Modeling of Neutrients Concentration Changes for Bahr Hadous Irrigating Drainage

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Abstract- This research aims to evaluate the concentration of the nutrients by measuring three parameter which are NH4+, NO3-, and PO43-. From the measured data we can suggest a third degree equation relates between concentration of nutrients concentration, flow rate, and the distance from point source. Evaluation of changes of the nutrients concentration for Bahr Hadous, lower Serow irrigating drainage show that an increasing of total ammonia NH4+, NO3-, and PO43- during September to December due to the lowering of flow rate of irrigation water through this period. The correlated data in the third degree equation have an absolute error less than 0.007 so, we can predict the feature changes of the Nutrients concentration in each season.

Key words- Modeling, Nutrients Concentration, Irrigating Drainage.

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1 INTRODUCTION

The use of wastewater in agriculture is a centuries-old practice that is receiving renewed attention with the increasing scarcity of fresh water resources in many arid and semi-arid regions of the world. Driven by rapid urbanization and growing wastewater volumes, wastewater is widely used as a low-cost alternative to conventional irrigation water: it supports livelihoods and generates considerable value in urban and peri-urban agriculture despite the associated health and environmental risks. Though pervasive, this practice is largely unregulated in low-income countries, and the costs and benefits are poorly understood [1].

Mathematical water quality models were developed since 1920.In 1925, the well-known model of Streeter and Phelps [2] described the balance of dissolved oxygen in rivers. In 1970, package DOSAG-1 was developed by the Texas Water Development Board to simulate point and distributed sources of carbonaceous and nitrogenous oxygen demand and their impact on the *DO* concentration in stream. DOSAG-1 was modified for EPA by Water Resources Engineers as DOSAG-3 by increasing the number of simulated constituents. In the same year Mash et al [3] developed the first version of probably the most popular model – QUAL-1 which allows for simulation of *DO* and *BOD*. QUAL model was improved and extended several times throughout the following years. In 1972, QUAL-1 was extended by Camp Dresser & McKee [4] by adding the option for computing algae, nutrients, and non-conservative pollution. In 1987, Brown and Barnwell [5] introduced two new versions: QUAL 2E and QUAL2E UNCAS. QUAL 2E contains an enhancement to algae-nutrient-*DO* interaction, whereas QUAL2E UNCAS enables uncertainty analysis including three options: sensitivity analysis; first-order, second-moment analysis; and Monte Carlo simulations. The second most popular water quality model is probably WASP5. Its first version was developed in 1983 by Di Toro [6] and modified in 1993 by Ambrose et al [7]. Model WASP5 consists of two engines: DYNAHYD5 [8] used for simulation of unsteady flow and WASP5 which simulates transport of pollution in the river. Majority of models, including the most popular QUAL2E and WASP5, use the traditional calibration technique involving trial and error. Model WODA (Water Oxidation Deoxidation Assessment)developed by Kraszewski and Soncini-Sessa [9] belongs to a newer generation of models that use automatic calibration techniques employing genetic algorithms. WODA is one dimensional steady-state water quality model that uses the advanced version of Streeter-Phelps model [2]. The model takes into account sedimentation, photosynthesis, and respiration of aquatic organisms as well as re-aeration and biodegradation.

Nutrient pollution is one of most widespread, costly and challenging environmental problems. It is caused by too much nitrogen and phosphorus in the air and water. Nutrients are chemical elements that all living organisms plants and animals need to grow. When too much nitrogen and phosphorus enter the environment usually from a wide range of human activities the air and water can become polluted. The primary sources of nutrient pollution are runoff of fertilizers, animal manure, sewage treatment plant discharges, storm water runoff, car and power plant emissions, and failing septic tanks. Excessive nitrogen and phosphorus in water and the air can cause health problems, damage our land and water, and take a heavy toll on the economy[10-12].

The problems of nutrient enrichment in Lakes are compounded by the influence of climate change on temperature and precipitation regimes and ecosystem changes caused by aquatic invasive species such as dreissenid mussels. As a result of these influences, Lakes has experienced a decline in water quality over the past decade, with impacts on ecosystem health, drinking water supplies, recreation and tourism, and property values [13].

