Korean J. Limnol. 41 (4): 423~430 (2008)

Review

Establishment of Alarm Criteria for Automatic Water Quality Monitoring System in Korea

Lim, Byung Jin*, Eun Young Hong, Hyunook Kim[1], Eun Sook Jeong, Woo Myung Heo[2] and Yoon Hee Kim[2]

(Water Quality Division, National Institute of Environmental Research, Incheon 404-708, Korea
[1]Environmental Engineering, University of Seoul, Seoul 130-743, Korea
[2]Department of Environmental Disaster Prevention Engineering, Kangwon National University, Samcheok 245-711, Korea)

As of September 2008, 45 Automatic Water Quality Monitoring Systems (AWQMS) have been installed at different sites on the 4 rivers to detect early the presence of pollutants in water and to issue an alarm. We count the number of issuing alarms by AWQMS, however, we will find the alarm has hardly been issued. The reasons for the scarcity of alarm issue are extensively being examined. The National Institute of Environmental Research attributes wrong alarm criteria for each AWQMS station to one the reasons. In this study, a suggestion has been made to modify the current alarm criteria to correspond with characteristics of river water quality. The current system with only two criteria (low and high) should be replaced as four-criteria systems (low, medium, high, and severe) based on cases of other advanced countries and stream conditions of Korea. The highest value of data collected for 5 years was suggested as the alarm criteria for each parameter. Meanwhile the alarm criteria for VOCs, phenol and heavy metals were established as same as drinking water quality criteria.

Key words : Automatic Water Quality Monitoring System, early detect the presence of pollutants, alarm criteria

INTRODUCTION

After the accident of water pollution by phenol occurred in Nakdong River on January 1994, the Ministry of Environment, Korea initiated the deployment of Automatic Water Quality Monitoring System (AWQMS) station to continuously monitor water quality of predetermined sites. As of September 2008, the AWQMS at 45 sites throughout all of the 4 national rivers have been built to detect early any pollution incident (Fig. 1). Each station was equipped with probe type sensors and automated flow-through type analyzing instruments, telecommunication system, data logging system, and alarm issuing system made it possible to effectively prevent any water pollution accident and to immediately report it to operators, if any. Since the first station of the system was installed, however, the alarm has not been issued many times. The alarm has been issued only 20 times since 2002 (EMC, 2007), 4 of the issued alarms were due to the influx of wastewater and snow-melt water, 6 due to the influx of non-point source pollution from first storm, 7 due to algal blooming right after increased temperature, and 3 due to unknown cause (Table 1). Interestingly, these alarms were issued only at 8 sites such as Seongseo and Jinju sites of Nakdong River, Gapcheon, Suknamcheon, Buyeo and Dae-

* Corresponding author: Tel: +82-32-560-7133, Fax: +82-32-568-2037, E-mail: limnolim@korea.kr

