EFFECT OF WATER PROPERTIES DISTRIBUTION IN TIGRIS RIVER DOWNSTREAM OF AL-DAURA POWER STATION [+]

Mahasan Jasam Nasar [**]　　　**Raafa Hashaim AL- sahelly** [*]

Abstract :

This research aims to study the effect of water properties (such as density and viscosity) and heated water temperature on temperature distribution in Tigris river downstream Al-Duara power station . For this purpose a numerical model is applied for estimating temperature diffusion and distribution in river .

Momentum and energy conservation equations are used to describe the temperature distribution along the study area . 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 which were then solved using Gauss- Elimination method .

The numerical model is verified by the comparison of observed data from AL-Daura power station with those computed by the model .The comparison results show agreement with maximum absolute difference of (18%) and correlation coefficient of (0.925). The results show that neglecting the effect of density difference causes a longitudinal and vertical retardation of isotherms of about (12.5% and 50%), respectively. Assumption of constant viscosity causesa longitudinal and vertical retardation of isotherms about (10% and 60%) , respectively . Increasing the heated water temperature from 40 ˚C to 60 ˚C causes a longitudinal advance of isotherms of about (32%) .

المستخلص

يهدف هذا البحث إلى دراسة تأثير بعض خصائص ماء النهر(كالكثافة واللزوجة) و اختلاف درجة حرارة الماء الحار على توزيع درجات الحرارة الناتجة من محطة كهرباء الدورة في نهـر دجلـة .ولهـذا الغرض تم بناء نموذج عددي رياضي لتمثيل توزيع وانتشار المياة الحارة المطروحة في النهر.

[+] Received on 23/1/2006 Accepted on 14/11/2006

[**] Asst.Lecturer/Masib Technical Insttute

[*] Prof. college of Engeneing /university of Baghdad

استخدمت معادلات حفظ الزخم و الطاقة لمعرفة توزيع درجات الحرارة خلال منطقة الدراسة . وتضمن النموذج العددي معادلات الاضطراب (K-ε) لحساب اللزوجة الدوامية . واعتمدت معادلات الضغط الهيدروستاتيكي لحساب الضغط في كل نقطة خاصة بالدراسة . تم تبسيط المعادلات التفاضلية المختلفة للحصول على معادلات جبرية خطية تم حلها بطريقة الحذف المتناوب (Gauss-Elimination)

تم التحقق من النموذج العددي من خلال مقارنة النتائج المقاسة من قبل محطة كهرباء الدورة على نهر دجلة مع النتائج المحسوبة من النموذج و أظهرت نتائج المقارنة ان النموذج مقبول إلى حد ما بنسبة خطا مطلق مقداره (% ١٨) ومعامل ارتباط مقداره (0.925).

أظهرت النتائج ان إهمال تأثير فرق الكثافة يسبب إعاقة طولية وعمودية للخطوط متساوية الحرارة مقدارها 12.5%, ٥٠%على التوالي . وافتراض ثبات اللزوجة يسبب إعاقة طولية وعمودية للخطوط متساوية الحرارة مقدارها 10%, 60%على التوالي . وان زيادة حرارة الماء الحار من ٤٠ م° الى ٦٠ م° يسبب تقدم لتلك الخطوط بالاتجاة الطولي مقدارة (٣٢%).

Introduction :

Thermal pollution occurs when heated water is discharged into rivers, lakes, oceans and other bodies of water. Many of the deleterious effects to aquatic life associated with thermal pollution stem from the increased rate of metabolism that occurs as temperature increases. Generally, the metabolic rate doubles for every 10 °C rise in temperature This causes an increased demand for oxygen by the organism [1].

An increase in water temperature brought about by discharging waste water into streams has various adverse effects . Stream waters which vary in temperature from one hour to the next are difficult to process effectively in municipal and industrial water treatment plants , and heated stream waters are of decreased value for industrial cooling . Indeed, one industry may so increase the temperature of stream that neighboring industry downstream can not use the water . Furthermore, warm water is lighter than cold , so that stratification develops, and this causes most fish life to retreat to stream bottoms . Since there may be less dissolved oxygen in warm water than in cold , aquatic life suffers , and less oxygen is available for natural biological degradation . Also, bacterial action increases in higher temperatures, resulting in accelerated depletion of the stream oxygen resources .Higher tempera hare water lowers dissolved oxygen content by decreasing the solubility of oxygen in water . Warmer water also causes aquatic organism to increase the respiration and consume oxygen faster , and it increases their susceptibility to disease, parasites and toxic chemicals[2].

