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The numerical modeling study of discharging brine into the Persian Gulf of Saudi Arabia

Haohong Weng[1], and Minghui Yu [1,*]

[1]State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan University, Wuhan 430072, China
Email: mhyu@whu.edu.cn

Abstract: The aim of this study is to scientifically select the plan for discharging concentrated brine into the sea. This study establishes a large-scale 2D numerical model of hydrodynamics-salinity(LM) for the Persian Gulf using the MIKE 21 FM model and MIKE 3 FM, nested within a small-scale 3D numerical model of hydrodynamics-salinity(SM) near the power plant. The boundary conditions for the SM tidal current calculations are provided by the results of LM.The boundary conditions for the SM tidal current calculations are provided by the results of LM. This study simulates the numerical model for the brine plume dispersion in the marine engineering section of the Saudi Ghazlan 1 expansion project. The model is calibrated and validated using measured tidal levels, currents, and salinity data, confirming that the boundary conditions are correct and computational parameters are appropriately selected. Overall, the established numerical model is demonstrated to be applicable for numerical simulation and prediction studies of brine and residual chlorine plume dispersion in the expansion project of the Saudi Arabia Ghazlan 1 combined-cycle power plant.

Based on the environmental regulation, this study proposes optimization recommendations that meet engineering optimization needs and environmental regulation. The main conclusions and recommendations are as follows:

The ambient salinity of seawater is 43 PSU. The power plant's outfalls discharge concentrated brine at a rate of 7,000 m³/h, with a concentration of 65.79 PSU. The residual chlorine concentration at the outfall is 1.5 mg/L. The preliminary design proposes a DN1200 outfall line extending 900m seaward with a flow velocity of 1.7 m/s. Its final 500m section incorporates 20 DN250 diffuser ports spaced 25m apart, angled at ±45° horizontally and ±45° vertically (directed toward the surface), discharging at 2.0 m/s. In the preliminary design scenario, whether the concentrated brine is discharged near the sea surface or near the seabed, it does not meet local environmental regulation.

Optimization considerations include: ①Changing port vertical angles from alternating (±45°) to uniform +45°; ②Evaluating 900m and 1000m outfall line lengths; ③Setting port elevations at 1.0m and 0.5m below average sea level. Comparative analysis of brine and residual chlorine plume dispersion under spring and neap tides shows compliant scenarios for either: 900m outfall line with diffuser ports at 0.5m below average sea level, or 1000m outfall line with diffuser ports at 1.0m below average sea level, both with ±45° horizontal and +45° vertical diffuser angles.

The recommended optimized scenario installs a 1.0 km outfall line with 20 DN250 diffuser ports on its terminal 500m section (25m spacing), vertically arranged 1.0m below average sea level. All diffuser ports are angled at ±45° horizontally and +45° vertically.

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