INTERNATIONAL JOURNAL OF ENVIRONMENTAL SCIENCE AND ENGINEERING (IJESE)
Vol. 5: 15- 23 (2014)
http://www.elac.pvamu.edu/pages/5779.asp
Prairie View A&M University, Texas, USA

Impact of El- Rahawy Drain on the water quality of Rosetta Branch of the River Nile, Egypt.

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ARTICLE INFO
Article History
Received: April.3, 2014
Accepted: July 29, 2014
Available online: Dec. 2014

Keywords:
El- Rahawy Drain
Rosetta Branch
River Nile
Pollution
Duflow model

ABSTRACT

There are many problems related to the pollution of water in Rosetta Branch of the River Nile, especially downstream El Rahawy Drain. As an example, in summer 2012 many tons of fish were found floating on the water. At the same time, thousands of people got different diseases due to the water pollution in this area. Here comes the importance of this study to know the impact of this pollution and how we can predict the size of it at the reasonable time as well as the procedure to control pollutants in this important ecosystem.

We solved the equations of conservation of mass, momentum and constituent concentration by using Duflow model and we got the following results:

1- In general, sections at which the values (levels) of H small correspond to the sections for which discharge (Q) is small and vice versa.
2- At constant time t, Q decreases as x increases, hence, $\frac{\partial Q}{\partial x} < 0$. At constant x, H increases as t increases, hence $\frac{\partial H}{\partial t} > 0$. This result confirms equation (1).
3- At El-Rahawy Drain, for t = 31 hours, the difference between the measured and simulated values of Dissolved Oxygen (DO) is small. Numerical studies showed that for $0 \leq t \leq 23$ h, this difference is large.
4- In general, the behavior of (DO) is opposite to the behavior of Biological Oxygen Demand (BOD).

Many solutions have been proposed to solve this disaster problem in this important ecosystem.

1. INTRODUCTION

The River Nile has played an extremely important role in the civilization, life and history of the Egyptian Nation. The extension of civilization and development has created major environmental problems which interact with nature and life. Rivers are the most important fresh water resources.

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ISSN 2156-7530

On the other hand, rivers provide us with shipping routes, connecting ports with our main cities, fishing and hydroelectric power stations provide electricity (Julianne, 2012).

The River Nile is subjected to several kinds of pollution including different agricultural, industrial and domestic pollution. Always engineering, biological, chemical studies are based mainly on taking samples and analyzing them after the disaster occurs. But the mathematical studies of pollution give the possibility to determine the value of the concentration of the pollutants along the river and for several days prior to the disaster. Hence, the mathematical treatment of the problem gives the best method to control the disaster.

Dissolved oxygen analysis measures the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. Oxygen gets into water by diffusion from the surrounding air, by aeration and a waste product of photosynthesis. Adequate dissolved oxygen is necessary for good water quality. Oxygen is a necessary element to all forms of life. If the dissolved oxygen concentration (DO) in water is below 5 mg /L, aquatic life is put under stress. The lower concentration, the greater stress, Oxygen levels that remain below 1-2 mg/L for a few hours cause death to a lot of fish, especially the sensitive species.

This study aims to determine the variation of DO, BOD and ammonia with time along the area of study using Duflow model and solving the equations of conservation of mass, momentum and constituent concentration by this model.

2. METHODOLOGY

2.1 Location of the study

The River Nile is one of the most important rivers in Africa. It is flowing a distance of over 6625 km from source to mouth, in a maximum width of 7.8 km. In Egypt alone it flows 1350 km from the Aswan High Dam to its discharge into the Mediterranean Sea. When the River Nile reaches the Delta, is divided into two branches Rosetta and Damietta (Zahran and Willis, 2003). The Rosetta Branch flows downstream Delta Barrage to the north- west where it ends with Edfina Barrage which releases excess water to the Mediterranean Sea. The annual discharge of water from Aswan High Dam is 55.5 $(10)^9 m^3$/year. The catchment of the Nile in Egypt has a population of over 75 million and the Nile receives agricultural, industrial and domestic wastes, whilst water is used for drinking, irrigation and industry (Fisher and Williams, 2006). In spite of the fact that River Nile is the artery of life in Egypt, unfortunately it is exposed to many kinds of chemical and biological pollutants in addition to the remains of agricultural wastes and dead animals that are thrown in it.

