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Water Quality of Shatt Al-Hilla River Within the Middle Euphrates Region

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Abstract

Water pollution for Shatt Al-Hilla river in Middle Euphrates region of Iraq (Babylon and Al-Diwaniya governorates) occurs in both rural and urban areas. In rural areas, drinking water from the river is usually polluted by organic substances from upstream users who use water for agricultural activities. To protect the water resources from pollution and deterioration which caused by natural pollutants or human activities, an environmental database was constructed and applied. To evaluate the pollutant concentrations, regression models were obtained by Data Fit Software program (version 8.0). A positive relation was obtained between total hardness, calcium, chloride, electrical conductivity, magnesium, total dissolved solids, no. of days suspended, rising and storm dust, and negative relation between total hardness and total alkalinity in Al-Hilla and Al-Hashimiya station. While calcium has positive relation with total hardness, chloride, electrical conductivity, magnesium, total dissolved solids, rising and storm dust and sulphate, and negative relation with temperature and discharge in Al-Hindya Barrage station. In Al-Diwaniya station total dissolved solids has positive relation with electrical conductivity, monthly rainfall totals, and no. of days of storm dust, and negative relation with temperature, no. of days of rising and suspended dust, and hydrogen ion concentration.

The results were compared with the Iraqi and WHO standards for domestic and irrigation purposes to determine pollution extend and suggest suitable solutions. A Comparison of the program output data (TDS, Ca, TH) shows that these parameters in some stations are within the Iraqi and WHO standards for domestic and irrigation purposes (i.e. TDS: Al-Diwaniya station), and (TH: in Al-Hill and Al-Hashimiya station). The results of the program are verified with data of year 2008 which is not included in regression model. This verification shows a good agreement with coefficient of determination ranged between "0.927 to 0.996".

الخلاصة

تلوث المياه في نهر شط الحلة لمنطقة الفرات الأوسط من العراق (بابل والديوانية) يحدث في كل من المناطق الريفية والحضرية. في المناطق الريفية مياه الشرب من النهر عادة ما تتلوث بالمواد العضوية عند المنبع بسبب استخدام المياه للأنشطة الزراعية. ولحماية الموارد المائية من التلوث والتدهور التي تسببها الملوثات الطبيعية أو الأنشطة البشرية، تم إنشاء وتطبيق قاعدة بيانات. ولتقييم تركيز الملوثات تم إيجاد نماذج انحدار باستخدام البرنامج الإحصائي Data Fit "8.0"، وقد وجد ان هناك علاقة طردية بين العسرة الكلية و الكالسيوم، الكلورايد، التوصيلية الكهربائية، المغنيسيوم، المواد الذائبة الكلية، وعدد الايام للغبار العالق والمتصاعد، وعلاقة عكسية بين العسرة الكلية والقاعدية الكلية في محطات الحلة والهاشمية، بينما للكالسيوم علاقة طردية مع العسرة الكلية، الكلورايد، التوصيلية الكهربائية، المغنيسيوم، المواد الذائبة الكلية، وعدد ايام الغبار العالق والمتصاعد وعلاقة عكسية مع درجة الحرارة والتصريف في محطة سدة الهندية. في محطة الديوانية المواد الذائبة الكلية ذات علاقة طردية مع كل من التوصيلية الكهربائية، السقوط المطري الشهري الكلي، وعدد الايام المغبرة وعلاقة عكسية مع درجة الحرارة، تركيز ايون الهيدروجين، وعدد ايام الغبار العالق والمتصاعد. حيث قورنت النتائج مع محددات منظمة الصحة العالمية (WHO) والمحددات العراقية لأغراض الشرب والسقي لتبيان مدى التلوث الحاصل واقتراح الحلول الممكنة. واظهرت نتائج المقارنة ان هذه المعاملات هي ضمن الحدود للمواصفة العراقية والعالمية مثل المواد الذائبة الكلية في محطة الديوانية والعسرة الكلية في محطتي الحلة والهاشمية. تم اختبار صلاحيةِ معادلات الانحدار المستخرجة بإجراء تحقيق باستخدام بيانات من عام 2008 والتي لم يتم تضمينها في نموذج الانحدار، وبين هذا التحقق تطابق جيد مع معامل تحديد تراوحت قيمته بين 0.927 إلى 0.996.

1. Introduction

Surface waters are used for a number of purposes including potable water sources, recreation, transportation, and aesthetics. With so many uses, water bodies are susceptible to affects that can degrade water quality. Therefore, mechanisms to protect surface waters, maintain current water quality, or reduce the degradation of surface water bodies are important. In Iraq, no one take care or gave the subject the reserved attention to monitor water quality. A few researchers studied acute area and a few parameters. These parameters are analyzed either by applying different statistical models or by qualitative comparison with available.

