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Simulation of Chlorinated Water Discharges from Power Plants on Estuaries and Rivers

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The fast-transient (tidal-transient), one-dimensional, discrete-element chemical transport model[1] and its associated computer code CHMONE[2] was applied to study the effects of chlorinated water discharges from power plants on tidal estuaries and controlled rivers. The mathematical model, which was developed as a part of the "Unified Transport Approach" (UTA) research project[3], has the capability to simultaneously predict the hydrodynamic, thermal and chemical composition of water as one-dimensional time-dependent distributions.

The chemical kinetics model[4] for the power plant chlorination process was formulated on the basis of three non-equilibrium chemical reactions with forward and reverse reaction rates that produce the inorganic chloramines NHCl and NH_2Cl and a composite representation of the organic amines such as RNH_2. A modular computer code CHLORN[4] was developed to simulate the chemical concentrations in the discharge water of the power plant cooling systems based on the plant operating conditions, the temperature, pH, and composition of the intake water and the schedule of chlorination cycles.

A typical computer simulation of the varying chloramine concentrations in the discharge water from a cooling tower blowdown is presented in Fig. 1 for six 8-hr chlorination cycles, starting from nonchlorinated initial conditions in the system. Results indicate that the concentrations in the discharge water attain quasi-steady-state conditions after about 40 hr of plant operation, and they vary between constant upper and lower bounds during the periodic chlorination cycles.

The slow chemical reactions associated with the hydrolysis of chloramines in the receiving water body were modelled by the general chemical kinetics model and its associated modular computer code CHMKIN[5]. The computer code CHMKIN was also employed in the parametric study of the complex chemical reactions associated with the chlorination of saline water in order to determine the effects of the changes in magnitudes of the forward and reverse reaction rate constants.

The results of a preliminary application of the transient one-dimensional application of the transient one-dimensional transport model CHMONE[1,2] are shown in Fig. 2 for the simulation of the hypothetical chlorination conditions from a power plant on the Hudson River under the assumption that the freshwater flow is high enough to limit the salinity intrusion zone downstream of the power plant. The results based on the chemical kinetics model for the chlorination of freshwater illustrate the capability of the model to simulate the periodic upstream and downstream movement of the high chloramine concentration peaks with the tidal flow conditions during the specified 8-hr chlorination cycle of the power plant.

The preliminary results indicate that NH_2Cl concentrations could gradually increase with the successive chlorination cycles in an estuary due to periodically reversing tidal flow conditions. The results also suggest the possibility that proper selection of the chlorination times relative to the tidal cycles could reduce the level and extent of the chloramine concentrations in an estuary.

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1. A. H. ERASLAN et al., "A Tidal-Transient, One-Dimensional, Discrete-Element Transport Model for Simulating Hydrodynamic, Thermal and Chemical Composition Conditions in Controlled Rivers and Estuaries for Predicting the Effect of Chlorination of Power Plant Discharges", ORNL/NUREG- (1977).

2. S. K. FISCHER et al., "CHMØNE: A Computer Code for Simulating Tidal-Transient, One-Dimensional Hydrodynamic, Thermal and Chemical Composition Conditions in Controlled Rivers and Estuaries for Predicting the Effect of Chlorination of Power Plant Discharges", ORNL/NUREG/TM- (1977).

3. A. H. ERASLAN et al., "Development of a Unified Transport Approach for the Assessment of Power Plant Impact", ORNL/NUREG/TM-89 (1977).

4. M. H. LIETZKE, "A Kinetic Model for Predicting the Composition of Chlorinated Water Discharged from Power Plant Cooling Systems", ORNL/NUREG-13 (1977).