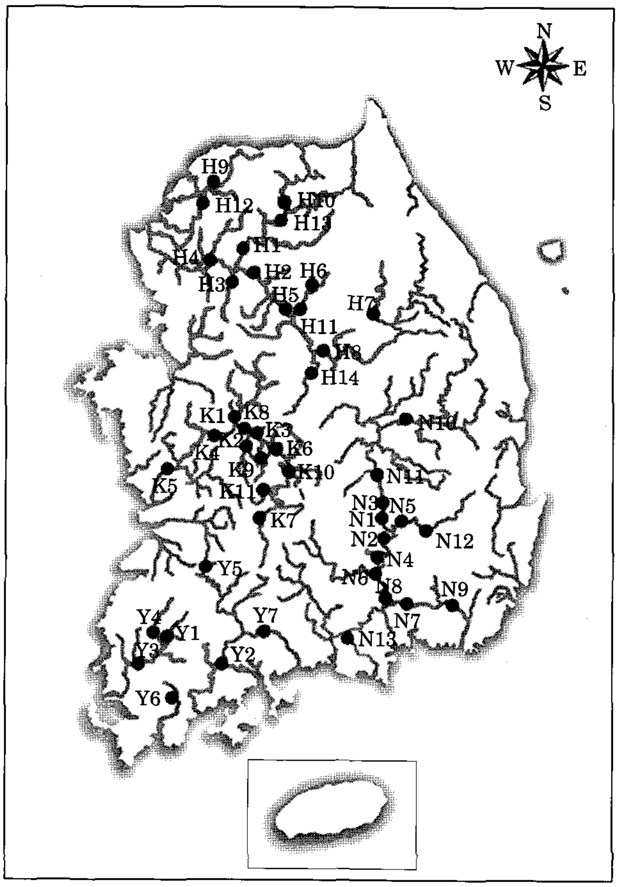

Fig. 1. The installation sites of Automatic Water Quality Monitoring Systems.

The abbreviations are as follows;

H1:Gapyeong	N2:Seongseo	K4:Gongju
H2:Yangpyeong	N3:Waegwan	K5:Buyeo
H3:Kyunganchun	N4:Goryeong	K6:Janggye
H4:Guri	N5:Gangchang	K7:Yongdamho
H5:Yeoju	N6:Jeokpo	K8:Hyundo
H6:Wonju	N7:Cheongam	K9:Okchoncheon
H7:Pyeongchanggang	N8:Chilseo	K10:Iwon
H8:Dalcheon	N9:Changam	K11:Bonghwangcheon
H9:Hantangang	N10:Yecheon	Y1:Seochanggyo
H10:Seosang	N11:Hyepyeong	Y2:Juamho
H11:Kangchun	N12:Namcheon	Y3:Naju
H12:Shincheon	N13:Jinju	Y4:Hwangryonggang
H13:Uiamho	K1:Mihocheon	Y5:Okjeongho
H14:Chungju	K2:Gapcheon	Y6:Tamjinho
N1:Seongju	K3:Daecheongho	Y7:Gurye

cheongho sites of Geum River, Seochanggyo and Juamho sites of Yeongsan River. The other sites have not issued any alarm. Due to the scarce of the alarm issues, the effectiveness and even usability of the entire AWQMS are being questioned. Therefore, it was urgent to improve the usability of the system and to expand it further.

The criteria for issuing any alarm of the system had been attributed to as one of the major reasons for the rare alarm issue. Therefore, researchers suggested that the current alarm criteria should be modified to boost AWQMS's surveillance function and to secure reliability of data. In this study, we reviewed similar systems in other countries and their alarm criteria and some suggestions were made to improve our system's alarm criteria.

Investigation of AWQMS and Alarm System for Monitoring Surface Water Pollution in Developed Countries

The United States Geological Survey (USGS, http://water.usgs.gov/nawqa/) and Environmental Protection Agency (EPA, http://cfpub.epa.gov/safewater/sourcewater/) have tested a number of water quality monitoring systems through the National Water Quality Assessment (NAWQA) program and Volunteer Monitoring Programs, respectively. Most of the water monitoring systems have been operated by the two agencies monitor stream water quality by manual analysis. However, the USGS has on-line collected hydrology data approximately at 1.5 million sites nationwide. The sites are monitoring pH, EC, temperature, DO, turbidity and Chl-*a*. The Center for Applied Aquatic Ecology has also operated the Real-Time Remote Monitoring (RTRM, http://www.ncsu.edu/wq/RTRM/NEMP/index.html/) system is which a bio-monitoring system is utilized to early detect toxic compounds in aquatic ecosystem. Ohio river (http://www.orsanco.org/watqual/drink/swap.asp/) and Clair river have

Table 1. Alarm status on Automatic Water Quality Systems.

