Case Study for:

Impact of WWTP effluent on drains water quality in Egypt.

By *D.S. Elmonayeri*

Abstract:

The stream sanitation and pollution control is dependent on natural self-purification, the ability of the stream to assimilate wastes and restore its own quality. The stream solvency in transit along its course reflected by the balance of outgo and income dictated by four primary self-purification factors: 1) stream runoff, 2) time of passage, 3) temperature and 4) reaeration. The dissolved oxygen (DO) profile resulting from specific organic waste loading has been considered as an indicator of the stream condition. In this work, an analytical model has been used to predict the DO profile along to drains in Egypt. The calculated DO shows a good agreement with those values obtained from the field measurements.

Introduction:

One of the most critical problems today, which requires a quick solution, is the failure of water to meet the required demands. This arose the need to protect the available surface water sources from pollution .One major source of surface water pollution is the discharging of raw-or treated -sewage into the surface water stream. The impact of pollution on the receiving water body is manifold and dependent upon the type and concentration of the pollutants (Nemerow and Dasgupta, 1991). The different pollutants, e.g. pathogens, suspended solids, organic matter, algae, nitrate, salts, etc. have different impacts on the surface water quality. For example, soluble organic, as represented by BOD , cause depletion of oxygen in the surface water resulting in fish killing, undesirable aquatic life, taste and odors .

The objective of the present study is to investigate the pollution level, using the concentration of dissolved oxygen, DO, as an assessment tool, downstream the discharge point of treated sewage in some drains in Egypt. This may be helpful in the prediction of the minimum distance between the location of the treatment plants along the drain to minimize the impact of their effluent on its water and allowing the drain to recover.

Manuscript received from Dr. D.S Elmonayeri on : 25/10/1999
Accepted on : 10/11/1999
Engineering Research Bulletin, Vol 23,No 1, 2000 Minufiya University, Faculty of Engineering , Shebien El-Kom , Egypt, ISSN 1110-1180

Theoretical Background:

The concentration level of pollution in the stream is influenced by too many factors such as dilution, physical, chemical and biological processes that may take place during the transportation of the fluid along the stream. The dissolved oxygen, DO, concentration in the stream has been used as a measurement of the organic pollution level in the stream. Many DO models have been developed James (1993). Streater and Phelps (1925) considered the two main influences; namely the oxygen decreases as a result from the exertion of BOD and the oxygen replenishment by reareation from the atmosphere. They developed their classical DO model by assuming one-dimensional, steady state and continuous discharge conditions, as follows:

$$D_t = (K_1\ L_0)/(K_a - K_1) * (10^{-k_1 t} - 10^{-k_a t}) + D_0 10^{-k_a t} \qquad (1)$$

Where:

D_t = DO deficit at any flow time t, days (or at any distance, x, downstream the pollution source, where x = (v, velocity * t, for steady state conditions), $D_t = C_S - C$, C_S = DO saturation concentration, C = DO actual concentration, K_1 = coefficient of deoxygenating, day $^{-1}$ = rate constant for BOD exertion, K_a = coefficient of reaeration, day $^{-1}$, L_o = initial ultimate BOD in the stream following the mixing of the pollutant, mg/l and D_o = DO deficit at point of waste discharge, mg/l.

Another basic DO model is the one-dimensional advection-dispersion-mass-transport equation. This equation may be written for a single first-order Decay process as follow (Ray, 1990):

$$\partial C / \partial t = -V\,\partial C / \partial x + \partial / \partial x\ (A_x D_L\ \partial C / \partial x)^{-k_1\ C} / (A_x \partial x) - K_1 C + \Sigma ri + \Sigma Ij \qquad (2)$$

Where:

C = concentration (M/L^3, M =mass) at any time, t, V = mean velocity (L/T) A_x = cross-sectional area (L^2) at any distance , x, D_L = Dispersion coefficient (L^2/T) , K_I = decay rate coefficient (T^{-1}), I = external input rate ; mass injected per unit time per unit volume of water (M/TL^3) , r = rate of oxygen loss and / or gain per unit time volume of water (M/TL ^{3})

The one-dimensional approach has been considered in equation (2) due to the fact that the streams are generally much longer than they are wide or deep.

