EPANET 모형에서 효율적인 염소분해계수의 적용

Effective Application of Chlorine Decay Coefficient for EPANET

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요　　지

유역에서의 하천 프랙탈은 본 연구의 목적은 상수도 배수시스템의 수질예측 모형인 EPANET의 수질보정을 위한 염소분해계수의 효율적인 적용을 평가하기 위한 것이다. 이를 위해 우선적으로 연구대상시스템의 특성에 따른 수질 및 관종별 염소분해계수를 실험에 의하여 분석하고, 대상블록에 대한 EPANET 모형의 수질보정을 위한 잔류염소분해계수의 3가지 적용방법을 검토하여 효율적인 적용방안을 도출하였다. 연구결과, 실험에 의한 염소분해계수는 계절적 특성과 관종 및 관경에 따른 다양한 결과를 보였으며, 각 방법에 따른 모의결과도 다양하게 나타났으며, 관종, 관경, 계절적 특성을 반영한 분해계수를 적용한 모의 결과가 현장분석된 잔류염소농도와 더 가깝게 예측되는 것으로 나타났다. 따라서 EPANET을 이용하여 잔류염소농도를 예측하기 위해서는 대상수질 및 관망의 특성을 반영한 잔류염소분해계수를 사용하는 방법이 가장 효율적일 것으로 사료된다.

핵심용어 : 배수시스템, EPANET, 염소분해계수

1. Introduction

Residual chlorine management of water distribution system related to biologic safety security and disinfection by-product control, and quality of water change for the deterioration by residual chlorine decrease is very important problem. Therefore, waterworks administrators are trying to set equal concentration, minimum pouring in concentration for supply of efficient chlorine concentration to prevent such secondary problem. But, characteristics of residual chlorine decay is various according to site-specific field condition in WDS. Specially, residual chlorine is difficult to forecast concentration change because of various characteristics of residual chlorine reaction, site-specific WDS, andhydro-dynamic condition of flowing, etc. Therefore, it is very difficult real condition to decide most optimal management concentration.

The most general form in estimate of residual chlorine in WDS is applied that first order equation by residual chlorine concentration and time. And it is limited by site-specific variety Recently, using equations are represented complex effect of bulk reaction of waterbody, wall

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effect, and mass transmission reaction that reflect pipeline characteristic of target area and water quality characteristic at first order equation.

Various influence factors of residual chlorine decay are roughness coefficient, initial concentration, k(decay coefficient), detention time, water temperature, the contaminant amount, diameter of pipe, etc, and influence factors of residual chlorine decay coefficient(k) value is very various according to researchers. Gotoh et. al are proposed that main factors in k value are contact area in pipe wall, water quality, water temperature, flow velocity, pipe materials, and are coating form, wet surface, temperature by Demongeot & Jarrige, Saunier & Jarrige and are diameter of pipe, pipe materials, and function of inflow velocity by Sharp et al. Therefore, residual chlorine decay is various according to characteristic of waterworks system, and Johnson (1987), Murphy(1985) represented that decay model is simple firstorder reaction.

Recently, Trussell represented quantitative relation of corrosion rate and chlorine residual consumption by influence factors of chlorine decay and LeChevallier et al. suggested mass transmission between bulk flowing and pipe wall by main chlorine consumption effect factors.. Also, Biswas et al developed chlorine decay model of steady state flowing condition including radial diffusion and continuous pipe wall reaction, flowing reaction of water as hydraulic factors. Rossman proposed mass transmission basis model applied to nonsteady flow condition and it is used wholewall reaction that have an effect on transmitted chlorine speed to pipe wall in fluid stream state.

Mathematical model that use computer into most economic/effective method to understand change characteristic of residual chlorine concentration in WDS is presented. Representative residual chlorine simulation model is the EPANET who develop in US EPA and that it is used extensively. When this pipeline network analysis models limit residual chlorine decaypath properly, there is characteristic that have efficiency and trustability.