Al-Masri and Ali (1985) evaluated some pollution concentrations such as total hardness, sulphates, alkalinity, chlorides, calcium and magnesium in Tigris river through Baghdad city. Water samples were taken from 16 different stations distributed along the river. The result of the study indicates that concentrations of total hardness, sulphates and calcium exceed the permissible limits.

Wasfi (1986) recorded the concentrations of different pollutants and their variation in Tigris river while passing through Baghdad city, during 1985. These pollutants were biological oxygen demand (BOD), pH-value, total hardness, bicarbonates, sulphurs, phosphate, chlorides, boron, fluorides, sodium, potassium, total dissolved solids (TDS), and suspended solids (SS). He found that concentrations of some pollutants such as total hardness and fluorides in Tigris river are over the Iraqi permissible limits of drinking water.

Al-Delaimi (1989) performed a study on the effect of some environmental factors and their correlation with the inlet of river in Baghdad city. He predicated models to simulate the effect of these environmental factors (temperature, turbidity, DO, pH and electrical conductivity) on the bacterial contents in river water by the adoption of single linear regression analysis test.

Al-Khaiat (1989) studied the qualities of raw water and treated water of Al-Karkh water treatment plant. the results show that Tigris river is very suitable to be treated by 30 Km north of Baghdad city.

Al-Malikey (1993) studied the determination of Tigris river water quality. He chose three stations for this purpose located at north, Middle and South of Baghdad city. The result of the study shows that Tigris river water of good quality to be treated at North of Baghdad city.

Jalut (1998) evaluated some of water quality parameters of Shatt Al-Hilla river in four treatment plants at Babylon governorate. He treated the parameters (temperature, pH-value, electrical conductivity, alkalinity, calcium, magnesium, chloride, hardness, total dissolved solids, and turbidity) statistically using stepwise regression analysis and he showed a noticeable increase in hardness, chloride and total dissolved solids for all water treatment plants.

Al-Husseini (1999) evaluated some of water quality parameters of Shatt Al-Hilla river in four main water treatment plants abstracting their water from the sites situated along the river were selected as a case study. These are Al-Hindya Barrage , Al-Hilla, Al-Hsien and Al-Hashimiya water treatment plants. He found there is a noticeable increase in concentrations of chloride and sulphate especially at Al-Hsien water treatment plant during the different periods of the year and there were clear effects of municipal wastes of Al-Hilla city on levels of turbidity and bacteria.

Al-Shukur and Al-Bedeyry (1999) made a study to determine the qualitative, properties of raw water and its suitability for different uses. Water samples collected from five different supply stations located along Shatt Al-Hilla during January 1995 until January 1998. Nine water quality parameters were analyzed including turbidity, electrical conductivity (Ec), total dissolved solids (TDS), total hardness (TH), calcium (Ca), magnesium (Mg), chloride (Cl), alkalinity and pH-value, Data analysis shows that the concentration of chloride, turbidity, total hardness and total dissolved solids were high in most months and it exceeded their level to be used for domestic and most industrial purpose .However, the irrigational purpose is not affected.

Kalel (2005) made a study for alteration of the following concentration parameters, turbidity, electrical conductivity, total hardness, calcium, magnesium, chloride, alkalinity, total dissolved solids, suspension solids and pH-value, for Al-Kufa and Al-Abasiya rivers and for (Al-Zarga-Al-Abasiya), (Kufa-AL-Abasiya) and (Al-Essa-Al-Abasiya) opposite stations. The resulting alteration in concentrations with regard to time and distance was also observed. These concentrations were compared to those of World Health Organization(WHO). For both branches the quality of water was checked, conducting hypothesis test at 95% level of confidence for where T-distribution had been used. It has been found that water quality for both branches did not exhibit any difference.