For a continuous discharge of wastewater into a stream, the concentration of the organic undergoes first-decay process. This approach can be applied for both carbonaceous BOD (CBOD) and nitrogenous BOD (NBOD). Thus the above equation for dissolved oxygen, one-dimensional steady-state conditions, can be deduced from the mass conservation to the following:

$$O = -v\, dC / dx + K_a (Cs - C) - K_1 C - P + R + I \qquad (3)$$

So, the time derivative term ($\partial C / \partial t$) is removed and the dispersion term can be neglected due to its negligible effects for a continuous discharge (Metcalf and Eddy, 1995)

P = reach photosynthesis (oxygen production) rate (M/TL^3)
R = reach respiration (oxygen consumption) rate (M/TL^3)
I = external input rate (M/TL^3)

Utilizing the above, Hughto and Schreiber (1982) introduced their analytical model which consists of three governing equations, one for each model constituent:

$$O = -u\, dD / dx - K_a\ (DS - D) + K_d\, b + K_n N - P + R - SD \qquad (4a)$$

$$O = -u\, dB / dx + K_d B - SB - DB \qquad (4b)$$

$$O = -u\, dN / dx + K_n N - SN - DN \qquad (4c)$$

Where:

u= reach velocity (m/day) , D = DO concentration (mg/l), B = CBOD concentration (mg/l), N = NBOD concentration (mg/l), x = streamwise direction (m), K_a = reach reareation rate (l/day) , K_d = CBOD decay rate(l/day), K_n = NBOD decay rate (l/day), DS = saturation of DO concentration (mg/l) , P = reach photosynthesis rate(mg/l/day), R = reach respiration rate (mg/l/day), SD = reach DO source rate (mg/l/day), SB = reach CBOD source rate (mg/l/day), SN = reach NBOD source rate (mg/l/day), DB = reach distribution CBOD source rate (mg/l/day) and DN = reach distribution NBOD source rate (mg/l/day)

The coefficient of reaeration, K_a has been estimated by many formulas.

The most commonly used formulas are those reported by Churchill et al. (1962):

$$K_a = (5.03 v^{0.969}) / H^{1.673} \qquad (5)$$

And by O'Conner and Dobbins (1958):

$$K_a = 3.93\, (v)^{1/2}\ / H^{3/2} \qquad (5a)$$

Or that by Owens and Gibbs (1964)

$$K_a = 5.32\ \frac{v^{0.67}}{H^{1.85}} \qquad (5b)$$

Another formula by Tsivoglou and Neal (1976) has been used to determine K_a based on energy dissipation, is:

$$K_a = C_e\, \Delta h / t_r \qquad (5c)$$

Where:

v = the stream velocity (m/s)
H = the stream depth (m)
Δ h = change in surface elevation ,(m)
t_r = travel time, d = x/v
Ce_{20} = escape coefficient at 20°C = $0.177 m^{-1}$ ($= 0.09\ m^{-1}$

For large streams with flows greater than 7 m^3/S.)

Ce = escape coefficient at any temperature, T, = $Ce_{20} * 1.022^{(T-20)}$

The coefficient of CBOD and NBOD decay rates (K_d and K_n) can be determined from a series of BOD measurements and using one of the least-squares method, Moore, etal 1950 and / or Fujimoto(1961). However, for simplicity, the CBOD decay rate, K_a, has been calculated according to equations 5,5a and 5b and the NBOD decay rate, K_n, has been taken 1/3 of the CBOD decay rate (Chapra, 1991.).

Materials and Methodology:

Numerous parameters can be analyzed in surface water quality investigations, ranging from heavy metals and oil products to pesticides, pH and oxygen concentration. It was decided to only focus on the required parameters for the solution of the above analytical model such as : CBOD, NBOD, temperature, pH and dissolved oxygen

Water samples were collected manually at different locations. These samples locations were typical from different drains y located upstream, outfall and downstream wastewater treatment plants outfall site. The Samples were collected and chemically analyzed by a team from National Organization for Potable Water and Sanitary Drainage (NOPWASD). The results of the chemical analysis, as well as, the location of the samples on the specified drain are shown in table (1).

