Simulation of Thermal Pollution at Tigris River due to Al-Dora Power Plant

Noor Shakir Mahmood¹, Dr. Thamer Ahmad Mohammad²
¹M.Sc. Student, Engineering College -Baghdad University
²Engineering College -Baghdad University

n.mahmood1310@coeng.uobaghdad.edu.iq
thamer.a.m@coeng.uobaghdad.edu.iq

Abstract Thermal water pollution is a cost saving in cooling process for the electrical industry but it has negative effect on environment. When thermal water is released from power plants into water bodies, it is harmful to marine life. High temperature reduces aerobic decomposition. As organic matter degrades, the amount of nutrients in water bodies is diminished. The study propose a solution to reduce the thermal effect of plant water using the CFD comsol software. The results shows that a change in the width of the channel of the plant hot water to 10 m reduce the thermal effect of the hot water plant, which leads to less environmental effect.

Introduction
Pollution has an impact on plants, livestock, humans and climate. Pollutants comprise substances of greater than natural abundance which are solid, liquid or gaseous, created by human activities that affect our environment [10]. There are many types of pollutions such as (Water Pollution, Air Pollution, Soil Pollution, Biological and Nuclear pollutions [1]. The rise in temperature of air and water is considered as a thermal pollution. Water pollutant is mainly resulted from heated industrial effluents and affected the river ecology. The rapid rise in temperature reduces the dissolved oxygen, DO in water it may kill fish and other species adapted to their particular temperature range by what is called thermal shock (water shock is either a rapid increase or decrease in the water temperature) [2, 3]. The release of heated water from thermal power plants into water bodies has a detrimental impact on aquatic life. It decreases aerobic decomposers' activity due to a high temperature and depletion of oxygen. The supply of nutrients in water
bodies is jeopardised when the decomposition of organic matter is limited. The photosynthesis rate for aquatic plants is reduced because of enzyme activity inhibitions with increased temperature. As a result of thermal pollution, prime productivity and diversity of aquatic plant species decreases [4]. Thus, it will destroy fish and other species, when they first open or shut down for reparation or other purposes [6].

Thermal pollution from energy production plants degrades river ecosystems that affect energy supply outside the natural environment [7]. When the temperature rises as low as 1 or 2°C (about 2 - 4°F), the fish, shellfish and plants can be killed or expelled by other animals, sometimes with undesirable results. In Iraq, there are six thermal power plants situated on Tigris River. The thermal power plants use a lot of water to cool the units and release hot water at a higher temperature to Tigris River and this pollute it. On this basis, four to six power plants are disposing huge volumes of hot water into Tigris River. The electricity generation in Iraq is increasing, which means that Tigris River receives more hot water from the power plant in future [9]. The disposed heated water from the plants in Tigris River damage.

In this study, a numerical model was employed to simulate how the hot water disposal from Al-Dora power production plant affects the variation of water temperature in river Tigris including the extent to which the effect will extend downstream.

Methodology

Al-Dora Thermal Power Plant

Al-Dora thermal power plant is located on the right bank of the Tigris River South of the Baghdad. Al-Dora power plant, consists of 4 steam turbine units with a design capacity of 160 MW per unit. AL-Dora power plant use open (once-through) system for cooling its condenser. Once-through cooling requires a great volume of water which is supplied from the Tigris river. After the cooling process heated water discharges back into the Tigris River. The daily average of water used to cool the condenser is 40000 m³/ hr. Figures 1 and 2 shows the studied region and location of the power plant.

![Figure 1: al dora power plant location from satellite image](image-url)
Experimental work

The data collection of the water temperature of the river near the power plant in order to study the effect of thermal pollution on the river. Different region cross sections have been located along the river flow path to study before and after the discharge pollution collected from the General Survey Authority. Also, the water speed, flow rate measurement was collect with the help of National Center for Water Resources Management using ADV device.

![Figure 2: the studied region of the river at different section](image)

The temperature were measured at different points in the river using a temperature and humidity meter type (HTC -2 ) ±0.1 accuracy at (25 cm) depth of the river and the result were located in a map, the distance from each measuring point was measured using GPS device.

Software

The Arc view 3.3 and Arc Map -Arc GIS 9 GIS software was used for the overlay impact analysis. As it was more convenient and easier to use analysis tool present in Arc view 3.3. In Geoprocessing tool box, dissolve features based on an attribute, Merge themes together, Clip one theme based on another, Intersect two themes, Union two themes, Assign data by location operation were present in one operation. The Arc Map -Arc GIS 9 was used for rest of the impact analysis mainly for operation provided with inbuilt Arc Catalogue and Arc toolbox in software.

CFD simulation

Computational fluid dynamics (CFD) has been widely used to explore new ideas due to saving cost and time. All required details of applying CFD technique to investigate the fluid flow and heat transfer performance using river geometry. It is broken down to sections describing and explaining each step of solving the CFD problem starting by giving a background of CFD, the COMSOL Multiphysics® software package, governing equations, the boundary conditions, and ending with a summary.