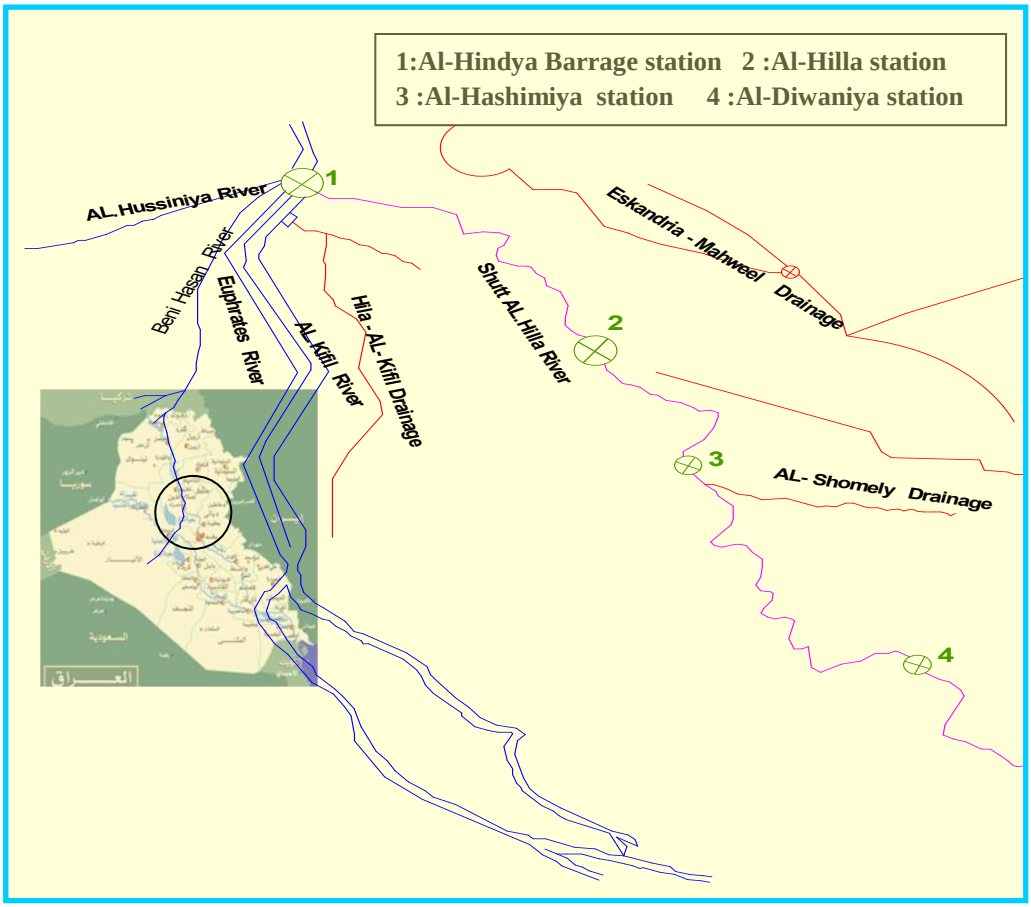
Fahd 2006, studied some of physical and chemical characteristics of Al-Masab Al-Aam river. Monthly samples were collected from two stations extended from November 2000 to October 2001. Results show monthly variation in air temperature ranged 14-43 ̊C and the light penetration was 38-64 cm. Dissolved oxygen concentrations and free CO_2 inversely correlated with water temperature. The total alkalinity of water was due to the bicarbonate and carbonate. Salinity between 4.20-8.4 g/L. Significant positive relation were found between water temperature, alkalinity and salinity, while negative relation between dissolved oxygen and temperature.

2. Data Collection

Shatt Al-Hilla river is a branch of Euphrates river at Al-Hindya Barrage town Fig. (1), its length through Babylon governorate is about (104) Km.), then Shatt Al-Hilla river branches into main rivers; Al-Dagarah and Al-Diwaniya river. The length of the later is about (124) Km, the center of Al-Diwaniya city lies about (53) Km from the river. To check the success of the program, data of water quality of the Shatt Al-Hilla river are being analyzed monthly, and the pollution levels are being determined. The program depend four sampling stations along the river including (Al-Hindya Barrage, Al-Hilla, Al-Diwaniya and Al-Hashimiya) as shown in Fig. (1) to gauge the degree of pollutants based on dependent variables.

In this study, water samples were analyzed at Al-Hindya Barrage station for the period between 2000 to 2008, period between 1987 to 2000 is analyzed for Al-Hilla station, and period between 1987 to 2000 for Al-Diwaniya and Al-Hashimiya stations, to construct the monitoring system along Shatt Al-Hilla river.

Fig. (1):



Map of the studying area.

Table (1) shows the independent and dependent variables for Shatt Al-Hilla river used in Al-Hindya Barrage, Al-Hilla, Al-Hashimiya and Al-Diwaniya stations. These parameters are chosen according to available data and the degree of relation between them, and the most related parameters are considered.

Table (1): Description of the independent and dependent variables for Shatt Al- Hilla river.

Stations	Variables									
	Independent									Dependent
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	y
Al-Hindya Barrage	Ec	TDS	So_4	TH	Mg	Cl	Ra	Q	T	Ca
Al-Hilla	TA	Ca	Cl	Ec	Mg	TDS	RD	-	-	TH
Al-Hashimiya	TA	Ca	Cl	Ec	Mg	TDS	SSD	RD	SD	TH
Al-Diwaniya	pH	Ec	Ra	SD	SSD	RD	T	-	-	TDS

Where: Ec : electrical conductivity (□s/cm),
TDS : total dissolved solids (mg/L),
So_4 : sulphate (mg/L),
TH : total hardness (mg/L),

Mg : magnesium (mg/L),
Cl : chloride (mg/L),
Q : discharge (m^3/sec),
Ca : calcium (mg/L),
pH : hydrogen ion concentration,
TA : Total Alkalinity (mg/L),
Ra : monthly rainfall totals (mm),
SSD : no. of days of suspended dust,
RD : no. of days of rising dust,
SD : No. of days of storm dust, and
T : ambient temperature (^{0}C).