The hydrological information, discharge water depth, and velocity, in the specified drains were obtained from the Drainage Research Institute (DRI).

Table (2) shows the measurements of DO, temp. PH ,EC, TDS., Turbs., velocity and dischargees which have been conducted on the same drains by DRI Figs. (1) and (2) show the schematic diagrams for the drains, the location of the measurement points and the interconnecting drains.

In the present work, the analytical model mentioned above(equations4a, 4b, and 4c)have been solved via computer, so that the information can be used actively to obtain a better and more precise picture on some existing drains and its pollution due to the discharging of waste water treatment plants effluents into them.

Table (1) Field test results (by NOPWASD) Manshia Sabry drain for (QuesnaWWTP)

No.	Analysis Type	Upstream 200 m	Outfall	Downstream 200 m	Downstream 1 Km	Downstream 2 Km	Unit
1	CBOD	33,00	56,00	47,00	58,00	34,00	mg/L
2	NBOD	4,00	4,00	4,00	4,60	2,00	mg/L
3	Temperature	32,00	23,00	21,00	22,00	21,00	C
4	PH	8,26	8,48	9,51	9,22	7,20	
5	Dissolved Oxygen	5,40	6,80	8,51	14,50	7,00	mg/L
6	Photosynthesis rate	22,80	20,80	24,00	32,80	13,20	mg/L/day
7	Respiration rate	12,80	12,00	11,20	6,00	15,60	mg/L/day
8	Suspended Solids	43,00	59,00	69,00	146,00	14,00	mg/L

Table (1a) Field test results (by NOPWASD) for Nabroh WWTP

No.	Analysis Type	Upstream 100 m	Outfall	Downstream2 Km	Crossing Pt.Om Elmohseneen Drain	Unit
1	CBOD	42,00	35,00	47,00	18,00	mg/L
2	NBOD	3,00	2,00	3,00	2,00	mg/L
3	Temperature	24,00	24,00	25,00	24,00	C
4	PH	7,80	8,20	8,00	7,40	
5	Dissolved Oxygen	6,20	2,80	2,80	4,20	mg/L
6	Photosynthesis rate	28,40	23,20	25,20	22,9	mg/L/day
7	Respiration rate	4,80	5,20	5,60	4,00	mg/L/day
8	Suspended Solids	27,00	16,00	32,00	20,00	mg/L

No.	Analysis Type	After Crossing Pt. 500 m	After crossing pt. 1 Km	After crossing pt. 2 Km	Unit
1	CBOD	21,00	26,00	41,00	mg/L
2	NBOD	2,00	3,00	3,00	mg/L
3	Temperature	23,00	24,00	25,00	C
4	PH	7,70	7,50	7,20	
5	Dissolved Oxygen	3,70	6,70	3,60	mg/L
6	Photosynthesis rate	24,80	20,00	20,40	mg/L/day
7	Respiration rate	3,60	3,60	3,60	mg/L/day
8	Suspended Solids	26,00	22,00	18,00	mg/L

