Evaluation of Advanced Water Treatment Operation

Seung-Hyun Kim
Kyungnam University

Abstract

This study evaluated advanced water treatment (AWT) system in Korea. There are currently 16 plants operating with AWT. However, no attempt has been made to evaluate AWT system. This study selected one water treatment plant with AWT (pre-ozonation + BAC). Using the operation data from 1995 to 2001 and pilot study results, the post-evaluation of the AWT system has been conducted. The study found that AWT improved water qualities of organic, ammonia, and turbidity, as expected. However, the extent of the improvement was generally short of the pilot study expectations.

Pre-ozonation failed to decrease coagulant consumption. The dosage increased rather than decreased. AWT was, however, successful to decrease chlorine consumption. The chlorine reduction was related to the change in raw water characteristics and AWT introduction.Pre-ozonation failed to decrease coagulant consumption. The dosage increased rather than decreased. AWT was, however, successful to decrease chlorine consumption. The chlorine reduction was related to the change in raw water characteristics and AWT introduction. Both operation of pre-ozonation and reduced ammonia loading were responsible for the reduction. AWT increased the operation cost. Maintenance, raw water, and power cost increased, while labor and chemical cost decreased. Manpower reduction resulting from automation caused the decrease of labor cost. The reduction of chlorine consumption caused the decrease of chemical cost.

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AWT INTRODUCTION

Background
History
Status

Background

- Deterioration of raw water sources
- Appearance of new contaminants
- Strengthened drinking water quality regulations
- Lost confidence in tap water

Korea Environmental Technology Research Institute (1996)

- Use tap water 4 %
- Use boiled water 61.5 %
- Use point-of-device for treatment 7 %
- Use others 27.5 %

History

- 1986: GAC introduction
  - GAC at Bupyong plant using Han river
- 1988: Ozone introduction
  - Ozone at Whamyung plant using Nakdong river
- 1991: Phenol accident
- 1994: Extensive installation
  - 16 plants in operation

AWT Status- I

- Location : Mostly at Nakdong river
  - Nakdong river: 11 plants
  - Han river: 3 plants
  - Kum river: 2 plants
- Size : Mostly at large-scale plants
  - < 50,000 ton/d: 4 plants
  - 50,000 ~ 100,000 ton/d: 3 plants
  - 100,000 ~ 500,000 ton/d: 6 plants
  - > 500,000 ton/d: 3 plants

AWT Status - II

- Process: Mostly ozonation/activated carbon
  - Ozonation 1 plant
    - Activated carbon is being added
  - GAC 5 plants
    - Han river 3, Nakdong river 1, Kum river 1
    - 1 plant (Han river) plans to add ozonation
  - pre-O_3 + BAC 4 plants/BAC 6 plants
    - 9 at Nakdong river, 1 at Kum river
    - 2 plants (Nakdong river) plans to add pre- O_3
    - 2 plants (Kum/Nakdong rivers) gave up pre-O_3

Background and Objective

- Background
  No attempt to post-evaluate AWT operation

- Objective
  Evaluate
  - whether AWT improved water quality
  - how AWT affected plant operation
    - Chemical consumption
    - Operation cost

Approach and Method

1. Selection of a water treatment plant with AWT for case study
2. Extraction and summarization of AWT's beneficial effects from pilot plant results
3. Evaluation using operation data
   - expected beneficial effects
   - Other effects

Selection of Water Treatment Plant

- Selection criteria
  - Representative of AWT in Korea
- Selection parameter
  - Raw water
  - Process

- *Why this plant?*
  - Raw water: Nakdong river
  - Process: AWT (pre-O_3 + BAC)

Pilot plants

Two pilot plant experiments

- 1991. 7 ~ 1992. 6 (1st. Experiments)
- 1995. 1 ~ 1995. 12 (2nd. Experiments)

1st. Pilot - Objectives

- Objectives
  Wa.er quality improvement by GAC/BAC
  - Effects of EBCT
  - Effects of carbon size
  - Effects of bed depth

1st. Pilot - Results

Average % Removal
- Ozone: dosage 1 mg/L, contact time 20 min
- Filtration: EBCT 12 min, bed depth 1.4 m

	GAC-1	GAC-2	BAC-1	BAC-2
$KMnO_4$ #	50	40	65	50
NH_4-N	85	85	90	90
ABS	60	50	80	65
THMFP	50	43	70	60
UV254	50	35	75	55

2nd. Pilot - Objectives

- Objectives
  Find out design parameters

- Target Contaminants
  - Trace Organics
  - T&O
  - THM
  - NH_3-N

Expected Benefits of AWT

Process (pre-O_3 + BAC)

- Removal of trace organics
- Increased organic removal
- Lengthened carbon life
- Improved disinfection
- Improved coagulation
- Suppression of THM formation
- Removal of T&O causing material

Comparison - Water Quality

1995~2001 Water Quality Data for Treated

	Pre-AWT	Post-AWT
• $KMnO_4$ #, mg/L	4.6	2.4
• ABS, mg/L	0.17	0.044
• THM, µg/L	27	26
• Turbidity, NTU	0.67	0.24
• NH_3-N, mg/L	0.039	ND

