RESILIENCE INDEX FOR CHLORINE ANALYSIS IN WATER DISTRIBUTION NETWORKS

S. Kaewsang, A. Pornprommin, S. Lipiwattanakarn

Kasetsart University

&

T. Wongwiset

Metropolitan Waterworks Authority

Presentation Contents

Introduction

01 Free chlorine is the most common disinfectant used around the world. Chlorination has been used to meet primary disinfection requirements and provide a residual disinfectant in distribution system.

02 The World Health Organization, free chlorine should be present in drinking-water distribution networks at a minimum concentrations of 0.2 mg/liter.

03 Chlorine can decay in networks by;

- The travel time from DMA inlet points to customer points (water age) is one of the most important factors causing the losses of chlorine in distribution networks.
- The reactions in bulk water and at pipe walls.

Objective

01 This study simulates water quality in a water distribution system by using EPANET model.

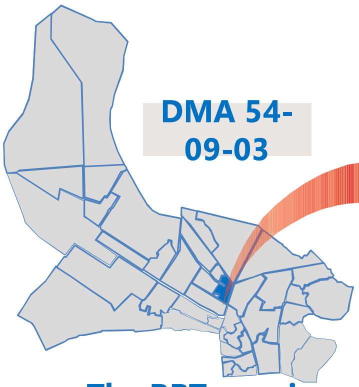
02 To analyze resilience index of free residual chlorine in the water distribution network for two cases.

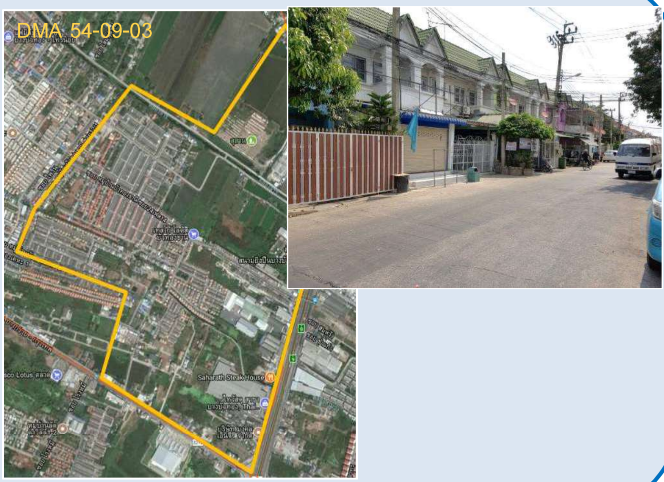
- Case 1 : A situation with water losses (%WL = 25%)
- Case 2 : A situation without water losses (%WL = 0%)

03 One water distribution network (district metering area 54-09-03 from Bang Bua Thong branch office) was studied.

Study Area

Study Area : DMA 54-09-03 in the Bang Bua Thong branch office (BBT)





Service area	: 2.10 km^2		
No. of users	: 2,457 connections	Pressure at DM	: 6.8 m
% of water loss	: 25%	Dist. pipe length	: 26.23 km
Types of dist. pipe	: PVC(80%) , AC(20%)		

Method

1. Data Collection ← Pipe, Customer, Area, Statistical data

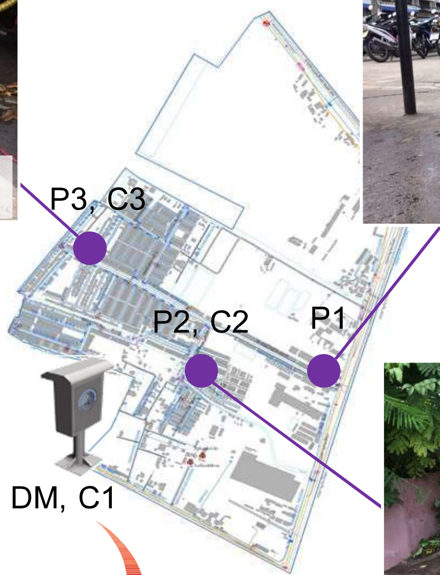
2. Model Building ← Import pipe and customer from GIS to EPANET

3. Pipe Network Simulation ← Import file .inp to EPANET

4. Model Calibration ← Hydraulic (water balance), Water Quality (Initial Quality)

5. Analyze resilience index of free residual chlorine in the water distribution network ← Analyze resilience index of free residual chlorine in the water distribution network.