Table (2) Field test results by (DRI) for Quesna and Nabroh

Location Code	Temp. °C	pH	Ec dS/cm	TDS (mg/l)	DO (mg/l)	Turb (FTU)	Discharge (m^3/sec)
Table (2a) Quesna Wastewater Treatment Plant							
1	16.3	8.74	2.11	1350	6.4	15	0.086
2	18.8	7.18	1.81	1292	9.3	60	
3	18.3	7.34	1.91	1222	0.4	85	0.286
4	17.8	7.85	1.67	1067	5.2	45	
5	18	7.88	1.8	1154	2.9	70	0.732
6	19.4	9.03	1.92	1231	10.7	15	
7	21.2	8.26	1.65	1053	6.5	10	0.028
8	18.9	8.51	1.88	1203	8.8	15	
9	17.1	8.24	1.31	838	5.8	65	0.279
10	18.6	8.87	1.72	1098	10.5	55	
11	18.1	8.27	1.43	918	7.3	50	
12	17.4	8.02	1.48	949	7.1	60	1.129
13	18.4	7.98	1.59	1014	3.8	40	2.135
14	20.8	7.98	1.33	847	11.9	20	0.048
15	18.6	7.35	1.63	1048	4	65	1.214
16	19.8	8.2	1.4	998	7.7	70	0.664
17	17.3	7.45	1.62	1035	5.6	55	0.939
b) Bella & Nabroh Wastewater Treatment Plant							
1	14.6	7.87	1.1	787	0.8	60	
2	13.6	7.61	0.6	428	3.9	15	
3	12.8	8	2.23	1588	1.1	60	
4	13.6	8.9	c	954	1.5	60	
5	14.2	7.5	1.29	918	1.7	55	0.484
6	15.6	7.71	1.7	1212	1.7	55	
7	15.2	7.75	2.17	1554	1.8	55	
8	14.6	7.75	2.17	1548	1.8	55	
9	15.6	7.48	2.54	1818	0.3	100	
10	15.2	7.48	2.34	1632	1.9	100	
11	14	7.54	2.27	1617	2	75	2.366
12	14	7.7	1.46	1040	4	70	
13	13.9	7.2	2.48	1779	2	70	5.697

Ec = Electric Conductivity in dS/m
TDS = Total Dissolved Salts in mg/l
Do = Dissolved Oxygen in mg/l
Turb = Turbidity