Cause / The number of case	Influx of pollutants (waste water, snow-melt water)	Influx of non-point source pollution after first storm	Algal blooming right after increased temperature	Unknown causes
20	4	6	7	3

*Unknown causes: The alarm was issued by a biological monitoring equipment. However, they could not find anything unusual after extensive manual analysis of water samples.

Table 2. Alarm criteria for water pollution in Germany (UBA, 2004).

	Stages	Description of systems	Weighting for the alarm index (points)	
			Upward deviation	Downward deviation
Basic measuring program	1	Multi-parameter measuring system		
		Temperature	5	0
		Dissolved oxygen concentration	5	20
		pH	20	20
		Conductivity	30	Alarm index deactivated (e.g. heavy rainfall)
		Turbidity	20	0
	2	Data aquisition by station computer		
Extended basic measuring program	3	Station computer with unusual event recognition and alarm index		
	4	Event-controlled sampling with subsequent laboratory investigation		
		Automatic sampling by means of self-emptying sampler (Manual sampling might also be possible at a manned station)		
		Laboratory investigations to ascertain causes and assess effects	positive results from laboratory causes the "notification level"	
	5	UV absorption measurement (SAC 254 nm)	20-65	0
Extended measuring program	6	Continuous bio test methods		
		Daphnia toximeter	85 a) 40 (for internal alarm threshold value) b) others 45 (for device alarm)	
		Algal toximeter	85	
		Mussel toximeter	86 (43 each channel)	
		Bacterial toximeter	85	
		Fish toximeter	85	
	7	Location-adapted measuring system		
		Radioactivity measurements	150	0
		GC/MS	"notification stage" is directly reached at limit infringement	
		HPLC / UV or MS	"notification stage" is directly reached at limit infringement	
		Oil detectors	85 ~ 150	0
		Fluorescence measurements	30 ~ 85	0
	8	Other measurement methods		
		Continuous photometric determination of fulvic acids (humic acids)	−20 ~ −65 (compensation UV-absorption measurement)	0
		Nutrient analysers (ammonia/nitrate)	20 ~ 65	0
		Organochlorine monitors	20 ~ 65	0
		Water level measurement	alarm index deactivated (e.g. heavy rainfall)	0
		TOC monitors	20 ~ 65	0
	9	Sampling collectors		
		Composit sampling devices		
		Centrifuges		
		Sedimentation tanks		
		Mussel storage tanks		
		Artificial membranes for bioaccumulation		

monitored on real time basis Volatile Organic Compounds (VOCs) to observe industrial wastewater.

Japan has installed AWQMS at 118 sites on public water bodies to continuously monitor general water quality parameters. In addition, the first grade telemetering systems have been installed at 248 sites along local streams and water data collected by the system are opened to the public. Several drinking water centers monitors toxicity and VOCs using on-line analyzers. However, there are no such a thing like an alarming system for public rivers in Japan.

Germany has a total of 38 automatic water monitoring sites along Elbe river (http://www. arge-elbe.de/) and Rhine river (http://www.lawa. de/). They measure general water quality parameters, toxicity, and VOCs. In their measurement system, there are nine stages (Table 2). In the first and second stages, which are operated by Basic Measuring Program, temperature, pH, Dissolved Oxygen (DO), Electric Conductivity (EC) and turbidity were continuously measured and analyzed by a computer. If unusual incident is identified in these stages, then water samples are analyzed by the Extended Monitoring Program (in which 3rd, 4th and 5th stages are included). At the 3rd stage, whether alarm is issued to operators is determined. If alarm is issued, a water sampling is made at the 4th stage. Noticeably, water samples' UV 254 is check at the 5th stage. In addition to the UV absorption test, a number of water quality parameters are extensively analyzed in the 6th through 9th stages, which are included in Extended Measuring Program. Germany is utilizing 2 different kinds of alarming system at Elbe Catchment Area for International Emergency Planning (EASE) project (UBA, 2004), the one is made up with 2 stages and the other 4 stages. The 2 stage alarm system (Yellow, Red) is issued when a water pollution accident is reported, while the 4 stage alarm system (low, medium, high, severe) is issued when the accident is reported by automated equipments at a monitoring site.

