Effect of Residual Chlorine on Marine Organisms for Huarun Caofeidian Power Plant

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Keywords: Power plant, Residual chlorine, Numerical simulation, Marine organisms.

Abstract. Aiming at influence of discharge thermal water from the Huarun Caofeidian power plant, a 2D hydrodynamic model was used to simulate the tidal current field of waters receiving residual chlorine in discharged thermal water in Caofeidian Coastal Area. With the computed tidal current field considered to be the hydrodynamic conditions of the residual chlorine transport simulation, the concentration distribution of the residual chlorine was predicted with a 2D convection diffusion model and its effect on the marine organisms was analyzed. The results show that, the area affected by residual chlorine water is 0.14 and 0.21 km$^2$ respectively in winter and summer. The residual chlorine concentration around the outfall is lower than most of the safety concentration for shellfish and Copepods. In winter and summer, some fish avoided reaction to the residual chlorine which area is 0.83 and 1.43 km$^2$ respectively.

Introduction

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. The North distance comprehensive service area of about 1.7 km, the distance 2.0 km from the west side of Qinglin highway, a harbor in the east coast of 1.5 km, next to the harbor port hinterland. According to the overall planning of Caofeidian Industrial Zone, Huarun Caofeidian power plant planning capacity of 4600MW + 2000MW, a phase of the project construction of Huarun Caofeidian power plant 2×300MW extraction condensing steam turbine has been put into operation in July 2009. Construction of the two phase of the project is 2×1000MW ultra supercritical domestic coal-fired generating units, the construction of flue gas desulfurization and denitrification facilities during the same period. The Huarun power plant is drained by open channel after discharge, and the drainage channel is about 80m wide. The drainage channel is located at the tidal channel, the width of which is about 227m. The locations of power plant Outfall refer with Fig. 1.

Figure 1. The locations of power plant Outfall.
Numerical Simulation
Calculation Area and Grid Layout

According to the calculation of integrity of purpose, the hydrological data and the model, the computational domain to Caofeidian Industrial Zone as the center, from the east to the west is 63.5km, from the South to the North is 48.5km, consisting of 9316 nodes and 18168 triangular units, The minimum unit space step in the Outfall area is about 50 meters.

Prediction Model

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

Continuous equation (Eq.1):
\[
\frac{\partial h}{\partial t} + \frac{\partial (Hu)}{\partial x} + \frac{\partial (Hv)}{\partial y} = 0
\]

Equation of motion (Eq.2, Eq.3):
\[
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + g \frac{\partial h}{\partial x} - f v + g \frac{\sqrt{u^2 + v^2}}{C^2 H} = K_x \frac{\partial^2 u}{\partial x^2} + K_y \frac{\partial^2 u}{\partial y^2}
\]
\[
\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + g \frac{\partial h}{\partial y} + f u + g \frac{\sqrt{u^2 + v^2}}{C^2 H} = K_x \frac{\partial^2 v}{\partial x^2} + K_y \frac{\partial^2 v}{\partial y^2}
\]

Among: h- water level; H-depth of water; u,v- Velocity components in the X and Y directions; f-Coriolis force coefficient; C-chezy coefficient, \(c = \frac{H^{1/6}}{n}\), n-Manning coefficient; \(K_x, K_y\)- Turbulent coefficients of flow in X and Y directions; t-time; g- Gravitational acceleration.

Dissipation mode (Eq.4):
\[
\frac{\partial HC}{\partial t} + \frac{\partial HuC}{\partial x} + \frac{\partial HvC}{\partial y} = K_x \frac{\partial^2 (HC)}{\partial x^2} + K_y \frac{\partial^2 (HC)}{\partial y^2} + Sm - Q
\]

Among: C-concentration; Sm-\((=qC_0, q\)- Emission amount, \(C_0\)-Emission concentration); Q-dissipation term(\(=KC, K\)- Attenuation coefficient, \(K=ln2/T_{1/2}, T_{1/2}=1h\)).

Definite Solution Condition

Initial condition: \(u(x,y) \big|_{t=0}=u_0(x,y); v(x,y) \big|_{t=0}=v_0(x,y); h(x,y) \big|_{t=0}=h_0(x,y)\).

Boundary condition: Land boundary- The normal velocity is 0;

Water boundary: \(h_w = h_w(t)\) or \(u_w = u_w(t); v_w = v_w(t)\).

Calculation Scheme

The displacement of caofeidian power plant is 83.3m³/s in summer and 59.1m³/s in winter. According to the above situation, the influence range of residual chlorine in summer and winter displacement is predicted respectively, and the emission concentration is predicted. The upper bound of residual chlorine quality is 0.5mg/L.

Numerical Simulation Results

According to the above pollutants dissipation equation for the calculation scheme for 30 weeks tide prediction calculation, the residual chlorine concentration field basically stable, the result is shown in Fig. 2-Fig. 3 and table 1. Can be seen from the chart, the summer area is located in the mouth side effects of residual chlorine concentration is greater than 0.20mg/L, the impact of water range basically in the mouth on both sides of the range of 1000m, the influence area is about 0.21 km²; 0.10mg/L concentration is greater than the impact of water area is 0.52 km²; 0.05mg/L concentration is greater than the impact of water area is about 1.43 km², basically in the range of influence in the tidal channel, will not affect a harbor water estuary. The influence area of residual chlorine in winter is located at the mouth of outfall, and the range of influence is less than summer.
Table 1. The maximum area affected by residual chlorine.

