EFFECT OF THEHYDRAULIC PROPERTIES OF TIGRIS RIVER ON TEMPERATURE DISTRIBUTION DOWNSTRAAM OF SOUTH – BAGHDAD POWER STATION+

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Abstract

This research aims to study the effect of hydraulic river properties namely,bed roughness and water-surface slope, on temperature distribution of water released from South-Baghdad power station on Tigris River. For this purpose, a two-dimensional numerical model was applied for estimating temperature distribution and diffusion in the river .

Momentum Conservation Equation and Thermal Energy Equation were used to describe the temperature distribution along the study reach The model incorporates the (k-ε) turbulence model to calculate the distribution of turbulent viscosity .The pressure distribution was determined using hydrostatic pressure equation . The partial differential equations were simplified to obtain the system of linear equations that were then solved using Gauss-Elimination method .

The numerical model was verified by conducting comparison of observed data from South-Baghdad station with those computed by the model .The comparison results show agreement with absolute error of (17%) and correlation factor of (0.940).

The results of the study show that increasing the bed roughness from 0.02m to 0.06m causes a longitudinal retardation of temperature distribution by about (24%) and vertical advance about (20%). Also Increasing of the water-surface slope from 4 cm/km to 10 cm/km caused a vertical retardation of temperature distribution about (30%) and a longitudinal advance about (19%)

المستخلص:

يهدف البحث إلى دراسة تأثير الخصائص الهيدروليكية للنهر مثل خشونة القاع وميل سطح الماء على توزيع درجات الحرارة المتولدة من محطة كهرباء جنوبي- بغداد في نهر دجلة . ولهذا الغرض تم بناء نموذج عددي رياضي لتمثيل توزيع و انتشار المياة الحارة المطروحة في النهر.

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استخدمت معادلة حفظ الزخم و معادلة حفظ الطاقة الحرارية لمعرفة توزيع درجات الحرارة خــلال منطقة الدراسة. كذلك تضمن النموذج العددي معادلات الاضطراب (k-ε) لحساب اللزوجة . واعتمــدت معادلة الضغط الهيدروستاتيكي لحساب الضغط في كل نقطة خاصة بالدراســة . تــم تبــسيط المعــادلات التفاضلية المختلفة للحصول على معادلات جبرية خطية تم حلها بطريقة الحذف المتناوب .

تم معايرة النموذج العددي من خلال مقارنة النتائج المحسوبة من النموذج العــددي الرياضـــي مــع النتائج المقاسة من قبل محطة كهرباء جنوب- بغداد على نهر دجلة و اظهرت نتائج المقارنة ان النموذج مقبول إلى حد ما بنسبة خطا مطلق مقداره (17%) ومعامل ارتباط مقداره (0.940).

أظهرت نتائج الدراسة ان زيادة خشونة قاع النهر من (٠,٠٢متر الى ٠,٠٦ متر) يسبب إعاقة فـــي توزيع درجات الحرارة بالاتجاة الطولي مقداره (٢٤%) وتقدم بالاتجاة العمودي مقدارة (٢٠%) . وكــذلك زيادة ميل سطح الماء من ٤ سم/ كم الى ١٠ سم / كم يسبب اعاقة في توزيع درجات الحــرارة بالاتجــاة العمودي مقدارها (٣٠%) وتقدم بالاتجاة الطولي مقدارة (١٩%) .

List of symbols

Symbols	Description	Units
C_1 ,C_2,C_μ	Constants in K-ε Turbulence Model	
C_p	Specific heat	W.S/(kg.˚K
g	Acceleration due to gravity	m/s^2
H	Heat exchange across the water surface	kg.˚K/(m^2 .s)
K	Turbulence Kinetic energy	m^2/s^2
k	Bed Roughness	m
P	Pressure	N/m^2
R	Correlation factor	
S	Water surface Slope	m/m
T_r	River water Temperature	˚C
U	Velocity in X-Direction	m/s
W	Velocity in Z-Direction	m/s
X	Horizontal Coordinate	m
Z	Vertical Coordinate	m
G	Rate of Production of turbulence Kinetic energy	
α	Heat Transfer Coefficient	w/(m^2.K)
ε	Dissipation Rate	m^2/s^3
μ	Viscosity	$N.s/m^2$
ρ	Density	kg/m^3