For EPANET model application in KOREA, choi et al(1996) applied to Daejeon city and Joo et al(1998) forecasted distribution of residual chlorine concentration to Chungchongbuk-do Chungwon-Kun K-Myun and Lee et al(1997) applied to Seoul city and Kim et al(2000) forecasted effect of residual chlorine and re-chlorine injection to Suwon city. Hydraulic and water quality correction act by important variable to apply EPANET model effectively, trace test by fluoridation that Joo et al(1998) applies of hydraulic correction is used much.. The other side, water quality correction must apply residual chlorine decay coefficient, k valuewith type of pipe, diameter of pipe and water quality characteristic for target pipeline system. But, all researches that is applied in KOREA apply free value by literature result. It is very important that establish suitable model each site-specific characters and waterworks system to improve accuracy of water quality analysis. Specially, research of suitable chlorine decay coefficient with type of pipe and water quality characteristic by an experiment is effective method of model correction

Generally, network analysis model is applied large scale pipeline networks more than 200mm and then prediction of water quality change for end zone of networks that consists of smaller diameter than 200mm is impossible. Therefore, estimate of water quality change is required urgently for effective management of residual chlorine concentration in end zone of networks such as small block among block system.

Therefore, This research was to evaluate identification of chlorine decay coefficient according to characteristics of research area experimentally and application of EPANET for small scale blockarea that most pipes consist of 200mm below and effective application method of residual chlorine decay coefficient with application of global and each coefficient for water quality correction of EPANET model.

2. Research Methods

2.1 Research Area

The research area of this study is selected S block in the D city. In S block, water supplied generations and populations are 17,785, 60,661 respectively. Especially, pipeline network of this area is one middle scale block which consists of 4 small scale block in block system of D city. Therefore, information such as pipeline characteristics and water demand, etc for model built are readily gained. The total length of input pipeline for EPANET are about 280 km, and types of pipe such as ductile cast iron pipe(DCIP) of 76%, epoxy lining pipe(EPS), cast iron pipe(CIP), PFP, stainless steel pipe(STS), steel pipe(SP), polyethylene pipe(PE) and pipe diameter as 100 mm of 27%, below 200 mm of 92% and over 500 mm of 3%.

2.2 Model Construction

A water quality and hydraulic modeling for water distribution system is very complex. The EPANET was developed by the US EPA and represented a third generation of public domain software is used in this study, For EPANET model construction, input data are mean water demand, pipeline network map data, demand pattern, and especially, minimum diameter of pipe inputted is 50 mm. Table 1 showed that input data of constructed model are composed the pipeline of 2,126, node number of 1,731, reservoir of 1, pump station of 1. Also, headloss formula for hydraulic analysis was the Hazen-Williams equations and Table 2 showed the input data for roughness coefficient.

Fig. 1 showed pipeline networks map of research area. Pipe diameters in research area are mostly distributed from 300 to 100 mm.

2.3 Model Correction

The methods for accuracy progress of EPANET model are used to correction of hydraulic and water quality, and the methods of water quality correction are wall effect experiment, model development and preview study for chlorine decay coefficient. In this study, hydraulic and water quality correction are used the values of Table 2 and wall effect experiment respectively.

Table 1. Characteristics of Model Input Data

Input Data File 1.PRN	Hydraulic Accuracy 0.010000
Output Report File.................. D1.OUT	Maximum Trials 40
Map File .... D.MAP	Quality Analysis .... CHLORINE
Number of Pipes 2126	Minimum Travel Time .... 60.00 min
Number of Nodes 1731	Maximum Segments per Pipe 100
Number of Tanks 1	Specific Gravity 1.00
Number of Pumps 1	Kinematic Viscosity .... 1.02e-06 sq m/sec
Number of Valves 0	Chemical Diffusivity .... 1.21e-09 sq m/sec
Headloss Formula .... Hazen-Williams	Total Duration .... 20.00 hrs
Hydraulic Timestep .... 1.00 hrs	

Table 2. Input Data for Roughness Coefficient

History of pipe	before 1976	1976 ~ 1985	1986 ~ 1995	after 1996
Roughness Coefficient	100	110	120	130

Fig. 1. System Map and Pipe Diameter Distribution of Research Area

2.4 Field Survey

Field survey for water quality analysis are performed for 7 sampling sites in research area and sampled 3 times from spring to summer. Analysis of water temperature, residual chlorine, conductivity, pH are carried out in field, and Fe, Zn, Cu, Ca, Cl^-, SO_4^{2-}, TOC, Hardness, Alkalinity are analysed in laboratory by the Standard Methods.

