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Proactive Management of Water Quality in Aquifer Storage Transfer and Recovery

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Abstract

This paper reports the status of an ongoing effort to ensure the quality of water produced at an Aquifer Storage Transfer and Recovery (ASTR) site in South Korea. ASTR is one of the managed aquifer recharge techniques in which water is intentionally recharged to suitable aquifers for subsequent recovery. Surface water injected to an aquifer is converted into water of drinkable quality by natural process. In an ASTR project being developed in the densely populated delta area of the Nakdong River basin, a new framework is being implemented in which water safety is addressed through the analysis and control of biological, chemical, and physical hazards from intake, pretreatment, injection and recovery, to distribution and consumption of water. The task is done by the incorporation of Hazard Analysis and Critical Control Point (HACCP) to the ASTR process. Originated from the food industry, HACCP identifies, evaluates, and controls hazards to ensure the safety of the product. Principles of HACCP were applied to the ASTR water production system. Hazard analysis revealed that most hazardous events were due to the chemicals transported in the basin. Risk assessment was conducted to identify the sources of chemicals which pose a potential threat to the water quality of the ASTR site. Such information will be valuable for the proactive management of chemicals at the basin scale. Critical control points (CCP) were determined by the decision tree method, and critical limits for water quality parameters at CCPs were established subsequently.

Keywords: aquifer storage transfer and recovery, HACCP, water quality, Nakdong River, risk analysis

1. Introduction

The Nakdong River, one of the four major rivers in South Korea, is a main source of drinking water for more than ten million people. The water quality of The Nakdong River has been deteriorated due to both routine emission from cities and water pollution incidents [1]. According to a consumer survey in South Korea, 32.5% of respondents do not drink tap water because they have concerns about raw water quality [2]. Hence, there exist imminent needs to improve drinking water quality and to protect raw water from pollution. To satisfy these needs, two technologies are combined.

First, Aquifer Storage Transfer and Recovery (ASTR) can be an alternative for quality improvement in drinking water production [3]. ASTR is a method to store surface water in an aquifer through an injection well and to recover the water through an extraction well (Fig. 1). A pilot plant is being developed in the delta of the Nakdong River.

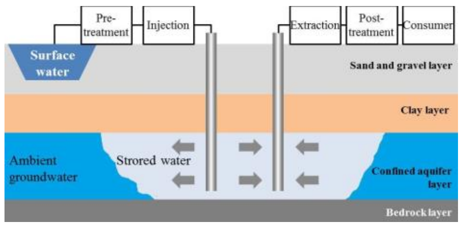

Fig. 1 The process of drinking water supply using ASTR

Second, Hazard Analysis and Critical Control Point (HACCP) is incorporated to ensure the water quality throughout the drinking water production process. HACCP is a tool to assess hazards and establish control systems to guarantee the safety of food. Recently, World Health Organization (WHO) and many countries including U.S and Australia tend to adopt HACCP

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for drinking water supply [4].

2. Method

The pilot study strictly follows the seven principles of HACCP [4]. First, a comprehensive list was created of all microbial, chemical and physical hazards having the potential to cause harm [5].

A unique feature of this study is that we conducted the risk analysis to obtain information for proactive management of chemical hazards in the entire basin. Potential risk can be expressed as a function of the amount of transfers, distance, and toxicity as in Eq. 1.

$$\text{Potential risk} = f(\text{amount of chemical transfers, distance, toxicity}) \quad (1)$$

Since the data of the amount of transfers were insufficient for probabilistic analysis, synthetic data were generated by using the stochastic method. The generated data were fitted to probability distributions. The potential risk for each city can be calculated and the most risky city becomes the target of special monitoring and management to reduce chemical risk posing on the ASTR site.

'Determining the critical control points' is a key issue in HACCP [5]. CCP is a major process to prevent and treat hazards efficiently. CCPs were determined by the decision tree method in which four questions were asked [6].

Then, critical limits for water quality parameters at CCP were established based on the literature and the legal regulations. Critical limits can be considered as the minimum baseline for which hazards do not affect human health.

3. Results and Discussion

Total 114 hazardous events were identified from the entire process in producing drinking water using ASTR. Various chemical, physical and microbiological hazards related to those hazardous events exist. Out of 114, nine major hazardous events were particularly screened; seven out of nine events originated from the catchment area. All these events involved chemical hazards. If the hazardous chemical events occurring in the basin could be properly managed, the risk to the drinking water supply can be significantly reduced.

The potential risk for 42 cities in the basin was analyzed for the period of 2001 to 2012. As for the probability density function needed for synthetic data generation, the Weibull distribution (2-parameter) was the most frequently chosen, while the normal and the Gumbel distribution followed. The city of Yangsan turned out to be the most potentially-risky city in terms of chemical hazards. It means that if a plan to mitigate chemical hazards in the Nakdong River basin is to be implemented, Yangsan should be the first city.

Ten processes for drinking water supply using ASTR were subject to the decision tree analysis. CCPs turned out to be catchment area, pre-treatment, injection, treatment, storage of treated water, and distribution to consumers. The process not classified as CCP is Point of Attention (POA) [7]. Although its importance is relatively lower, proper attention should be given to POAs.

Critical limits for water quality parameters at CCPs were developed to monitor and control microbial, chemical and physical hazards.

4. Conclusions

Integration of ASTR and HACCP was implemented to ensure water quality on drinking water supply in a densely populated area. Natural filtration of low-quality surface water in an aquifer can enhance public trust in water supply among consumers. In addition, the application of HACCP will reduce the risk and eventually improve the negative recognition on drinking water. Although the pilot study is in its early phase, its influence to the water supply system in this region cannot be neglected.

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References

[1] J. K. Lee, T. O Kim, and Y. J. Jung, "Analysis of domestic water pollution accident and response management (in Korean)," Journal of Wetlands Research, vol. 15, no. 4, pp. 529-534, 2013.

[2] S. H. Cho, Y. J. Lee, and H. B. Yoon, "Korean's perception and attitudes regarding their tap water (in Korean)," Korean Public Health Research, vol. 32, no. 2, pp. 130-140, 2006.

[3] P. Dillon, "Future management of aquifer recharge," Hydrogeology journal, vol. 13, pp. 313-316, 2005.

[4] A. Tavasolifar, B. Bina, M. M. Amin, A. Ebrahimi, and M. Jalali, "Implementation of hazard analysis and critical control points in the drinking water supply system," International Journal of Environmental Health Engineering, vol. 1, no. 3, pp. 1-7, 2013.

[5] A. H. Havelaar, "Application of HACCP to drinking water supply," Food Control, vol. 5, no. 3, pp. 145-152, 1994.

[6] Codex (Codex Alimentarius Commission), "Hazard Analysis and Critical Control Point (HACCP) System and Guidelines for its Application." Annex to CAC/RCP 1-1969, Rev. 3, 1997.

[7] T. Dewettinck, E. Van Houtte, D. Geenens, K. Van Hege, and W. Verstraete, "HACCP (Hazard Analysis and Critical Control Points) to guarantee safe water reuse and drinking water production - a case study," Water Science & Technology, vol. 43, no. 12, pp. 31-38, 2001.