Rosetta Branch extends about 240 km long the Delta Barrage; the average width is about 200 m. Rosetta Branch constitutes an important waterway for the River Nile. It is controlled by the new Delta Barrage in the downstream and Edfina Barrage in the upstream. The presence of Edfina Barrage on Rosetta Branch gives the chance for renewing its water once a year, during the winter closing period (when canals are closed to carry out maintenance and constructions). The main use of Rosetta Branch water is for drinking, irrigation, industry and fishery.

2.2 Model schematization

2.2.1 Network layout:

The area of study was represented by a net work of 10 nodes and 9 sections. The section is defined as the distance between two successive nodes. The nodes are taken at locations of wastewater discharge, at the abstraction points at sampling locations and also at different cross sections along the area of study. The area of study Network layout in Duflow model is shown in Fig. (1).

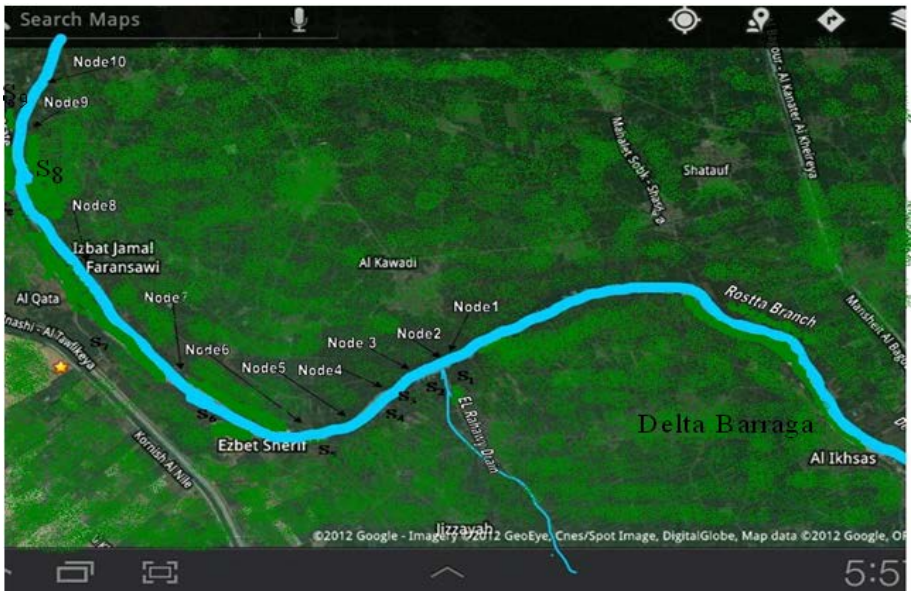


Fig. 1: Map showing the selected Nodes at the area of investigation along the River Nile, Rosetta Branch.

2.2.2Control data:

The simulation period to calibrate the model is the fieldwork period (February 2010). The time step is calculated at 120 seconds to avoid the instability and inaccuracy of the results. The Rosetta Branch water quality control software design and the simulation model are given in Bureau ICIM (1995) and Donia (2002).

2.3Chemical analyses

The Biological Oxygen Demand (BOD) was determined by measuring the quantity of dissolved oxygen in mg/L, required by aerobic bacteria for degradation of organic matter. This was done by diluting suitable portions of the sample with oxygen saturated water (consists of phosphate buffer, magnesium sulfate, calcium chloride, ferric chloride solutions) and measuring the dissolved oxygen in the mixture both immediately and after a period of five days of incubation at 20^0C. Blank of dilution oxygen saturated water were also measured. Oxygen was measured by oxygen electrode using electrode dissolved oxygen meter (Hack company model 16046). The difference between initial dissolved oxygen and the oxygen after five days equals BOD in mg/L (Donia, 2002).

