DISPERSION OF CONSERVATIVE POLLUTANTS IN DIYALA RIVER APPLYING ONE DIMENSIONAL MODEL

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ABSTRACT

A study concerns the dispersion of pollutants in Diyala River using one-dimensional Finite difference technique (implicit method) to solve the simplified dispersion equation. The model starts at Diyala barrage and extended to the confluence of the Tigris - Diyala rivers, and for 203-Km length. The simplified dispersion model results were verified by comparison with the analytical solution for different time increments. The calibration of the model was conducted on 31/11/1998 using measured data (discharge, velocity, cross sectional area, total dissolved solids (TDS), chloride (CL), and sulfate ($SO_4^{=}$)) concentrations at the same day and the results indicated a good agreement between the computed and measured data. The verification of the model is accomplished on (13/12/98,27/12/98,10/1/99,25/1/99) and the results indicates also the accuracy of the applied model to simulate the conservative salts (TDS, CL, $So_4^{=}$) in the river.

الخلاصة

تم أجراء دراسة لتشتت الملوثات المحافظة في نهر ديالى وذلك ببناء نموذج رياضي عددي أحادي البعد للتعبير عن معادلة التشتت لهذه الملوثات وتم التأكد من النموذج من خلال تطبيق معادلة التشتت المبسطة مع الحل التحليلي لنموذج أحادي البعد ولمصدر تلوث مستمر واثبت النموذج دقة نتائجه.

تم استخدام النموذج المحدث والذي يتضمن دراسة مقطع النهر من جسر ديالى والى تقاطعه مع نهر دجلة وبمسافة ٢٠٣ كم بوجود مصادر التلوث المرافقة له والمتضمنة (مبزل الخالص الشمالي ، مبزل النهروان - مبزل السارية ، مبزل الخالص الجنوبي ، ومعمل الرستمية الجديد والقديم)، وتم معاملة تلك المبازل على أساس إنها مصادر تلوث نقطية (point source).

تم إجراء فحص المعايرة من خلال مقارنة التراكيز الملحية المقاسة في النهر مع تلك المحسوبة في النموذج بتاريخ ٣١/ ١١ / ١٩٩٨ولمحطتين على النهر، وباستخدام المعلومات المقاسة المتمثلة في التصريف، سرعة مقطع القناة، الأملاح الكلية الذائبة، الكلوريدات والكبريتات وكانت النتائج متقاربة بين المعلومات المقاسة والمحسوبة في٣١/ ١١ / ١٩٩٨ فيما تم إجراء التحقق للتواريخ (١٣ / ١٢ / ٩٨ ، ٢٧ / ١٢ / ٩٨ - ١٠ / ١ / ٩٩ ، ٢٥ / ١ / ٩٩) وأثبتت الفحوصات دقة النتائج المستحصلة.

KEY WORDS

Study the Dispersion by using one dimension, model

INTRODUCTION

Fresh waters are facing an increasing load of disposal of polluted water due to the rapid growth of industrial and municipal activities as well as to increase of land drainage due to agricultural activities and land saltation. Outfall effluents with high pollutant concentrations and / or high salinity levels are discharged to fresh water causing near field and far field pollution conditions in the river [Petrus (1990)]. The total dissolve solids (TDS), chloride (CL^-) and sulphate ($So_4^=$) are used in this study as principle indicators of water quality variation in Diyala River from Diyala barrage to Tigris-Diyala confluence reach.

OBJECTIVES

1- Examine the concentration distribution along the river obtained from the numerical solution of one-dimensional flow for steady state conditions.
2- Specify the segment of the study reach in which the concentrations of pollutants in water exceed the allowable limits of irrigation water.
3- Locate the places of drains that affect water quality of the Diyala River.