σ	Prandtle Number	

Introduction:

Thermal pollution occurs when waste water is discharged into rivers, lakes, sea and oceans . The discharge of thermally polluted water from power stations, petroleum –refineries and other industrial plants into water bodies is becoming an increasing threat to our water resources [1]

Bodies of water lose and gain heat much more slowly than do land or mass, and under most circumstances , water temperature is fairly constant and changes gradually with the season. Recently emerging as special environmental issue is the problem of the thermal pollution of the water resources . Thermal pollution refers to the degradation of the aquatic environment by heat [2]

The discharge of heated water into river has several important effects on the river and its environment including a change in the local climate, a reduction in the river discharge because of increased evaporation, alternation in the living conditions for aqueous life. [3].

Raithby et al. [4] present a three-dimensional model to predicte the motion and mixing of thermal discharges entering lakes. Good agreement was found between observed and predicted temperature indicating that the model can be used for the prediction of thermal single discharge or two interacting discharges of heated water into a river and the basic method of computation has been applied with good success to predict the motion and mixing of thermal discharge entering rivers.

Daws [5] presents an analytical and numerical analysis of the cooling process of hot water discharge from a steam power plant into rectangular pond. The flow pattern is found to be strongly affected by the type of configured aspect ratio .

Al-Challabi [6] developed a numerical model for the simulation of the spread and mixing of thermally polluted water disposed into a river. The results show that a smooth-bed velocity distribution causes faster spreads than rough- bed velocity distribution .

Bormans and Webster [7] obtained excellent agreement between measured and simulated temperature profiles under a wide range of river discharge and meteorological facing .

Joody [8] developed one and two dimension numerical model for the simulation of the spreading of the thermally polluted water disposed into the river from Al-Daura power station . The results are discussed for two cases, the first case neglects the effect of vertical velocity while the second case includes it.

The main objectives of the present work are to apply a two-dimensional model to simulate the thermal pollution in Tigris river downstream South-Baghdad power station then to study the effect of hydraulic conditions of river such as bed roughness and water-surface slope on the temperature distribution .

Numerical modeling:

Numerical model of thermal pollution is a set of partial differential equations as follows [9] :

1. **Momentum Conservation Equations :**

- **Horizontal Momentum Equation :**

$$\rho\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial X}+W\frac{\partial U}{\partial Z}=\frac{\partial}{\partial X}\left(\mu\frac{\partial U}{\partial X}\right)+\frac{\partial}{\partial Z}\left(\mu\frac{\partial U}{\partial Z}\right) \qquad \text{..........1}$$

- **Vertical Momentum Equation :**

$$\rho\frac{\partial W}{\partial t}+U\frac{\partial W}{\partial X}+W\frac{\partial W}{\partial Z}=\frac{\partial}{\partial X}\left(\mu\frac{\partial W}{\partial X}\right)+\frac{\partial}{\partial Z}\left(\mu\frac{\partial W}{\partial Z}\right)-\frac{\partial p}{\partial Z}+\rho g_Z \qquad \text{........2}$$

2. **Thermal Energy Equation :**

$$\rho\frac{\partial T}{\partial t}+U\frac{\partial T}{\partial X}+W\frac{\partial T}{\partial Z}=\frac{\partial}{\partial X}\left(\frac{\mu}{\sigma}\frac{\partial T}{\partial X}\right)+\frac{\partial}{\partial Z}\left(\frac{\mu}{\sigma}\frac{\partial T}{\partial Z}\right)-\frac{\alpha\,(T-T_r)}{C_p.H} \qquad \text{.........3}$$

3. **K-ε turbulence model :**

- **K-Equation :**

$$\rho\frac{\partial K}{\partial t}+U\frac{\partial K}{\partial X}+W\frac{\partial K}{\partial Z}=\frac{\partial}{\partial X}\left(\frac{\mu}{\sigma}\frac{\partial K}{\partial X}\right)+\frac{\partial}{\partial Z}\left(\frac{\mu}{\sigma}\frac{\partial K}{\partial Z}\right)+G-\rho\varepsilon \qquad \text{....4}$$