Ammonia NH_4 is the third form of nitrogen compounds which occurs naturally in water bodies arising from the breakdown of nitrogenous organic and inorganic matter in soil and water, excretion by biota, reduction of the nitrogen gas in water by micro-organism and from gas exchange with atmosphere. It is also discharged into water bodies by some industrial processes and also a component of municipal waste. At certain pH values, high concentrations of ammonia are toxic to aquatic life. Total ammonia concentrations were measured in surface waters are typically less than 0.2mg/L-N but may reach to 2 – 3 mg/L-N. Higher concentrations could be an indication of organic pollution such as from domestic sewage, industrial waste and fertilizer runoff.

Potable water contains massive quantity of ammonium chloride (NH_4CL) (52- 105 g) by human adults over three days may result in headache, insomnia, nausea, diarrhea and a failure in glucose tolerance. A dose of (6 – 8 g) daily for 6 -9 days resulted in increased urinary output of renal ammonia and urinary magnesium calcium and phosphate (Hussein *and Hesham*, 2008).

EL Bouraie *et al*. (2011) analyzed the water quality in Rosetta Branch of the River

Nile at the outlet of EL Rahawy Drain, and compared their results with the water quality standards of Egypt (Law 48/1982). Badr *et al*. (2006) followed the seasonal variation of pH, dissolved oxygen; trace metals (Fe, Zn, Cd, and Pb) and major cations in surface and bottom water of EL Rahawy Drain.

One of the scenarios of treatment the pollution is to divert the water from El Rahawy Drain to desert and reuse it for wooden trees. This scenario is the best environmental and economical sound solution (Donia, 2002; Hussein and Hesham, 2008).

2.4 The Model description

We model the flow in Rosetta Branch (RB) as being one-dimensional, using a single spatial parameter x (m) to describe the distance down the (RB) from Delta Barrage as origin. All physical quantities, such as H, Q, constituent concentration (C), are only allowed to vary with x. The physical quantities are treated as homogeneous across (RB) cross-section. This assumption was justified by fulfilling Dobbins criterion (Dobbins, 1964). The flow is also assumed to be unsteady. The Duflow package (Bureau ICIM, 1995) satisfies all the above assumptions in our study from Node 1 to Node 10. Hence, we used it for solving the coupled conservation equations of mass, momentum and constituent concentration (C). C may be one of Dissolved Oxygen (DO) or Biological Oxygen Demand (BOD) or Ammonia (NH_4), etc. The mathematical translation of the laws of conservation of mass, momentum and constituent concentration (C) can be expressed mathematically (Bureau ICIM, 1995) as:

Mass conservation equation:

$$B\frac{\partial H}{\partial t}+\frac{\partial Q}{\partial x}=0 \qquad (1)$$

Momentum conservation equation:

$$\frac{\partial Q}{\partial t}+gA\frac{\partial H}{\partial x}+\frac{\partial(\alpha Q v)}{\partial x}+\frac{g|Q|Q}{C_1^{\,2}AR} = b\gamma w^2\cos(\Phi-\phi) \qquad (2)$$

The mass transport constituent equation:

$$\frac{\partial(B_1C)}{\partial t} = -\frac{\partial(QC)}{\partial x}+\frac{\partial}{\partial x}(AD\frac{\partial C}{\partial x}) + P \qquad (3)$$

$$Q = vA \qquad (4)$$

holds and where: t is the time [sec], x is the distance as measured along the channel axis (co-ordinate) [m], $H(x,t)$ is the water level with respect to reference level[m], $v(x,t)$ is the mean velocity (averaged over the cross-sectional area) [m/s], $Q(x,t)$ is the discharge at location x and at time t [m^3/s], $R(x,H)$ is the hydraulic radius of cross-section [m], $A(x,H)$ is the cross-sectional flow area $[m^2]$, $b(x,H)$ is the cross-sectional flow width [m], $B(x,H)$ is the cross-sectional storage width [m], g is the acceleration due to gravity [m/s^2], $C_1(x,H)$ is the coefficient of De Chezy [m^2/s], $w(t)$ is the wind velocity [m/s], $\Phi(t)$ is the wind direction [degrees], $\phi(x)$ is the direction of channel axis in degrees, measured clockwise from the north [degrees], $\gamma(x)$ is the dimensionless wind conversion coefficient, C is the constituent concentration [g/m^3], D is the Dispersion coefficient [m^2/s], B_1 is the cross-sectional area [m^2], P is the production of the constituent per unit length of the section [g/m. s], α is the correction factor for non – uniformity of the velocity distribution in the advection term, defined as:

$$\alpha = \frac{A}{Q^2}\int v^2(y,z)\,dydz \qquad (5)$$

where the integral is taken over the cross-section A [m^2].

The production term (p) of the equation includes all physical, chemical and biological processes to which a specific constituent is subject to. Equation (3) can be written as:-

in $\frac{\partial S}{\partial x} + \frac{\partial (B_1 C)}{\partial t} - P = 0$ (6) tity of the constituent passing a cross- section per unit of time):

$$S = QC - AD\frac{\partial C}{\partial x} \qquad (7)$$

Equation (7) describes the transport by advection and dispersion. Equation (6) is the mathematical formulation of the mass conservation law, which states that the accumulation at a certain location x is equal to the net production rate minus the transport gradient (Bureau ICIM, 1995).

2.5 Initial and boundary conditions

To start the computations by using Duflow package, initial and boundary conditions for H, Q and C are required. These initial conditions (values) must be supplied for each node. These values can be based on historical measurements, obtained from previous computations or from a first reasonable guess. The input measured water levels (H), discharge (Q) and water quality variables (DO, BOD, NH_4) at different nodes are given in Table (1).

Each measurement in this table is the arithmetic mean of three measurements; the first is near the west bank, the second is in the middle of the Rosetta Branch and the third is near to the east bank.

Table 1: Measured values in Rosetta Branch

Locations	Distance from Delta Barrage in km	Dissolved Oxygen (DO) mg/L	Biological Oxygen Demand (BOD) mg/L	Ammonia (NH_4) mg/L	Discharge (Q) m^3/h	Level (H) m
Node 1	9.9	7.5	4.5	0.2	386.66	9.57
Node 2	10	3.27	59	5.36	418.4	9.41
Node 3	10.7	5.3	42	5.7	417.77	9.33
Node 4	11.2	6.11	20.3	2.88	414.95	7.59
Node 5	12	6.1	24.3	1.9	407.11	6.25
Node 6	13	4.67	20.67	4.42	412.95	5.28
Node 7	16	2	34.3	5.70	419.15	4.05
Node 8	20	1.1	33	6.67	415.69	2.92
Node 9	25	0.55	22.5	5.81	417.76	2.91
Node 10	26.2	0.5	16.3	6.09	417.08	2.78

3. RESULTS AND DISCUSSION

The flow of wastewater was calculated for all sections in the area of study at different time levels. The time levels are given in hours (h) and are measured from the start of the calculations $t = 0$. The values of the levels (H) were measured in meters (m), the values of discharge (Q) were measured in (m^3/h), the values of (DO), (BOD) and NH_4 were measured in (mg/L).

Figure 2 shows the variation of the values of the discharge (Q) along the area of study from section 1 up to section 9 at different time from (t = 0 h) up to (t = 28 h). So, from Figure 2, it is clear that:-

1- At any time t, Q decreases as the fluid flows from section 1 up to section 9. This is due to the use of the fluid in different operations (agriculture, domestic, seepage,).
2- At time 23 h the values of Q were big, from section 2 up to section 3, the maximum values of Q lie in this area due to the presence of El Rahway Drain.

