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EVALUATION OF VARIATIONS IN QUALITY OF WATER IN DISTRIBUTION NETWORKS USING EPANET

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ABSTRACT

Water quality satisfaction is one of the major problems faced in drinking water distribution system. In most of the developing countries, chlorination is a common practice for disinfection, as it is required for protection against future contamination in water distribution networks (WDN). But unwanted disinfectant by-products, tastes and odours are formed due to higher levels of free residual chlorine (FRC). An index named as uniform chlorine coefficient (UCC) is introduced to express the equity of FRC in distribution of water among the nodes in WDN. It may be useful to evaluate the quality of water in WDN. Water distribution system modelling software package EPANET is used to compute UCC. Simulation studies were conducted by varying location of tank and applied chlorine to WDN.

Key words: Free residual chlorine, Uniform chlorine coefficient, AFRC, ADIG.

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1. INTRODUCTION

Water is extremely important to life and sufficient quantity of clean and safe drinking water is required for maintenance of life. Water should be free from impurities and bacteria. So it is necessary to supply adequate quantity of superior quality of water in present society. Natural water must be purified before supplying to the consumer level. Disinfection process is the most important in treatment of water because it plays an important role in killing pathogenic bacteria from filtered water in water treatment plant. Chlorine is most commonly used disinfectant for water disinfection as it is cheap, easy to handle and capable of providing residual disinfecting effects for long periods. Chlorine can react with variety of materials both within bulk water and from the pipe wall, when chlorine travels through the pipes in distribution network[1].It can protect against future contamination of water in distribution system. But it's disadvantage is that when used in greater amounts it imparts bitter and bad taste to water, sensitive- tongued consumers may not like such water. FRC is an indicator of good water quality. According to World Health Organisation (WHO2004) recommended permissible limit for free residual chlorine (FRC) is 0.2-0.5mg/l[2]. According to USEPA (2005) stages 1 and 2 DBP rules, permissible limit for FRC is 0.2- 4mg/l[3][4]. Excessive chlorine dosages lead to the development of carcinogenic disinfection by-products like trihalomethanes. [5][6][7].

Many studies report research on maintaining chlorine residuals within limit and uniform throughout the system [8]. Balancing between high disinfectant concentrations near the source and loss of pathogenic bacteria control at the outer limits of network is necessary. In distribution system FRC can vary at different junctions time to time depending on flow track and average time of water reaching a particular point [1]. Applying high chlorine dose at the source is not enough to maintain uniform chlorine concentration throughout the system especially in case of large networks [9]. By reducing residence time of water in distribution system, FRC can be improved. Water from the treatment plant may contain different compounds which can react with chlorine. These might have different mechanism, some of them are much more rapidly react than other. It is not possible to model all of these reactions separately. To describe chlorine decay, there are so many kinetic models, these are first order kinetic model, complex models like second order model, power law expressions, parallel first order models [10]. Frist order decay model is simple, represents chlorine decay in water in acceptable way. First order decay model for chlorine is

$$C_t = C_0 e^{-kt}$$

Where C_t = chlorine concentration at any time t (mg/l), C_0 = initial chlorine concentration(mg/l), t = time in days, k = decay constant, it is function of bulk decay rate constant, wall decay rate constant, flow velocity, pipe radius, kinematic viscosity of water and chlorine's molecular diffusivity[11]. The above rate expression is used in a dynamic water quality model, EPANET. It can track the residuals of chlorine in every part of any complex water distribution network. First order kinetics was used in most of studies on chlorine network modelling [12]. In many optimization studies wall decay coefficient is neglected [4][13][14]. In this study, only bulk decay coefficient is considered, wall decay coefficient is negligible and neglected.

2. PROPOSED APPROACH

The main objective of this paper is to study equity of FRC at all nodes at all times in water distribution network. In this study, water quality simulation is done using water distribution system modelling software package, EPANET, a public domain developed by the United States Environmental Protection Agency (EPA) water supply and water resources division. This package can perform extended period simulation of hydraulic and water quality behaviour within pressurized pipe networks. In this study simulated values of FRC are converted into an uniform coefficient, named as uniform chlorine coefficient (UCC). It is defined to express the equity of FRC in distribution of water among the nodes.