- **ε- Equation :**

$$\rho\frac{\partial \varepsilon}{\partial t}+U\frac{\partial \varepsilon}{\partial X}+W\frac{\partial \varepsilon}{\partial Z}=\frac{\partial}{\partial X}\left(\frac{\mu}{\sigma}\frac{\partial \varepsilon}{\partial X}\right)+\frac{\partial}{\partial Z}\left(\frac{\mu}{\sigma}\frac{\partial \varepsilon}{\partial Z}\right)+C_1\frac{\varepsilon}{K}G-C_2\rho\frac{\varepsilon}{K} \qquad \text{......5}$$

4. **Turbulent Dynamic Viscosity Distribution :**

$\mu = C_\mu * \rho * (K^2 / \varepsilon)$ 6

5. Pressure distribution a long the river depth :

$$P = g\int_0^Z \rho dz$$ 7

The set of partial differential equations above are solved by finite difference technique . Assumptions are used to transform these equations from non-linear to linear equations [10].These equations are formalized and simplified in a two-dimensional numerical model using Alternative Direction Implict-Explicit method (ADI) with Upwinding technique. The resulting system of linear equations was then solved using Gauss-Elimination method . A computer program was used to perform computation of the simulation model . It is written in Quick Basic language .

Measurment and field work

A visit to the South-Baghdad power station was in order to prepare the data of river water temperature required for the research. The information about Tigris river were obtained from [11].The comparison of the observed data obtained from South-Baghdad power station with predicted results obtained from the numerical model was carried out for model verification .The results of this comparison show agreement with maximum absolute error of about (17%) and correlation factors of (0.940) as shown in fig (1).

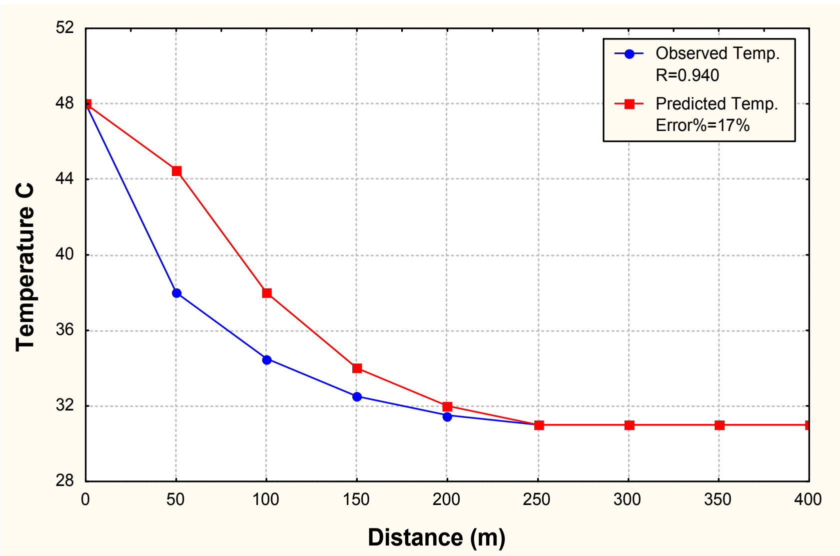


Figure (1) : The comparison between Observed Data from power plant and Predicted Data from the numerical model .

Results And Analyses

Fig (2-a,b,and c and 3.a,b,and c) show the effect of roughness height of river bed and water surface slope on the longitudinal and vertical temperature distribution . These parameters have a direct effect on river velocity. In order to conduct this , the results were taken at heated water temperature equal to 48˚C into 500m length reach of Tigris river downstream of outfall at water temperature equal to 31˚C.