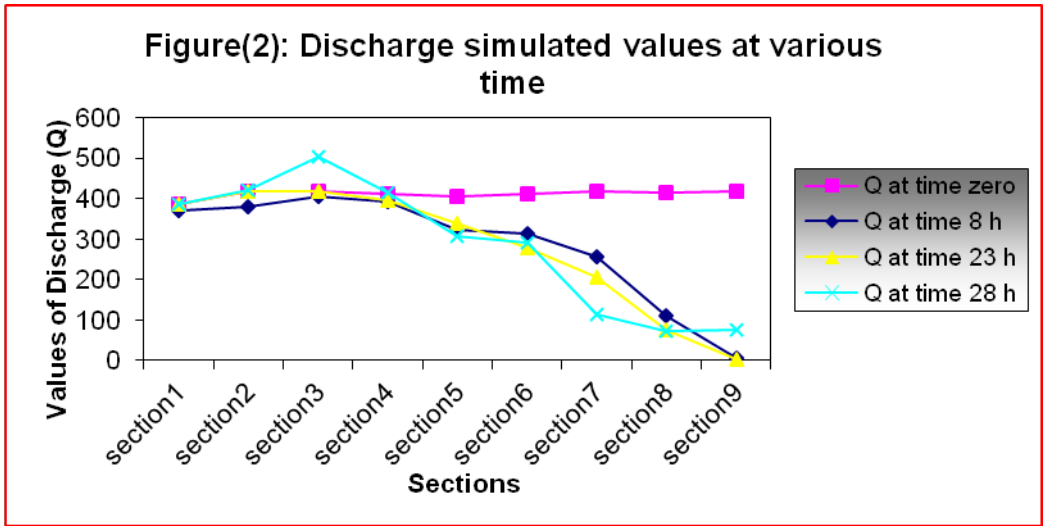


Figure 3 shows the variation of the values of the levels (H), along the area of study from node 1 to node10 at different time from the beginning (t = 0) up to (t = 31 h). From Figure 3, it is clear that:

1- At any time t, H decreases as the fluid flows from node 1 up to node10. The reason for this is that the water in the stream is used for industrial, agricultural and domestic purposes.

2- This may be also due to the sedimentation of the suspended bodies in the flow.

3- In general, at any node as the time t increases, H increases. An opposite effect was noticed for the case $t = 0$ h from node 2 up to node 4.

4- For $t = 31$ h the values of H are big from node 2 up to node 5. Although the value of H is big at node 2, the value of DO at this node was minimum (Figure 4).

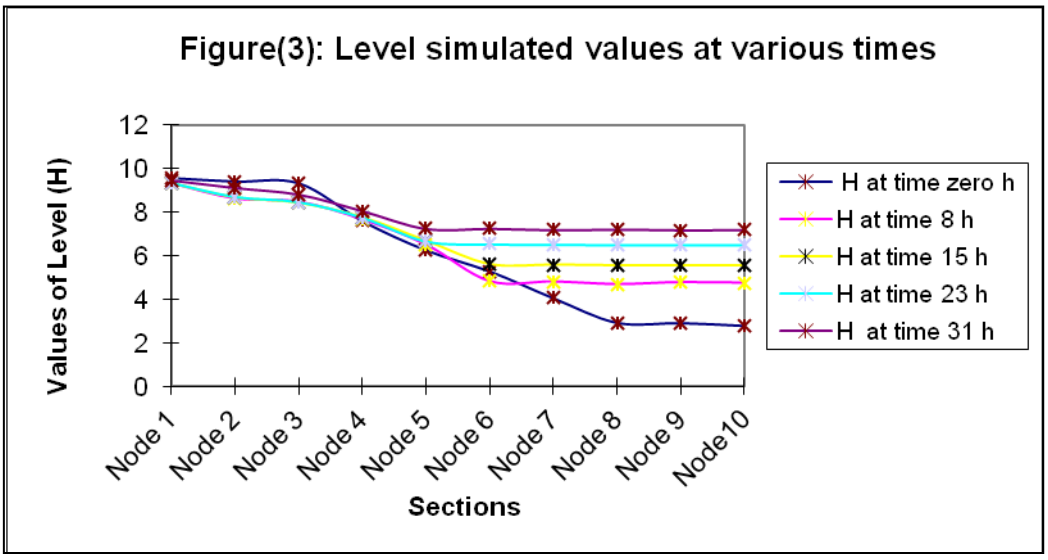


Figure 4 shows a comparison between the measured values of DO and the simulated values at different time from (t = 0 h up to t = 31 h), throughout the area of study. From Figure 4, it is clear that:-

1- The minimum difference between the measured and simulated results for DO is obtained at t = 31 h.

