anoxic conditions in deep water and in sediment (Bhatt et al., 2011). The main hazards associated with this are: eutrophication of deep reservoir water, remobilization of nutrients, metals and organic contaminants from sediments and their availability to organisms (plants, sediment dwellers), and infiltration of pore water charged with contaminants and organic carbon to the ground water (El-Ayouti and Abo-Ali, 2013).

The chemistry of physico-chemical parameters and biological characteristics play a discriminative role for assessment of water quality in the vicinity of the hydropower plant area. Water quality parameters like temperature, pH, total dissolved solids, electric conductivity, dissolved oxygen, turbidity, hardness, chemical oxygen demand, Ca, Mg, K, Na were measured and compared with guidelines stated by WHO and EC standards and with the Egyptian law 48/1982 concerned with protection of the River Nile from pollution (WHO, 2004).

A major impact on surface water quality may stem from biological processes such as bacterial contamination due to the release of water from wastewater treatment plants and diffuse run-off. Also, in particular conditions, sediment contamination may contribute to the persistence of contamination in the overlying water (Mananda et al., 2010). Water turbidity can be increased by high plankton and algal concentrations and there may be a proliferation of mosquitoes and other insects leading to the risk of spreading malaria. Thus the study now focuses to identify impacts on river water quality regarding physicochemical and biological characteristics making a comparative analysis with future studies of the Environmental Impact Assessment of the project. Figure (1) illustrates the proposed project.

2. Materials and Methods

2.1 Site description

The government of Egypt is replacing the existing Assiut barrage in Upper Egypt with a new structure incorporating a power plant. The old barrage was constructed in the year of 1902 to reserve water for irrigation of farmland in the region. Over the years the riverbed has degraded, especially after commissioning of the Aswan High Dam, and the stability of the barrage may eventually be threatened during low flow periods. This led to the decision to construct a new barrage and is making use of the water energy with a power plant. The location stated at (27° 12' 19" N, 31° 11' 26" E) is at the river approximately 400 km downstream of the old barrage in North-east of Assiut city. Figure (2) shows the construction pit for the New Assiut Barrage and the Hydropower Plant.

2.2 Collection of water samples

As shown in Table (1), water quality parameters such as temperature, pH, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), and conductivity were measured in the water samples taken from the sites around the project, using a thermometer, pH meter, conductivity-meter and TDS meter respectively (Mahananda et al., 2010). For dissolved oxygen (DO), samples were collected into 300 ml plain glass bottles and the DO fixed using the azide modification of the Winkler's method (Chindeu et al., 2011).

Samples of bacteriological analysis were collected into sterilized plain glass bottles. All samples were stored in icebox and transported to the National Research Center (Water Pollution Research Unit Laboratories). The results obtained were also compared against the threshold values of WHO (2004), National drinking water quality (NDWQS 2062 B.S.) and guidelines set by the European Union (EU).

Descriptive statistics of the data set are presented in Table (6) and were carried out to simplify its interpretation and to define the parameters responsible for the main variability in water quality variance (Verma et al., 2012). Also correlation factors for water quality parameters were determined to reveal much more about the combination of any

parameters that are more effective on water quality. Mean values of different physicochemical and biological characteristics (Mean $\pm$ SD and range) are shown in Table (3).

2.3 Statistical analysis

The obtained data were processed statistically using the software SPSS.16. Standard Deviation SD, the mean, the minimum, the maximum and the range values were determined.

2.4 Biological characteristics

Eight stations were chosen for samples of Algae (Figure 3) on basis of the 4 sites located upstream and the other four sites located downstream of the existing barrage of the River Nile and around the project site.