Average of free residual chlorine at all nodes at all times of WDN is calculated and it is named as AFRC. Average divergence of FRC at all nodes at all times of WDN from the range of 0.2-0.5mg/l is calculated and it is named as ADIG. UCC is defined as

$$\text{UCC}= 1 - \frac{ADIG}{AFRC}$$

If FRC is exactly in the range of 0.2-0.5mg/l at all nodes in WDN, then ADIG will be zero and UCC also would be one. If UCC value is less than one, it indicates FRC among the nodes is not uniform and not within the range of 0.2-0.5mg/l.

3. RESULTS AND DISCUSSIONS

In the present study, first a two looped network (network 1) is taken which is an example network. For this network, AFRC, ADIG values are calculated in Microsoft Excel for a period of 24hours by taking FRC values from extended period simulation in EPANET software. Studies are conducted to find UCC values by taking applied chlorine as 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8, 2.0 mg/l. To study the effect of location of tank on UCC, for network 1 tank is connected to node 4. Node and link data for network 1 is given in table 1.

Table 1 Node and link parameters for network 1

Node	Demand (m^3/h)	Link	Length (m)
2	30	1	1000
3	30	2	1000
4	30	3	1000
5	30	4	1000
6	30	5	1000
7	30	6	1000
		7	1000
		8	1000

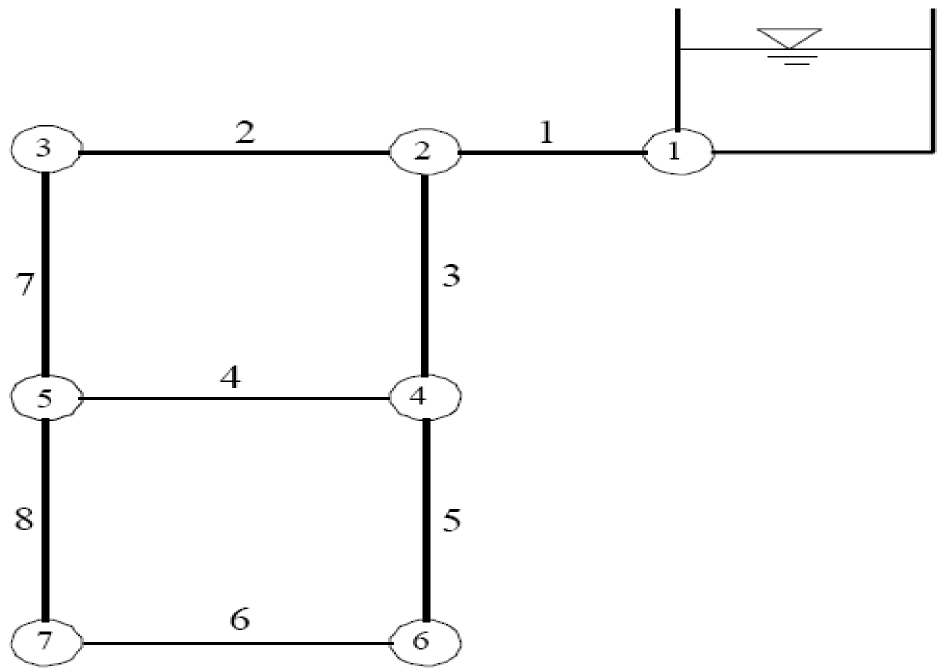

Figure 1 Layout of network 1

For network 1(Fig 1), as the applied chlorine increases UCC decreases as shown in Fig. 2,3. There is significant effect on changing the location of tank i.e. when connecting tank to new location, UCC values have slight increase as shown in Fig. 3 when compared to Fig 2. It has significant effect on UCC. As the applied chlorine increases ADIG increases in both cases as shown in Fig 2, 3.