Netherland operates the AWQMS at six sites, in which general water quality parameters (pH, DO, EC, turbidity), ion-prone material (Cl, F, NH_4), VOCs and bio-monitor in water flowing into the Rhine River and the Meuse River. The central and regional governments work together to manage the early alarm system, although each of them plays its own role and has a different water

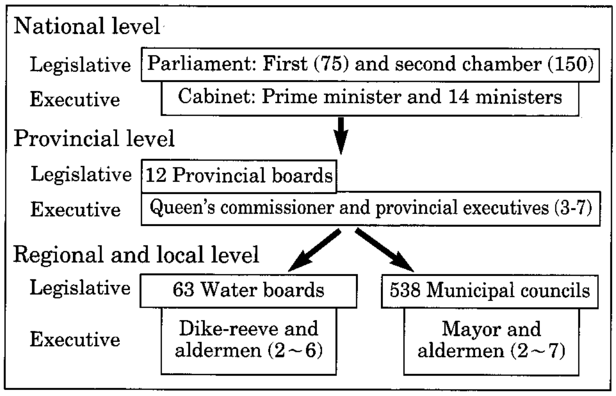

Fig. 2. The water management Hierarchy in Netherlands (Pieter Huisman, 2002).

board. The alarm criteria for water pollution are determined through the discussion between drinking water manufacturers, public health specialists and environmental engineers. A pollution alarm is issued according to the result from biological and chemical analysis; if the concentration of a pollutant keeps exceeding an alarm criteria for at least 2 hours and would affect ecosystem and human health (Fig. 2).

Examining Propriety of Water Pollution Alarm Criteria

The criteria for water pollution alarm of the AWQMS in Korea were established in compliance with "The Principle of Establishing Alarm Criteria for Each Parameter (The Ministry of Environment, 2008)." The criteria are also considering the general water quality of each specific site; they were set up for drinking water, and water of rivers receiving and not receiving industrial effluent. When the criteria was set up, water quality data collected for the past year were statistically analyzed. Sometimes, information obtained via manual water analysis was utilized.

Examining a Link Between Water Pollution Alarm System and National Emergency Management Guideline

The existing 2 stages (low, high) alarm system was modified to make 4 stages (low, medium, high, severe) alarm system by examining "National Emergency Management Guideline (NSC, 2004)."

The detail description of the National Emergency Management Guideline is shown in Table 3.

Table 3. The alarm system set by National Emergency Management Guideline (NSC, 2004).

Type	Description	Note
Low (L, Blue)	The status that an indication exists but activity level is very low and it is unlikely to increase to natwional crisis in the near future	Monitoring the indication
Medium (M, Yellow)	The status that an indication is comparatively active and it tend to develop to the national crisis	Cooperation system
High (H, Orange)	The status that an indication is very active and the developing speed and possibility is very high to come to the national crisis	Checking the defense procedure
Severe (S, Red)	The status that an indication is very active and it is certain to come to the national crisis as the developing speed and possibility is severe	Plunging into immediate defence activity

Table 4. The current alarm system of AWQMS (NIER, 2006).

Stage	Conditions of issuing alarm and revocation
Low	1. Two or more of pH, DO, EC, TOC and VOCs exceed their alarm criteria for more than 30 mins or two or more of 9 VOCs exceed their alarm criteria for more than 30 mins 2. The bio-monitor level exceeds its criteria for more than 30 mins (in case where daphnia are used for the bio-monitor, they should exceed at both chamber)
High	1. The bio-monitor exceeds its alarm criteria for more than 30 mins and one or more of pH, DO, EC, TOC and VOCs exceed their alarm criteria 2. The bio-monitor exceeds twice of its alarm criteria twice for more than 30 mins and one or more of pH, DO, EC, TOC and VOCs exceed twice of their alarm criteria 3. Two or more of pH, DO, EC, TOC and VOCs exceed twice of their alarm criteria for more than 30 mins or two or more of 9 VOCs exceed their alarm criteria twice for more than 30 mins 4. A real pollution accident is confirmed after low alarm issued
Revocation	Calling off the issued alarm when the issuing condition is disappeared

Table 5. The revised alarm system.