<table>
<thead>
<tr>
<th>Season displacement</th>
<th>&gt;0.20mg/L</th>
<th>&gt;0.10mg/L</th>
<th>&gt;0.05mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>0.21</td>
<td>0.52</td>
<td>1.43</td>
</tr>
<tr>
<td>Winter</td>
<td>0.14</td>
<td>0.30</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Discussion

Analysis of the Influence of Residual Chlorine on Phytoplankton

The residual chlorine in the thermal discharge of the power plant will be the main factor affecting the phytoplankton, while the thermal shock of the warm water drainage has little effect on phytoplankton. The cooling water of chloride and its emission near the water area inhibited the photosynthesis and respiration of phytoplankton, and the primary productivity decreased [1]. Residual chlorine in 0.20mg/L can kill 60%~80% entrained algae [2], but phytoplankton have a strong recovery potential for residual chlorine. Even if 20% of phytoplankton populations are killed, the net impact of the ocean can also be neglected [3]. The numerical simulation results show that the water affected area of residual chlorine is greater than 0.20mg/L, the summer is 0.21km$^2$, and the winter is 0.14km$^2$. The residual chlorine emissions will have a direct impact on the phytoplankton in this area.

Effects of Residual Chlorine on Zooplankton

The main factors for the toxic effects of residual chlorine on aquatic biotoxicity in cooling water are residual chlorine concentration and time of action, and also affected by temperature rise (delta T) and water temperature. It was found that the toxicity of *Acartia omorii Bradford* was enhanced by the increase of delta T and exposure time [4]. Simulation of power plant cooling system temperature and residual chlorine in different seasons natural temperature effects on mysids and gammarus, found that the toxicity of residual chlorine on the two kinds of aquatic organisms with natural temperature and T increased. Zhi-bing JIANG et al. found that in winter, exposure time less than 30 min, delta T is less than or equal to 12℃, residual chlorine concentration for safety class foot radial 0.31~4.55mg/L; summer exposure time less than 30 min, delta T is not higher than 8℃ when copepods chlorine safety concentration was 0.15~0.41 mg/L[5]. Huarun Caofeidian power plant project cooling water through the drainage channel length of about 7.5km to the outfall, the outfall of the residual chlorine concentration is lower than the most copepods chlorine safety concentration has little effect on residual chlorine emission engineering area of copepod zooplankton animal.

Effects of Residual Chlorine on Shellfish

Residual chlorine can cause shellfish filter feeding rate, foot activity frequency, open and closed frequency of the shell, oxygen consumption, the amount of foot silk secretion, and excretion of
excretion, etc., so as to lose the attachment ability of shellfish [6]. When the residual chlorine concentration was lower than 1mg/L, the shellfish could still open the shell for feeding, but the feeding rate decreased [7]. When the concentration is higher, the shellfish is forced to close the shell, relying on the energy stored in the body and the anoxic respiration to survive, until the energy is completely consumed or the metabolic waste reaches the toxic level [8]. According to the related research results, shellfish, clams in the residual chlorine concentration is 0.5~2.0 mg/L, the temperature 29~30℃ higher mortality [9]. The design of the outfall of the Huarun Caofeidian power plant project shows that the residual chlorine concentration is between 0.1~0.5mg/L. Therefore, the residual chlorine emission of the project will not affect the shellfish in the engineering sea area.

**Effects of Residual Chlorine on Fish**

Residual injury to the gills, the fish gill tissue lesions, such as hyperplasia, hypertrophy, bleeding, filled with mucus and gill shorter and gill epithelial tissue edema, and the epithelial cells and their tissue microcirculation (capillary) separation [10]. Chlorine may also through the fish gill tissue infiltrated into the blood, the methemoglobin reduction of hemoglobin oxidation in the blood can carry oxygen into not carry, also may inhibit the methemoglobin reductase activity, resulting in the ability of blood carrying oxygen decreased [11]. Chlorine will reduce fish oxygen consumption, increased respiratory frequency [12] operculum, fish body oxygen consumption rate with the increase of residual chlorine concentration decreased with the concentration of chlorine opercular respiratory rate increased [13]. The toxicity of residual chlorine to fish mainly depends on residual chlorine concentration and exposure time, and is also affected by temperature, salinity, pH and organic matter of [14].

The effect of temperature and residual chlorine on the avoidance response of fish to chlorine was in the range of 0.04~0.41 mg/L[15]. In this paper, the numerical simulation results show that the impact of water area in summer is greater than 0.05mg/L residual chlorine concentration was about 1.43km², the winter is about 0.83 km², the range of fish will have on the project avoidance reaction chlorine emissions.

**Conclusion**

The numerical simulation results show that the residual chlorine concentration is 0.21km² in summer and 0.14 km² in winter, and the residual chlorine emission will have a direct effect on the phytoplankton in this area.

The residual chlorine concentration of this project is lower than that of most copepods and shellfish, and the residual chlorine emission has little effect on the plankton and shellfish in the engineering sea.

Numerical simulation results show that in the two seasons of winter and summer, about 0.83 km² and 1.43 km² respectively, some fish will avoid the residual chlorine in the project.

**Reference**