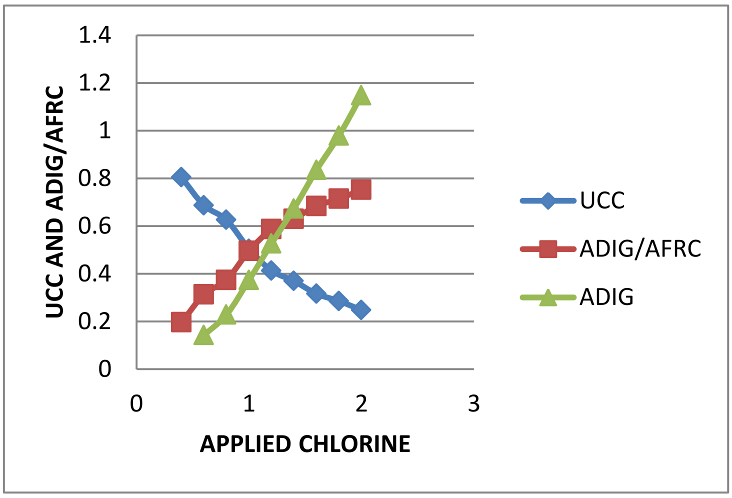

Figure 2 Variations in UCC and ADIG/AFRC with applied chlorine for network 1

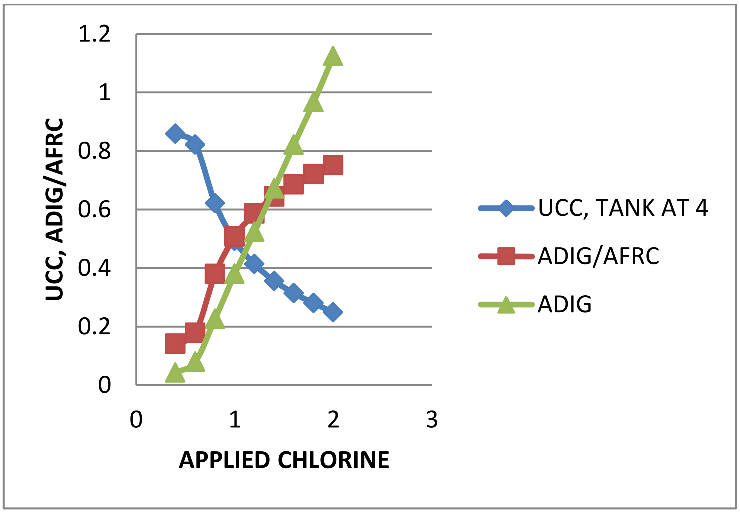

Figure 3 Variations in UCC and ADIG/AFRC with applied chlorine for network 1, tank at node 4

Similar studies are conducted on Hanoi network (network 2). Hanoi network is one of the standard networks to test optimisation by many researchers[15]. For this network, AFRC, ADIG values are calculated in Microsoft Excel for a period of 24hours by taking FRC values from extended period simulation in EPANET software. Studies are conducted to find UCC values by taking applied chlorine as 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8, 2.0 mg/l. To study the effect of location of tank on UCC, for network 2 tank is connected to node 18. Node and link data for network 2 is given in table 2.

Table 2 Node and link parameters for network 2

Node	**Demand (m^3/h)**	**Node**	**Demand (m^3/h)**	**Node**	**Demand (m^3/h)**	**Node**	**Demand (m^3/h)**		
2	890	10	525	18	1345	26	900		
3	850	11	500	19	60	27	370		
4	130	12	560	20	1275	28	290		
5	725	13	940	21	930	29	360		
6	1005	14	615	22	485	30	360		
7	1350	15	280	23	1045	31	105		
8	550	16	310	24	820	32	805		
9	525	17	865	25	170				
Link	**Length (m)**	**Link**	**Length (m)**	**Link**	**Length (m)**	**Link**	**Length (m)**	**Link**	**Length (m)**
1	100	8	850	15	550	22	500	29	1500
2	1350	9	800	16	2730	23	2650	30	2000
3	900	10	950	17	1750	24	1230	31	1600
4	1150	11	1200	18	800	25	1300	32	150
5	1450	12	3500	19	400	26	850	33	860
6	450	13	800	20	2200	27	300	34	950
7	850	14	500	21	1500	28	750		