3. Statistical analyses and regression models

In water quality studies correlation analysis is used to measure the strength and statistical significance of the association between two or more random water quality variables. Random in this case means that the variables are not under the control of the investigator and are, therefore, measured with an associated error.

The multiple regression analysis was used to build the present models, in which when number of parameters of water quality over eight without parameters of ambient, we neglected the parameter having the correlation coefficient (r) lower than 0.20 like turbidity at Al-Hilla and Al-Hashimiya station and T, SD and SSD in Al-Hilla station. Table (2), (3), (4) and (5) show the correlation matrix in Al-Hindya Barrage, Al-Hilla, Al-Hashimiya and Al-Diwaniya station respectively.

Table (2): Correlation Matrix of Shatt Al-Hilla river in Al-Hindya Barrage station

	X1	X2	X3	X4	X5	X6	X7	X8	X9	Y
X1	1									
X2	0.825	1								
X3	0.564	0.574	1							
X4	0.489	0.501	0.810	1						
X5	0.256	0.306	0.571	0.544	1					
X6	0.603	0.617	0.810	0.748	0.432	1				
X7	0.233	0.167	0.365	0.380	0.120	0.299	1			
X8	-0.082	-0.222	-0.097	-0.175	0.034	-0.306	-0.131	1		
X9	-0.135	-0.082	-0.257	-0.188	0.013	-0.228	-0.541	0.268	1	
Y	0.565	0.640	0.841	0.897	0.423	0.907	0.390	-0.395	-0.241	1

Table (3): Correlation Matrix of Shatt Al-Hilla river in Al-Hilla station

	X1	X2	X3	X4	X5	X6	X7	Y
X1	1							
X2	-0.0931	1						
X3	-0.0389	0.6521	1					
X4	-0.2003	0.6506	0.590	1				
X5	-0.2357	0.0856	0.108	0.272	1			
X6	-0.2401	0.5370	0.382	0.757	0.265	1		
X7	-0.1072	0.2492	0.205	0.213	-0.043	0.014	1	
Y	-0.2445	0.9477	0.641	0.730	0.339	0.630	0.279	1

Table (4): Correlation Matrix of Shatt Al-Hilla river in Al-Hashimiya station

	X1	X2	X3	X4	X5	X6	X7	X8	X9	Y
X1	1									
X2	-0.183	1								
X3	-0.083	0.583	1							
X4	-0.124	0.630	0.525	1						
X5	-0.318	0.266	0.468	0.414	1					
X6	-0.128	0.702	0.472	0.539	0.265	1				
X7	-0.033	0.145	0.021	0.028	0.097	-0.056	1			
X8	-0.064	0.266	0.195	0.152	0.195	0.131	0.639	1		
X9	-0.039	0.217	0.083	0.114	0.041	0.169	0.434	0.334	1	
Y	-0.330	0.929	0.686	0.716	0.542	0.675	0.225	0.341	0.221	1

Table (5): Correlation Matrix of Shatt Al-Hilla river in Al-Diwaniya station

	X1	X2	X3	X4	X5	X6	X7	Y
X1	1							
X2	0.196	1						
X3	0.134	-0.069	1					
X4	-0.152	-0.038	-0.007	1				
X5	0.065	-0.083	-0.339	-0.086	1			
X6	0.003	-0.080	0.089	0.157	0.459	1		
X7	0.108	0.179	-0.648	-0.096	0.471	0.191	1	
Y	-0.170	0.569	0.346	0.353	-0.459	-0.397	-0.287	1

A multiple non-linear regression models in three forms were used for each design requirements to choose which form gives the best fitting of data. The regression models that were proposed and investigated can be seen in table (6).

Table (6): The Proposed Models

Rank	Equation Description
A	$y = \exp(b_1 x_1 + b_2 x_2 + ... + b_k x_k + G)$
B	$y = b_1 x_1 + b_2 x_2 + ... + b_k x_k + G$
C	$y = b_1 x_1 + b_2 x_2 + ... + b_k x_k$