3.Results and Discussions



Figure (1): The proposed project of New Assiut Barrage and its Hydropower plant



Figure (2): The construction pit for the New Assiut Barrage and Hydropower Plant



Figure (3): A map showing the project site and water sample locations

Table (1): Water quality test methods and test units

Parameters	Test unit	Method
PH*	-	Thermometer
Temperature*	°C	Electrometric
Turbidity	NTU	Spectrophotometric
Electrical conductivity*	μS/cm	Electrometric
Total dissolved solids*	mg/l	Electrometric
Total suspended solids	mg/l	Filtration
Total alkalinity	mg/l as CaCO ₃	Titration & Electrometric
Total hardness	mg/l as CaCO ₃	Titration, Na EDTA
Total Nitrogen	mg/l	Kjeldahl method
Lead (Pb)	mg/l	Atomic Absorption Spectrophotometric (AAS)
Dissolved oxygen(DO)	mg/l	Titration and Electro-photometric
Chemical oxygen demand (COD)	mg/l	K ₂ Cr ₂ O ₇ Digestion
Biological oxygen demand (BOD)	mg/l	5 days incubation
Total Coli- form	CFU/100 ml	Membrane filter
Fecal Coli- form	CFU/100 ml	Membrane filter

Table (2): shows the sampling locations and GPS coordinates

No.	Location	Lat. N	Long. E
S ₁	1.5 km upstream of existing barrage In the east side of the river	27° 11' 21"	31° 11' 34"
S ₂	1.5 upstream of existing barrage in West side of the river	27° 11' 25"	31° 11' 42"

S ₃	1 km upstream of existing barrage In the east side of the river	27° 11' 34"	31° 11' 28"
S ₄	1km upstream of existing barrage In the west side of the river Nile	27° 11' 40"	31° 11' 35"
S ₅	1.6 km downstream of Assiut new barrage, in the west side	27° 12' 58"	31° 11' 32"
S ₆	3 km downstream of Assiut new barrage	27° 12' 58"	31° 9' 53"
S ₇	1.4 km downstream of Assiut barrage, west side	27° 12' 35"	31° 10' 34"
S ₈	1 km downstream of new Assiut barrage, east side	27° 12' 28"	31° 10' 51"

Global Position System (GPS) device (Garmin 62s) was used to define the coordinates of these sites as shown in Table (2).

3.1 Physicochemical Parameters

3.1.1 Temperature

Temperature of surface water around the project of the New Assiut Barrage and its Hydropower station varies from 23.8 °C to 27.6 °C with an average value of 25.7 °C as shown in Table (4). The average value lies within the allowable levels where temperature of water in streams and rivers through out the world varies from 0 to 35 °C. The temperatures of water affects some of the important physical properties and characteristics of water: thermal capacity, density, specific weight, viscosity, surface tension, specific conductivity, salinity and solubility of dissolved gases and etc. (Mustafa and Aris, 2011). Chemical and biological reaction rates increase with increasing temperature. Reaction rates usually assumed to double for an increase in temperature of 10 °C.

3.1.2 pH

Acidity indicates the corrosiveness of acidic water on steel, concrete and other materials. The average value of pH was 8.3 where it varies in water sample analysis from 8.1 to 8.5 and not exceeded the limits (6.8-8.5) stated by the USEPA and the standards suggested by the Egyptian law 48/1982 (pH= 7.8).

3.1.3 Total Hardness

The total hardness in surface water samples ranged from 130-140 mg/l with an average value of 135 mg/l showing a moderately hardness as indicated in Table (4). The slight increase of hardness can be interpreted by the dissolved solids from construction works and the industrial wastewater resulting from washing sand and gravel and releases into the river water. Hardness is correlated with TDS (Total dissolved solids). It represents total concentration of Ca²⁺ and Mg²⁺ ions, and is reported in equivalent CaCO₃. Other ions (Fe²⁺) may also contribute. Hardness expressed as mg/L CaCO₃ is used to classify waters from "soft" to "very hard". This classification is summarized in Table (3).

Table (3): Hardness Concentration and Classification of Natural water (Hem, 1971)

Hardness as mg/L	Classification
0-60	Soft
61-120	Moderately hard
121-180	Hard
>180	Very hard

Hardness observed for streams and rivers throughout the world ranges between 1 to 1000 mg/l. Typical concentrations are 47 mg/l to 74 mg/l CaCO_3 (WHO, 2004). Hardness is an indicator to industry of potential precipitation of calcium carbonates in cooling towers and boilers, interference with soaps and dyes in cleaning and textile industries and with emulsifiers in photographic development. Hard water is less corrosive than soft. Treatment usually left to consumer (domestic, industrial, etc.) depending on needs.