For effective simulation of water quality change in pipeline utilizing EPANET model which select in this research, water quality correction is carried out about bulk and wall reaction for chlorine decay. In this study, wall effect experiment are performed to correction about residual chlorine decay coefficient(kw) related wall reaction in July. Wall effect experimental apparatus is used bench scale that an experiment used pipes that is PE, PVC, DCIP, and did by length 200mm of whole pipe that use in an experiment. Also, an experiment of bulk state is used triangle flask that can ignore roughness coefficient to correct residual chlorine decay coefficient(kb) value in bulk state.

3. Result and Discussion

3.1 Analytical Survey

The analytical survey focused first on the residual chlorine decay on the distribution systems. Table 3 showed the results of water quality analysis from spring to summer for 7 sampling sites. Residual chlorine appeared a little lower than 0.2 mg/L that is drinking water criteria to April, May at site 6, but was expose that satisfy drinking water criteria on the whole. However, residual chlorine is appeared on the whole high taking by summer, because this keeps residual chlorine concentration high worrying microbes re-growth of summer in WTP. The tendency of water quality variations for some contents such as Cl^-, SO_4^{2-}, Hardness, Alkalinity, conductivity is overtaken in sampling season, and metal ions such as Fe, Cu, Zn, are to variations depend on sampling site, especially, Fe is highly leached according to increasing water demand from May.

Table 3. Result of Water Quality Analysis

Site	Residual Chlorine (mg/L)	Temp. (?)	pH	Conductivity (μs/cm)	Hardness (mg/L)	Alk. (mg/L)	Ca (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	Fe (mg/L)	Cu (mg/L)	Zn (mg/L)	TOC (mg/L)
1	0.41-0.55	15.6-23.6	6.8-7.1	187-216	63-73	21.0-35.5	20.0-28.4	19.6-29.8	21.7-28.6	0.018-0.037	0.009-0.014	0.017-0.019	1.38-1.41
2	0.31-0.42	16.1-24.2	6.8-7.0	188-219	64-73	21.0-42.3	20.8-33.8	17.2-28.6	26.3-29.6	0.018-0.036	0.001-0.014	0.014-0.028	1.35-1.22
3	0.36-0.53	15.8-25.7	6.8-7.0	187-216	63-74	21.2-29.1	19.2-22.9	16.9-28.2	21.1-29.6	0.021-0.051	0.007-0.008	0.019-0.026	1.32-1.30
4	0.36-0.53	15.9-23.5	6.8-7.1	187-218	63-72	22.0-26.0	20.0-23.6	17.1-28.7	20.0-29.7	0.019-0.042	0.007-0.013	0.016-0.017	1.30-1.31
5	0.22-0.32	15.3-23.9	6.9-7.1	188-226	63-73	20.0-32.2	20.0-25.6	17.2-29.8	20.0-29.2	0.022-0.044	0.002-0.013	0.019-0.029	1.43-1.29
6	0.16-0.23	16.1-24.6	6.9-7.0	187-229	63-76	21.2-30.0	20.1-31.1	16.9-28.6	19.7-29.1	0.0190.039	0.003-0.022	0.032-0.043	1.36-1.33
7	0.28-0.40	15.7-23.7	6.9-7.1	188-221	64-73	20.6-30.0	17.0-25.6	17.1-28.1	20.1-28.7	0.01-0.048	0.008-0.02	0.044-0.079	1.35-1.34

3.2 Results of Wall Effect Experiment

Table 4 represented the results of wall effect experiment for research area compared with application values of Joo et al.(1998). Wall reaction coefficient, k_w are represented various results according to types of pipe, diameter of pipe and seasons, and k_w values of PVC, PE, DCIP Ø100, DCIP Ø80 on summer are 0.0212, 0.0268, 0.3954, 0.4839 m/day, respectively. Therefore, values of DCIP are highly more 2 times than values of PVC and PE. The characteristic of chlorine decay with types of pipe, diameters of pipe, and seasons is certainly represented. From this experiment results, effect that get in pipe wall decay reaction of residual chlorine according to each pipe(roughness coefficient) is different, and then prediction of water quality change in WDS using water quality and hydraulic model must apply each type of pipe, diameter of pipe other residual chlorine decay coefficient value. Therefore, To increased the modelling accuracy of water quality as chlorine residual, the application of chlorine decay coefficient with field conditions is needed.

