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CASE STUDY

Design of Wastewater Treatment Plant for Phenol Removal

CHALLENGE

Wastewater generated from coke oven by-product plants in the steel industry contains high concentrations of phenol, typically ranging from 600 to 3900 mg/L. Environmental regulations in India, as defined by the Central Pollution Control Board (CPCB), require phenol concentrations in discharged effluent to be reduced to 1 mg/L. Conventional treatment methods such as biological oxidation, activated sludge, adsorption, and chemical oxidation struggle to achieve such low phenol levels reliably, especially at industrial scale, while also facing issues related to high operating costs, toxic by-products, and process inefficiencies.

SOLUTION

A wastewater treatment plant was theoretically designed and simulated using the CHEMCAD® process simulator, focusing on the removal of phenol via supercritical CO_2 extraction. The process employs counter-current extraction where supercritical CO_2 selectively removes phenol from wastewater. The extracted phenol is subsequently separated and recovered through a distillation column, while CO_2 is depressurized, separated, recompressed, and recycled within the system. The PSRK (Peng–Soave–Redlich–Kwong) thermodynamic model was selected to accurately predict phase behavior under supercritical conditions. Comprehensive equipment modeling included pumps, compressors, heat exchangers, valves, extractors, separators, and a distillation column.

Wastewater Treatment*

- **Industry / Organization:** Iron and Steel Industry (Coke Oven By-product Plant
- **Project Type:** Wastewater treatment plant design and process simulation
- **Geographical Context:** India (reference to integrated steel plants regulated by CPCB)
- **Process Overview:** Treatment of phenol-rich wastewater using supercritical CO_2 extraction, simulated using CHEMCAD® process simulator

RESULTS

Simulation results demonstrated that nearly all phenol present in the wastewater feed stream was removed. Approximately 7.8 kmol/h of phenol entering the system was recovered, with treated water containing almost zero phenol concentration. The effluent quality met and exceeded CPCB discharge standards. The simulation also successfully converged material and energy balances, validated phase envelopes, and provided detailed sizing data for critical equipment such as the distillation column.

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TANGIBLE BENEFITS

- Reduction of phenol concentration in treated wastewater to below 1 mg/L, ensuring regulatory compliance.
- Recovery of high-purity phenol as a valuable by-product.
- High CO_2 recovery and recycling, minimizing operating costs and environmental footprint.
- Reduced reliance on biological treatment systems and associated operational limitations.
- Availability of detailed equipment sizing and operating parameters to support plant fabrication and scale-up.

FIGURE 1 - Flow diagram of the phenol wastewater treatment plant with supercritical CO_2 simulated by CHEMCAD.

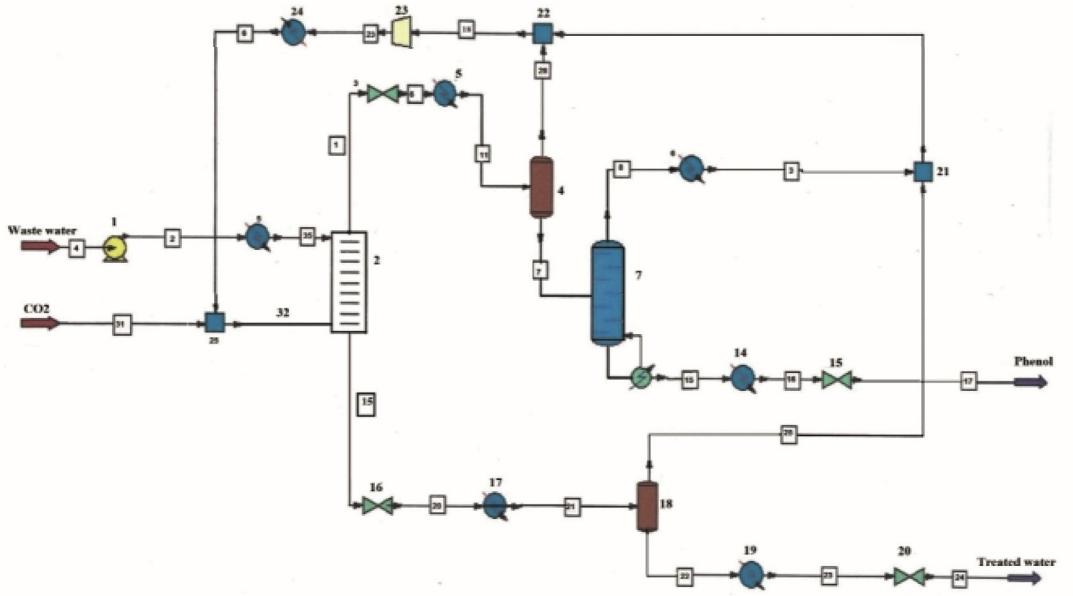

FIGURE 2 - Phase envelope for phenol removal stream (#17) (top), Phase envelope for treated water stream (#24) (bottom)