3.1.4 Total Dissolved Solids

The mean value of total dissolved solids TDS was 183.5 mg/l, less than the permissible level stated by the Egyptian law 48/1982 (500 mg/l), and also less than the value suggested by USEPA (500mg/l). Total dissolved solids (TDS) are a measure of salt dissolved in a water sample after removal of suspended solids. TDS is residue remaining after evaporation of the water. The TDS load carried in streams throughout the world has been estimated by (Tc gobanoglous, 1985) to 120 mg/L. Turbidity is a measure of the light-transmitting properties of water and is comprised of suspended and colloidal material. It is important for health and aesthetic reasons.

The concentration of total dissolved solids (TDS) is related to electrical conductivity (EC; $\mu\text{S}/\text{cm}$) or specific conductance. The conductivity measures the capacity of water to transmit electrical current. The conductivity is a relative term and the relationship between the TDS concentration and conductivity is unique to a given water sample and in a specific TDS concentration range. The conductivity increases as the concentration of TDS increase. TDS and conductivity affect the water sample and the solubility of slightly soluble compounds and gases in water (e.g. CaCO_3 , and O_2). In general, the corrosiveness of the water increases as TDS and EC increase, assuming other variables are kept constant.

3.1.5 Electrical Conductivity

The value of electrical conductivity EC varies from 285 to 330 $\mu\text{S}/\text{cm}$ with an average value of 317.8 $\mu\text{S}/\text{cm}$. EC is the measure of cations and anions in water samples and shows the concentration of dissolved salts which it contributes in prediction of water quality. The Egyptian law 48/1982 for River Nile Protection from Pollution stated that the $\text{EC} > 5 \mu\text{S}/\text{cm}$, where the Food and Agriculture Organization FAO suggested the value of EC to be $< 3 \mu\text{S}/\text{cm}$.

3.1.6 Dissolved Oxygen

The measured values of dissolved oxygen varies from 7.6 to 7.8 mg/l with average value of 7.7 mg/l as shown in Table (4). Typical dissolved oxygen concentrations observed in streams and rivers throughout the world are 3 to 9 mg/l. The observed range of dissolved oxygen concentrations is 0 mg/L (anoxic conditions) to 19 mg/L (supersaturated conditions). Dissolved oxygen is important in natural water because many microorganisms and fish require it in aquatic system. Dissolved oxygen also establishes an aerobic environment in which oxidized forms of many constituents in water are predominant. Under anoxic conditions in water, reduced forms of chemical species are formed and frequently lead to the release of undesirable odors in water (Wahaab and Badway, 2004). Thus the study now focuses to identify impacts on river water quality regarding physicochemical and biological characteristics making a comparative analysis with the studies of the Environmental Impact Assessment will be carried out during operational phase of the project. It is revealed that most physico-chemical parameters are coincide with permissible levels for water drinking according to guidelines stated by the WHO or USEPA for water quality assessment.

Table (4): Statistical analysis of physico-chemical parameters

Parameter	Min.	Max.	Mean	SD	Range
pH	8.1	8.5	8.3	0.28	8.1- 8.5
EC	285	330	317.3	31.8	285 - 330
T ($^{\circ}\text{C}$)	23.8	27.6	25.7	0.68	23.8 - 27.6
TDS	175	192	183.5	12.02	175 - 192
DO	7.6	7.8	7.7	0.14	7.6 - 7.8
HCO_3	130	140	135	7.07	130 - 140

SO ₄ ²⁻	0.3	29	20	7.4	0.3 - 29
Cl ⁻	14	20	16.4	1.0	14 - 20
COD	18	21	19.5	2.12	18 - 21
Ca	24	28	26	2.82	24 - 28
Mg	12	16.7	14.4	3.32	12 - 16.7
K	5	5.1	5.05	0.07	5 - 5.1
Na	30	35.6	32.15	3.23	30 - 35.6

3.1.7 Chemical Oxygen Demand

Measurements of water quality samples of surface water showed that Chemical Oxygen Demand COD reached the value of 19.5 mg/l and varies from 18 to 21 mg/l. The allowable level for COD stated by the law 48/1982 is < 10- 15. The slight increase in the measured values is due to consumption of oxygen taken up by aquatic organisms in water to digest the organic matter released from construction works.

