Performance evaluation program of water treatment plant in Korea

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Abstract Recognizing the composite correction program (CCP) has been successful in improving drinking water quality in the USA, the Ministry of Environment (MoE) of Korea has initiated a similar program since 1998. After three years' work, the research team has proposed an evaluation program. Water treatment plants have been classified into four groups based on their capacities because this has best represented current standings of the plant. Group 1 consists of small plants having a capacity of less than 5,000 m^3/day. The plants in Group 4 have capacities of more than 100,000 m^3/day. Group 2 consists of small to medium sized plants of 5,000–50,000 m^3/day, whereas the plants in Group 3 have capacities between 50,000 m^3/day and 100,000 m^3/day.

The evaluation documents and the treatment goals for each group also have been established in consideration of manpower and characteristics of the facilities. The disinfection goal has been set up to ensure 0.5 log removal of *Giardia* regardless of the group, whereas the turbidity goal has been differentiated from 0.1 NTU to 0.5 NTU. A flow chart and a detailed inspection list identifying the vulnerable points of the plant have been prepared to help the operators to know how best to improve the performance. The education programs for operators also have been practiced.

The MoE has prepared a quantitative evaluation list to score water treatment plants by their capacities, facilities, manpower and the local government's financial supports. The MoE has graded water treatment plants nationwide and local governments have been ranked by the plants in their areas. The resulting grades have been announced annually so that community citizens knew where their community was positioned and how much attention their local government has paid to the waterworks. The performance evaluation program strongly backed up by the MoE is going to be spread out nationwide step-by-step. Thus, things are happening in Korea. However, some of the concepts and principles could be referred to the countries that are planning to introduce a similar program.

Keywords Disinfection; evaluation; performance; turbidity; water treatment plant

Introduction

The composite correction program (CCP) has been successful in improving drinking water quality in the USA (Renner *et al*., 1993; Consonery *et al*., 1997; US EPA, 1991a, 1998). Since 1998, the Ministry of Environment (MoE) of Korea has initiated a similar program. The program has tried to establish the following:

- a series of documents to evaluate the performance of water treatment processes;
- treatment goal for each process such as flocculation, sedimentation, filtration and disinfection;
- flow chart guiding to the vulnerable points in plant;
- education programs to train the performance evaluators;
- implementing means for the state governor to allocate the budget to secure the vulnerable points emerged during the performance evaluation.

A research group has been formed to set up the performance evaluation program for

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water treatment plants in Korea. The interim program has been applied to eight water treatment plants and remodeled to fit better. More plants would be evaluated in 2002 to refine the program. Probably, by the end of 2002, the local governments would be ready to accept the comprehensive evaluation program. Then the program backed up by the MoE would be spread out nationwide step-by-step. The outline of the performance evaluation program in Korea could be referred to the countries that are planning to introduce a similar program.

Objectives of the CCP

Evaluation documents according to the classification of plants

There are 408 rapid sand filtration plants in Korea. Daily production capacities of the plants range from several hundred cubic metres to more than one million cubic metres. Therefore, it was not reasonable to prepare only one set of documents to evaluate the performance of all the water treatment plants. Furthermore, the goals and monitoring frequency of plant performance should be different according to the capacity and the manpower of the plant. The plants have been classified into four groups based on their capacities and documents containing different details for each group have been prepared.

- *Group 1*. Small plants having capacity less than 5,000 m^3/day. There are 212 plants and the population served by the plants in this group is less than 2%. The filters are usually valveless automatic filters and located in small towns.
- *Group 2*. Small to medium-sized plants having a capacity of 5,000–50,000 m^3/day. There are 125 plants and the population served is about 5%. The plants have flocculation chambers, sedimentation basins and gravity filters even though they are small.
- *Group 3*. Medium-sized plants having a capacity between 50,000–100,000 m^3/day. There are 31 plants and the population served is about 10%. The plants are big although their facilities are old and inefficient. Their budget is quite tight.
- *Group 4*. Large plants having a capacity of more than 100,000 m^3/day. There are 40 plants that supply water to about 70% of the population. They are located in larger cities and have well-organized management and operation parties.

The documents to evaluate performance of the plants in each group have been prepared in consideration of their manpower and facilities. The major investigation items for each group have been summarized in Table 1 (Korean Water Resources Corporation, 2001a) As shown, the items for Group 1 are very simple to ensure injection of coagulant, turbidity of filtrate and disinfection process. Because the operators' knowledge of water production is limited, when the operators find something wrong, they are encouraged to call the local government for technical assistance. However, since the operators and the managers in Group 4 plants are well educated and experienced persons, they are expected to put right their facilities only if they identify the vulnerable points. Thus, the evaluation documents for Group 4 are prepared to help them to investigate each detail of the plant including instrumentation.