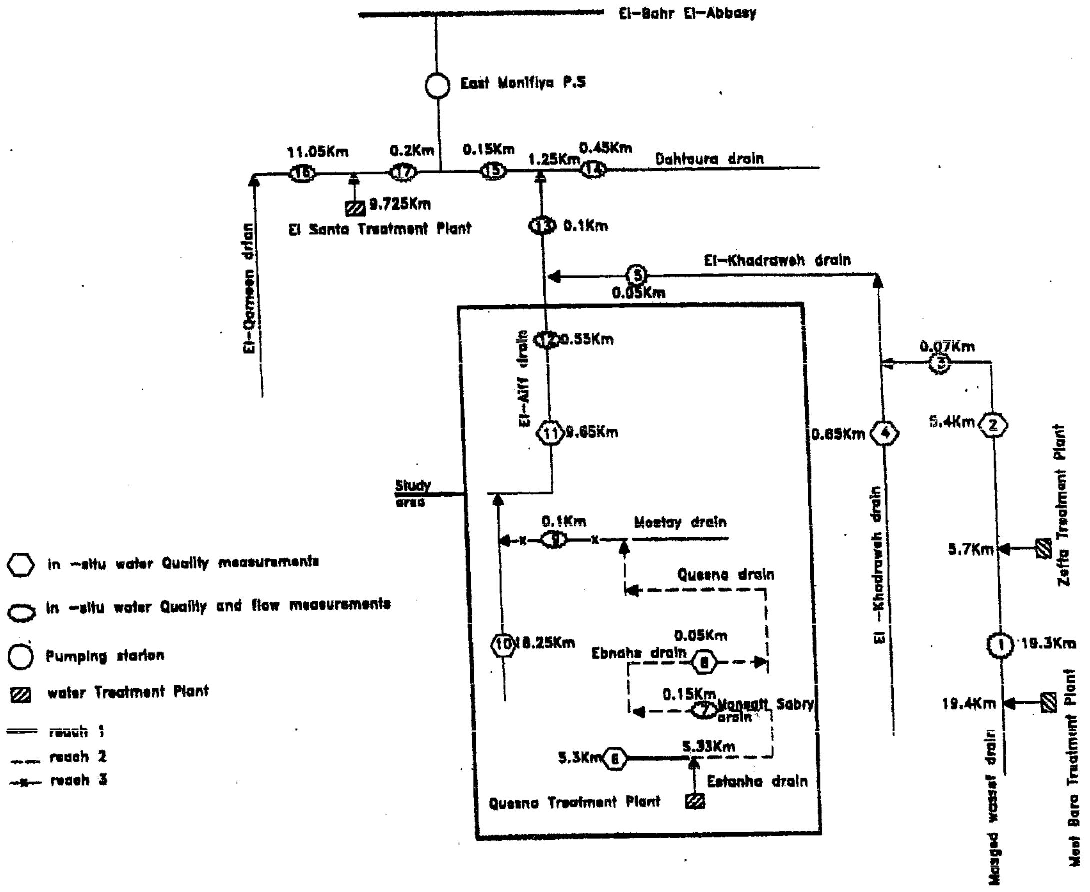

Figure (1):Schematic diagram for the drain recieving Quesna WWTP Effluent

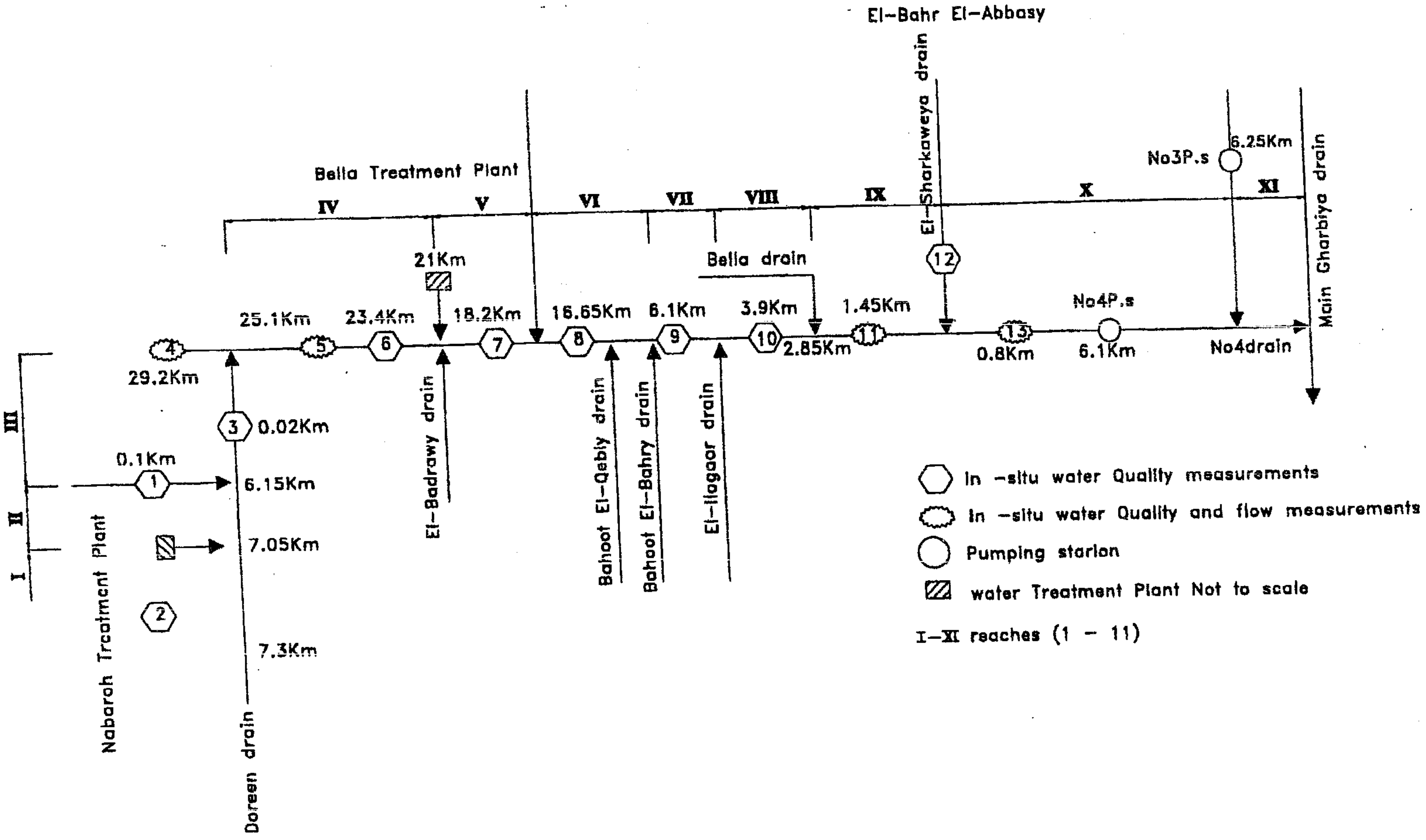

Figure (2):Schematic diagram for the drain recieving Nabaroh WWTP Effluent

Results and Discussion:

The analytical models presented in equations 2 & (4a-4c) have been used to predict the DO profile at both Quesna and Nabroh drains after loading them with the effluent of the WWTP'S. Solving equation 4 has been dealt with amortization of organic matter in terms of the carbonaceous matter (CBOD) which represents the true dissolved oxygen demand of the stream. Simultaneously, nitrogenous matter (NBOD), which may be converted to oxidized nitrates and, consequently, draw the dissolved oxygen of the stream has been considered. The DO profile along the stream after introducing the WWTP effluent has been calculated. . In order to solve the analytical model, the receiving stream was divided to three reaches for Quesna drain and eleven reaches for Nabroh drain depending on the existing boundary conditions.

The results of the calculated DO are presented in figs(3 and 4) for both drains analyzed in this study. Figs.(3 and 4) show the specific level of the predicted and measured DO at different distances from the pollution source point. Fig. (3) shows the predicted DO resulted from loading the drain with a discharge of 0.06 m^3/ S (5000 m^3/d) from Quesna WWTP.

The obtained results for Nabroh drain for the different concentrations of the DO as a result of discharging the flow of the Nabroh WWTP effluent to the drain are shown in fig. (4).

The obtained results showed that the recovery in Quesna Estanha drain started to take place at a distance of 5.5 Km from the outfall point for the discharge value. The recovery at Nabroh drain started at a distance of 29 km from the pollution source point.

Verification was made in comparison of the computed DO profile against those observed in the field. This necessitated the determination of both carbonaceous and nitrification decay rates has been shown and they have been adjusted for temperature at the time of sampling along the stream.

The overall comparison of the observed DO profile and the computed one are shown in figs (3 and 4) for both drains. A remarkably good agreement is evident which warrants the acceptance of these deoxygenation rates used in the above study.

It should be mentioned here that the DO profile resulting from specific organic waste loading has stability only to the extent that the waste loading remain steady, and that a stable river regime is established and prevails during the time of passage downriver. Thus, it is fundamental to have long term analysis of hydrologic and biologic variability to rational the analysis. The use of the present model can be utilized to reach model practical solutions for waste disposal and pollution once these analysis has performed on the specific stream.

Conclusions:

The present work showed that the DO concentration along the hoste stream is highly affected by the initial DO concentration in the discharged WWTP effluent. The presented simplified model, (eq.4) for the prediction of the DO concentration, with the limitation mentioned in the text, compare well with those results obtained from the field measurements.