3.1.8 Major Cations

The major cations were found in surface water samples of calcium Ca²⁺, magnesium Mg²⁺, sodium Na⁺ and K⁺ with the average value of 26; 14.4; 32.15 and 5.05 mg/l respectively. Calcium is the most prevalent cation in water where it varies from 24 to 28 mg/l and second inorganic ion to bicarbonate in most surface water. Calcium is considered the primary constituent of water hardness and precipitates as CaCO₃ in iron and steel pipes. A thin layer of CaCO₃ can help inhibit corrosion of the metal. However, excessive accumulation of CaCO₃ in boilers, hot water heater, heat exchangers and associated piping affects heat transfer and could lead to plugging of the piping. However, calcium concentrations of 40 to 120 mg/l are more common (Tandale and Mujawar, 2014).

Magnesium is not abundant in rocks as calcium. Therefore, although magnesium salts are more soluble than calcium, less magnesium is found in surface water. The concentration of value of magnesium reached 14.4 mg/l as have been mentioned above, but distribution of magnesium cations in water samples ranges from 12 to 16.7 mg/l and sodium and potassium varies from 30 to 35.6 and 5 to 5.1 mg/l respectively.

3.1.9 Major Anions

The average values of chloride, sulfate, bicarbonate and nitrate anions were 16, 14.6, 135 and 0.76 mg/l respectively, as shown in table 4. Bicarbonate HCO₃⁻ is the principal anion found in natural water. These ions are very important in the carbonate system, which provides a buffer capacity to natural water and is responsible in a great measure for the alkalinity of water. One source of bicarbonate ions HCO₃⁻ in surface water is the dissociation of carbonic acid H₂ CO₃ that is formed when carbon dioxide CO₂ from the atmosphere, or from animals (e.g. fish) and bacterial respiration, dissolves in water.

In addition to bicarbonate anions, such as chloride Cl⁻, sulfates SO₄²⁻ and nitrates NO₃⁻ are commonly found in surface water. These anions are released during the dissolution and dissociation of common salt deposits in geologic formation. The value of chlorides measured in water samples ranged from 14 to 20 mg/l, with an average value of 16.4 mg/l. The concentration of chloride anions Cl⁻ determines the water quality because the quality of water was mg/l, where the worse after increasing in the concentration of these anions which limit possibilities of using of natural water for different purposes (household, agriculture, industry and etc.). Principal source of chloride anions Cl⁻ in surface water are magmatic rock formations that include chlorine- content minerals. The second source of this anions is Ward Ocean from where a considerably amount of chloride anions enter in the atmosphere. From atmosphere chloride anions Cl⁻ enter the surface water in result of interaction between precipitation and soil.

The sulfate anions SO₄²⁻ are frequently found in surface water as the results of the substances from plant and animal origin. The increase concentration of the sulfate anions, at one hand brings about change for the worse of some physical characteristics of water (taste, smell and etc.) and on the other hand has destructive influence upon human consumption. The measured value of sulfates was 14.6 mg/l and it varies from 25 to 29mg/l in water

samples. The concentration of sulfate anions SO_4^{2-} fluctuates in a wide range in surface water from 5 to 60 mg/l (Tandale and Mujawar, 2014).

The measured value of nitrates NO_3^- in surface water around the New Assiut Barrage and its Hydropower Plant was 0.79 mg/l, but the nitrate distribution in water area under investigation varies from 0.06 to 2 mg/l. Nitrate anions NO_3^- are found in surface water as a result of bacteriological oxidation of nitrogenous materials in soil. That is why the concentration of these anions rapidly increases in summer when the process of nitrification takes place very intensively. Another important source for dressing of the surface water with nitrate anions is precipitation, which absorb nitric oxides and convert them into nitric acid. A great deal of nitrate anions enters in surface water together with domestic water and water from industry, agriculture and etc (Jena et al., 2013). Nitrate anions are one of the indicators for the degree of the pollution with organic nitrate- content substances.