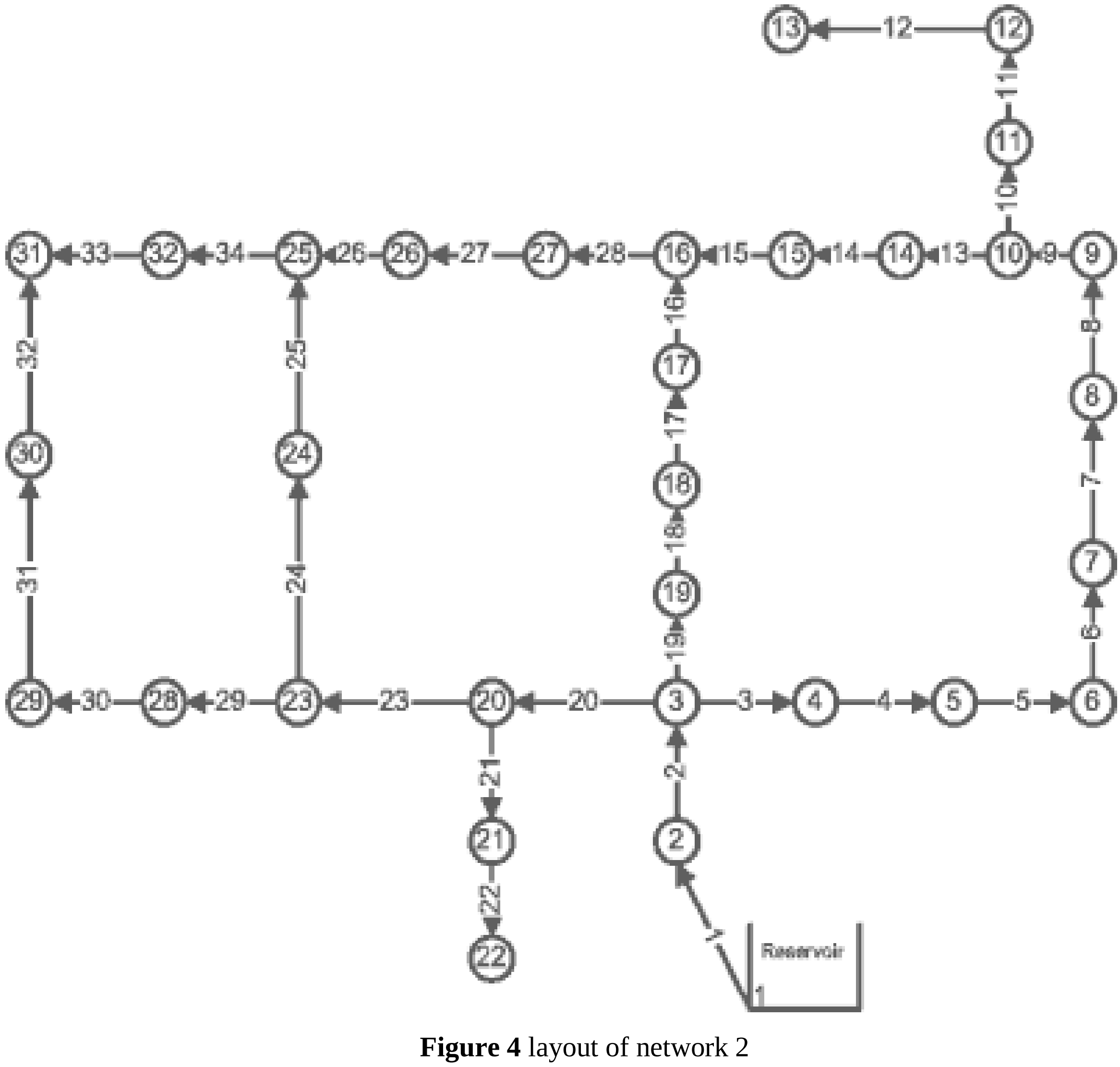

Figure 4 layout of network 2

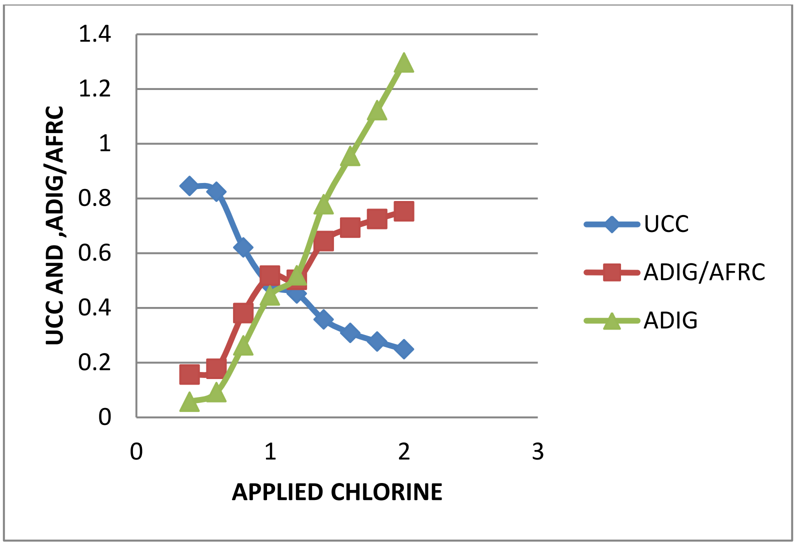

Figure 5 Variations in UCC and ADIG/AFRC with applied chlorine for network 2

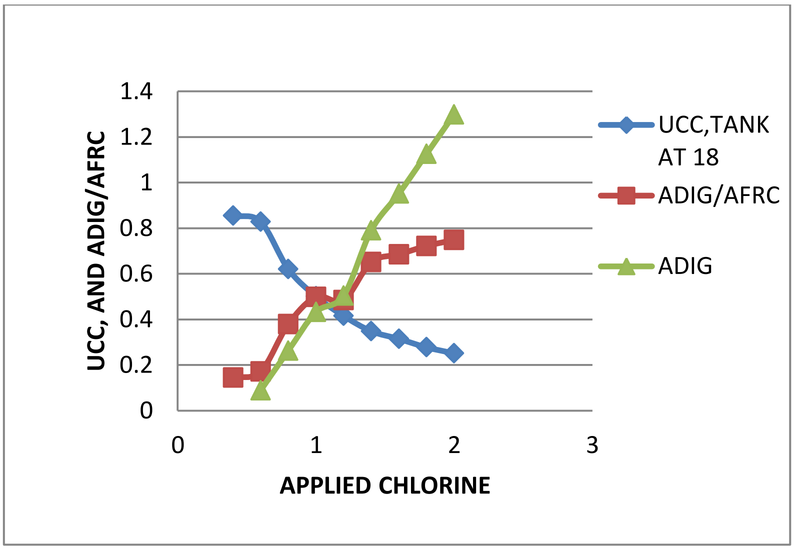

Figure 6 Variations in UCC and ADIG/AFRC with applied chlorine for network 2, tank at 18

For network 2(Fig 4) as the applied chlorine increases UCC decreases as shown in Fig. 5,6. There is significant effect on changing the location of tank i.e. when connecting tank to new location, UCC values have slight increase as shown in Fig. 6 when compared to Fig 5. It has significant effect on UCC. As the applied chlorine increases ADIG increases in both cases as shown in Fig 5, 6.

4. CONCLUSIONS

- For measuring the equity of FRC in distribution of water among the nodes, a coefficient is defined, named as UCC.
- As the applied chlorine increases, ratio of ADIG and AFRC increases.
- As the applied chlorine increases, ADIG decreases.
- When applied chlorine is 0.4mg/l, UCC value has improved.
- Tank location within the network affects the UCC.
- By using UCC as design criteria, a methodology for optimal design of WDN using genetic algorithms can be continuation of this study.