Bruce Mcenroe and Subhash [3] investigated the two-dimensional submerged heated jet discharged into a shallow stagnant water . The model discusses two cases ; the effect of inertia force , surface heat and bottom friction are included in the first case and are neglected in the second case .

Al- Challabi [4] developed anumerical model for simulation of the spread and mixing of thermally polluted water disposed into the flow The results show that, river with smooth-bed-velocity-distribution caused faster spreads than that for the rough-bed- velocity- distribution .

Li-Renyu and Righetto [5] present unsteady state two dimensional model to simulate the velocity and temperature field in the estuary of the Yangtza River in Brazil. It was found that the simulation by using (K-ε) model can provide more details of flow fields and temperature distribution than that one obtained by using phenomenological algebraic for models of eddy viscosity and diffusivity .

Cakirolgu and Yurteri [6] present a mathematical model to predict the long-term effects of once-through systems on local fish population. The simulation indicates that entertainment and impingement may lead to population reduction of about 2% to 8% in the long run .Kadhem [7] developed a two- dimensional model for simulation and prediction of the spreading and miing of thermally polluted water disposed into river flow released from South- Baghdad power station starting from the outfall up to 500m downstream of the river . Results indicate a considerable effect of temperature change on water parameters like (T.D.S, T.S.S, EC, DO) .

In this research , the two-dimensional numerical model is used to solve the temperature distribution in Tigris water river downstream Al-Daura power station then to study the effect of some water properties (such as density and viscosity) on temperature distribution .

<u>Numerical Modeling</u> :

Numerical model of thermal pollution is a set of partial differential equations as follows : [8]

1. **Navier-Stokes Equations (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 :**

$$\rho\frac{\partial W}{\partial t}+U\frac{\partial W}{\partial X}+W\frac{\partial W}{\partial Z}=\frac{\partial}{\partial X}\left[\mu\frac{\partial W}{\partial X}\right]+\frac{\partial}{\partial Z}\left[\mu\frac{\partial W}{\partial Z}\right]-\frac{\partial P}{\partial Z}+\rho g \quad ....2$$

2. **Thermal Energy Equation :**

$$\rho\frac{\partial T}{\partial t}+U\frac{\partial T}{\partial X}+W\frac{\partial T}{\partial Z}=\frac{\partial}{\partial X}\left[\left[\frac{\mu}{\sigma}\frac{\partial T}{\partial X}\right]\right]+\frac{\partial}{\partial Z}\left[\left[\frac{\mu}{\sigma}\frac{\partial T}{\partial Z}\right]\right]-\frac{\alpha(T-T_r)}{C_P*H} \quad ....3$$

3. **K-ε turbulence model :**

- **K-Equation :**

$$\rho\frac{\partial K}{\partial t}+U\frac{\partial K}{\partial X}+W\frac{\partial K}{\partial Z}=\frac{\partial}{\partial X}\left[\frac{\mu}{\sigma_K}\frac{\partial K}{\partial X}\right]+\frac{\partial}{\partial Z}\left[\frac{\mu}{\sigma_K}\frac{\partial K}{\partial Z}\right]+G-\rho\varepsilon ......4$$

- **ε- Equation** :

$$\rho\frac{\partial \varepsilon}{\partial t}+U\frac{\partial \varepsilon}{\partial X}+W\frac{\partial \varepsilon}{\partial Z}=\frac{\partial}{\partial X}\left[\frac{\mu}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial X}\right]+\frac{\partial}{\partial Z}\left[\frac{\mu}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial Z}\right]+C_1\frac{\varepsilon}{K}G-C_2\rho\frac{\varepsilon}{K} ....5$$

Density- Temperature relationship.

$\rho = -0.0055T^2 + 0.0182\,T + 1000.1$ ………..... 6

4. **Turbulent Dynamic Viscosity Distribution :**

$\mu = C_\mu * \rho * (K^2/\varepsilon)$ …………7

5. **Pressure distribution a long the river depth :**

$$p = g\int_0^Z \rho\, dZ \quad ....8$$

Finite difference is used for the solution of the above partial differential equations . Assumptions are used to transform these equations from non-linear to linear equations [9].These equations are formalized and simplified in a two-dimensional vertical and horizontal direction using Alternative Implist-Explicit method (ADI) with **upwinding** technique . The resulting system of linear equations were then solved using **Gauss- Elimination** method . A computer program is an essential research tool used to perform computation of the simulation model . It is written in Visual Fortran -97 language .