Theoretical Background

One Dimensional Dispersion of Pollutants in River Flow

The diffusion - convection equation in its generalized one - dimensional form is [Blair (1980)]:

$$\frac{\partial c}{\partial t}+U\frac{\partial c}{\partial x}=D_l\frac{\partial^2 c}{\partial x^2}\;..............(1)$$

Where:

C = concentration of pollutant, (M/L^3).
t = time coordinate, (T).
U= average velocity for the reach , (L/T).
X = space coordinate, (L).
DL= Longitudinal dispersion coefficient, (L^2/T).

Longitudinal Dispersion Coefficient

Samples are taken from difference depths and it is found that no obvious variation in constituent concentrations of (TDS), (CL^-) and ($SO_4^=$). Therefore, only longitudinal dispersion coefficient is taken into consideration.

Imara -- Al-Thamiry (1997) presented dispersion coefficients as follows:

$$D_{I-TH}=\frac{U*T^2}{160\ *\ R^{5/6}\ *\ n}\;..........\;......(2)$$

In which:

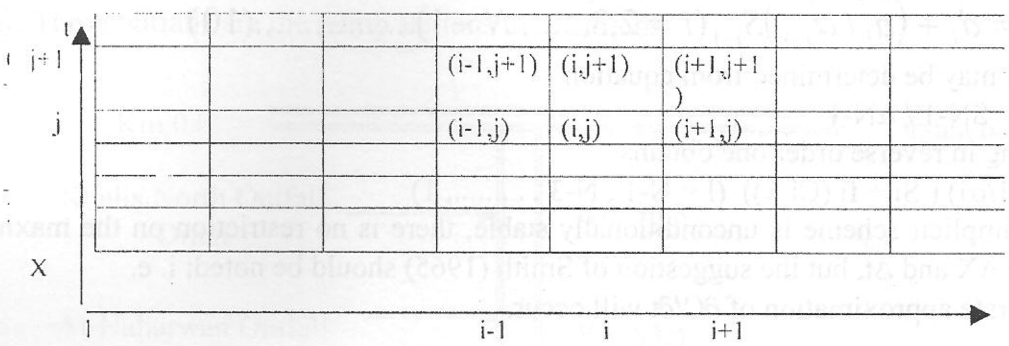
D_{I-TH} = Imara–Al-Thamiry dispersion coefficient, (m^2/sec).
n = Manning's roughness coefficient, dimensionless.
U = average velocity, (m/sec).
R = hydraulic radius, (m).
T = Top width, (m).

Finite Difference Simulation

In the implicit method, the partial derivations of concentration are expressed in terms of unknown and known concentration differences.

This produces a system simultaneous of linear equations. Every equation has three unknown concentrations at time (j+1) and one to three known concentration of time (j). These equations must be solved simultaneously to find the concentration for time step (j+1) .One of the possible finite differences approximation of equation (1) is the Crank-Nicolson Scheme is;

There are three unknown concentrations and three known concentrations in equation above. The graphical representation of the system is shown in **Fig.(1).**



Fig(1) The Implicit Scheme

At the boundary point I = 1 and I = N one must have some information about C1 and CN and all time step levels and this is given by the boundary conditions. Separating the unknown values of equation from the know values, result in:

a(Ci-1,j+1) + b(Ci,j+1) + f(Ci+1,j+1)= a(Ci-1,j) + b(Ci,j) + f(Ci+1,j) ...(4)

Where the coefficients are given by [Razoky , (1984)]

$$a = -D_L \frac{\Delta t}{\Delta X^2} - U \frac{\Delta t}{\Delta t} \text{.....................}(5)$$

$$b = 2\left(D_L \frac{\Delta t}{\Delta X^2} \right) + U . \frac{\Delta t}{\Delta X} + 2 \text{...........}(6)$$

$$f = -D_L \frac{\Delta t}{\Delta X^2} \text{.................................}(7)$$

The matrix of coefficients for the simultaneous equations resulting from equations is tri-diagonal . It has only three non-zero terms per row, one on the main diagonal and one on either side of it. The resulting system of equations are solved by Gauss's elimination method as:

1- when there are N-1 interval mesh points along each time row , equation can be written very generally as :

$$-a_1 . C_0 + b_1 C_1 - f_1 C_2 = d_1 \text{.......... ....}(8a)$$

$$-a_2 C_1 + b_2 C_2 - f_2 C_3 = d_2 \text{.......... ....}(8b)$$

$$-a_i C_{i-1} + b_i C_i - f_i C_{i+1} = d_i \text{.......... ....}(8c)$$

$$-a_{N-1} C_{N-2} + b_{N-1} C_{N-1} = dN - 1 \text{.......... ......}(8d)$$

Where a's, b's, f's and d's are known, C's is set by the boundary condition (generally taken as unity) from equation, C1 can be eliminated from the second equation, and the new second equation used to eliminate C2 from the second equation, and the new second equation used to eliminate C3 from the third equation above and so on.

2- from the equation above one can evaluate the value of αi, Si as follows:
With: $\alpha 1 = b1$, $S1 = d1$

$$\alpha_i = b_i - (a_i / \alpha_{i-1}) f_{i-1} (i = 2,3,\ldots., N-1) \ldots\ldots\ldots\ldots\ldots.(9)$$

$$S_i = d_i + (a_i / \alpha_{i-1}) S_{i-1} (i = 2,3,\ldots., N-1) \ldots\ldots\ldots\ldots\ldots.(10)$$

3- CN-1 may be determined from equation
CN-1 = SN-1 / αN-1

4- Solving in reverse order one obtains
Ci = (1/αi) (Si + fi (Ci-1)) (I = N-1 , N-3 , ..., 1)

As the implicit scheme is unconditionally stable, there is no restriction on the maximum spatial mesh size ΔX and Δt, but the suggestion of Smith (1965) should be noted; i. e.
Or inaccurate approximation of ∂C/∂t will occur.

$$\frac{D_L \Delta t}{\Delta X^2} \leq 1.0 \ldots\ldots\ldots\ldots\ldots\ldots(11)$$

Where:
ΔX = distance increment (L)
Δt =time increment

Sources, Sinks, and Chemical Reactions

Equation (1) can be modified to allow for sources and sinks and for certain kinds of chemical reactions. To include sources or sinks , the term S is added to the right hand side of equation (1) . This term can be formulated mathematically in several ways, [Wang (1982)]. A simple and generalized form of this term used is expressed for conservative pollutants as follows
For conservative pollutants the first term in equation (12) can be neglected then:

$$S = C_P * \frac{q_S}{A} + \frac{C_P * Q_S}{\Delta X * A} \ldots\ldots\ldots (12) \qquad S = \frac{C_P * Q_S}{\Delta X * A} \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

Where:
Qs= point source discharge, (L^3/T).
qs= non - point source discharge, ($L^3/T/L$).
A= Cross - sectional area, (L^2).
Cp= concentration of salts, (L^2/T).

Furthermore, the pollutants in equation (13) may consider as "continuous" or "discontinuous/puls" source depends on the operating rule of the drains or the nature of the pollutants in the river.
For explicit method the boundary condition for the second source is:
$C(\pm\infty, t)=0$ ...(14)
$C(X, 0) =0$ ...(15)
$C(X_2, t_2)=Ca_1+S$ ...(16)
Where:

Ca_1 = the concentration of the first source at the second source location
X_2 = distance between the first and second source respectively
t_2 = the time to start the effect of the second source .

Description of the Study Reach

Two hundred and three kilometers (203 km) length of the Diyala river was studied in this work, the reach of study starts from Diyala Barrage, and extended to the confluence of the Tigris – Diyala river .