Nutrients are necessary for the survival and growth of aquatic plants which are the base of the food chain for all other aquatic organisms. Although a number of nutrients (such as nitrogen, phosphorus, silica, carbon, potassium, calcium, and magnesium) are needed by plants for growth and reproduction, nitrogen and phosphorus are the two of particular interest that are more commonly monitored by volunteer monitoring programs. Nitrogen and phosphorus are the nutrients that limit plant growth in most aquatic systems. Nutrient levels in an aquatic system vary depending upon temperature, rainfall, runoff, biological activity, and the flushing of the aquatic system [14].

Nutrient levels are generally higher in the spring and early summer and impact the aquatic system in several ways. High nutrient levels can accelerate eutrophication of a waterway. Eutrophication is characterized by abundant growths of phytoplankton (microscopic plants and algae) called algal blooms that may block sunlight from submerged aquatic vegetation. These algal blooms result in lower dissolved oxygen levels as decomposition of their organic matter consumes the dissolved oxygen [15].

Developing nutrient criteria for the nation’s waters is currently a hot issue. The debate centers on determining the limiting nutrient for a particular type of water in a particular ecoregion. Currently, Virginia has not yet adopted water quality standards for nutrients except for total ammonia as it relates to the toxicity to aquatic animals and nitrate for public drinking water supplies. Nitrate levels in public water supplies should not exceed 10,000 ug/l (micrograms/liter), or 10 mg/l. The Virginia Department of Environmental Quality (DEQ) currently designates “nutrient enriched waters” where there is degradation due to excessive nutrients [16].

For free-flowing streams, the maximum concentration for total phosphorus is 200 ug/l, or 0.20 mg/l; while it is only 50 ug/l, or 0.05 mg/l, for lakes. DEQ has recently begun the process of developing nutrient water quality standards. Nutrient water quality standards are scheduled to be adopted as follows: in 2005 for tidal tributaries to the Chesapeake Bay; in 2006 for lakes; and in 2007 for freshwater streams [17].

Nutrient concentrations in aquatic systems are influenced by both natural and human sources. Natural sources of nitrogen and phosphorus include decomposition of organic matter, nitrogen fixation of atmospheric nitrogen by certain bacteria and algae, and geologic formations rich in nitrogen or phosphorus. Human sources include discharges from wastewater treatment plants, storm water runoff, livestock wastes, fertilizer runoff from lawns and agricultural fields, groundwater seepage from failing septic systems, planting of nitrogen fixing plants (such as clover or beans) in agricultural fields, and atmospheric deposition (including acid rain) from the burning of fossil fuels [18].

2. MATERIALS AND METHODS

2.1. Data Collection of El-Salam Canal

During the study, all the available rainage water resources that can be mixed with El-Salam canal are determined (Bahr Hadous, lower Serow) in addition to other resources still under construction to be mixed with the canal (Farascour drain, and expansions of lower serow pumps station) in order to study the effect of these resources on mixing ratios from drains being studied (South Hosainia plain, and El-Taweel). The necessary data about El-Salam Canal and Drains and drainage stations planned to be mixed with El-Salam Canal are summarized as following:

The water policy of El-Salam Canal project aims at reclaiming and cultivating 620.000 feddans, of which 220.000 feddans are located in the west of Suez Canal as a first stage, and 400.000 feddans located in the East of Suez Canal as a second stage depending on using drainage water mixed with the Nile water with a portion 1:1.

A lot of studies have been made concerning the quantity and quality of drainage water for a whole year. The results of theses studies show :

- 2.1 billion m^3/year from Damietta branch.
- 0.435 billion m^3/year from lower Serow.
- 1.905 billion m^3/year from Bahr Hadous.

So the total water resources that will used is 4.450 billion m^3. Namely, the amount of water that will be used in the first stage in the west of Suez Canal to irrigate 220.000 feddans is 1.790 billion m^3/year, 558 billion m^3/ year will be taken from lower Serow drain, and 336 billion m^3/year from Bahr Hadous drain, and 900 million m^3/year from the Nile (Damietta branch).

2.1.1.1. Water requirements of the sites of El-Salam Canal project

Theses requirements needed to irrigate 400000 feddans in the east of Suez Canal are estimated according to crop structure, and maximum drainage needed. The results show the following:

1. The maximum drainage needed for the project according to the suggested crop structure is 146.498 m^3/sec.
2. Total annual water requirements of agriculture is 2435 million m^3/year.
3. Total annual water requirements of agriculture and other usages is 2595 million m^3/year.