ASSUMPTIONS :

In order to simplify the analysis , equations were used with the following assumptions :

1. The river is rectangular open channel with complete mixing in the transverse direction .
2. The flow is uniform .
3. The river velocity is constant .
4. The fluid is incompressible .
5. The effect of wind speed on the velocity distribution is neglected .
6. The river surface is planer .

Measurments and Field Work :

A visit to Al- Daura power station was made in order to prepare the data for the study .The information about Tigris river have been obtained from [10]. Observed data collected from the plant and predicted data computed from the numerical model at time of disposal equal to (300sec) and time interval equal to (1sec) as shown in Table (1) .

Table.1 Observed and Predicted Temperature Data :

DISTANCE (M)	OBSERVED TEMPERATURE .˚C	PREDICTED TEMPERATURE. ˚C	ABSOLUTE DIFFERENCE. %
Outfall	46	46	0
50	36	42.5	18
100	32	36	12.5
150	31.5	33	4.8
200	30.5	31	1.6
250	30	30	0
300	30	30	0
350	30	30	0
400	30	30	0

The model verification was carried out by conducting a comparison between the observed data obtained from AL-Daura power station and the predicted results computed by the numerical model as shown in Fig (1) . The comparison shows agreement with maximum absolute difference of about (18%) ; the correlation coefficient of these results is (0.925).

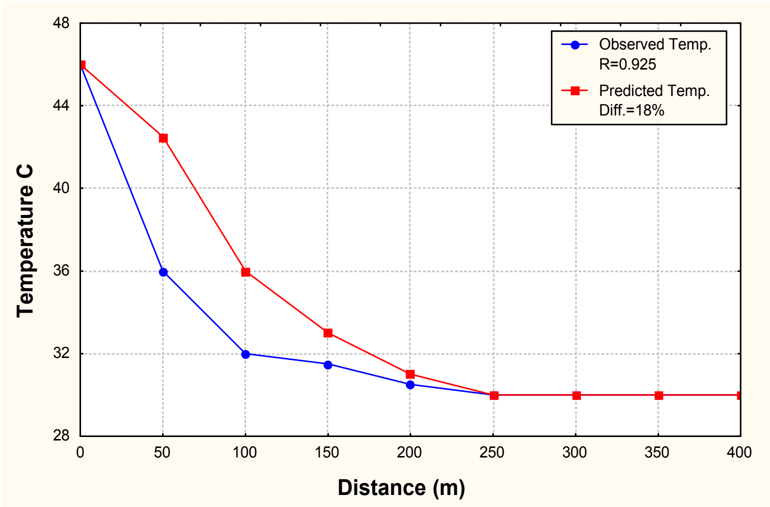


Figure (1) : Comparison between Predicted Temperature from a numerical model and Observed Temperature from AL-Daura Power Station .

<u>Results and Analyses :</u>

Figu (2,3 and 4) show the effect of some water properties considered in the research on the longitudinal and vertical temperature distribution in Tigris river . The results were taken as continuous point disposal of a heated water at temperature equal to (50˚C) into water river at temperature equal to (30 ˚C).

<u>1.Effect of Density Difference :</u>

The density difference between the heated water and the river water has been considered in order to study the effect of density difference on temperature distribution .The comparison between neglecting and including density effect is shown in Fig (2) . This figure shows :

- A decrease in the longitudinal temperature distribution in case of neglecting the density effect . For example , the isotherm of (34 ˚C) reaches about 155m away from the outfall in case of including density effect , while it is about 130m away from the outfall in case of neglecting the density effect . This can be attributed to the effect of a buoyancy force on the spreading and mixing of the temperature .
- Isotherms are retarded vertically in case of neglecting the density effect . For example, the isotherm of (40˚C) is about 1.5m in depth when the density effect is neglected, while the same isotherm has reached to the bottom when

the density effect is included . This is due to the neglecting of the downward vertical motion of heavier parts (cold parts).