1. Effect of Roughness Height (k) on Temperature Distribution

Fig (2-a,b,and c) shows the effect of variation in roughness height on temperature distribution . The following can be deduced from those figures :

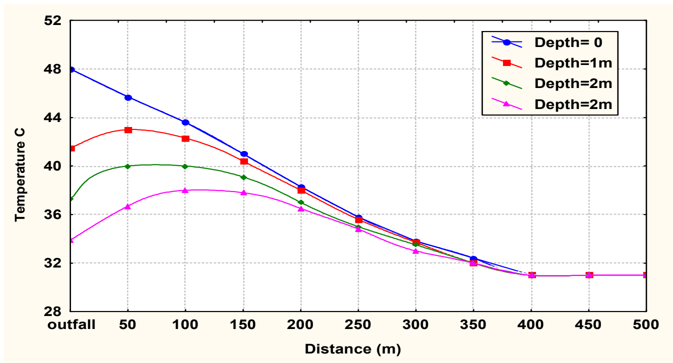
- Increasing the roughness height causes vertical advance of thermal pollution toward the bottom bellow the outfall . For example, at depth of 3m the temperature reached 33.5˚C when k=0.02m , while at the same depth, the temperature reached (33.9˚C, 34.5˚C)when k=0.04m and 0.06m, respectively . This can be attributed to the effect of buoyancy forces which result when thermal polluted water is hotter than ambient river water .
- Increasing the roughness height causes decrease in river velocity so that the longitudinal temperature distribution will decrease and vice versa . For example, the longitudinal thermal distribution extends to (380m) downstream of the outfall in case of k=0.02m, while it has reached (325m, 260m) distance from the outfall in case of k=0.04m and 0.06m, respectively. This is caused by the effect of longitudinal convection which decreases due to the decreases in the longitudinal velocity .

2. Effect of Water Surface Slope (S) on Temperature Distribution

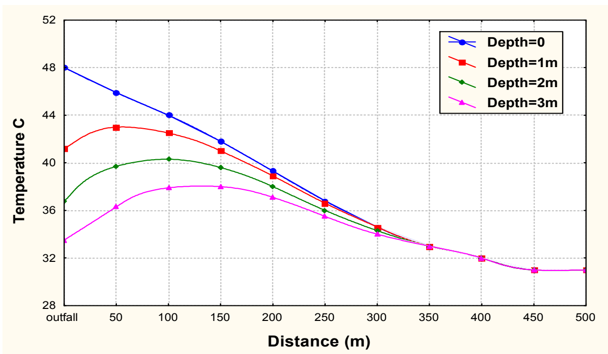
Fig (3-a,b,and c) shows the effect of changing the water surface slope on temperature distribution . It can be seen that :

- Increasing the water surface slope will cause an increase in the longitudinal temperature distribution due to increase in the river velocity . For example, the thermal pollution reached (275m) in length in case of S=4cm/km , while it reached (300m and 350m) in case of (S=7cm/km and 10cm/km), respectively . This can be attributed to the effect of longitudinal convection which is greater with a higher water-surface slope .

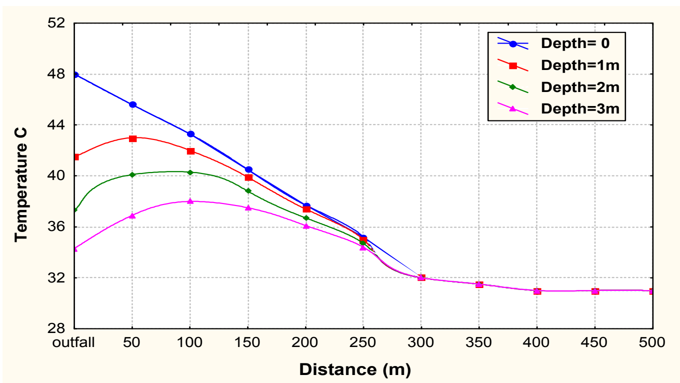
• Increasing the water surface slope causes vertical retardation of thermal pollution the outfall . For example , from fig (3-a,b,and c) , at depth of (3m) , the temperature reached (34˚C) at S=4cm/km , while at the same depth, the temperature reached (33.5˚C and 33˚C) at (S= 7cm/km and 10cm/km) respectively . This can be attributed to the effect of buoyancy force and the increase in vertical diffusion with decrease in water surface slope .