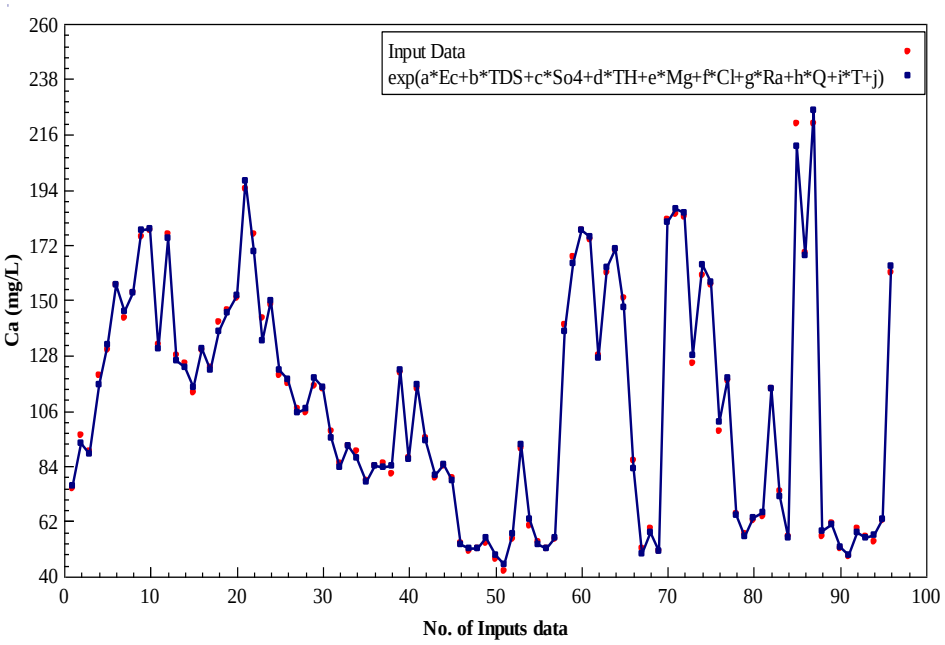
Where; y = dependent variables
x1, x2, …, xk = the independent variables.
b1, b2, b3, …bk = are model coefficients,
and G = model constant term.

The regression models of Shatt Al-Hilla. river that were proposed and investigated for the four stations were shown in table 7, a positive relation was obtained between total hardness, calcium, chloride, electrical conductivity, magnesium, total dissolved solids, no. of days suspended, rising and storm dust, and negative relation between total hardness and total alkalinity in Al-Hilla and Al-Hashimiya station, While calcium has positive relation with total hardness, chloride, electrical conductivity, magnesium, total dissolved solids, rising and storm dust and sulphate, and negative relation with temperature and discharge in Al-Hindya Barrage station. In Al-Diwaniya station total dissolved solids has positive relation with electrical conductivity, monthly rainfall totals, and no. of days of storm dust, and negative relation with temperature, no. of days of rising and suspended dust, and hydrogen ion concentration.

plot models of these stations were presented in Figs. 2 to 5. The proposed models of Shatt Al-Hilla river have the rank A for Al-Hindya Barrage and Al-Hashimiya stations, while have the rank B for Al-Hilla and Al-Diwaniya stations.

Table (7): The proposed models of Shatt Al-Hilla river

Station	Rank	Equation	Std. Err.	R^2
Al-Hindya Barrage	**A**	Y= exp(-0.0004*X1+0.0005X2+0.0005*X3+ 0.0013*X4-0.0049X5-0.0034*X6+0.0025*X7 0.0017*X8 + 0.0033*X9+3.6529)	2.522	0.997
Al-Hilla	**B**	Y=0.436*X1+2.654*X2+0.005*X3+0.027*X4+ 3.980*X5+0.059*X6+2.379*X7-21.973	20.617	0.983
Al-Hashimiya	**A**	Y=exp(0.00053*X1+0.00406*X2+0.00019*X3+ 0.00019*X4+0.00320*X5 +0.00001*X6 + 0.00594* X7 + 0.00168*X8 0.00882*X9 + 5.29827)	14.328	0.989
Al-Diwaniya	**B**	Y=46.033*X1+0.111*X2+3.536*X3+18.545*X 4+0.030*X5-9.873*X6+0.899*X7+819.688	20.467	0.908



of Shatt Al-Hilla river in Al-Hindya Barrage station.