2.Effect of Viscosity :

Fig (3) shows a comparison between the results for variable and that for constant viscosity . It can be seen that :

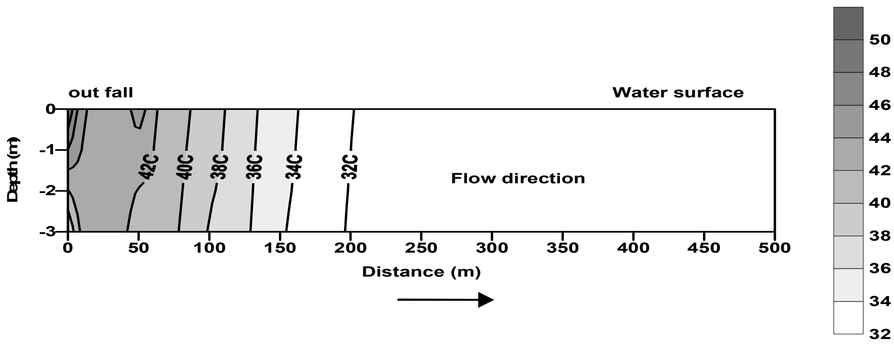
- isotherms advanc vertically toward the river bottom in case of assuming variable viscosity more than that in the case of viscosity considered constant . For example, the isotherm of (44˚C) has reached near the water surface in case viscosity is constant, while the same isotherm has reached the bottom in case viscosity is variable . This can be attributed to the effect of vertical diffusion in advancing the isotherm vertically in case viscosity is variable .
- in the longitudinal direction , isotherms in case of constant viscosity are retarded longitudinally . For example, the isotherm of (42˚C) has reached about (40m) incase of viscosity is constant , while the same isotherm reaches about (60m) in case viscosity is variable. This is because of a longitudinal turbulent mixing which is responsible for the transport of the pollutant and greater effect on the generation of buoyancy force and on longitudinal convection.

2- Effect of Released Heated Water Temperature (Td) :

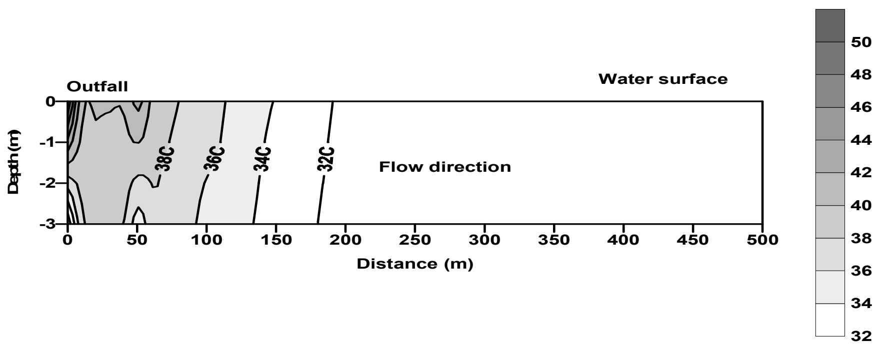
The effect of temperature difference between the heated water temperature and River water temperature was carried out . Two values of heated water temperature (60˚C and 40˚C) with constant value of water river temperature were studied . Comparison of the results is shown in Fig (4). This figure shows :

- the longitudinal distribution of isotherms increases with the increase the heated water temperature and vice versa. For example, the isotherm of (32˚C) is located at a distance of 220m from the source (outfall) in case of heated water temperature Td=60˚C , while the same isotherm is located about 155m from the source in case of Td=40˚C . This can be attributed to the increase in velocity caused by decrease in density and viscosity with temperature .

- Near the outfall location , the isotherms are closer to each other. This may be due to decrease in the density by temperature disposal , leading to a decrease in the injection momentum .