Comparison Result - I

- Statistical analysis conducted to find the water quality improvement: t-test at a confidence level of 0.05
  - Water quality improved
    - Turbidity, $KMnO_4$ #, NH_3-N, ABS
  - No improvement
    - THM
- AWT is not the only reason for such improvement
  - Change in raw water quality

Change in Raw Water Quality - I

- Organics
  - Decreased loading
    - BOD, mg/L: 4.9 (94~97) 3.1 (98~01)
    - COD, mg/L: 7.5 (94~97) 5.3 (98~01)
    - $KMnO_4$, mg/L: 14.5 (95~97) 10.0 (98~01)
    - ABS, mg/L: 0.34 (94~96) 0.24 (97~01)
    - Chlorophyll-a, μg/L: 90 (95~97) 36 (98~01)
  - Decreased biodegradability
    - BOD/COD: 0.65 (94~98) 0.50 (99~01)

Change in Raw Water Quality - II

- Inorganics
  - Decreased loading
    - NH_3-N, mg/L: 0.75 (94~97) 0.14 (98~01)
    - Alkalinity, mg/L: 60 (95~97) 42 (98~01)
  - No change
    - No change in NO_3-N: 2.8 mg/L
    - No change in T-N: 5.5 mg/L
    - No change in T-P: 0.18 mg/L
- Increased turbidity & DO
  - Turbidity, NTU: 9.5 (94~96) 20.7 (97~01)
  - DO, mg/L: 8.6 (94~95) 10.2 (96~01)

Consequences of Raw Water Change

- Decreased coagulant dose
  - Decreased organic loading (BOD,COD, $KMnO_4$)
  - Decreased ABS loading
  - Increased turbidity loading insignificant because coagulant dose controlled by organic loading
- Decreased pre-chlorine dose
  - Decreased chlorophyll-a loading
  - Decreased NH_3-N loading

Comparison - % Removal

1995~2001 Water Quality Data for Treated

	Pre-AWT	Post-AWT
• $KMnO_4$ #	72	76
• ABS	56	84
• Turbidity	92	98
• NH_3-N	94	100

Comparison Result - II

- Statistical analysis confirmed the improvement in contaminant removal performance by AWT (t-test at confidence level of 0.05)
- How much improvement?

	1^{st} Pilot	2^{nd} Pilot	Actual
$KMnO_4$ #	65 %	-	6 % (76)
*UV254	75 %	40 %	9 % (71)
ABS	80 %	-	50 % (84)
NH_4-N	90 %	< 10 %	100 %
Turbidity	-	-	7 % (98)

Actual performance indicates the comparison of % removal efficiencies between before and after AWT

*value indicates UV254 removal efficiency by BAC

Chemical - I

- Disinfection
  - Chemical used as disinfectant:
    - Cl_2 disinfectant/ClO_2 discontinued, $Ca(OH)_2$ (temporary use)
  - Decrease in Cl_2 dose after AWT addition
    - Pre-Cl_2 dose decreased due to pre-O_3, but increased from 2000
    - Unlike pre-Cl_2, post-Cl_2 dose kept increasing despite the lower residual (0.9 ppm vs 0.7 ppm)

	Before	After	Now
Pre-Cl_2 dose	16.46	2.02	4.86
Post-Cl_2 dose	0.81		2.23

Chemical - II

- Coagulant
  - Chemical used as a coagulant
    - PACS (major coagulant): Al_2O_3 17 ± 1%, SG > 1.35
    - PACl (discontinued): Al_2O_3 10~11 %, SG 1.19
    - LAS (backup coagulant): Al_2O_3 8 %, SG 1.32
  - Change in 1996
    - PACS replaced PACl ⇒ PACS+LAS
    - NaOH replaced lime as a base

Chemical - III

- Increased coagulant dose after AWT addition
  - Coagulant dose increased by 20 % (5.06 to 6.09 mg/L as Al_2O_3), contrary to the pilot expectation of 40 % reduction
  - Returned to the pre-AWT condition recently (4.94 mg/L)
  - Base continuously decreased (3.76 to 2.47 mg/L)

	Pre-AWT	Post-AWT	Now
Coagulant, mg/L as Al_2O_3	5.06	6.09	4.94
Base, mg/L	3.76	2.47	0.98

Operation Cost - I

- Expected AWT's effect on operation cost
  - Labor cost ⇒ increase
  - Maintenance cost ⇒ increase
  - Raw water (no effect)
  - Power cost ⇒ increase
  - Chemical cost ⇒ decrease

Operation Cost - II

Labor cost
- Decreased due to employee reduction

	Pre-AWT	Post-AWT
Chemists	10	7
Office	20	18
Operator	71	34
	101	59

Maintenance/Raw water cost
- Increased
- More steep increase in raw water

Operation Cost - III

Power cost
- No change for intake operation
- Increase for plant operation operation
  - due to GAC
  - due to ozonation

Chemical cost
- Decrease due to coagulant and Cl_2
- Reason
  - Reduced organic loading ⇒ reduced coagulant consumption
  - Reduced NH_3-N loading ⇒ reduced Cl_2 consumption
  - Addition of Pre-O_3

Conclusion

- AWT improved water quality
  - Organics, Turbidity, ABS, NH3-N,
  - No effect was observed for THM reduction
- AWT reduced chemical consumption
  - Cl_2 consumption reduced
- AWT increased operation cost