3.1.10 Correlation Coefficient

The correlation coefficients of physico- chemical parameters of water samples were calculated and depicted in Table (5). It was found that there is a significant correlation in the following systems: EC- TDS ($r=0.98$), Na- T° ($r=0.60$), T° - Ca ($r=0.89$), TDS- Na ($r=0.56$), NO_3^- - Mg ($r=0.78$) and HCO_3^- - SO_4 ($r=0.77$) etc. It can be concluded that the total dissolved solids in presence of raised temperature, may enhance the solubility of particles to give more turbidity to the water system. This deteriorates water supply intake and pumps of irrigation system. Also its have been noted from statistical analysis that EC present in water with high level leads to dissolve of water salts giving increase in salinity of water. So working in rivers and lakes requires more strict regulations for dust release in waters. Table (5) shows the correlation coefficients of physico-chemical properties.

Table (5): Correlation coefficients of physico-chemical parameters:

	pH	EC	T °C	TDS	DO	HCO ₃	COD	Ca	Mg	K	Na	SO ₄	NO ₃
pH	1	-0.6	-0.10	-0.72	0.059	0.60	0.36	-0.23	-0.19	-0.83	-0.02	0.14	0.35
EC		1	-0.18	0.98	-0.24	-0.73	0.32	-0.014	0.079	0.27	0.60	-0.60	0.16
T °C			1	-0.12	0.41	-0.10	0.29	0.89	-0.77	-0.20	-0.29	0.34	-0.99
TDS				1	-0.32	-0.70	0.21	-0.05	0.03	0.40	0.56	-0.45	0.10
DO					1	0.11	0.11	0.30	-0.22	-0.2	-0.22	-0.66	-0.4
HCO ₃						1	0.31	-0.50	-0.15	-0.33	0.02	0.77	0.11
COD							1	0.35	-0.55	-0.75	0.39	-0.7	-0.30
Ca								1	0.53	-0.02	-0.49	-0.60	-0.84
Mg									1	0.52	-0.13	0.08	0.78
K										1	-0.28	-0.23	0.2
Na											1	-0.05	0.28
SO ₄												1	0.35
NO ₃													1

3.2 Biological Characteristics:

Biological characteristics of water samples surrounding the project of the new Assiut barrage and its hydropower plant were studied and it was found an abundance of green algal count, blue – green algal and diatoms. This enrichment is due to dissolved of organic species and phosphorus and nitrogen as nutrients of micro-organisms. Table (6) shows the results of different algal counts in water samples.

Table (6): Biological properties and their statistical analysis:

Parameters & Date	Total green algal	Diatoms	Chlorophyll
1/1/2014	3955	3933	13.5
1/2/2014	972	885	1.78

1/3/2014	246	211	1.78
1/4/2014	791	307	17.4
1/5/2014	4863	4546	11.7
1/6/2014	3300	2700	12.4*
1/7/2014	2605	860	18.3
1/8/2014	3404	2700	17.6
1/9/2014	820	3404	10.9
1/10/2014	370	704	17.2
1/11/2014	2113	808	18.6
1/12/2014	995	2115	20.1
Min.	995	2115	13.5
Max.	3955	3933	20.1
Mean	2475	3024	16.8
SD	20.039	12.85	4.66

4. Conclusion

This study is an attempt to evaluate the water quality in the River Nile around the New Assuit Barrage and its Hydroelectric Station using analysis of the physicochemical and biological characteristics. The following points were concluded:

1. The physicochemical parameters measured of the surface water upstream and downstream of the barrages lie within the permissible limits according to the Article (49) of decree No. 92/ 2013 of law 48 of 1982 on the protection of the River Nile from pollution.
2. In some points of the investigated area observed that the clarity of water has impaired due to turbidity, TDS, and TSS resulting from project construction works. This situation is lasted through settlement of debris and dilution of the river but for the suspended particles it may travel to long distances downstream across the river.
3. Algal counts increase in water body due to the solubility of nutrients of organic species and this may leads to eutrophication and increase consumption of the dissolved oxygen and this deteriorates the aquatic organisms. Also the abundance of algae in waters leads to more turbidity in water systems.

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