Effect of temperature drainage on marine organisms for Huarun Caofeidian power plant

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Abstract. In the form of numerical simulation, the influence of temperature rise of temperature drainage on marine environment during the operation of Huarun Caofeidian power plant was studied. The numerical simulation results show that the affected area is about 500m on both sides of the outfall, and the temperature increase of 0.5 ℃ was basically located in the tidal channel, which will not affect the water intake. Analogous to other related power plant projects, the power plant temperature drainage may cause the number of plankton increased around the drainage area, the species of fish decreased within the rising of 3 ℃ in the summer and no significant negative impact on the benthic organism.

1. Introduction

In recent years, with the construction of coal-fired power stations and nuclear power stations, a large number of cooling water has been discharged into the offshore area, which has gradually highlighted the problem of Marine thermal pollution [1]. The elevated water temperature will cause the dissolved oxygen content in water to reduce and bring adverse effect to fish and other aquatic life and reproduction, but also bring water eutrophication and deterioration of water quality and other environmental problems. Many experts predict that marine thermal pollution will become one of the largest pollution types in the 21st century. In this paper, the influence of temperature drainage on the marine environment is studied by means of numerical simulation and is provided theoretical support for other related research.

Huarun Caofeidian power plant is located in the south central part of Caofeidian Industrial Zone, in the industrial zone on the north side of the planned iron and steel production base of HeBei province. The distance is about 1.7km from comprehensive service area in the north, 2.0km from the west side of Qinglin highway, 1.5km from a harbor in the east coast. It is next to the harbor port hinterland. According to the overall planning of Caofeidian Industrial Zone, Huarun Caofeidian power plant’s planning capacity is 4600MW + 2000MW. The first phase of 2×300MW extraction condensing steam turbine has been put into operation in July 2009. The scale of the second construction phase of the project is contained 2×1000MW ultra supercritical domestic coal-fired generating units, the construction of flue gas desulfurization and denitrification facilities is also equipped during the same period. The discharge of Huarun power plant is drained by open channel which is about 80m wide. The drainage channel which is about 227m wide is located at the tidal channel. The locations of the power plant Outfall refer with figure 1.
2. Numerical simulation

2.1. Calculation area and grid layout
According to the hydrological data and model calculation, the computational domain takes Caofeidian industrial zone as the center which was 63.5km from the east to the west, 48.5 km from the South to the North. It was composed of 9316 nodes and 18168 triangular elements. The minimum unit space step in the drainage area of this project was about 50 meters.

2.2. Prediction model
The influence of temperature rise caused by cooling water on environment was predicted by the combination of two-dimensional power flow model and dissipative model.

2.2.1. Basic equations of two-dimensional tidal current and diffusion. Continuous equation:

\[
\frac{\partial h}{\partial t} + \frac{\partial (Hu)}{\partial x} + \frac{\partial (Hv)}{\partial y} = 0
\]

Equation of motion:

\[
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + g \frac{\partial h}{\partial x} - f v + g \sqrt{u^2 + v^2} \frac{u}{C^2 H} = K_x \frac{\partial^2 u}{\partial x^2} + K_y \frac{\partial^2 u}{\partial y^2}
\]

\[
\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + g \frac{\partial h}{\partial y} + f u + g \sqrt{u^2 + v^2} \frac{v}{C^2 H} = K_x \frac{\partial^2 v}{\partial x^2} + K_y \frac{\partial^2 v}{\partial y^2}
\]

h is water level, H is depth of water, u and v are velocity components in the X and Y directions, f is coriolis force coefficient, C is chezy coefficient. In \( C = \frac{H^{1/6}}{n} \), \( n \) is manning coefficient, \( K_x \) and \( K_y \) for turbulent coefficients of flow in X and Y directions, \( t \) is time, \( g \) is gravitational acceleration.