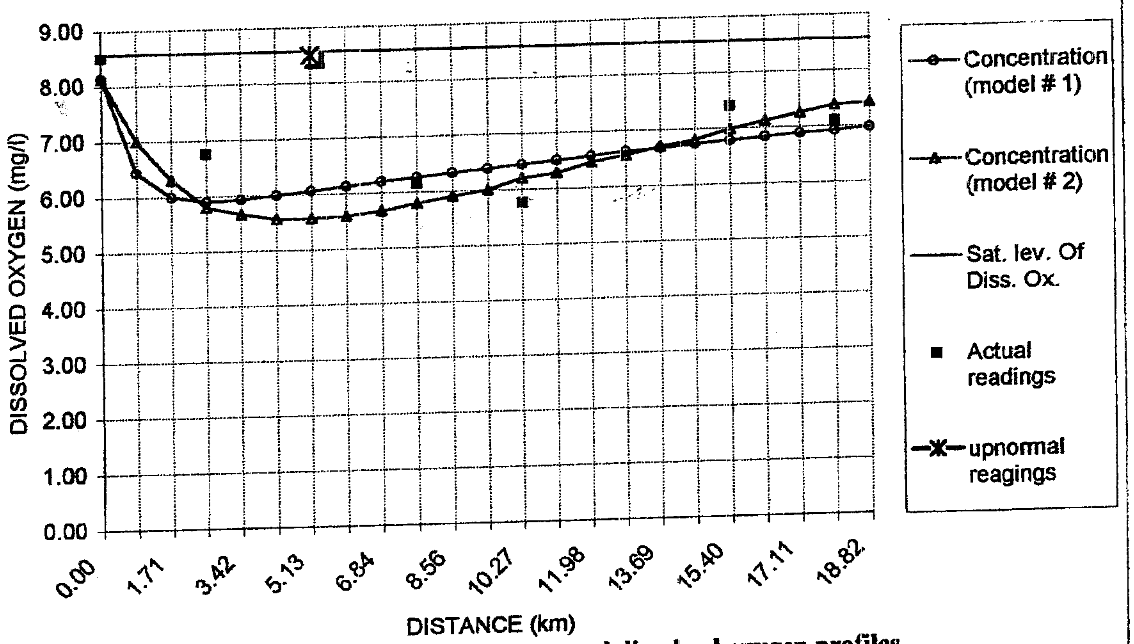

Fig. (3) : Observed dissolved oxygen Vs computed dissolved oxygen profiles for Quesna WWTP effluent

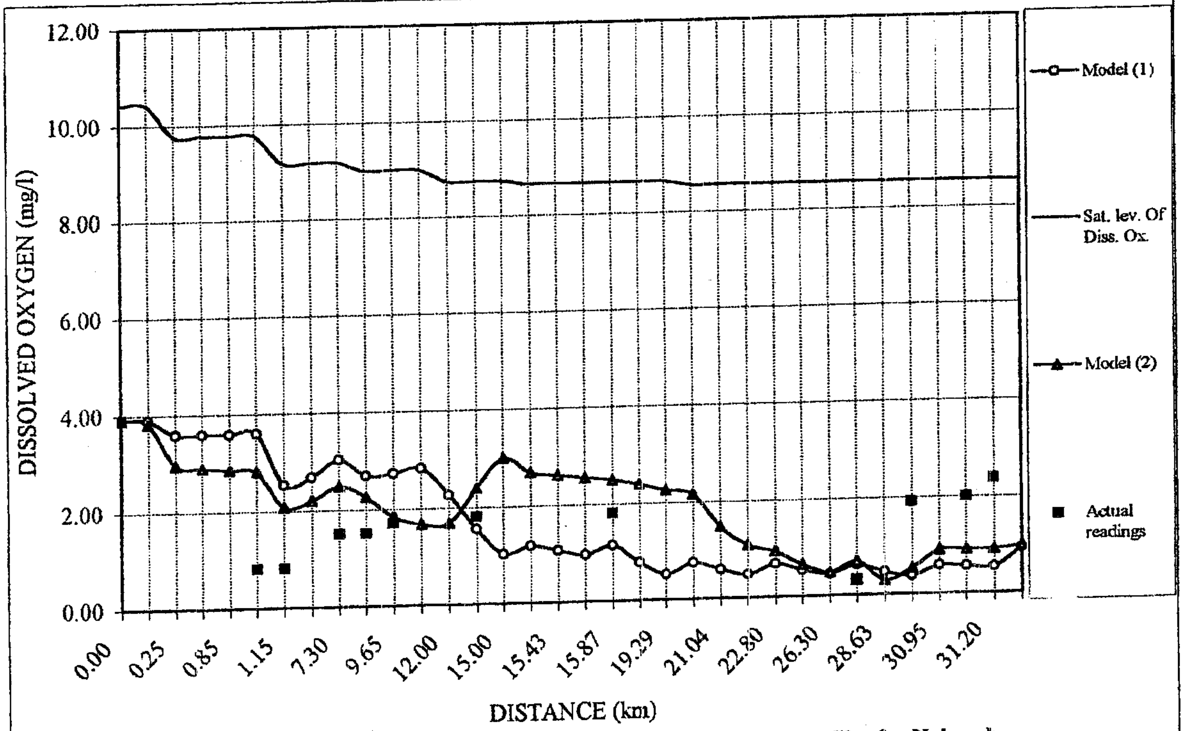

Fig. (4) : Observed dissolved oxygen Vs computed dissolved oxyjen profiles for Nabaroh WWTP effluent