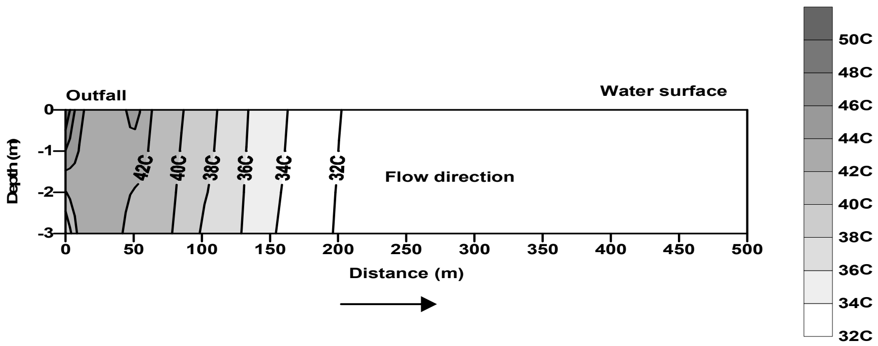


a-Including Density Effect

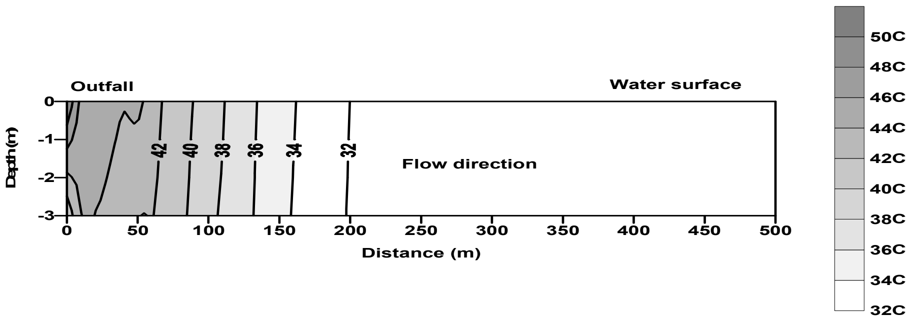


b-Neglecting Density Effect

Figure (2) : Effect of Density Difference on the Temperature Distribution .

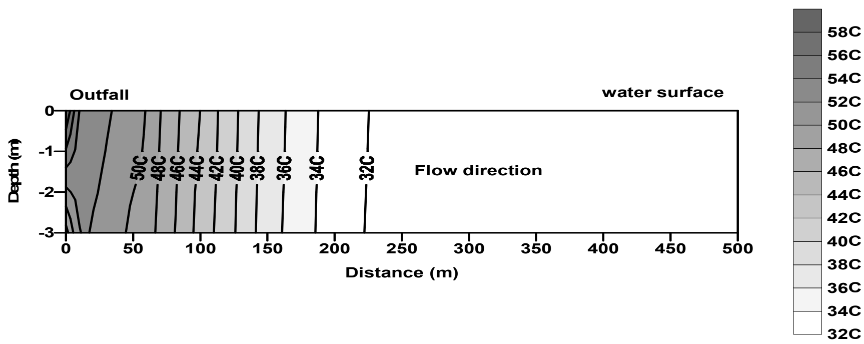


a-Constant Viscosity

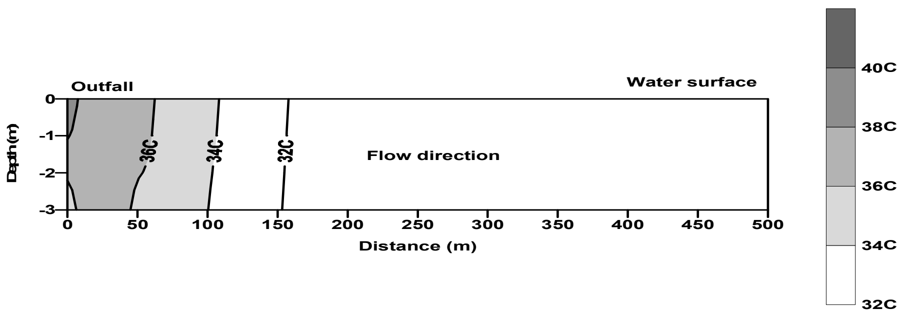


b- Variable Viscosity

Figure (3) : Effect of Turbulent Viscosity on the Temperature Distribution .



a-Heated Water Temperature (Td = 60 ˚C)



b- Heated Water Temperature (Td = 40 ˚C)

Figure (4) : Effect of Heated Water Temperature (Td) on the Temperature Distribution .

Conclusions:

1. The formulation of the numerical model can be used to find the temperature distribution in Tigris river downstream of AL-Daura power station . This is because of the agreement of the model results with those obtained from field measurements .
2. Difference between the heated water density and the river water density has considerable effect on the temperature distribution in the river. Neglecting the effect of density difference causes a longitudinal and vertical retardation of isotherms of about (12.5% and 50%), respectively .
3. Viscosity effect on temperature distribution in water river, assumption of constant viscosity causes a longitudinal and vertical retardation of isotherms near the outfall of about (10% and 60%) , respectively.
4. The difference between heated water temperature and river water temperature has considerable effect on the temperature distribution . Increase in the heated water temperature from 40˚C to 60˚C causes a longitudinal advanc of isotherms by about (32 %).

LIST OF SYMBOLS :

Symbols	Description	Units
C_μ ,C_1, C_2	constants in K-ε Turbulence Model	
C_p	specific heat	W.S/(kg.˚K)
g	acceleration duo to gravity	m/s^2
H	heat exchange across the water surface	kg.˚K/(m^2.s)
K	turbulence Kinetic energy	kg/s
p	pressure	N/m^2
R	correlation factor	
Tr	river water temperature	˚C
Td	heated 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	

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