Technical Status of Remediation Technologies in Radionuclide-contaminated Groundwater of Nuclear Facilities

In-Ho Yoon*, Hee-Man Yang, Chan-Woo Park, Il gook Kim, Sung-Man Kim, and Kune-Woo Lee
Korea Atomic Energy Research Institute, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Republic of Korea
*ihyoon@kaeri.re.kr

1. Introduction

It was recently reported that radionuclides are contaminated in groundwater at nuclear power plants and nuclear facilities in the United States. The main radionuclides in the groundwater were analyzed as strontium, tritium, cesium, and cobalt. Many institutes have conducted the research development for the monitoring and remediation of radionuclides in groundwater. The pump and treatment (P&T) were applied to remove the radionuclides in the groundwater in various nuclear sites [1,2]. At the Hanford site, strontium in the groundwater was removed using a permeable reactive barrier (PRB) containing the apatite as adsorbent [3]. It was recently reported that the flow of the groundwater is obstructed using the funnel-and-gate method, and contaminated iodine was removed through precipitation using silver chloride at the Savannah River Site [1,2]. This study analyzed the radionuclide contamination and the recent remediation technology used for the groundwater in nuclear facilities.

2. Remediation technology of radionuclide-contaminated groundwater

2.1 *Savannah River Site, USA*

In 2004, the pump and treatment (P&T) system was replaced by a hybrid funnel-and-gate system that was installed about 1,000 feet upgradient from Fourmile Branch. The purpose of the funnel-and-gate is to slow migration of contaminated groundwater and to funnel it through in situ treatment zones at the gates. Extensive geologic characterization showed that much of the plume migrated along "troughs" at the top of the clay layer that confines the lower aquifer. The walls (or engineered subsurface barriers) were installed across these features to slow contaminant migration and force it through the gates (Figure 1).

The treatment zones at the gates attenuate migration of uranium, Sr-90, and I-129 by sorption or precipitation. Tritium migration is slowed by the walls and additional decrease in tritium concentrations is achieved when the stratified plume mixes with less contaminated groundwater as it migrates up through the gates.

Treatment zones for uranium and Sr-90 at the gates are maintained by neutralizing acidity of the groundwater and mineral surfaces with injections of an alkaline solution. This treatment causes sorption of the contaminants and precipitation of uranium phases. Periodic injections are performed, with the frequency at each gate dictated by sentry monitoring wells located downgradient [1,2].

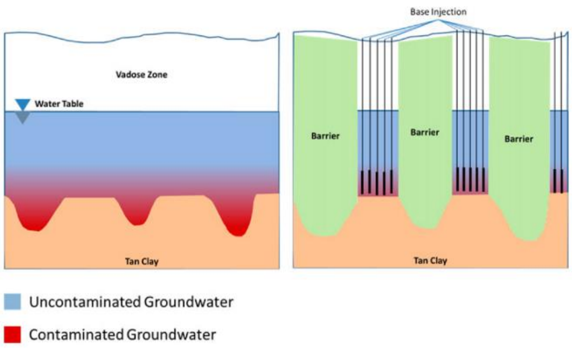

Fig. 1. Cross-sectional conceptual model of funnel-and-gate with base injection system before (left) and after installation [2].

2.2 *Hanford site, USA*

Apatite is a type of calcium phosphate that attracts strontium. In 2006 a test was conducted to see if apatite, in the form of fish bones, could prevent strontium from entering the Columbia River. Apatite was pumped into the ground and the water table along 300 feet of shoreline. It created a sort of curtain through which groundwater passes. As the water passes through, strontium attaches to the calcium phosphate holding it in place.

The strontium concentrations are highest within several feet of the water table. When the river rises, it pushes into the hyporheic zone, elevating the water table and allowing the apatite to capture more strontium. The 2006 test was extremely successful. Since then, more apatite has been injected along the shoreline. Eventually apatite will be injected into about 2,500 feet of shoreline [3].

2.3 Fukushima site, Japan

In Fukushima site, Water used to cool molten fuel during the accident and groundwater have mixed, generating approximately 300 tons of contaminated water per day. Countermeasures are being implemented based on the following three basic polices.

Isolating (groundwater from contamination sources) - Impermeable walls of frozen soil (land side) is that groundwater flows into the buildings are prevented by using ice walls created by freezing soil in the ground around the buildings. Pumping up groundwater (groundwater bypass and sub-drains) is that wells (sub-drains) near the buildings and wells installed in the hills (groundwater bypass) pump up groundwater, minimizing inflows of groundwater into the buildings and the quantity of contaminated water generated.

Preventing leakage of contaminated water - Impermeable steel wall (sea side) is that a 780-meter-long wall of 30-meter-tall steel pipes was constructed on the sea side of Units 1 through 4, which has been gradually improving the water quality in the surrounding sea area. Installation of additional water tanks is that water tanks for storing contaminated water are being systematically installed to ensure adequate storage capacity.

Removing contamination sources - Removal of radioactive materials was focused on cesium and strontium. Removal of radioactive materials other than tritium (hydrogen-3) was conducted and stored in water tanks after removal of radioactive materials other than tritium. The water stored in the tanks has been treated to purification. The question of how to handle the purification treatment water in the tanks is being considered in close consultation with local communities and experts [4].

3. Conclusions

Many institutes have conducted the research development for the monitoring and remediation of radionuclides in groundwater. The pump and treatment (P&T) were applied to remove the radionuclides in the groundwater. However, the treatment cost was sharply increased in the case of long-term operation. The groundwater remediation method should be applied according to the characterization of the nuclear site. In Savannah River site, P&T method was applied in high contaminated site, and Funnel & gate was installed in intermediate contaminated site. In low contaminated site, natural attenuation method was applied with monitoring method. In Koir-1 NPP, the groundwater remediation method (P&T, Funnel & gate, and natural attenuation) will be applied according to characterization of the nuclear site (groundwater flow, geological characteristics, unsaturated zone, saturated zone, and radionuclide).

ACKNOWLGEMENT

This work was supported by a National Research Foundation of Korea grant funded by the Korean government (MSIP) (No. 2017M2A8A1092471).

REFERENCES

[1] Remediation Management of Complex sites. RMCS-1. Washington, D.C.: Interstate Technology & Regulatory Council (ITRC), 2017.

[2] Eddy-Dilek, C., K. Kostelnik, and M.E. Denham. 2016. “The Challenge of Moving Science into Practice: Lessons Learned and New Approaches.” Waste Management Symposium, Phoenix, Arizona, March 6-10.

[3] Cleaning Hanford’s Groundwater & Protecting the Columbia River, Publication Number: 08-05-001.

[4] Important Stories on Decommissioning, Fukushima Daiichi Nuclear Power Station, now and in the future, 2017.