Method



Data Collection

- Data of model building
  - * Pipe properties (Diameter, C)
  - * Consumption of users (Demand, Demand Pattern)
- Data of model calibration
  - * Pressure (P1, P2, P3)
  - * Free residual chlorine concentrations measured (C1, C2, C3)
  - * Flow and pressure at inlet point (DM)

Reference : Bang Bua Thong branch office

Method

Reliability of chlorine distribution

- Hydraulic reliability in water distribution systems generally means the capability of the systems to satisfy water demands and pressure in both normal and critical situations such as pipe burst, fire and emergency demands.

- A measure of hydraulic reliability often used in water distribution systems is a **resilience index.** This surplus allows a network to overcome critical operating conditions.

- The higher resilience index value can show the higher hydraulic reliability in a system.

- In term of water quality, a concept of resilience index was implemented to investigate the reliability of chlorine distribution in this study.

Method

Concept of resilience index for chlorine (I_r)

Input total FRC Cl_{tot}	Internal FRC lost Cl_{int}	
	External FRC to users Cl_{ext}	
		Lost due to water age Cl_{age}
		Lost due to water reaction Cl_{rea}
		Lost due to leak flow Cl_{leak}

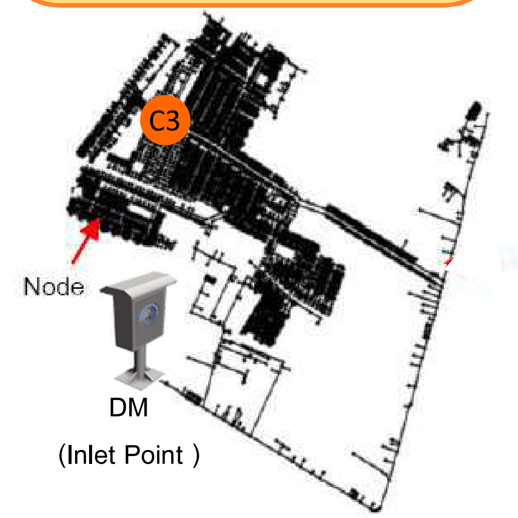
$$I_r = 1 - \frac{(Cl_{int})}{(Cl_{int,max})}$$

*FRC = Mass of free residual chlorine

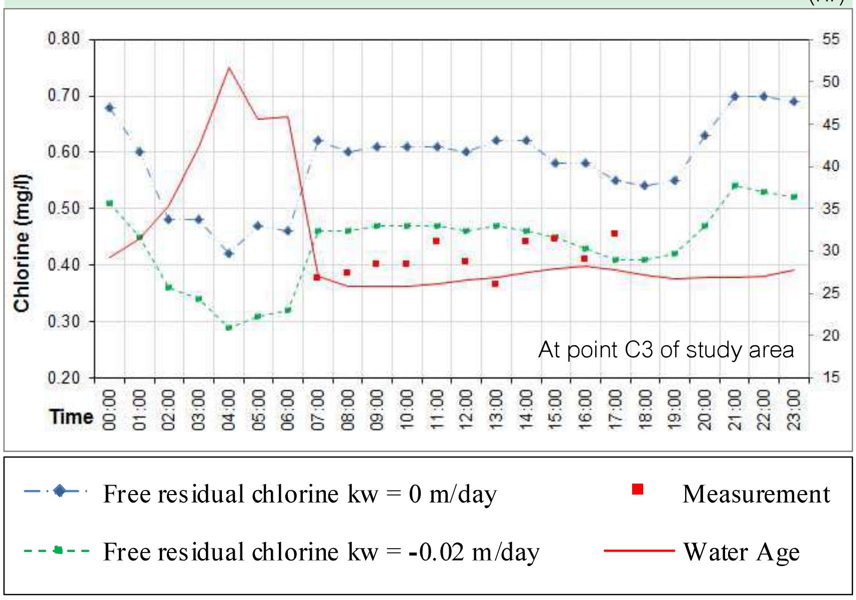
Results

The situation with water losses

- Hydraulic model calibration
  - Emitter (C) = 0.1211 m^2/d
  - Inlet Pressure = 6.34 m
- Water quality model calibration
  - K_w = 0 and -0.02 m/d
  - K_b = -0.3432 d^{-1}



Comparison of water age and free residual chlorine concentration at point C3



- The results show that inverse relationship between water age and free residual chlorine concentration. This mean that water age is the major factor of chlorine decay.