2.2. Field Measurements

Many field measurements have been done on some items of water quality that are affected by storing and transporting water samples. Field measurements have been done on drainage in six locations in the stream. These locations are:-

1- H_1, which located at distance about 10.2 km from point source
2- H_2, which located at distance about 9.2 km from point source
3- H_3, which located at distance about 6 km from point source
4- H_4, which located at distance about 4.3 km from point source
5- H_5, which located at distance about 0.7 km from point source
6- H_6, which is point source

2.2.1. Items of water quality

During the one-year- study, many different measurements have been made on the items of water quality during a whole year to find out different changes in water quality in order to ensure the good quality of drained water represented by the samples collected according to measurement standards concerning collecting storing, and transporting samples which will undergo laboratory analyses some field measurements of the items of water quality have been made on samples:

- Ammonia, NH_4^+
- Nitrates, NO_3^-

- Phosphates, PO_4^{3-}

2.2.2. Drainage measurement

Drainage of stations is measured by collecting daily data of water level in the outfall of pumps, in addition to calculating the hydrostatic pumping of units. Operating hours of each unit are stated daily, then the drainage of different units is calculated through the special equations of each station or unit.

Drainage is also calculated at different water levels several times in order to reach the relation between drainage and water level or depth. The field data processing is done through Hydro program which is designed specially to calculate drainage and find out the statistic relation between drainage and water level in order to reach the mathematical relation that corresponds to drainage through following water level or depth.

3. RESULTS AND DISCUSSION

3.1. Nutrients Determination

Figures (1-3) shows the corresponding nutrients concentration changes during 12 month for the samples which collected from the agriculture Drainage system of Bahr Hadous . The graph shows that there is an increasing of nutrients concentrations during September to December. The increasing of nutrients concentrations are due to the lowering of flow rate of irrigation water through this period.

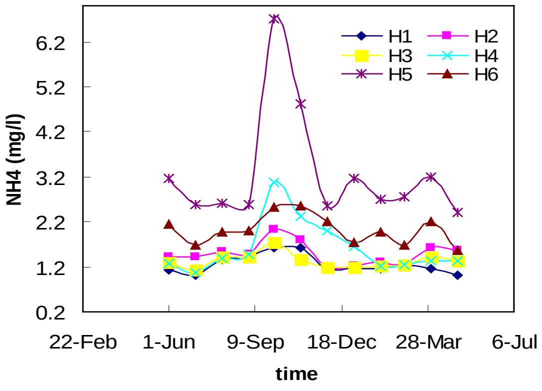


Fig. 1: Variation of NH_4^+ concentration.

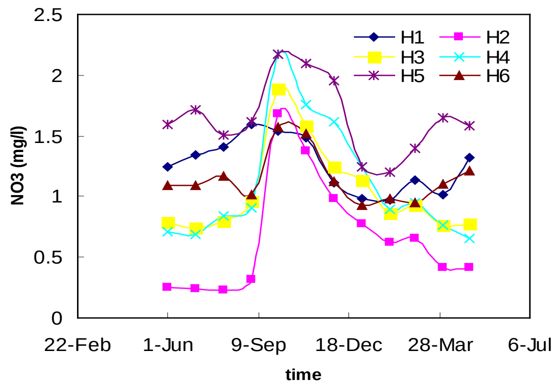


Fig. 2: Variation of NO_3^- concentration.

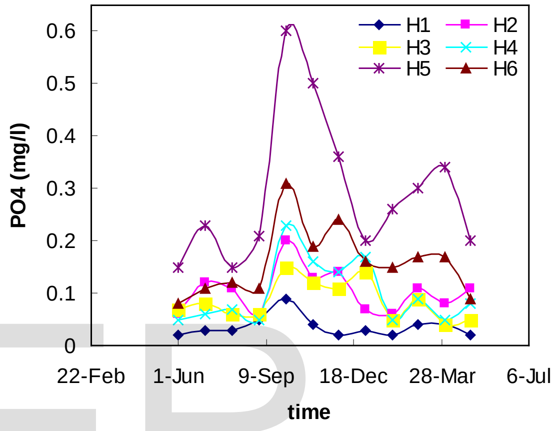


Fig. 3: Variation of PO_4^{3-} concentration.