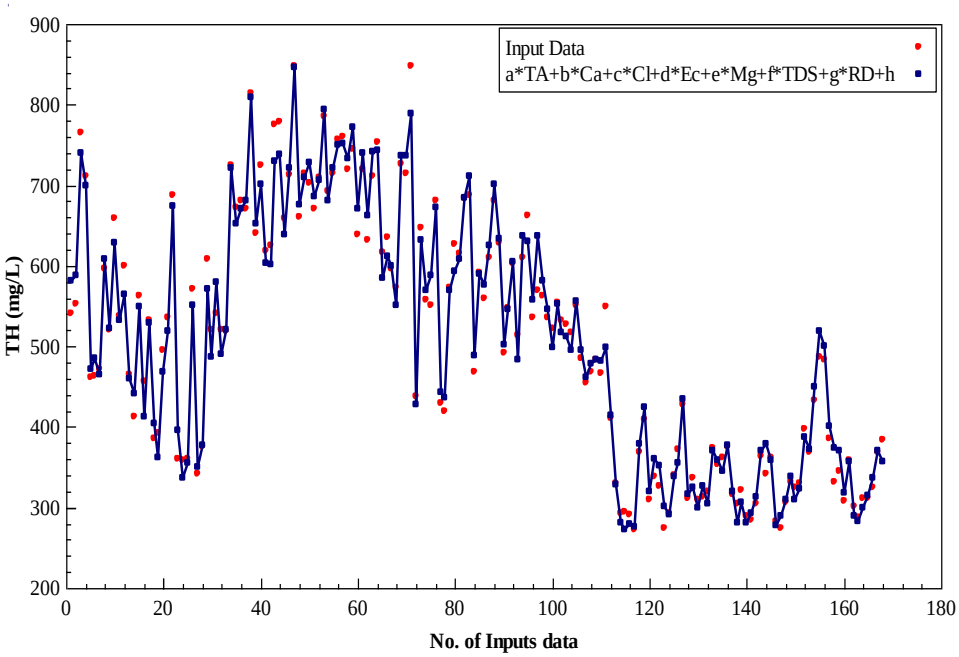


Fig. (3): Plot model of Shatt Al-Hilla river in Al-Hilla station.

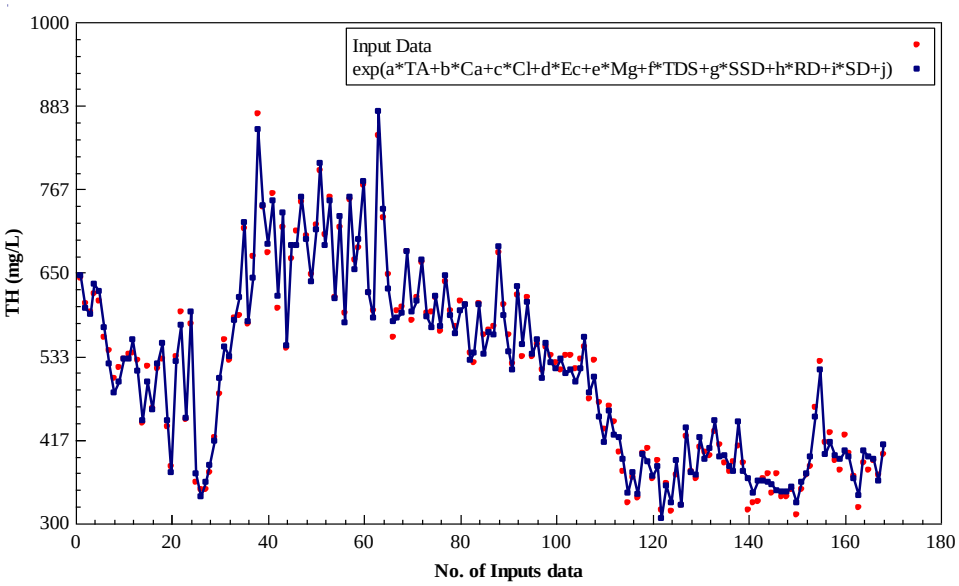


Fig. (4): Plot model of Shatt Al-Hilla river in Al-Hashimiya station.

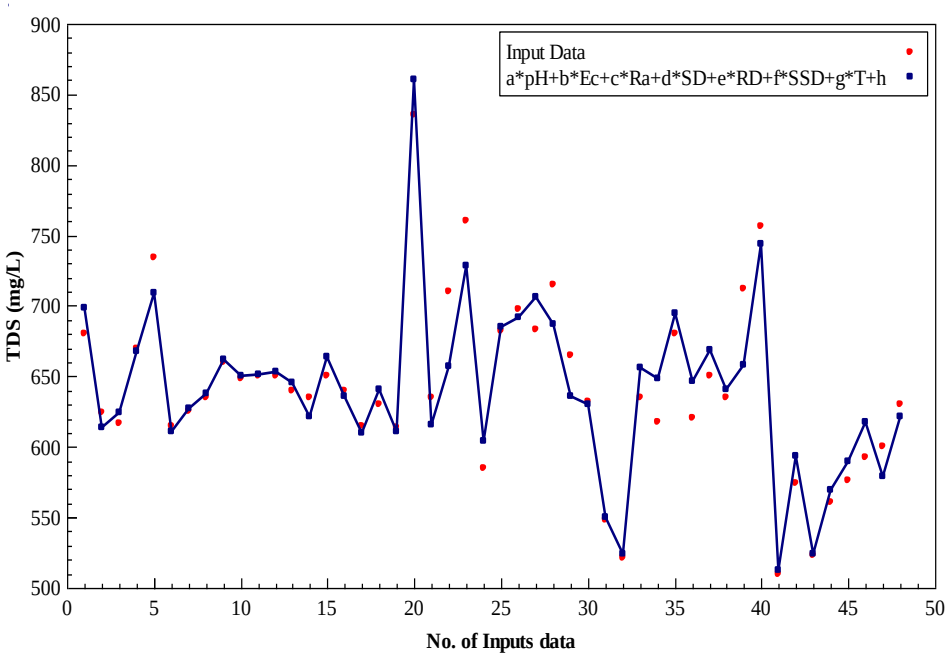


Fig. (5): Plot model of Shatt Al-Hilla river in Al-Diwaniya station.