a. Bed Roughness = 0.02m

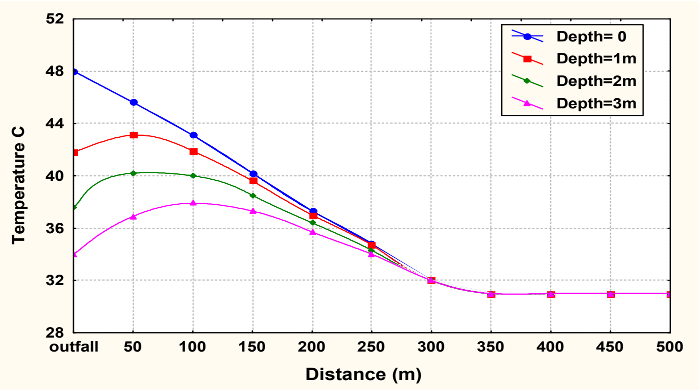


b. Bed Roughness = 0.04m

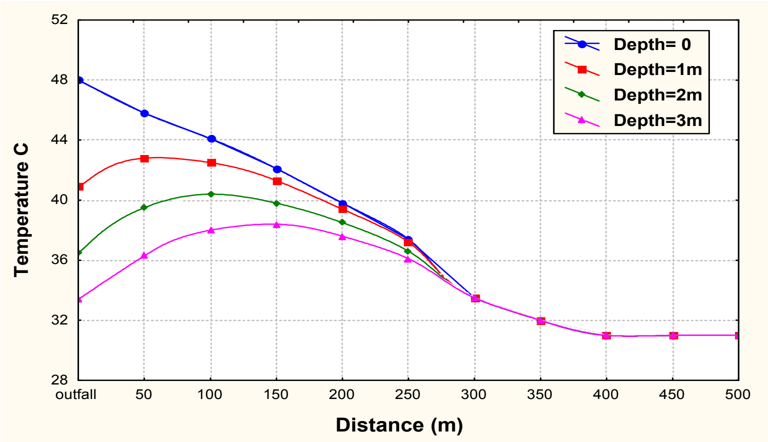


c. Bed Roughness = 0.06m

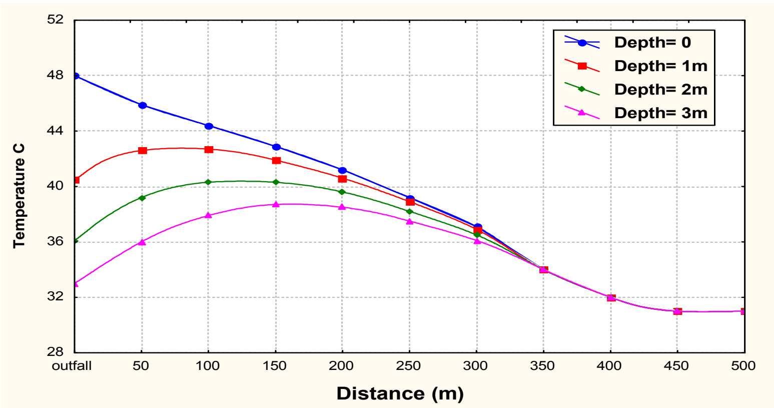
Figure (2) : Effect of River Bed Roughness on Temperature Distribution



a. Water-Surface Slope =4cm/km



b. Water-Surface Slope= 7cm/km



c. Water-Surface Slope= 10cm/km

Figure (3) :Effect of Water Surface Slope on Temperature Distribution

Conclusions

1. The formulation and scheme of the numerical model can be used to find the temperature distribution in Tigris River downstream of South-Baghdad power station. This is because of the agreement of the model results with those obtained from field measurements .
2. The roughness height of the river bed has a considerable effect on the temperature distribution in Tigris river . Increasing the roughness height from 0.02m to 0.06m causes a longitudinal retardation of thermal pollution of about (24%) and vertical advance of about (20%).
3. The water surface slope has a considerable effect on the temperature distribution in the river . Increasing the slope from 4cm/km to 10 cm/km causes a vertical retardation of thermal pollution of about (30%) and a longitudinal advance about (19%).

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