2.2.2. Dissipation mode.

\[
\frac{\partial HT}{\partial t} + \frac{\partial HuT}{\partial x} + \frac{\partial HvT}{\partial y} = K_x \frac{\partial^2 (HT)}{\partial x^2} + K_y \frac{\partial^2 (HT)}{\partial y^2} + M - KsT
\]
T is temperature difference, $K_x$, $K_y$ are x direction and y direction diffusion coefficient, $K_s$ is water surface integrated heat dissipation coefficient, M is temperature drainage source.

2.3. Calculation scheme
The discharge capacity of Caofeidian power plant in summer and winter was 83.3 m$^3$/s and 59.1 m$^3$/s respectively. The discharged cooling water arrived at the outlet through the open channel and the water temperature decreased by about 4℃ during the transmission from 9.6℃. Based on the above, the influence range of temperature rise was predicted on the basis of surface dissipation depended on summer and winter displacement.

Considering the dissipation of channel surface in summer, the calculated source strength was 717.28 KKcal /s. Considering the dissipation of channel surface in winter, the calculated source strength was 484.96 KKcal /s.

2.4. Numerical simulation results
According to the water temperature diffusion equation, the above calculation scheme was calculated by 30 tidal current cycles. The temperature rise field was basically stable, and the results were shown in figure 2, figure 3 and table 1. It could be seen that the water range of temperature rise >4℃ was basically in the 500m range of both sides of the drain. The water range of temperature rise of >0.5 ℃ was basically located in the tidal channel, and would not affect the intake waters.

Table 1. The maximum impact range of temperature rise.

| Season | >4℃ | >2℃ | >1℃ | >0.5℃ |
|--------|-----|-----|-----|-------|
| Summer | 0.14| 0.34| 1.08| 2.75  |
| Winter | 0.09| 0.21| 0.55| 1.68  |

Figure 2. The maximum possible range of temperature rise in summer.

Figure 3. The maximum possible range of temperature rise in winter.
3. Discussion
In general, when the water temperature rises ≤3℃, the number of phytoplankton species will increase of 50% on average and the number of zooplankton species will increase of 76% approximately [2]. Deng Rui [3] confirmed that the biodiversity index near the outfalls was relatively lower and the amount of planktonic algae was higher. This phenomenon was limited in the area affected by the temperature drainage. But Li Bin [4] thought there was more phytoplankton biomass, higher species diversity index and evenness index of average in affected area than the natural water temperature regions. Our modulus simulation shows that the influence of water body is basically in the 500m range of both sides of the drain when the variation range of water temperature rise >4℃. It can be concluded that the number of plankton in the 500m of the outfall may be increased during the operation of the power plant.

The highest tolerance temperature of benthic organism is generally 35-42 ℃, a few species can withstand the high temperature of 40-50 ℃. A few species have poor tolerance to high temperature and can only withstand the range of 30-32℃ degrees [5]. Zheng Lin [6] believed that temperature drainage do not adversely affect benthic communities, and that there are more benthos species in elevated temperatures. The impact of temperature rise in Caofeidian power plant area is limited to the partial sea area of the outfall, and the temperature drainage will not cause obvious negative impacts on the benthic organism.

For most warm water fishes, they can be adapted to about 1 ℃ temperature rise which generally does not affect the growth of fish in summer. But when the temperature rose above 3 ℃, the fish might suffer significantly unfavorable influence [7]. The variation range of the water temperature near the project is between 1.5 ℃-27.5 ℃. It is concluded that the temperature change caused by the temperature drainage is still in the survival range of most fishes during the spring, autumn and winter. So no significant impact will happen to the fish. In summer, the range of temperature rise of 3 ℃ is above about 0.44km². The species and catch of fish will be affected and the survival rate of floating eggs and larvae will be reduced.

4. Conclusion
Analogous to other related power plant projects, the power plant temperature drainage may cause the number of plankton increased around the drainage area, the species of fish decreased within the rising of 3 ℃ in the summer and no significant negative impact on the benthic organism.

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