Table 4. Comparison of Chlorine Decay Coefficient

Contents		Bulk decay coeff. $k_b(day^{-1})$	Wall reaction coefficient $k_w(m/day)$			
Preview study		-2.0	-0.1, -0.05			
This study	Seasons		PVC	PE	DCIP100	DCIP80
	Winter	-0.3984	-0.0008	-0.0022	-0.0245	-0.0276
	spring	-1.3454	-0.0105	-0.0129	-0.1814	-0.3005
	summer	-2.1812	-0.0212	-0.0268	-0.3954	-0.4839

3.3 Hydraulic Analysis

Fig. 2 and Fig. 3 are showed the results of hydraulic simulation based on the waterdemand of each node for research area. Fig. 4 represented the variations of flow velocity with timeat pipe 2007 located on the end zone of pipeline networks. Water demand of velocity of flow in pipe 2007 is recording maximum 0.052 m/sec in many time zones, and is showing lowest 0.02 m/sec at night that water demand is few. Fig. 3 showed the variations of flow velocity with time at pipe 1100 located nearly on the reservoir. Velocity of flow distribution in pipe 1100 in pipe 2007 and is appearing similarly but within the velocity of flow is expressing high value more than about decuple thanpipe 2007. Fig. 4 showed the results of velocity simulation for the research area. Therefore. the retention time of pipelines located on the end zone of pipeline networks in block system are increased and concentration of chlorine residual are insufficiently lowed.

Fig. 5 represented that distribution of head loss in research area are showed by average 8.76 m/km in reservoir neighborhood that within the velocity of flow is fast by average 0.048 m/km in end zones that within the velocity of flow is less.

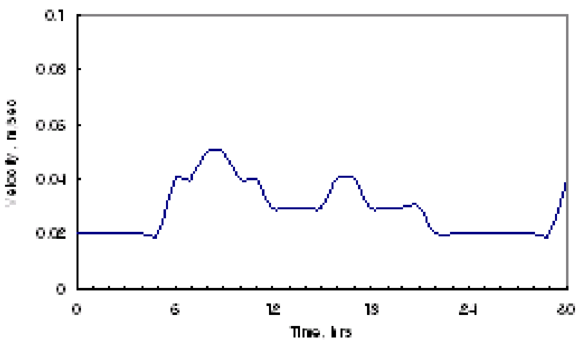


Fig. 2. Simulation of Velocity at Pipe 2007 (Dia. : 80mm)

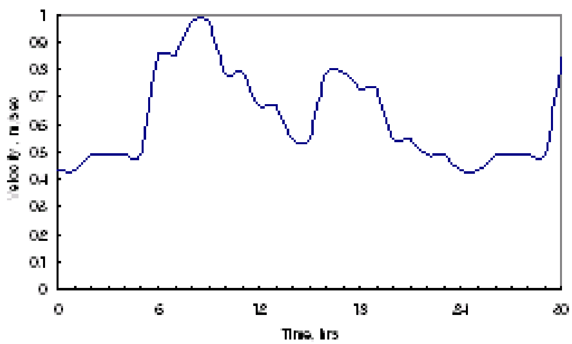


Fig. 3. Simulation of Velocity at Pipe 1100 (Dia. : 50 mm)

Fig. 4. Results of Velocity Simulation.