Fig.(2) illustrated the scheme and the descritized form of the Diyala river system within the study reach. Seven outfalls were recorded and concerned as point sources of pollutants, which discharge to the river. These outfalls are the pump stations of the drains

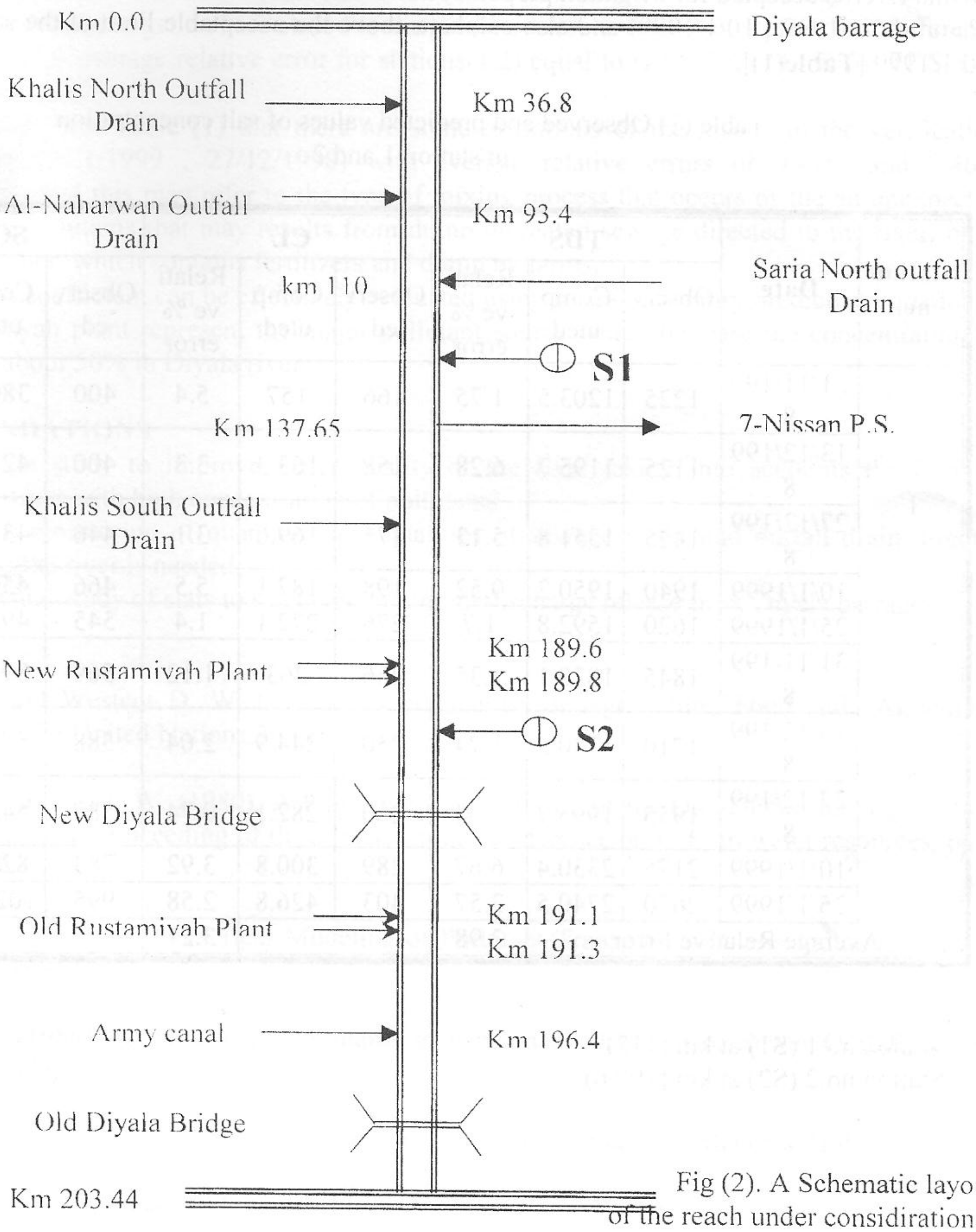


Fig (2). A Schematic layout of the reach under considiration.