5. A. H. ERASLAN et al., "CHMKIN: A General Chemical Kinetics Computer Code", ORNL/NUREG- (1977).

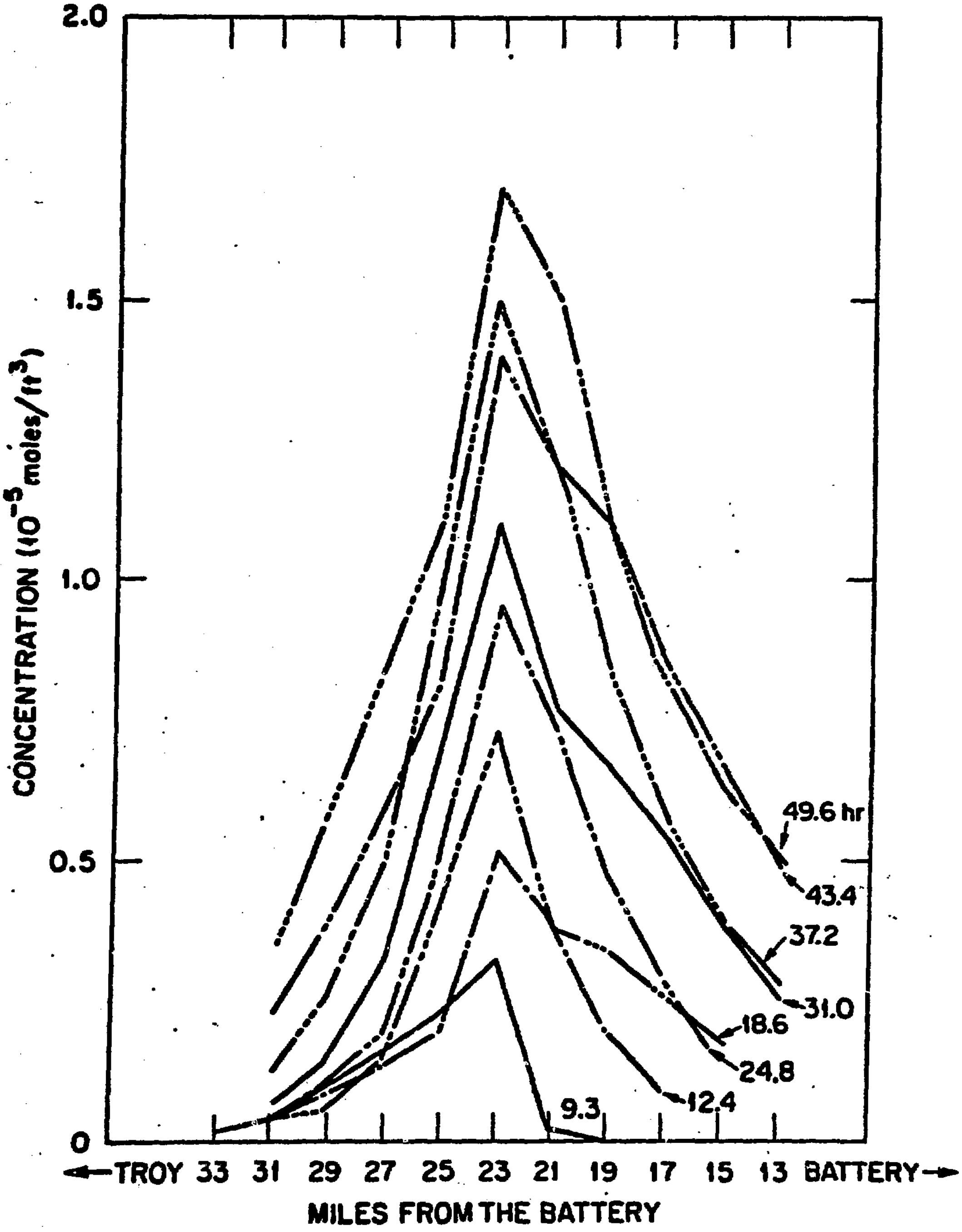

Fig. 2. Computer simulation of NH_2Cl concentration distributions from a hypothetical power plant discharge in the Hudson River (freshwater zone) during successive chlorination cycles.

