

## List of Figures

<b>Figure</b>	<b>Title</b>	<b>Page</b>
2.1	Drinking water distribution system network (Walski et al. 2003; USEPA 2005).	13
2.2	Distribution System interactions affecting water quality (USEPA 2005)	32
2.3	Local and global optimizers	59
3.1	Simple link-node representation of a water distribution system (Source: Rossman, 2000).	79
3.2	Sample network for calculation of hydraulic parameters at each node (Example 1).	80
3.3	Modelled sample network using EPANET simulation Model.	84
3.4	Sample network for calculation of chlorine concentration at each node	85
3.5	Computation of residual chlorine concentration at each node for Case II (Example network)	95
3.6	Residual chlorine concentration at Node 4 for Case I	96
3.7	Residual chlorine concentration at Node 4 for Case II.	96
3.8	Residual chlorine concentration at Node 5 for Case I.	96
3.9	Residual chlorine concentration at Node 5 for Case II	96
4.1	Distribution network used for Study ( Example Problem)	104
4.2 (a)	Minimum, average and maximum concentration of residual chlorine for case I, scenario I( Example Problem)	106
4.2 (b)	Minimum, average and maximum concentration of residual chlorine for case I scenario II( Example Problem)	106
4.3(a)	Minimum, average and maximum concentration of residual chlorine for case II, scenario I( Example Problem)	107
4.3(b)	Minimum, average and maximum concentration of residual chlorine for case II, scenario II( Example Problem)	107
4.4	Sample Network of the Cherry Hill-Brushy Plains. ( Case Study 1; Source: Clark et al. 1994)	110
4.5	Network Hydraulic Behaviour of Cases I & II ( Case Study 1)	112
4.6	Tank concentration of residual chlorine ( case I and II) for Case Study 1	112
4.7(a)	Average residual chlorine concentration and standard deviation for all nodes (case I) for Case Study 1	113

4.7(b)	Average residual chlorine concentration and standard deviation for all nodes ( case II) for Case Study 1	113
4.8	Study Area of Vadodara City DWDS	115
4.9	Drinking water distribution networks of Vadodara city selected for study.	120
4.10	Subhanpura Distribution Water Distribution System Network (Case Study 2)	122
4.11(a)	Determination of bulk chlorine decay coefficient for sample 1 (Case Study 2)	123
4.11(b)	Determination of bulk chlorine decay coefficient for sample 2 (Case Study 2)	123
4.11(c)	Determination of bulk chlorine decay coefficient for sample 3 (Case Study 2)	123
4.12	Water head in tank ( EPS of ten days for last 24 hours).for Case Study 2	124
4.13	System flow balance ( EPS of ten days for last 24 hours) for Case Study 2	125
4.14	Tank concentration of residual chlorine ( EPS of ten days for last 24 hours) for Case Study 2	125
4.15	Minimum, average and maximum concentration of residual chlorine for all nodes (EPS of ten days for last 24 hours) for Case Study 2	126
4.16	Variation in demand for 24 X 7 continuous water supply ( Case Study 3)	129
4.17	Demand for Intermittent water supply of 4 hours in a day ( Case Study 3)	130
4.18	Channi Drinking Water Distribution Network ( Case Study 3)	130
4.19	Water Head in tank for scenario 1 and 2 ( Case Study 3)	131
4.20	System flow balance of scenario 1 for 24 X 7 water supply ( Case Study 3)	132
4.21	System flow balance of scenario 2 for intermittent water supply of 4 hours ( Case Study 3)	132
4.22(a)	Contour plot of pressure peak hour of 8 a.m. to 9 a.m. for scenario 1 ( Case Study 3)	133

