Characterization of Groundwater Colloids Sampled from KAERI Underground Research Tunnel (KURT)

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1. Introduction

It has been reported that colloid formation of radionuclides by sorption of radionuclides on negatively charged naturally occurring colloidal matters can drastically increase the mobility of the radionuclides released from a radioactive waste repository [1]. Therefore, the roles of colloids in the radionuclide migration could be very important in terms of safety assessment on a radioactive waste repository. To assess the effects of mobile natural colloids on the radionuclide migration in geological media, it is necessary to obtain information about colloid characteristics such as elemental composition, size distribution, and concentrations under relevant solution conditions [2]. These properties determine the distribution of the radionuclide between the dissolved and the colloidal phases and the mobility of the radio-colloids in a considered migration medium.

Therefore, in this study, physicochemical properties of natural groundwater colloids sampled from a deep granite groundwater in the KAERI Underground Research Tunnel (KURT) are investigated to characterize the behaviors of natural groundwater colloids in a deep granitic groundwater.

2. Experimental

2.1 Sampling and Separation

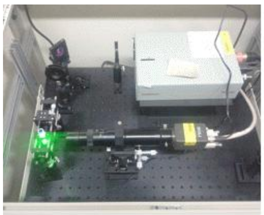
The ground water used in colloid characterization was sampled from a water conducting fracture in depth of 234-244m of the DB-1 borehole using a multi-packer system located in the left module of KURT. About 40 L of groundwater was sampled using a specially designed aluminum carboy with a flow rate of 400 mL/min. A pre-filter of 450 nm pore size (Millipak 40, Millipore) was installed in the sampling line to remove larger particulate matters than 450 nm.

The sampled groundwater is a fresh granitic groundwater of $NaHCO_3$ type with a temperature of 16.8^{o}C, pH 8.5, Eh of ~190 mV, electric conductivity (EC) of 174 μS/cm, and dissolved oxygen of 0 ppm.

A tangential flow ultra-filtration system (Pellicon Mini, Millipore) with an ultra-filter of 10,000 NWML pore size (BIOMAX, Millipore) was used to separate and concentrate groundwater colloids from the sampled groundwater. About 40 L of groundwater was concentrated into 400 mL using the tangential flow ultra-filtration system.

2.3 Characterization Methods

For the characterization of groundwater colloids, various analytical methods were used. Elemental compositions of groundwaters before and after the tangential flow ultra-filtration were measured by ICP-MS (inductively coupled plasma mass spectrometry; Ultramass 700, Varian) and then compared each other to determine the elemental composition of the groundwater colloids. The composition and size of the groundwater colloids were also analyzed by a FE-TEM (Field Emission-Transmission Electron Microscopy, JEM-2100F, JEOL) with EDX (Energy Dispersive X-ray Spectroscopy, Oxford INCA Energy) using the concentrated groundwater by the tangential flow ultra-filtration. Finally the size and concentration of the groundwater colloids were determined by a LIBD (Laser-Induced Breakdown Detection) system using the pre-filtered groundwater sample [3]. Figure 1 shows the LIBD system.



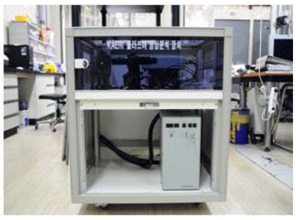


Fig. 1. A LIBD system used to determine the size and concentration of groundwater colloids.

3. Results and Discussion

3.1 Analysis by ICP-MS with EDX

Table 1. The determined elemental concentrations of the groundwater colloids analyzed by ICP-MS.

Element	Concentration	
	ppb (μg/L)	%
Ca	13.5	66.0
K	0.1	0.6
Mg	3.4	16.4
Na	1.8	8.6
Si	1.7	8.4
Total	20.5	100.0

Table 1 shows the result of groundwater colloid characterization using ICP-MS. After separation and concentration of groundwater colloids using the tangential flow ultra-filtration system, the concentrations of the some major elements such as Ca, K, Mg, Na, and Si composing of the groundwater colloids was estimated and shown in Table 1. The groundwater colloids are mainly composed of Ca and Mg and little of K, Na, and Si. The concentration of the groundwater colloids based on the ICP-MS analysis was also calculated as about 20 ppb.