4. Verification of regression model

Verification of the obtained model can be made by plotting the data of the year 2008 which were not included in the building of the regression model versus modeling data. The results were compared with the Iraqi and WHO standards for domestic and irrigation purposes to determine pollution extend and suggest suitable solutions. A Comparison of the program output data (TDS, Ca, TH) shows that these parameters in some stations are within the Iraqi and WHO standards for domestic and irrigation purposes (i.e. TDS: Al-Diwaniya station), and (TH: in Al-Hill and Al-Hashimiya station).

The results were compared with the Allowable limits of water quality parameters in surface water body used as domestic and irrigation water source according to Iraqi and WHO standards (Abbawi & Mohsen, 1990, WHO, 2005) (table 8) to determine pollution extend and suggest suitable solutions. Qualitative properties of Shatt Al-Hilla river for drinking and irrigation water source at sampling sites were within the water quality standards (table 9).

The obtained model was also calibrated by the following equation:

$$y = ax^{b}$$

Verification of regression model is shown in Figs. (2 to 5). These Figs. showed that the experimental data are correlated well with modeling data with coefficient of determination ranged between 0.927 for Al-Hindya Barrage station to 0.996 for Al-Hashimiya station.

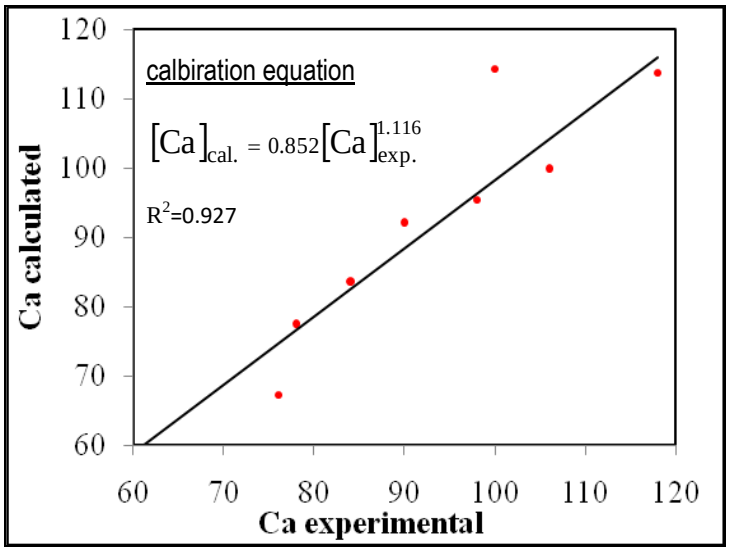


Fig.(6): Verfication of regression model for Shutt Al-Hilla river in Al-Hindya Barrage station.

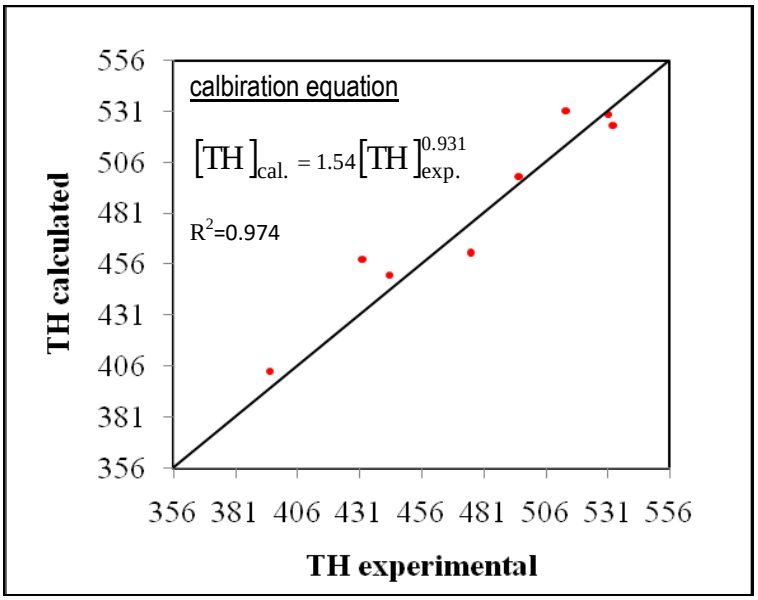


Fig.(7): Verfication of regression model for Shutt Al-Hilla river in Al-Hilla station.