3.2. Nutrients Models

Curve fitting for the main variables (Figs. 4-7) for the Drainage system was used to correlate the data in the three dimensional and to obtain a third order equation to predict the feature changes of the ammonia load concentration for each season. The form of the third order equation is:-

$$z= a+bx+cy+dx^2+fy^2+gx^3+hy^3+ixy+jx^2y+kxy^2$$

where,
z = is the variable concentration (NO_3^- ,NH_3^- and PO_4^{3-}) mg/l
x = distance from point source, km
y = flow rate, m^3/hr, and
a, b, c, d, f, g, h, I, and j are constants

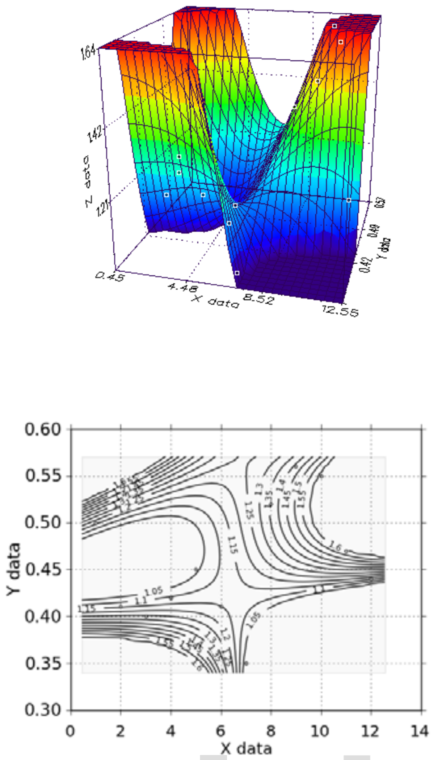


Fig. 4: NH_4^+ surface and contour polluting for Autumn.

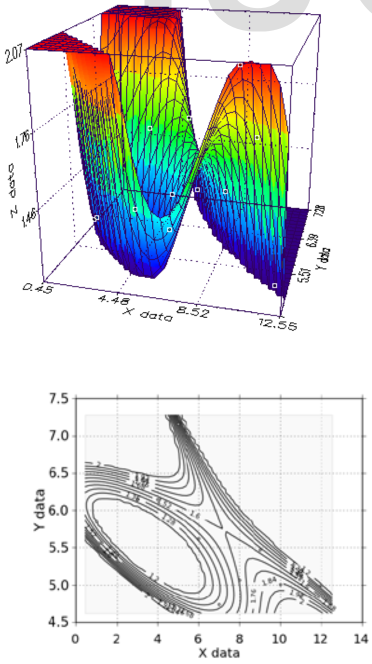


Fig. 5: NH_4^+ surface and contour polluting for summer.

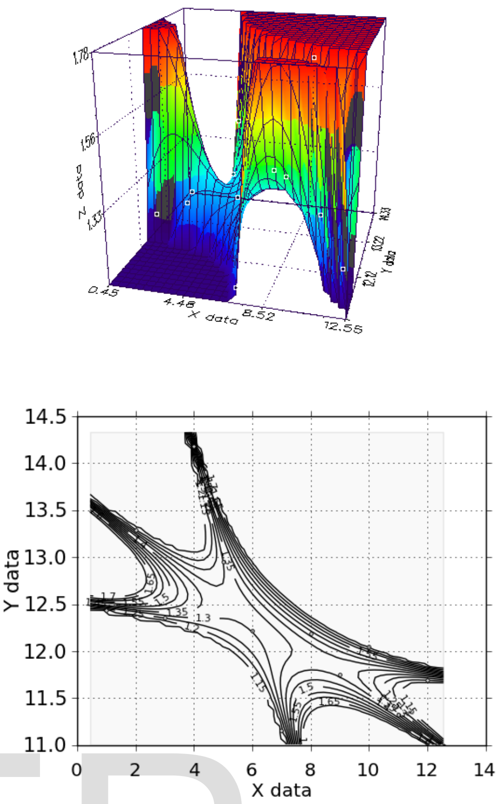
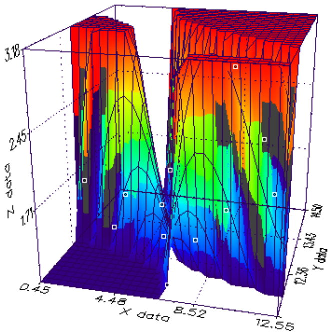


Fig. 6: NH_4^+ surface and contour polluting for winter.