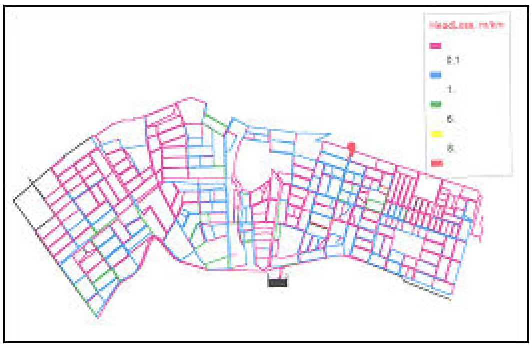
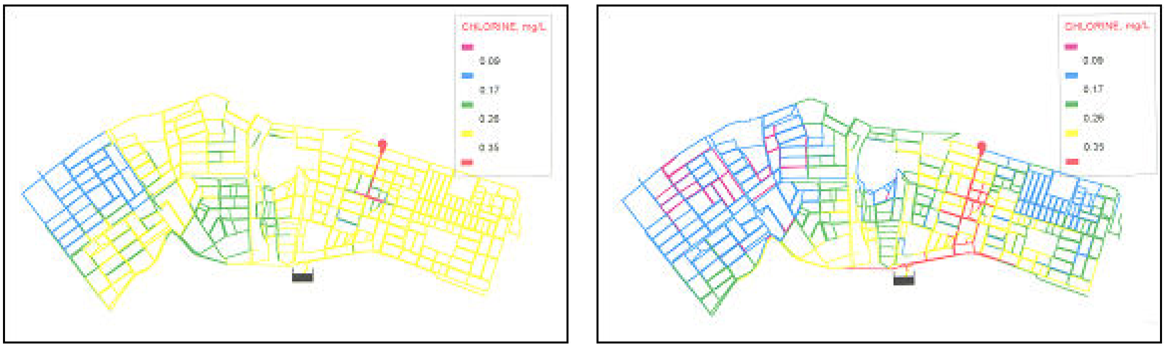
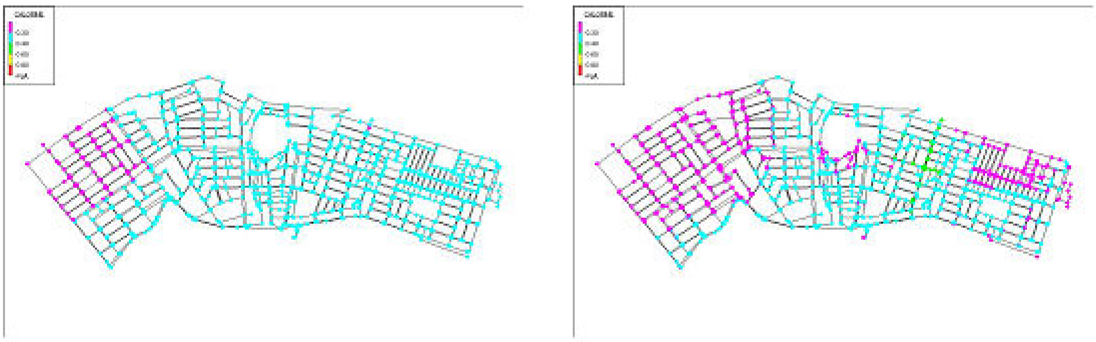


Fig. 5. Results of Headloss Simulation



(a) Duration time = 1:00 hrs (b) Duration time = 10:00 hrs

Fig. 6. Results of Chlorine Simulation with Time on Summer



(a) Duration time = 1:00 hrs (b) Duration time = 10:00 hrs

Fig. 7. Results of Chlorine Simulation with Time on Spring

3. Conclusions

(1) Wall reaction coefficient, k_w are represented various results according to types of pipe, diameter of pipe and seasons, and k_w values of PVC, PE, DCIP Ø100, DCIP Ø80 on summer are 0.0212, 0.0268, 0.3954, 0.4839 m/day, respectively.

(2) The results of hydraulic simulation based on the water demand of each node for research area represented that distribution of flow velocity and headloss are related to waterdemand and detention time in pipeline networks.
(3) Simulation results by EPANET are represented that water quality change of block area in water distribution system shows different results according to hydraulic characteristic with seasons and to application of chlorine decay coefficient such as K_b and K_w with type of pipe, diameter of pipe, and seasons.

Therefore, field application of EPANET model for prediction of waterquality change must use to K_b and K_w reflected upon characteristics of site-specific pipeline networks and water quality. Also, optimal size of blockarea for fieldapplication of EPANET or network analysis model is determined to middle block area from the viewpoint of economics and effectiveness for management of water distribution system, if history of management failure related deterioration of water quality was not appeared.

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