Stage	The condition of issuing and Revocation
Low	1. Two items or more exceed their alarm criteria among pH, DO, TN, TP, EC, TOC, VOCs, phenol, heavy metals (Cu, Pb, Zn, Cd) 2. When bio-monitor exceeds its criteria, the status should be preserved over 30 minutes
Median	1. Two items or more exceed their alarm criteria twice among pH, DO, TN, TP, EC, TOC, VOCs, phenol, heavy metal (Cu, pb, Zn, Cd) 2. While bio-monitor exceeds its criteria over 30 minutes, one item or more exceed their alarm criteria among pH, TOC, VOCs, phenol, heavy metals (Cu, Pb, Zn, Cd) or one item or more exceed their alarm criteria twice among EC, TN, TP, TOC, Chl-*a*
High	While bio-monitor exceeds its criteria over 30 minutes, one item or more exceed their alarm criteria three times among pH, DO, TN, TP, EC, TOC, VOCs, phenol, heavy metalsl (Cu, Pb, Zn, Cd)
Severe	Following low alarm, the developing rate is severe as well as quite fast and being ascertained as a pollution accident
Revocation	Calling off the issued alarm when the issuing condition is lower than Low stage

※Note : 1. The Minister of Environment is in charge of announcing monitoring parameters and their alarm criteria
2. The exceeding criteria of pH means that the status less than pH 5 or more than pH 11 is preserved over 30 minutes

This guideline classifies an accident to 4 different stages (i.e., low, medium, high and severe) according to the extent of the accident. In general, such of the 4 stages is issued sequentially. Sometimes one stage can be skipped to higher stage when a situation is severe and urgent.

Table 6. The result of examining the alarm criteria by each item (I).

	Site	Item	Existing criteria	Operation result ('03~'06)	Operation result ('07)	Final criteria
Han River	H2	TOC ($mg L^{-1}$)	>5.0	>4.5	>4.0	>4.0
	H3	TOC ($mg L^{-1}$)	>11.0	>9.0	>6.2	>6.5
Nakdong River	N1	EC ($ms cm^{-1}$)	>0.50	>0.40	>0.32	>0.35
		TN ($mg L^{-1}$)	>10.0	>5.0	>4.4	>4.5
		NO_3-N ($mg L^{-1}$)	>5.0	>4.0	>2.9	>3.0
	N2	DO ($mg L^{-1}$)	<0.3	<3.0	<1.5	<3.0
	N3	EC ($ms cm^{-1}$)	>0.50	>0.45	>0.31	>0.35
	N4	EC ($ms cm^{-1}$)	>1.10	>0.75	>0.55	>0.55
	N5	EC ($ms cm^{-1}$)	>2.00	>1.90	>1.20	>1.20
	N6	EC ($ms cm^{-1}$)	>0.70	>0.60	>0.51	>0.55
	N7	EC ($ms cm^{-1}$)	>0.70	>0.60	>0.41	>0.45
	N8	EC ($ms cm^{-1}$)	>0.70	>0.50	>0.39	>0.40
	N9	EC ($ms cm^{-1}$)	>0.70	>0.50	>0.43	>0.45
	N10	EC ($ms cm^{-1}$)	>0.50	>0.30	>0.20	>0.20
	N12	EC ($ms cm^{-1}$)	>2.00	>1.00	>0.79	>0.80
	N13	EC ($ms cm^{-1}$)	>0.70	>0.60	>0.48	> 0.50
Keum River	K1	EC ($ms cm^{-1}$)	>3.00	>1.00	>0.80	>0.80
		TOC ($mg L^{-1}$)	>10.0	>9.5	>7.4	>7.5
	K2	DO ($mg L^{-1}$)	<1.2	–	<1.3	<1.3
		EC ($ms cm^{-1}$)	>1.00	>0.90	>0.62	>0.65
Yongsan River	Y1	TOC ($mg L^{-1}$)	>12.0	>10.0	>6.4	>6.5
	Y2	EC ($ms cm^{-1}$)	>0.20	>0.15	>0.12	>0.12
	Y4	pH	<6.0, >10.0	<6.5, >9.5	<6.8,>9.4	<6.8, >9.4
		DO ($mg L^{-1}$)	<3.0	<4.0	<2.6	<4.0
		EC ($ms cm^{-1}$)	>0.75	>0.30	>0.26	>0.30