Results

The situation with water losses

- Hydraulic model calibration

  Emitter (C) = 0.1211 m^2/d

  Inlet Pressure = 6.34 m

- Water quality model calibration

  K_w = -0.02 m/d

  K_b = -0.3432 d^{-1}

The situation without water losses

- Hydraulic model calibration

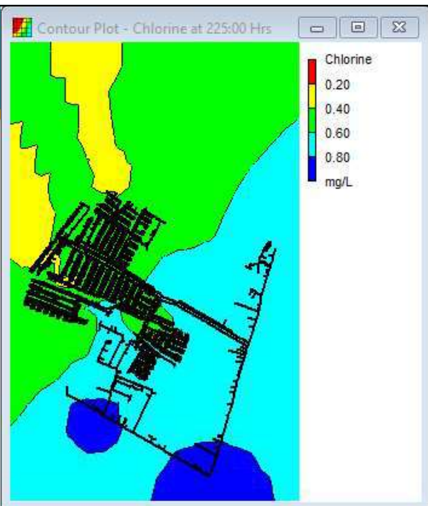
  Emitter (C) = - m^2/d

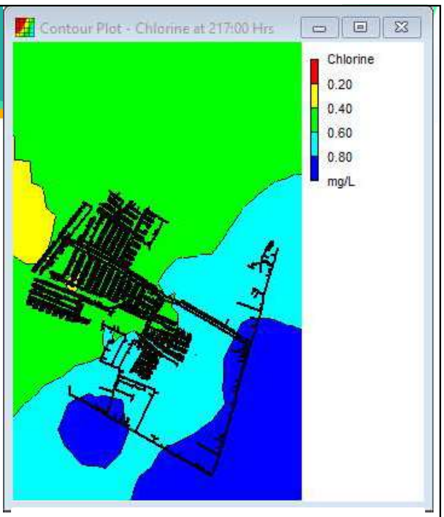
  Inlet Pressure = 6.34 m

- Water quality model calibration

  K_w = -0.02 m/d

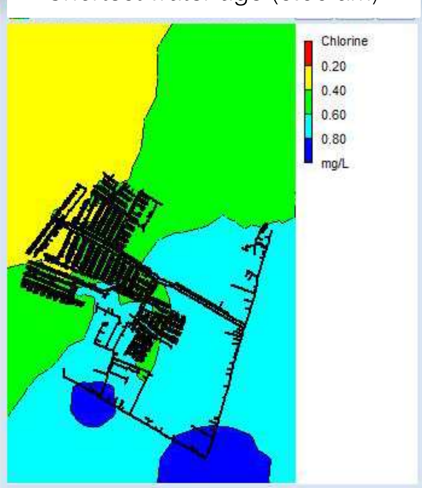
  K_b = -0.3432 d^{-1}

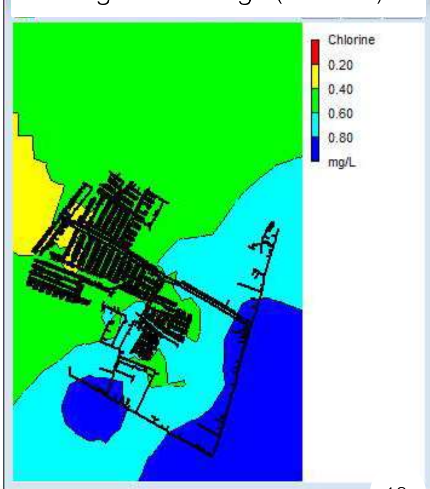




Shortest water age (8:00 am)

Longest water age (4:00 am)





Contour of free residual chlorine of the situation with (Top) and without (Below) water losses

Results

Results of free residual chlorine for 24 hours in cases with and without water losses

Free Residual Chlorine	%WL = 25% Grams (%)	%WL = 0% Grams (%)	Change (%)
Cl_{tot}	2,996 (100%)	2,153 (100%)	-28
Cl_{ext}	1,887 (63%)	1,342 (62%)	-29
Cl_{int}	1109 (37%)	811 (38%)	-27
$Cl_{ext,min}$	482	482	0
$Cl_{int,max}$	2,514	1,671	-34
I_r	0.559	0.515	-7.9

- Reducing water losses can reduce the chlorine input (C_{tot}).
- A smaller value of Cl_{int} implies that the losses and decay in the system reduces. This is good for the system.
- A smaller value of Cl_{ext} means that users are receiving less chlorine concentration.
- I_r reduce by 7.9%. This result indicated that the reliability in the area became lower.