REFERENCES

[1] Lewis A.Rossman, Robert M. Clark, Walter M. Grayman "Modelling Chlorine Residuals in Drinking-Water Distribution Systems", Journal of Environ. Eng. ASCE, Vol.120, No.4, 1994, pp. 803-820.

[2] WHO (World Health Organization) (2004). Guidelines for drinking-water quality, Geneva.

[3] USEPA (U.S. Environmental Protection Agency) (2005) "Economic analysis for the final stage 2 disinfectants and disinfection byproducts rule." 815-R-05-010, Washington, DC.

[4] Nilufar Islam, Rehan Sadiq, Manuel J. Rodriguez "Optimizing Locations for Chlorine Booster Stations in Small Water Distribution Networks" J. Water Resour. Plann. Manage ASCE, Vol.143, No7, 2017, pp. 04017021-1-15.

[5] G. R. Munnavali, M.S. Mohan Kumar "Optimal Scheduling of Multiple Chlorine Sources in Water Distribution Systems" J. Water Resour. Plann. Manage. ASCE, Vol.129, No.6, 2003, pp. 493-504.

[6] A. S. Al-Omari, M. Hanif Chaudary "Unsteady-state Inverse Chlorine Modelling in pipe networks" J. Hydraulic Engineering ASCE, Vol.127, No.8, 2001, pp. 669-677.

[7] M. Rashidul Islam, M. Hanif Chaudary, Robert M. Clark "Inverse Modelling of Chlorine Concentration in Pipe Networks Under Dynamic Condition" J. Environ. Eng. ASCE, Vol.123, No.10, 1997, pp. 1033-1040

[8] Tryby, M.E., Boccelli, D. L. Koechling, M. T., Uber, J. G., Summers, R. S., Rossman, L. A. "Booster Chlorination for managing disinfectant residuals" J. Am. Water Works Assoc., 1999, 91(1), pp. 95-108.

[9] Celia D. D'Souza, M.S. Mohan Kumar " Integrated Approach in the Quantitative and Qualitative Control of Water Distribution Systems through Control Systems" J. Hazard. Toxic Radioact. Waste ASCE, Vol.16, No.2, 2012, pp. 142-157.

[10] Brain Carrico, Philip C. Singer "Impact of Booster Chlorination on Chlorine Decay and THM Production: Simulated Analysis" J. Environ. Eng. ASCE, Vol.135, No.10, 2009, pp. 928-935.

[11] Robert M. Clark, Lewis A. Rossman, Larry J. Wymer "Modelling Distribution System Water Quality: Regulatory Implications" J. Water Resour. Plann. Manage. ASCE, Vol.121, No.6, 1995, pp. 423-428.

[12] James C. Powell, John R. West, Nicholas B. Hallam, Christopher F. Forster, John Simms "Performance of Various Kinetic Models for Chlorine Decay" J. Water Resour. Plann. Manage. ASCE, Vol.126, No.1, 2000, pp. 13-20.

[13] Boccelli, D.L., Tryby, M.E., Uber, J.G., Rossman, L. A., Zierolf, M. L., Polycarpou, M. M. "Optimal scheduling of booster disinfection in water distribution systems" J. Water Resour. Plann. Manage. ASCE, Vol.124, No.2, 1998, pp. 91-111.

[14] Propato, M., Uber, J. G, "Linear least-squares formulation for operation of booster disinfection systems" J. Water Resour. Plann. Manage. ASCE, Vol.130, No.5, 2004, pp. 367-376.

[15] Muzaffar M. Eusuff, Kevin E. Lansey "Optimization of Water Distribution Network Design Using the Shuffled Frog Leaping Algorithm" J. Water Resour. Plann. Manage. ASCE, Vol.129, No.3, 2003, pp. 210-225.

[16] Raman deep Singh Bali and Puneet Sharma, Quality o f Water in Chandigarh (Panchkula And Mohali Region). International Journal of Civil Engineering and Technology, 7(4), 2016, pp.539–541.