Setting treatment goals and monitoring frequency

Once the documents have been composed, the treatment goals should be set. Without the established goals to be compared with parameters indicating plant performance, it is hard to say whether the plant performance is satisfactory or not. The performance goals in the USA are unique regardless of plant capacity. However, the manpower and facilities are quite different, based on the plant capacities resulting in divergent performance. If the treatment goals that could be achieved in the plant having a capacity of more than 100,000 m^3/day are applied to the small plants, the operators in small plants may give up being engaged in the performance evaluation program. Thus, the annual turbidity records from 164 plants have been investigated and the 95% turbidity record of each plant has been plotted to establish the

Table 1 Investigative items to evaluate performance of the plant in each group

Group	Investigation items
Group 1	Practice of coagulant injection
	Turbidity of filtrate
	Concentration of residual disinfectant at the effluent of filtrate storage tank
Group 2	Peak flow rate
	Jar test to determine the proper amount of coagulant
	Mixing power in coagulation chamber
	Dividing flocculation chamber
	Residence time in flocculation chamber
	Mudball in filter
	Filtration velocity
	Turbidity of filtrate (6 measurements in a day)
	Amount of backwashing water
	Storage tank volume and low water level
	Concentration of residual disinfectant
Group 3	Investigation items for Group 2 and:
	Injection point of coagulants
	Adequacy of the flocculation chamber structure not to break formed floc
	Inlet and outlet structure of the sedimentation basin
	Occurrence of short circuit in the sedimentation basin
	Depth of media in filter
	Filter backwashing rate and duration
	Control of disinfectant injection
Group 4	Investigation items for Group 3 and:
	Size distribution of filter media
	Amount of suspended solids in the surface layer of filter before and after backwashing (to find the most effective backwashing sequence)
	Filter profile after backwash
	Residence time in the filtrate storage tank at peak flow
	Baffle installation to ensure plug flow in filtrate storage tank
	Adequacy of instrumentation.

turbidity goals. The 95% turbidity record is the numerical value that 95% of the turbidity samples measured in a plant were less than or equal to. The plots have been rearranged according to the pre-classified four groups and shown in Figure 1. (Choi *et al*., in press).

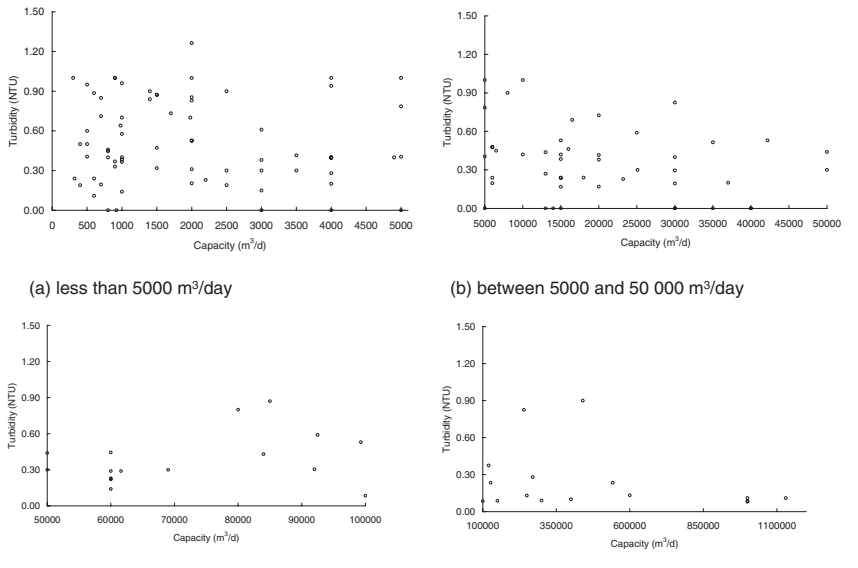

Figure 1 Plots of 95% turbidity record of plants in each group

Based on this investigation, the turbidity goal for each group has been established in consideration of the possible achievement (Korean Water Resources Corporation, 2001a). After the turbidity goal, the target for disinfection process has to be established. The disinfection practices of plants have been investigated and CT values have been calculated. The calculated CT value has been compared with the CT value required to remove 0.5 log *Giardia* and cumulative plots has been prepared in Figure 2. The plot means that the plants that have CT_{cal}/CT_{req} values less than 1 reach 55% among the 307 plants investigated through the design documents. The plants that have CT_{cal}/CT_{req} values less than 1 reach 71% among the 263 plants investigated through operating practice survey. (Yoon *et al.*, 1998). It has been recognized that accomplishing 0.5 log removal of *Giardia* is quite difficult at present. However, the disinfection goal has been set as 0.5 log removal of *Giardia* in consideration of health effect (US EPA, 1991b).