Results and discussion

GIS image analysis

Water temperature is an important parameter for the physical and biochemical processes occurring within water as well as in air-water interactions because temperature regulates physical, chemical, and biological...
processes in water. Water temperature also influences the solubility and availability of various chemical constituents in water. Most importantly, this parameter affects dissolved oxygen concentrations in water; as oxygen solubility decreases with increasing water temperature. It is also very important to analyze the temporal variations due to seasonal changes. Thermal infrared bands are able to measure the amount of infrared radiant heat emitted from land surfaces and the radiant temperature of water bodies that have environmental and economic import. Figure 3 shows Water temperature in freely flowing rivers is unstable because the characteristics of these rivers like the channel shape, and in-stream objects cause a turbulent flow regime. Sensing of water temperature in rivers is more complex than in other waterbodies because of their much smaller dimensions and difficulties of determination so different measurement were taken from the river and plotted using the GIS software as shown in figure 3 and 4. Stream and river temperature is crucial especially in the entrance of the hot water of the plant to the river which endangered fish populations, which are sensitive to increased water temperature. For the selection of appropriate band or bands, careful consideration on the least amount of instrument noise and atmospheric effects is necessary for accurate calculation of the water temperature. However, an average of multiple bands can provide a better estimate of the actual temperature reducing the noise of images related to atmospheric or sensors differences. The general indication is 5°C different from the main water stream to the feed stream which is enough to cause an environmental pollution of the fish population in water river.

![Temperature Contours for Al Dora Power Plant](image)

**Figure 3:** Contour image of the GIS plot for temperature distribution
Figure 4: GIS image thermal image with thermal boundaries

COMSOL simulation

The Navier-Stokes, continuity and heat equations need to be solved with the appropriate initial conditions, assumptions and boundary conditions. This section deals with the solution of the governing coupled Navier-Stokes equation with the heat equation. Further, we describe in details the algorithm that is followed in simulating the heat transfer and laminar flow in COMSOL Multiphysics 5.1.

In this study, the case considered is single-phase laminar forced convective flow of water. Heat transfer by convection is the thermal energy transfer in the presence of a temperature difference as a combination of advection (fluid motion in bulk) and diffusion (random molecular motion). The subsequent sections will focus on the assumptions, initial conditions, boundary conditions, governing equations and steps in COMSOL for setting up the model and for simulating the laminar flow coupled with heat transfer in the river.

Assumptions and Initial Conditions

Water is considered to be the fluid in the model which undergoes steady, laminar. The density of the fluid is taken to be constant, thereby making the incompressible fluid approximation valid. This assumption was also taken in the works of [10,11,12,13]
Table 1 Values for the Material Properties of Water

| Property                        | Name  | Value | Unit       |
|--------------------------------|-------|-------|------------|
| Dynamic viscosity              | mu    | 0.0008509 | Pa*s       |
| Ratio of specific heats        | gamma | 1.0   | 1          |
| Heat capacity at constant pressure | C_p  | 0.00418 | J/(kg*K)   |
| Density                        | rho   | 996.59 | Kg/m³      |
| Thermal conductivity           | k     | 0.6   | W/(m*K)    |

Gravitational forces are neglected since the system is horizontal and also that the static pressure under gravity is very low (P = ρgh; 1000kg/m³ *9.81m/s² *100μm = 0.9 Pa).

Simulation case and solutions

Original case

The water distribution in river was simulated using the comsol software and the solution proposed was simulated using the same software. The solutions were changing the width of channel to change the velocity inlet of water to the river and thus change the mixing behavior. The original case shown in figure 5 was the width of channel was 4 m and the result was similar to the GIS one.

Figure 5: original case simulation using COMSOL
Solution case 1

The first solution adopted was changing the width of channel from 4 m to 8 m and the result shown in figure 6.

![Image of figure 6 showing COMSOL results for the 8m width channel]

As shown in figure 6, increasing the width of the channel reduces the inlet velocity and helps the main stream of the river to mix and thermally reduce the thermal effect of the entering water.

Solution case 2

The second solution taken was changing the width of channel from 4 m to 10 m and the result shown in figure 7. Increasing the width of the channel reduces the inlet velocity and helps the main stream of the river to mix and thermally reduce the thermal effect of the entering water.
Figure 7: comsol result of the 10m width of channel

Conclusion

The advantages of using thermal water as a heat source in the production of electricity include cost and money saving for the power industry but damage to the environment. Boiling or otherwise distorting water at power plants can damage marine life when the temperature is raised, aerobic decomposition increases. When organic matter is incorporated into water, the level of nutrients diminishes. The main objective of the investigation is to discover a way to lower the plant's heating costs by means of CFD comsol the findings: changing the width of the channel to 10 m improves the thermal impact, which then results in lower environmental impact.

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