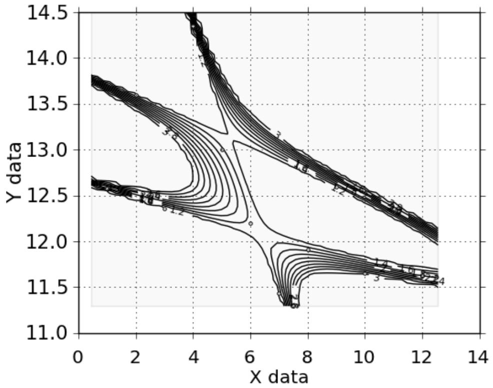


Fig. 7: NH_4^+ surface and contour polluting for Spring.

Table (1): Constants and squared absolute error.

Parameter		Constants	absolute error
NH_4^+	Autumn	a = 31.7998 b = -3.55869 c = -141.2595 d = -0.10998 f = 168.46117 g = -0.000814 h = -15.70307 i = 17.55457 j = 0.2789568 k = -21.5958	0.0033
	Summer	a = 293.856 b = -32.65573 c = -124.2041 d = 1.240406 f = 17.2171 g = -0.01659 h = -0.772666 i = 9.3821657 j = -0.1729621 k = -0.673332	0.0075
	Winter	a = -2824.480 b = 212.3568 c = 587.6145 d = -3.35064 f = -40.262718 g = 0.0108197 h = 0.907053 i = -31.3858 j = 0.258864 k = 1.1538223	0.0067
	Spring	a = -13641.77 b = 942.2998 c = 2816.4957 d = -13.13789 f = -191.7778 g = 9.052967 h = 4.299358 i = -13.78043 j = 97.834 k = 5.02152	0.0016

NO_3^-	Autumn	a = 15.864745 b = -1.2364217 c = -75.174457 d = -0.0439064 f = 106.414668 g = -0.0010843 h = -31.223139 i = 6.72376975 j = 0.12273004 k = -8.539008	0.0048
	Summer	a = 429.720184 b = -55.511629 c = -175.79888 d = 1.81721605 f = 22.9154162 g = -0.0219274 h = -0.9173298 i = 16.6070896 j = -0.2565576 k = -1.2577	0.0410
	Winter	a = -6650.132 b = 521.04082 c = 1376.1049 d = -8.205588 f = -93.66594 g = 0.02927596 h = 2.0917309 i = -77.091555 j = 0.6316980 k = 2.8372482	0.0585
	Spring	a = -9664.5586 b = 662.91010 c = 1998.1006 d = -9.3839838 f = -136.29475 g = 0.0389475 h = 3.0627414 i = -96.833341 j = 0.6982586 k = 3.5235294	0.0146
PO_4^{3-}	Autumn	a = 3.4240427 b = 0.0850377 c = -21.807365 d = -0.0267285 f = 43.821916 g = 0.0005057 h = -27.75752 i = 0.1836544 j = 0.0380835 k = -0.584352	0.000084
	Summer	a = 31.700169 b = -5.368304 c = -11.701008 d = 0.10988844 f = 1.20309966 g = -0.0010946 h = -0.0215623 i = 1.77012176 j = -0.0166690 k = -0.1471930	0.00299
	Winter	a = -498.161363 b = 39.4340253 c = 103.248755 d = -0.6193410 f = -7.0345633 g = 0.00224797 h = 0.15711557 i = -5.85352894 j = 0.04.778138 k = 0.21611935	0.0007
	Spring	a = -1475.91281 b = 103.718543 c = 304.268319 d = -1.4380843 f = -20.674724 g = 0.0059221 h = 0.4621246 i = -15.189953 j = 0.10702326 k = 0.5543566	0.0064

From the Table (1) we can show that the equation has law absolute error which mean that we can predict the changes of the nutrients concentration from this equation with high accuracy.

4. CONCLUSIONS

Evaluation of changes of the nutrients concentration for Bahr Hadous, lower serow irrigating drainage show that:-

1- Increasing of NH_4^+ during September to December due to the lowering of flow rate of irrigation water through this period

2- NO_3^- and PO_4^{3-} increased also during the same period

3- The data correlated in an third order equation with law absolute error and we predict the feature changes of the nutrients concentration in each season.

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