Flow chart guiding to the vulnerable points in a plant

When the plant performance parameters fall short of the goals, a flow chart is needed to determine the vulnerable points in the plant. Without the flow chart, the operators in the plant are unable to determine what to do to improve performance. The potential

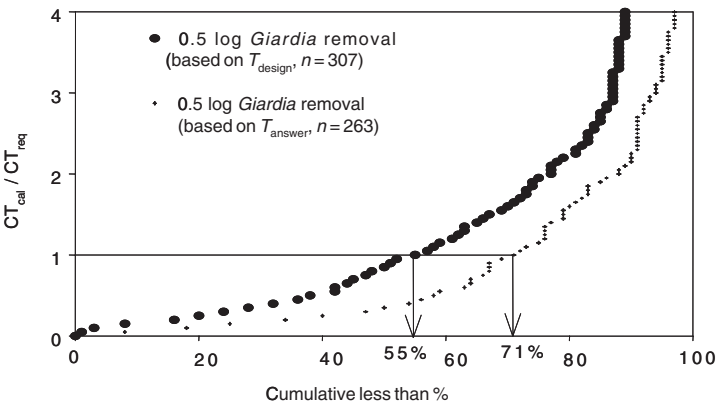

Figure 2 Cumulative plot having the CT_{cal}/CT_{req} value less than the designated value

Table 2 Treatment goals for the plants in each group

Group	Treatment goal	Monitoring frequency
Group 1	Less than or equal to 0.5 NTU in at least 95% measurements taken in a year. 0.5 log removal of *Giardia* by disinfection	At least 4 measurements in a day at a representative point after filter and before chlorination. A CT calculation/day at peak flow
Group 2	Less than or equal to 0.5 NTU in at least 95% measurements taken in a year. 0.5 log removal of *Giardia* by disinfection	At least 6 measurements in a day at a representative point after filter and before chlorination. A CT calculation/day at peak flow
Group 3	Less than or equal to 0.3 NTU in at least 95% measurements taken in a year. No more than 0.5 NTU after backwash. 0.5 log removal of *Giardia* by disinfection	Continuous turbidity monitoring at a representative point after filter and before chlorination. Record the highest turbidity in every 4 hours. A CT calculation/day at peak flow
Group 4	Less than or equal to 0.1 NTU in at least 95% measurements taken in a year. No more than 0.3 NTU after backwash. 0.5 log removal of *Giardia* by disinfection	Continuous turbidity monitoring for every filter. Record the highest turbidity in every 4 hours. A CT calculation/day at peak flow

performance graph which is a useful tool in the comprehensive performance evaluation program in the USA may not be good enough to reveal the real problems of the plant in Korea. Thus, the simplified schematic flow chart guide to the weak points has been prepared and is shown in Figure 3 (Korean Water Resources Corporation, 2001a). The detailed checklists to improve each process have also been prepared. With the schematic flow chart and the detailed check list, the plant operator may find which areas require concentration to improve the facilities and water quality. The necessary instructions to follow the checklist may be found in the performance evaluation documents prepared in advance.

Education program

The educational courses for performance evaluators have been established in the Education Center of Korean Water Resources Corporation which is a government supported water supply company (Korean Water Resources Corporation, 2001b). The education courses consist of lectures and field experience for two weeks. A two week education course may not be enough for the local plant operators to evaluate performance of water treatment plant, but the course helps spread the basic concept and purpose of the performance evaluation program. Furthermore, it has produced helpers in the local government to cooperate with consultants and/or engineers specialized in performance evaluation. About 200 operators and managers have graduated the education course. Since the spirit of the performance