2- At t = 31 h, from section 1 up to section 2 the values of DO are decreasing. The minimum value of DO lies in section 2, where El Rahawy Drain exists, this confirms the fact that the values of DO decrease while BOD increase (see Figure 5).
3- From section 3 up to section 5 the values of DO were increasing; this may be due to the fact that in this region the concentration of the pollutants decrease and may be due to the aeration.
4- From section 5 up to section 9, the values of DO were decreasing. This may be due to the fact that H is small at this area and the concentration of NH_4 is increasing (see Figure 6).
5- The dissolved oxygen ranged from 7.75 mg/L in section 2 to 0.5 mg/L in section 9 at t=8 h, but the concentration of DO required for maintains of healthy fresh water would be over 5 mg/L (the Egyptian law 48).

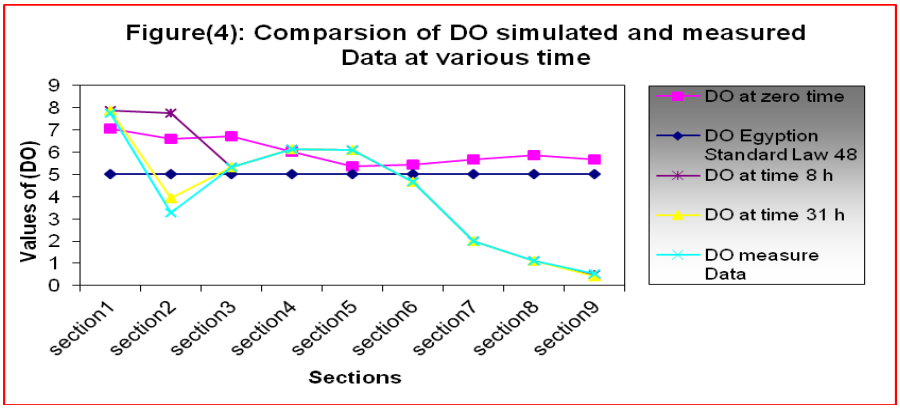


Figure 5 shows a comparison between the measured values of BOD and the simulated values at different time from (t = 0 h up to t = 31 h), throughout the area of study. From Figure 5, it is obvious that:

1- At t = 8, 31 h, the values of BOD were equal.
2- The minimum difference between the measured and simulated values for BOD began from section 3 up to section 9 for any time t. From section 1 up to section 3, the difference between the measured and simulated value was big.
3- From section 2 up to section 3 the values of BOD are increasing for the simulated values. This is due to the presence of EL Rahawy Drain in this area.