Table 7. The result of examining the alarm criteria by each item (II).

Site	Item criteria	Existing criteria	Amended	Amendatory reason
H12	DO ($mg L^{-1}$) EC ($ms cm^{-1}$)	<5.0 >2.0	<3.0 >3.0	The DO and EC frequently exceeded alarm criteria because flux is insufficient and algae including organic materials affect it without pollution accident
N1	PO_4-P ($mg L^{-1}$)	>0.1	>0.5	The phosphate frequently exceed alarm criteria because of non-point sources during heavy rain in summer
N12	DO ($mg L^{-1}$)	<5.0	<4.0	The river has a characteristic that the DO is always maintained at low value even without any pollutant influx

After conducting a survey of operators with Environmental Management Corporation (EMC) which is in charge of AWQMS operation, it was found that the current alarm system could result in a confusion due to its 2 stages alarm system (Table 4). Therefore, it was decided to modify the current alarm system to comply with the guideline and to take advantage of the statistical data analysis performed to set up water quality criteria and alarm system by developed countries.

Proposal of 4 Stage Alarm System for AWQMS

In order to make the alarm systems more effectively, current 2-stage alarm system was modified to have 4-stage (Low=L, Medium=M, High =H, Severe=S). In the case of the L-stage of the proposed alarm system, Total Nitrogen (TN), Total Phosphrous (TP), phenol and heavy metals is added to the parameters which is monitored at the L-stage of the current 2 stage alarm system. The

Table 8. The alarm criteria for each water quality parameter.