Conclusions

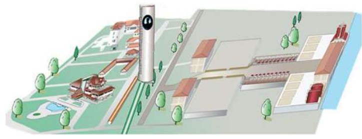
- Reducing water losses can help to decrease the input chlorine mass into the system.
- Flows and velocities in pipes decrease due to no water losses, water age increases, and, consequently, chlorine concentration decreases.
- The reliability of chlorine distribution can help water companies to regulate input chlorine mass into the system for maintain chlorine concentration (WHO $\geq$ 0.2 mg/l) at users.

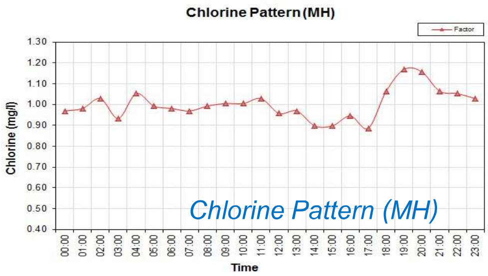
Thank you for your attention

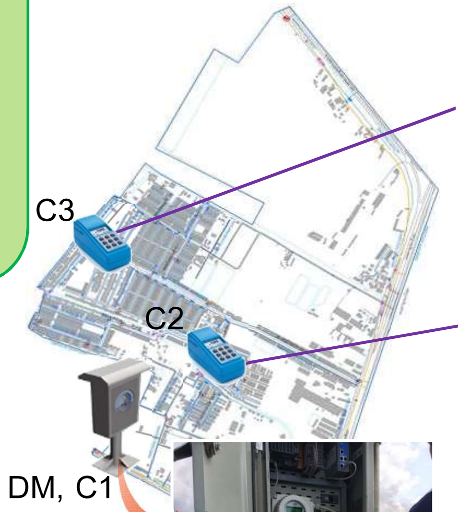
Method

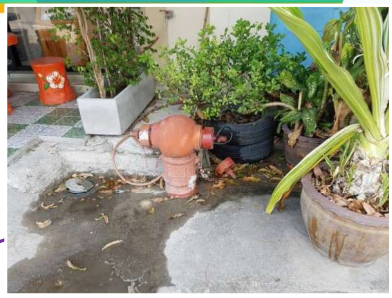
Data Collection of water quality model

- Data of model building
  - * Chlorine Pattern (MH)
- Data of model calibration
  - * Free residual chlorine concentrations measured (C1, C2, C3)





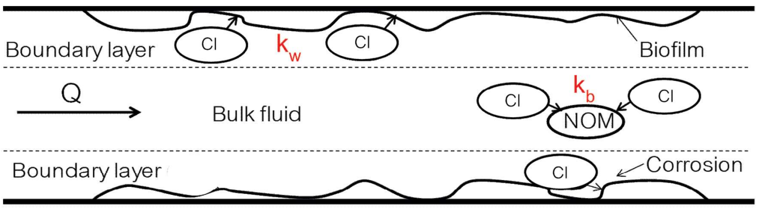




Reference : Bang Bua Thong branch office

Method

Water Quality Reactions



Reaction zones within a pipe.

$$R = K_b C + \frac{A}{V} K_w C$$

R	=	Reaction rate
K_b	=	Bulk Reaction Coefficient (d^{-1})
K_w	=	Wall Reaction Coefficient (m/d)
C	=	Free residual chlorine concentration
A/V	=	Surface area per unit volume within the pipe
NOM	=	Natural Organic Matter
Cl	=	Free chlorine

Bottle Test

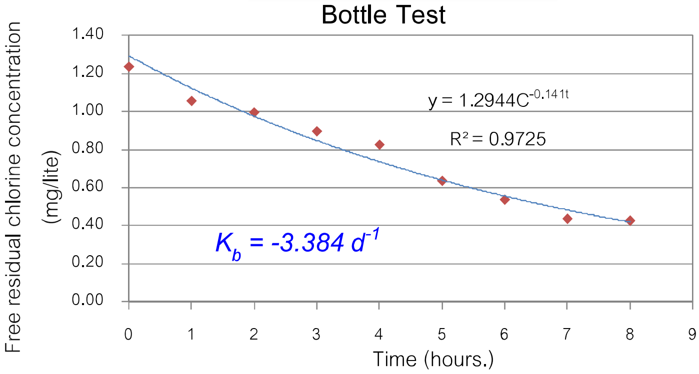


Diagram of laboratory method used in calibrating K_b.