Results and Discussion

It was found from the study of constituents of Diyala river water quality that total dissolved solids (TDS), chloride (CL^-), and Sulphate (SO_4^-) are present in significant concentrations, so they are selected for this study.

The model is based on the one-dimensional convective-dispersion equation for conservative substance, that was solved using implicit technique, and the model based on the gathered data, which recorded on (31/11/98) To (25/1/99), for TDS, CL and $SO_4^=$.

Calibration of the model is achieved by applying it to an independent set of data using the model and the results established the model validity,its applicability and the results are listed in Table (1) also for station (1) and station (2) respectively.

Table (2) represent the laboratory determinations needed to evaluate common irrigation water quality problems [Ayers, (1985)], and its seen from **Table (1),** that in general water quality in Diyala river is accepted for irrigation purposes, however (TDS) exceed the allowable limit at station (2) on (25/1/1999 . 10/1/1999) and also sulphate above the acceptable limit at the same station on 10/1/1999 [**Table(1)**].

Table (1) Observed and predicted values of salt concentration in station 1 and 2

Station no.	Date	TDS			CL^-			$SO_4^=$		
		Observed	Computed	Relative % error	Observed	Computed	Relative % error	Observed	Computed	Relative % error
1	31/11/1998	1225	1203.5	1.75	166	157	5.4	400	380.1	4.98
	13/12/1998	1125	1195.7	6.28	158	163.3	3.3	400	425.4	5.97
	27/12/1998	1425	1351.8	5.13	175	169.6	3.1	446	431.2	3.3
	10/1/1999	1940	1950.2	0.52	198	187.1	5.5	466	450.7	3.28
	25/1/1999	1620	1592.8	1.7	276	272.1	1.4	545	493.7	9.41
2	31/11/1998	1845	1820.1	1.35	266	263	1.12	569	575.6	1.15
	13/12/1998	1710	1740.3	1.74	250	244.9	2.04	588	571.1	2.87
	27/12/1998	1955	1995.7	2.04	280	282.1	0.74	587	543.2	7.46
	10/1/1999	2175	2330.4	6.67	289	300.8	3.92	783	820.1	4.52
	25/1/1999	2670	2740.5	2.57	403	426.8	2.58	995	1020.2	2.47
Average Relative Error				2.98			3.21			4.69

Note:

- Station no.1 (S1) at km (112)
- Station no.2 (S2) at km (190.6)

Table (2) Laboratory determinations needed to evaluate common irrigation water quality problems [Ayers. (1985)].

Water parameter symbol	Unit	Usual range in Irrigation water
TDS	mg/l	≤ 2000
CL^-	mg/l	≤ 1050
$SO_4^=$	mg/l	≤ 960

CONCLUSIONS

The following conclusions are drawn on the basis of the result obtained from the model:

2- The observed data, in general are closed to the predicted results from the implicit finit difference method with an average relative error for stations(1,2) equal to (2.98, 3.21, 4.69) for TDS, CL, SO4 respectively.

3- It is noticed from Table (1) that there are some deviations of the results in the verification periods on (25/1/1999 , 27/12/1998) with average relative errors of 9.41% and 7.46% respectively, and this may refer to the type of mixing process that occurs or the an unexpected location of pollutants that may results from dump untreated sewage directed to the river, or to the drain water. which contains fertilizers and dump by farms.

4- Dispersion coefficient can be effectively evaluated using Imara-Althamiry predictive equation.

5- Al-Rustamiyah plant represent the major pollutant source which increase the concentration of salts with about 50% in Diyala river.

RECOMMENDATIONS

2- Optimization study to improve water quality of the river taking into accounts the outfalls discharge water with high concentration of pollutants.

3- Continuous monitoring of quantities and qualities of sewage water and outfall drain directly disposed to the river is needed.

4- Environmental study of slats to select the minimum discharge release from Diyala barrage.

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