River Site	Item																		
	pH	DO ($mg\ L^{-1}$)	EC ($ms\ cm^{-1}$)	TOC ($mg\ L^{-1}$)	TN ($mg\ L^{-1}$)	TP ($mg\ L^{-1}$)	Chl-*a* ($mg\ m^{-3}$)	Turbidity (NTU)	NH_3-N ($mg\ L^{-1}$)	NO_3-N ($mg\ L^{-1}$)	PO_4-P ($mg\ L^{-1}$)	Cu ($\mu g\ L^{-1}$)	Pb ($\mu g\ L^{-1}$)	Zn ($\mu g\ L^{-1}$)	Cd ($\mu g\ L^{-1}$)	Bio-monitor		Bio-monitor (Daphnia)	
																Bacteria	Fish	Left	Right
H1	<6.0, >9.5	<5.0	>0.15	>2.5													>30		
H2	<6.0, >9.5	<5.0	>0.40	>4.0														>10	>10
H3	<6.0, >9.5	<4.0	>0.80	>6.5														>10	>10
H4	<6.0, >9.0	<5.0	>0.30	>5.0													>30		
H5	<6.0, >9.0	<5.0	>0.30	>5.0													>30		
H6	<6.0, >9.0	<5.0	>0.30	>4.0													>30		
H7	<6.0, >9.5	<5.0	>0.25	>3.0	>5.0	>0.15											>30		
H8	<6.0, >9.5	<5.0	>0.25	>3.5	>5.0	>0.15											>30		
H9	<6.0, >9.5	<5.0	>0.70	>5.0														≤20, ≥750	≤20, ≥750
H10	<6.0, >9.5	<5.0	>0.15	>2.5	>3.0	>0.2		>900											
H11	<6.0, >9.5	<5.0	>0.30	>5.0														>10	>10
H12	<6.0, >9.0	<3.0	>3.0	>15.0														>15	>15
H13	<6.0, >9.5	<5.0	>0.15	>2.5	>3.0	>0.2													
H14	<6.0, >9.5	<5.0	>0.30	>3.0	>3.5(>4.5)	>0.2	>15.0												
K1	<6.0, >8.5	<1.5	>0.80	>7.5												<20		≤20, ≥555	≤20, ≥555
K2	<6.0, >8.5	<1.3	>0.65	>8.0														≤20, ≥586	≤20, ≥586
K3	<6.0, >10.0	<5.0	>0.20	>3.0	>3.0	>0.3	>15.0											≤20, ≥711	≤20, ≥711
K4	<6.0, >9.0	<3.5	>0.60	>5.0														≤20, ≥785	≤20, ≥785
K5	<6.5, >9.5	<5.0	>0.50	>5.0														≤20, ≥723	≤20, ≥723
K6	<6.0, >10.0	<5.0	>0.20	>3.0	>3.0	>0.3	>15.0											>10	>10
K7	<6.0, >10.0	<5.0	>0.20	>5.0	>3.0	>0.3	>15.0											>10	>10
K8	<6.0, >9.0	<5.0	>0.30	>3.0	>3.0	>0.3			>0.5	>2.5								>10	>10
K9	<6.0, >10.0	<3.5	>0.60	>7.0	>7.0	>0.5													
K10	<6.0, >9.5	<5.0	>0.20	>3.0	>3.0	>0.1													
K11	<6.0, >9.5	<4.5(<3.5)	>0.30	>5.0	>5.0	>0.5													
N1	<6.0, >9.0	<5.0	>0.35	>5.0	>4.5	>1.0	>50.0		>1.0	>3.0	0.5	>5							≤20, ≥500
N2	<6.0, >8.5	<3.0	>2.00	>15.0									>50	>20	>1,000	>10			>15
N3	<6.0, >9.0	<5.0	>0.35	>5.0															>15
N4	<6.0, >9.0	<5.0	>0.55	>7.5															>15
N5	<6.0, >9.0	<5.0	>1.20	>10.0															>15
N6	<6.0, >9.5	<5.0	>0.55	>7.0															≤20, ≥715
N7	<6.0, >9.5	<5.0	>0.45	>7.0															≤20, ≥716
N8	<6.0, >9.5	<5.0	>0.40	>7.0															≤20, ≥800
N9	<6.0, >9.7	<5.0	>0.45	>7.0															≤20, ≥950
N10	<6.0, >9.0	<5.0	>0.20	>5.0															>15
N11	<6.0, >9.5	<5.0	>0.50	>5.0				>900											>15
N12	<6.0, >8.5	<4.0	>0.80	>15															>15
N13	<6.0, >9.0	<5.0	>0.50	>7.0															>15
Y1	<6.0, >9.0	<3.0(<1.0)	>0.75	>6.5														>40	
Y2	<6.0, >9.5	<5.0	>0.12	>2.5	>1.0	>0.2	>15.0											>40	
Y3	<6.0, >9.0	<3.0(<2.0)	>0.60	>8.0														>40	>10
Y4	<6.5, >9.5	<4.0	>0.30	>12.0															>10
Y5	<6.0, >10.0	<5.0	>0.20	>5.0	>3.0	>0.15	>25.0												>10
Y6	<6.0, >9.5	<5.0	>0.15	>5.0	>1.0	>0.15	>15.0										>20		
Y7	<6.0, >9.0	<5.0	>0.20	>5.0	>3.0	>0.15													>10