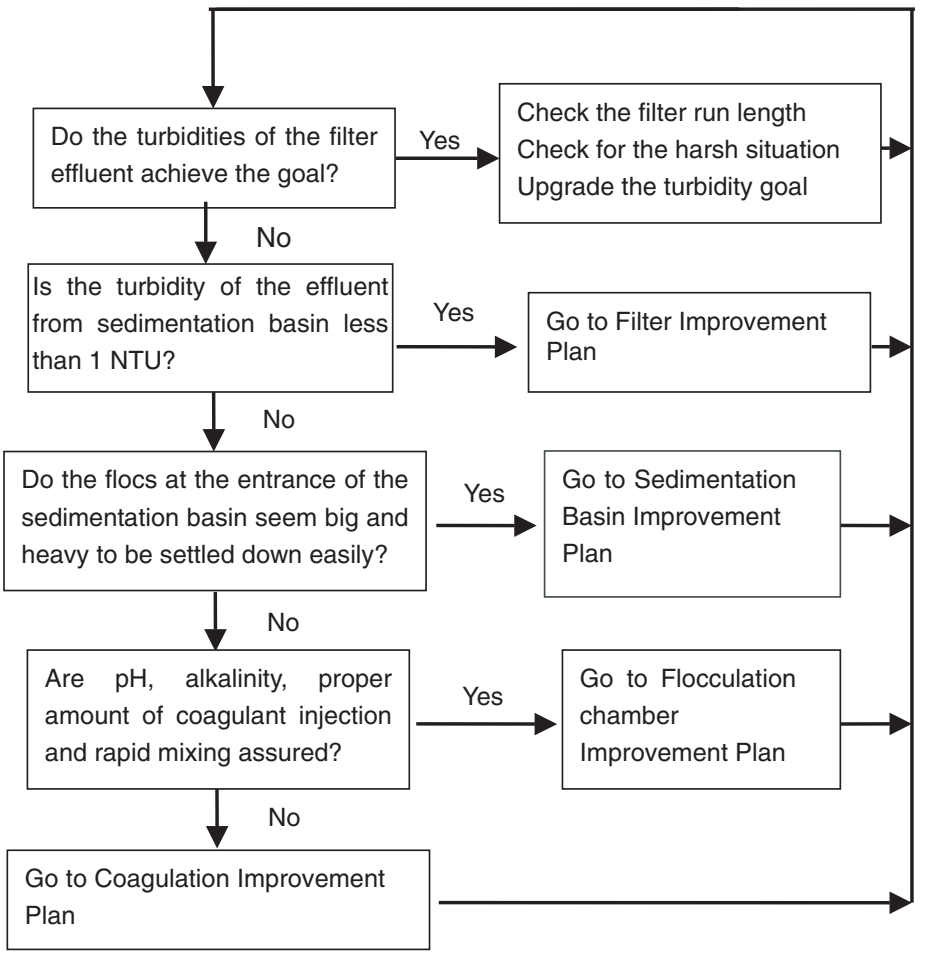

Figure 3 Schematic flow chart as a guide to the vulnerable points in the plant

evaluation program is to make the operators find the vulnerable points of their facilities and improve the most needed facilities, the education program may be composed to help the operators understand the whole process and the correlation among evaluation documents, treatment goals and flow charts with checklists.

Implementing means to secure the vulnerable points

Although the weak points are revealed because of the performance evaluation, local governor may ignore the retrofitting plan because of their tight budget. Therefore, MoE is also setting up several compelling means for local governors to allocate budget with priority to the water works. The MoE has prepared a quantitative list to evaluate water treatment plants by their capacities, facilities, manpower and the local government's financial standing. The evaluation list has been given to each water treatment plant and local government in advance. The MoE has graded water treatment plants nationwide and local governments have been ranked by the plants in their areas. The resulting grades are announced annually, so that community citizens know where their plants are positioned and how much their local government has paid attention to the waterworks. The MoE has practiced this annual grading program for two years. Several local governments have refused to accept the results and some have asked to modify the evaluation list, leading to turmoil. However, it has been a great impact for the local governments. The MoE plans to modify the evaluation list to correctly reflect the situation and continue this program. The MoE also plans to connect the amount of financial support with their effort to improve waterworks.

Summary

The outline of the performance evaluation program in Korea has been introduced. Water treatment plants have been classified into four groups based on their capacities. The evaluation programs also have been prepared to reflect the current status of the plants in each group. The treatment goals for turbidity and disinfection have been established in consideration of the possible achievement. A flow chart and detailed checklist guiding operators to the vulnerable points of the plant have been prepared so that they know where to concentrate to improve plant performance. The education program for operators and the implementing policies have been practiced to help the program be effective. The program, strongly backed up by the Ministry of Environment, is going to be spread out nationwide step-by-step. Thus, things are happening in Korea. However, some of the concepts and principles could be referred to the countries that are planning to introduce a similar program.

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