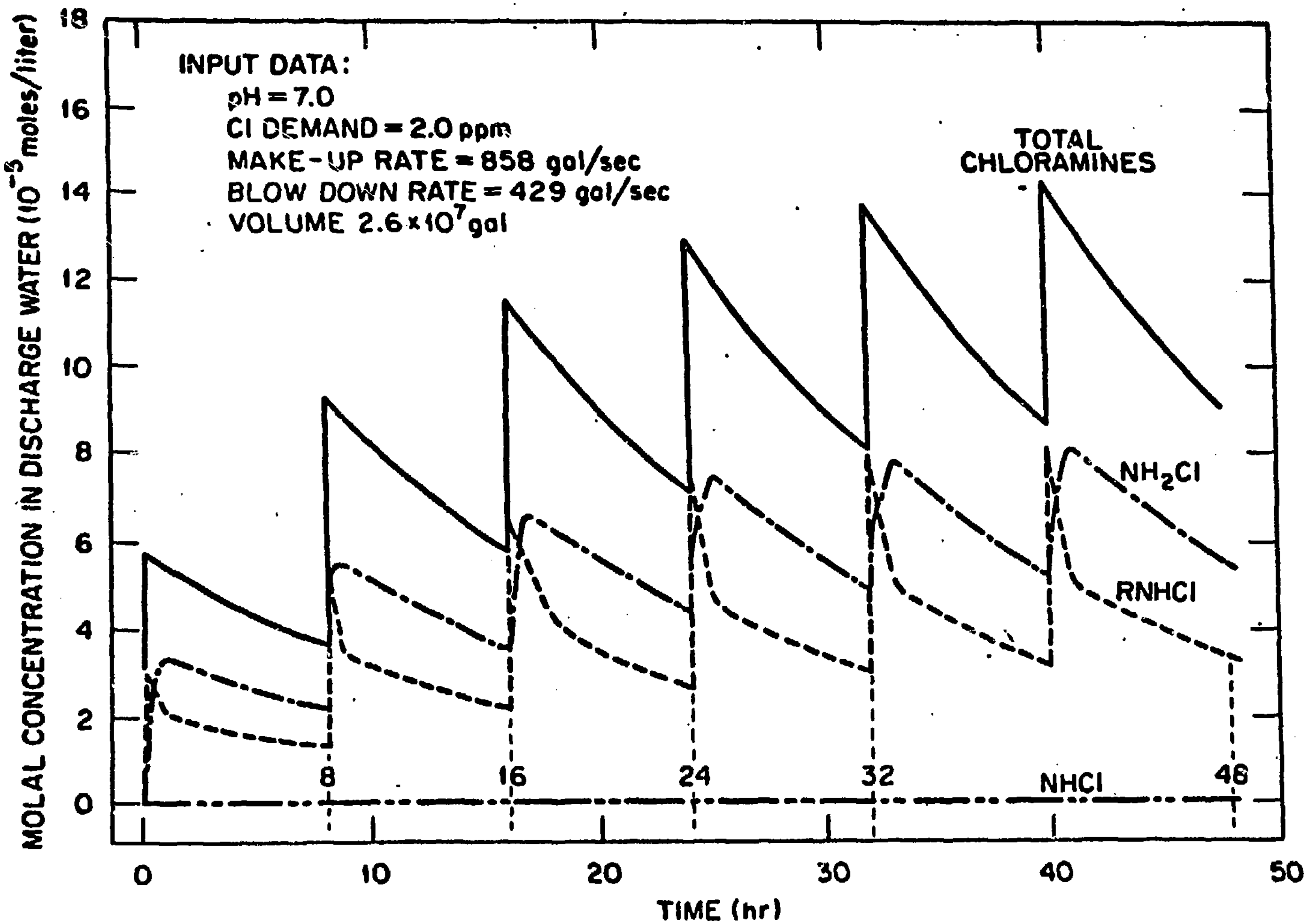

Fig. 5. Computer simulation of chloramine concentrations in discharge water from a cooling tower for six 8-hr chlorination cycles.