VOCs	Dichloromethane	1,1,1-Trichloroethane	Benzene	Carbontetrachloride	Toluene	Trichloroethylene	Ethylbenzene	Xylene	Tetrachloroethylene
Unit ($\mu g\ L^{-1}$)	>20	>100	>10	>2	>700	>30	>300	>500	>10

※ DO (considering weather condition) : K11 (Jul.~Aug. : <3.5 $mg\ L^{-1}$), Y1 (Nov.~Mar. : <3.2 $mg\ L^{-1}$, Apr.~Oct. : <1.0 $mg\ L^{-1}$), Y3 (Oct.~Apr. : <3.0 $mg\ L^{-1}$, May~Sep. : <2.0 $mg\ L^{-1}$)
※ TN (considering weather condition) : H14 (Jul. ~ Sep. : >4.5 $mg\ L^{-1}$)

same alarm criteria as that of the current system was applied to the bio-monitor. M-stage and H-stage were classified based on the concentration of individual pollutants. If any of the individual pollutants exceeds double of its alarm criteria, then alarm of M-stage is issued. If any of the individual pollutants exceeds triple of its alarm criteria, then alarm of H-stage is issued. If the pollution accident is confirmed after the alarm of H-stage is issued, S-stage is issued (Table 5).

Suggestion of the New Alarm Criteria on Water-Quality Parameters

Water quality data collected at each AWQMS station from 2003 to 2006 were extensively examined and compared with the current alarm criteria. After comparing the data and existing alarm criteria, the highest value of annually collected data was set as a new alarm criteria (but in case of DO, low pH, low impulse, lower value is established). Water quality standard for drinking water was applied to the alarm criteria for VOCs, phenol, and heavy metals. Table 6 shows strengthened alarm criteria of each water quality parameter. There are some sites in which alarm criteria should be adjusted to make surveillance more effective, because water quality has been getting better through improved wastewater treatment facilities around the sites. Meanwhile other sites such as Shincheon, Namcheon, and Seongju were needed to loose the criteria because several parameters too much frequently exceed its alarm criteria without causing any adverse effect on water environment (Table 7).

The alarm criteria for new monitoring sites (Chungju, Bonghwangcheon, Iwon, Tamjinho, Gurye) were established by examining the manual water monitoring data and water characteristics described in "The principle for establishing alarm criteria by each item".

For the next few years, we will examine the water quality data collected at each AWQMS station and determine how effective the modified alarm system in finding a pollution accident and issuing an alarm. In fact, the alarm criteria should be continuously modified to face varying environmental and operation conditions.

LITERATURE CITED

Abschlussbericht von EASE (Entwicklung von Alarmkriterien und Stoerfallerfassung in Messstationen (im Elbeeinzugsgebiet) fuer die internationale Gefahrenabwehrplanung). 2004. Hamburg Institut fuer Hygiene und Umwelt.

Environmental Management Corporation (EMC). 2007. The operation and management manual for the Automatic Water Quality Monitoring System.

National Security Council (NSC). 2004. National Emergency Management Guideline. No. 124 by precedential instruction.

National Institute of Environmental Research (NIER). 2006. Adjusting Alarm Criteria and Parameter of Automatic Water Quality Monitoring System in Korea. 301p.

The Ministry of Environment, Japan. 2005. The Environmental White Paper in Japan.

The Ministry of Environment, Korea. 2008. The operation plan of the Automatic Water Quality Monitoring System. 50p.

Umweltbundesamt (UBA). 2004. Development of Alarm Criteria and Detection of Major Incidents in Measuring Stations in the Elbe Catchment Area for International Emergency Planning (EASE). 332p.

Pieter Huisman. 2002. How the Netherlands Fiance Public Water Management. Official Publication of the European Water Association (EWA). 11p.

(Manuscript received 23 October 2008,
Revision accepted 29 November 2008)