3.2 Analysis by FE-TEM with EDX

The result of groundwater colloid characterization by FE-TEM is shown in Fig. 2. The concentrated groundwater sample by the tangential flow ultra-filtration was used for the FE-TEM analysis.

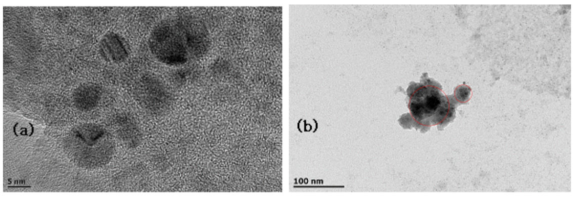


Fig. 2. KURT groundwater colloids analyzed by FE-TEM: (a) very small colloids with a size of about 5 nm, (b) most of colloids were observed to have a size of about 100 nm. Red circle is the region of EDX analysis.

As shown in Fig. 2(a), very small colloidal nano-particles about 5 nm were found and these particles are presumed as crystalline Fe-oxides. However, most of groundwater colloids were observed to have a size of about 100 nm as agglomerates of smaller particles as shown in Fig. 2(b).

The result of EDX analysis also reveals that the groundwater colloids are composed of Al (9.8 atomic %), Si (37.5%), P (30%), S (5.9%), Ca (13.6%), and Fe (3.1%). This result is also similar to the analysis result by ICP-MS.

3.3 Analysis by LIBD

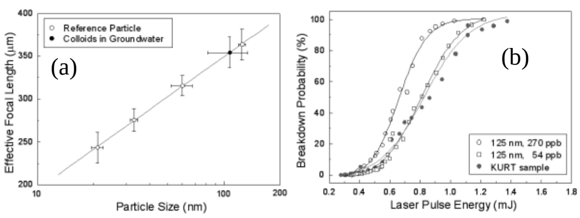


Fig. 3. Result of characterization of KURT groundwater colloids by LIBD [3].

As shown in Fig. 3(a), the result of colloid characterization by LIBD shows that average size of the KURT groundwater colloids is 108±26 nm. It is noticeable that this colloid size is very similar to the size measured by FE-TEM. The concentration of KURT groundwater colloid estimated by comparing S-curve with standard colloid particles is less than 50 ppb, as shown in Fig. 3(b). This colloid concentration is also similar to the concentration estimated by ICP-MS.

3.4 Comparison of Results

The characteristics of groundwater colloids sampled from KURT are compared with other results and shown in Table 2.

Table 2. Comparison of the characteristics of the groundwater colloids with those of other studies.

Sampling site	Depth (m)	pH	Concentration (ppb)	Size (nm)	Composition
Sweden					
Non-saline	275	8.0	43±43	50~500	clay, silica $Fe(OH)_3$
Saline	500	7.9	20±20	50~500	clay, silica $Fe(OH)_3$
Switzerland					
Leuggern	1650	7.9	20	10~1000	illite, silica
Zurzach	500	8.0	10	10~1000	illite, silica
Canada URL	500	~8.0	300±300	5~1000	clay, organic calcite
	240	~7.0	~264	1~450	organics carbonates aluminosilicates
Korea Yuseong	450	~9.9	~200	400	aluminosilicates Fe-oxides calcite
Korea KURT	240	8.5	20	50-100	aluminosilicates organics Fe-oxides calcite

3. Conclusions

In this study, the groundwater colloids sampled from KURT were characterized by various analysis methods. The results show that the KURT groundwater colloids are presumed to exist as aluminosilicates, calcite, metal oxides, and organics. The average size and concentration of the KURT groundwater colloids are about 100 nm and 20 ppb, respectively. The obtained data about groundwater colloids will be used in evaluating the roles of natural colloids in the radionuclide migration through fractured rock media.

ACKNOWLEDGEMENT

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