

## Abstract

The prime objective of any drinking water distribution system (DWDS) is to make water available to all consumers in proper quantity, pressure and with acceptable quality in terms of flavour, odour, and appearance. The water should be free from microbial contamination to safeguard the community against waterborne diseases like cholera, dysentery, typhoid fever, hepatitis-A etc. But unfortunately in many developing countries like India, safe drinking water is not available for human consumption and poor water quality is one of the causes of increasing health problems. In India, to control the pathogenic microorganisms in drinking water distribution systems generally high disinfectant dose is added at the supply source to compensate the disinfectant losses. Disinfectants, such as chlorine produces potential carcinogens like DBP at higher concentrations. Therefore it is very essential for any water supply authority to manage the chlorine disinfection within lower and upper limit of residual chlorine to safeguard the consumers from water borne diseases and harmful disinfection by products (DBPs) simultaneously. Hence to simulate and evolve the strategies for the effective management of chlorine disinfection within DWDS is very necessary. Looking to the need of such studies the water distribution system model such as EPANET is coupled with optimization techniques for effective management of chlorine which reduces the overall mass rate of chlorine and reduction in cost of chlorine application.

The prime objective of the present study is to develop the decision support models (DSM) by developing the coupled simulation-optimization model for managing chlorine disinfection in DWDS. The specific objectives and scope of study with water quality concerns of drinking water distribution system of the research study are to develop the hydraulic and water quality models for a branch and actual field network of DWDS. These models coupled with the optimization techniques are used to analyse the hydraulic and water quality parameter (residual chlorine) and to evolve the methodologies to determine the optimal scheduling and location of booster chlorination stations. The another objective of the study is to develop the impact matrix for the rapid conclusions regarding impact of addition of chlorine on concentration of residual chlorine at various locations in DWDS and to carry out the cost analysis to check the economic feasibility of installation of booster chlorination stations.

To achieve the objectives the hydraulic and water quality models are developed for the branch network and actual field networks using using EPANET simulation model. Initially explicit equations are developed in terms of flow and chlorine mass rate for quick computation of the residual chlorine concentration at various nodes to understand the principles of hydraulic & water quality model and also to check the effect of booster chlorination on residual chlorine concentration for the branch network. For the large field network it is difficult to use the manual calculation using such equations, therefore EPANET simulation model is selected for the hydraulic and water quality modeling purpose. EPANET is applied to to develop the hydraulic and water quality models for the branch network initially and later for actual networks of Vadodara city such as Subhanpura, North Harni, Manjalpur and Channi to understand the effect of mode of water supply, chlorine application strategy ( source and booster chlorination), effect of travelling time on chlorine concentration. EPANET simulation model is used to develop impulse response coefficients and simulation model based on impulse response coefficient is coupled with optimization model. Linear Programming (LP) and Particle Swarm Optimization (PSO) techniques are used for optimization model. Manjalpur and North Harni DWDS are selected as the base network for the application of coupled simulation optimization models for the optimum scheduling of mass rate of chlorine and later used to decide the optimal location and number of booster stations. Further the impact matrix is developed using impulse response coefficients for rapid conclusions of

impact of addition of chlorine on concentration of residual chlorine at various locations in DWDS for booster chlorination.

The results of the simulation studies suggest that booster chlorination provides effective chlorine management strategy by supplying uniform distribution of chlorine, minimizing cost and at the same time prevents the problems due to excess chlorination such as DBP. However, for the small distribution network, the travelling time of chlorine is normally less than supply hours and in such cases booster chlorination is not much cost effective. The simulation optimization model also helps to find the critical locations for sample collection and sensor placement for the monitoring of chlorine in the drinking water distribution systems. The results of both coupled simulation optimization model using LP and PSO give similar results which suggest the overall reduction in chlorine mass rate (29-34% ) and uniform distribution of chlorine at all the locations within the DWDS. The cost analysis of booster stations shows that the chlorine solution cost is the major cost in operating the booster stations and the objective function selected to minimize the mass rate of chlorine is justified to provide the economical solution for the installation of booster stations. Thus, the present study provides various decision support models which can be effectively used for the overall management of chlorine disinfection for any DWDS and can safeguard the consumers against microbial contamination and DBP formation.

**Key words:** Drinking water distribution system (DWDS), EPANET, Simulation model, Conventional chlorination, Booster chlorination, Linear programming(LP), Particle swarm optimization (PSO), Coupled simulation-optimization model, Optimal scheduling, Optimum location, Impact matrix.