4.22(b)	Contour plot of pressure peak hour of 8 a.m. to 9 a.m. for scenario 2 ( Case Study 3)	133
4.23	Tank concentration of residual chlorine (Scenario 1 and 2) for Case Study 3	134
4.24	Minimum, average and maximum concentration of residual chlorine (Scenario I) for Case Study 3.	134
4.25	Minimum, average and maximum concentration of residual chlorine (Scenario II) for Case Study 3.	135
4.26	Minimum residual chlorine concentration for selected nodes (6 a.m. to 7 a.m. for scenario 1 and 2) for Case Study 3.	135
4.27	North Harni Distribution Network (Case Study 4)	139
4.28	Tank concentration of residual chlorine ( case I and II) for Case Study 4	140
4.29	Minimum, average and maximum concentration of residual chlorine (Case I) for Case Study 4	142
4.30	Minimum, average and maximum concentration of residual chlorine (Case II) Case Study 4	142
4.31	Average residual chlorine concentration and standard deviation for all nodes ( Case I) for Case Study 4	143
4.32	Average residual chlorine concentration and standard deviation for all nodes ( Case II) for Case Study 4	143
4.33	Variation of residual chlorine concentration at each node ( case I and case II) for Case Study 4	144
4.34	Manjalpur Distribution Network (Case Study 5)	146
4.35	Tank concentration of residual chlorine (Case I and Case II) for Case Study 5	148
4.36	Minimum, average and maximum concentration of residual chlorine (Case I) ) for Case Study 5	149
4.37	Minimum, average and maximum concentration of residual chlorine (Case II) ) for Case Study 5	149
4.38	Contour Plot of Residual Chlorine (Case I) ) for Case Study 5	150
4.39	Contour Plot of Residual Chlorine (Case II) ) for Case Study 5	150
5.1	Steps in the development of simulation-optimization model for water quality management in DWDS	154

5.2	Manjalpur and North Harni Drinking Water Distribution System Network, Vadodara, Gujarat, India.	160
5.3	Manjalpur DWDS network	162
5.4	Tank concentration for residual chlorine (Case I and Case II) for Case Study 6	168
5.5	Minimum, average and maximum concentration of residual chlorine for all nodes.(Case I) for Case Study 6	169
5.6	Minimum, average and maximum concentration of residual chlorine for all nodes. (Case II) for Case Study 6	169
5.7	Average concentration and standard deviation for all nodes. (Case I) for Case Study 6	170
5.8	Average concentration and standard deviation for all nodes. (Case II) for Case Study 6	170
5.9	Percentage variation in total chlorine mass rate for % variation in bulk decay coefficient (Case Study 6).	171
5.10	Tank concentration for residual chlorine (Case I and Case II) for Case Study 7	175
5.11	Minimum, average and maximum concentration of residual chlorine for all nodes.(Case I) for Case Study 7	176
5.12	Minimum, average and maximum concentration of residual chlorine for all nodes. (Case I) for Case Study 7	176
5.13	Average residual chlorine concentration and standard deviation for all nodes. (Case I) for Case Study 7	177
5.14	Average residual chlorine concentration and standard deviation for all nodes. (Case II) for Case Study 7	177
5.15	North Harni DWDS network	180
5.16	Tank concentration for residual chlorine (Case I , Case II and Case III) for Case Study 8	184
5.17	Minimum, average and maximum concentration of residual chlorine for all nodes ( Case I) for Case Study 8	185
5.18	Minimum, average and maximum concentration of residual chlorine for all nodes (Case II) for Case Study 8	185
5.19	Average residual chlorine concentration and standard deviation for all nodes. (Case I) for Case Study 8	185

5.20	Average residual chlorine concentration and standard deviation for all nodes. (Case II) for Case Study 8	186
5.21	Contour Plot of residual chlorine for Conventional Chlorination ( Case I) for Case Study 8	187
5.22	Contour Plot of residual chlorine for Conventional Chlorination ( Case II) for Case Study 8	187
5.23	Contour Plot of residual chlorine for Conventional Chlorination ( Case III) for Case Study 8	188
5.24	North Harni Distribution network (Deficit flow conditions)	194
5.25	Tank concentration of residual chlorine (Case I and Case II) for Case Study 10	198
5.26	Minimum, average and maximum concentration of residual chlorine for all nodes (Case I) for Case Study 10	199
5.27	Minimum, average and maximum concentration of residual chlorine for all nodes (Case II) for Case Study 10	199
5.28	Average residual chlorine concentration and standard deviation for all nodes (Case I) for Case Study 10	200
5.29	Average residual chlorine concentration and standard deviation for all nodes (Case II) for Case Study 10	200
5.30	Variation of residual chlorine concentration at each node after 240 hours for EPS for Case Study 10	200
5.31	Concept of modification of a searching point by PSO	206
5.32	Flow Chart for PSO Model	209
5.33	Simulation Model for coupling with optimization Model.	213
5.34	Coupled Simulation-Optimization Model installed in MATLAB	213
5.35	Variation in fitness function after each iteration for two decision variables ( Case Study 11)	215
5.36	Variation in fitness function after each iteration for three decision variables ( Case Study 11)	215
5.37	Particle's position for two decision variables after different iteration (Case Study 11).	217
5.38	Variation in fitness functions at different Iteration (Case Study 13: NH-1H-PSO-OL)	224
5.39	Decision Support Model (DSM) for management of chlorine disinfection in DWDS	241