The model (eq.4) took into consideration many parameters which control the level of oxygen changes in the stream to predict the DO profile along the stream.

Finally, further field investigations are needed to establish the model and to take into consideration the effect of the sediment oxygen demand in the mechanistic fashion.

References:

1. Chapra, S.C., (1991) "A Toxicant Loading concept for organic contaminants lakes" j. Environ. Engr. 117(5) : 656 – 677.
2. Churchill, M.A., Elmore, H.L. and Buckingham, R.A. (1962) "Prediction of stream Reaeration Rates" J. San. Eng. Div. ASCE SA4: 1 Proc. Paper 3199.
3. Fujimoto, Y., (1961): "Graphical use of first-stage BOD Equation", J.WPCF, vol 36, no.1
4. Hughto, RJ and Schreiber, RP (1982) "Micro computer water Quality Simulation Model" Civil Eng. Computer Services- ASCE.
5. James, A.,ed (1993): "An Introduction to Water Modeling" , John Wiley and Sons, West Sussex, England.
6. Metcalf & Eddy Inc. 1995: "Wastewater Engineering Treatment, Disposal and Reuse", 3rd Ed. McGraw-Hill Publishing company Ltd. New York.
7. Moore, E.W., Thomas, H.A. and Snow, W.B. (1950): "Simplified Method for Analysis of BOD Data" Sewage Ind. Wastes, vol 22, no. 10.
8. Nemerow, N.L., Dasgupta, A. (1991): "Industrial and Hazardous Waste treatment", Van Nostrand Reinhold Company, New York.
9. Ray,C. (1990) "Use of Qual-I and Qual-II Models in evaluating waste loads to streams and rivers". Environ. Modeling for Developing Countries Tycooly Publishing, London, pp 65-79
10. Streeter, H.W. and Phelps, E.B. (1925): "A Study of the Pollution and Natural purification of the Ohio River, III Factors concerning the Phenomena of Oxidation and Reaeration". U.S. Public Health Service, Pub. Health Bulletin No. 146.
11. Tisvoglou, E.C. and Neal, L.A. (1976): "Tracer Measurements of Reaeration: III Predicting the Reaeration Capacity of Inland Streams" J. Water pol, Control, Fed.48 (12), P1. 2669-2689.

تأثير صرف خارج محطات معالجة مياه الصرف الصحي علي خواص مياه المصارف في مصر

د/ ضياء صلاح الدين المنيري

يعتمد التحكم في مدي تلوث مياه المجاري المائية علي قدرتها في التنقية الذاتية و احتواء الملوثات الملقاة بها. و تعتمد قدرة المجري المائي في التنقية الذاتية في اتجاه مساره علي أربعة عوامل رئيسية و هي :-

١- سرعة المياه.
٢- الزمن.
٣- درجة الحرارة.
٤- معدل التهوية.

و قد تم اعتبار أن منحني الأكسجين الذائب علي طول مسار المجري المائي كدليل علي مدي تلوث المجري.و بناءاً علي ذلك فقد تم استخدام نموذج رياضي لحساب نسبة الأكسجين الذائب علي مسار المصارف في جمهورية مصر العربية. و قد تم أخذ قراءات حقلية عند مواقع مختلفة علي طول مسار المجري المائي و مقارنتها مع النتائج من النموذج الرياضي و أوضحت تطابق جيداً بينها مما يسهل عملية المحاكاة في الظروف المماثلة عند تحديد العوامل و المعدلات المطلوبة لحل لنموذج الرياضي.