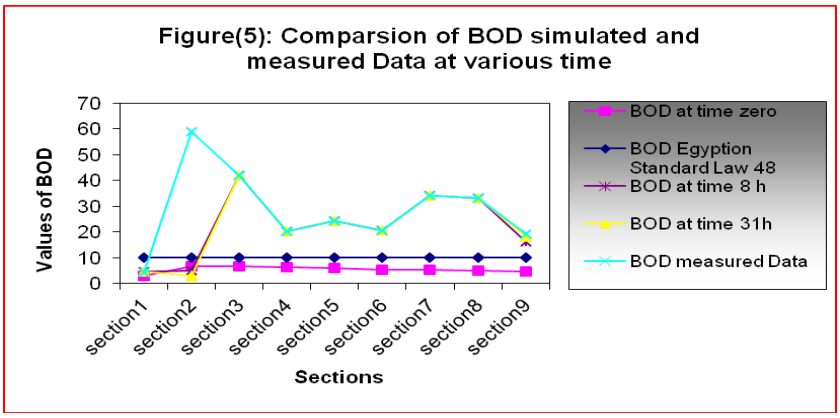
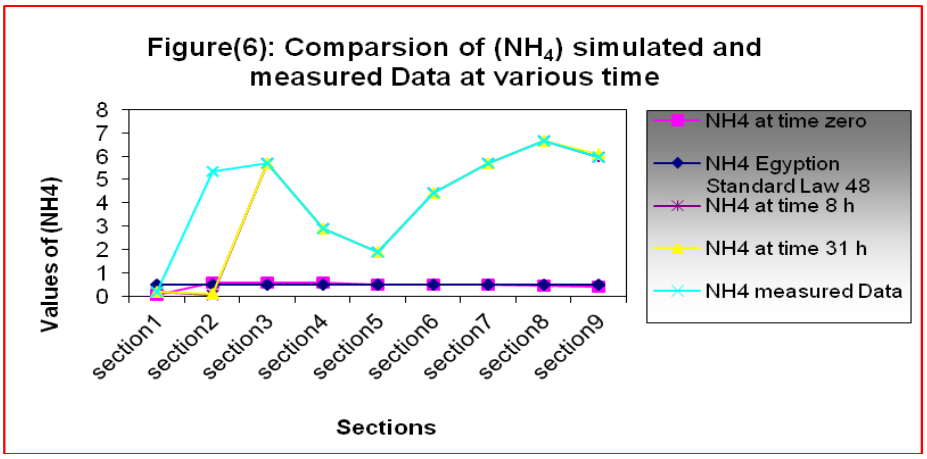


Figure 6 shows a comparison between the measured and simulated values of NH_4 at different time from t = 0 h up to t = 31h throughout the area of the study. From Figure 6, it is clear that the behavior of NH_4 is similar to that of BOD at different time t throughout the area of study.



From Figures 4, 5 and 6, as expected, the behavior of DO at different time t throughout the area of study is opposite to the behavior of both BOD and NH_4. The best zone from which water is taken for drinking or irrigation is 11.2 km $\leq x \leq$ 13 km, where x is measured from Delta Barrage (i.e. 1.2 km from El-Rahawy Drain). In this zone DO is maximum and BOD as well as NH_4 are minimum. Hence, the self purification in this zone is maximum.

For each pollution source in El-Rahway Drain, several treatment alternatives could be implemented. The main objective of water quality management regarding pollution in this location is based on reducing the pollutants by choosing one of these alternative treatments:

1- Treatment by releasing adequate discharges from Delta Barrage in Rosetta Branch to reduce the high concentrations of pollutants during the period of low demands (January-February) to the Mediterranean Sea.
2- Treatment by stream aeration. The aeration techniques increase dissolved oxygen concentrations that have become unacceptably low. It is important to keep in mind that most artificial aeration techniques can only be applied to limited areas due to cost and scaling issues (Upper Mississippi, 2006).
3- Treatment using aeration biofilm, allows simultaneous removals of nitrogenous and xenobiotic organic compounds, which have previously been mineralized in multiple reactors.
4- Treatment to divert the waste water to the desert and reuse it for wooden trees.
5- The engineered wetland treatment is the optimum treatment to satisfy with the input constraints and minimum treatment cost (Donia, 2002).
6- Some of the wastewater can be reused for color fish aquaculture.
7- The wastewater can be treated by recycling it and using it in many different projects.
8- The Jonglei Canal is a project that has been proposed, to provide water which wasted and vaporized in swamps of Bahr-Jabal area, south of Sudan. The Jonglei canal scheme was first studied by the government of

Egypt in 1946 and plans were developed in 1954-1959. Construction work on the canal began in 1978 but the outbreak of political instability in Sudan has frozen work for many years. By 1984 when the civil wars brought the works to a halt, 240 km of the canal of a total of 360 km had been excavated. The estimated income of the Jonglei canal project would produce 3.5 - 4.8 x 10^9 m³ of water per year, an increase of around five to seven per cent of Egypt's current supply. The canal's benefits would be shared by Egypt, South Sudan and Sudan.

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