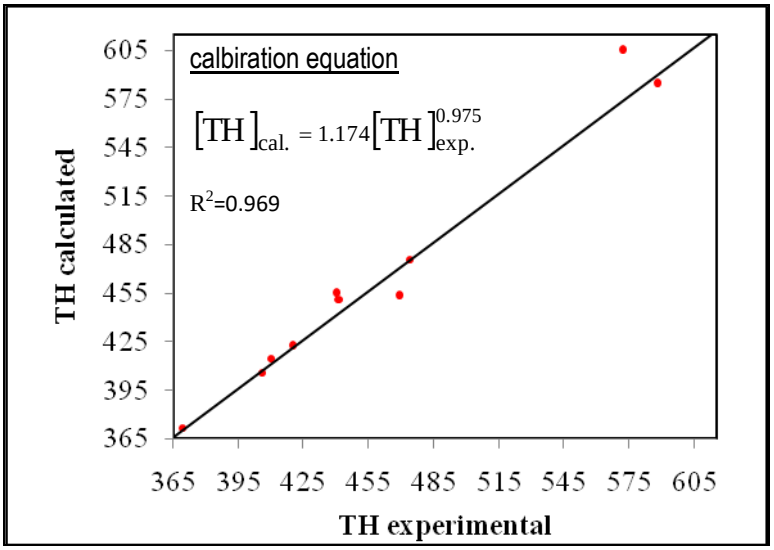


Fig.(8): Verfication of regression model for Shutt Al-Hilla river in Al-Hashimiya station.

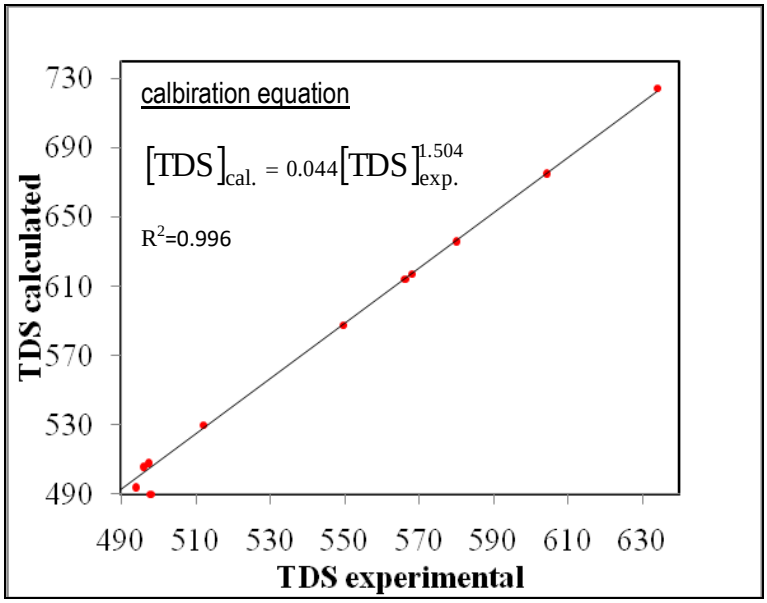


Fig.(9): Verfication of regression model for Shutt Al-Hilla river in Al-Diwaniya station.

Table (8): Allowable limits of water quality parameters in surface water body used as domestic and irrigation water source according to Iraqi and WHO standards (Abbawi & Mohsen, 1990, WHO, 2005).

Parameter	Unit	Domestic water standards		Irrigation water standards
		Iraqi	WHO	WHO
pH		6.5-8.5	6.5-8	6-8.5
Ec	□s/cm	2000	-	<250 Excellent, 250-750 Good and 750-2000 Permissible
Ca	mg/L	200	75-200	0-200
Cl	mg/L	200	250-600	0-300
Mg	mg/L	50	30-150	0-50
TA	mg/L	170	5-200	-
TDS	mg/L	1500	500-1000	0-700 Excellent, 700-2000 Good and >2000 Unsuitable
TH	mg/L	500	100-500	
Tur	NTU	<10	5-25	
So_4	mg/L	200	200-400	

Table (9): Qualitative properties of Shatt Al-Hilla river for drinking and irrigation water source.

Station	Raw water suitability for following purposes		
	Demotic		Irrigation
	Iraqi	WHO	WHO
Al-Hindya Barrage	Suitable	Suitable	Suitable
Al-Hilla	Suitable	Suitable	__
Al-Hashimiya	Suitable	Suitable	__
Al-Diwaniya	Suitable	Suitable	Excelent

5. Conclusion

From this study the following conclusions are obtained :

1. From statistical analysis, it was found a positive relation between calcium, electrical conductivity, total dissolved solids, total hardness, magnesium, chloride and rain, and negative relation between calcium, discharge and temperature in Al-Hindya Barrage station.
2. A positive relation was obtained between total hardness, calcium, chloride, electrical conductivity, magnesium, total dissolved solids, no. of days suspended, rising and storm dust, and negative relation between total hardness and total alkalinity in Al-Hilla and Al-Hashimiya station.
3. A Comparison of the program output data (TDS, Ca, TH) shows that these parameters in some stations are within the Iraqi and WHO standards for domestic and irrigation purposes (i.e. TDS: Al-Diwaniya station), and (TH: in Al-Hill and Al-Hashimiya station).
4. The regression models for Shatt Al-Hilla river in those stations are more suitable to predict the pollutants concentrations.
5. A good management for Shatt Al-Hilla river in the middle Euphrates region important to protect the soil of region and surface water from pollution.

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