Hydrogeochemistry and Origin of Saline Groundwater in Fennoscandian and Canadaian Shields

Eunhye Kwon [a*], Kyung-woo Park [a]
[a]*Disposal Performance Demonstration R&D Division, Korea Atomic Energy Research Institute,111 Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon*
[*]*Corresponding author: ehkwon@kaeri.re.kr*

***Keywords :** high-saline groundwater, seawater intrusion, glacial/interglacial period, hydrogeochemistry

1. Introduction

Deep saline groundwater, being geochemically stable and having a long residence time without participating in meteoric water circulation, is reported to be a favorable condition for locating spent nuclear fuel disposal facilities[1]. In the crystalline rock of the Fennoscandian Shield where Finland and Sweden are located, as well as in the Canadian Shield where Canada is located, saline groundwater has been observed. On the other hand, South Korea exhibits fresh water characteristics, despite having similar crystalline bedrock. Therefore, this study was conducted to investigate the mechanisms behind salinity differences and to compare the disposal safety between saline groundwater and fresh groundwater conditions.

2. Methods and Results

2.1 Classification of groundwater salinity

Saline groundwater is classified into four groups based on Total Dissolved Solids(TDS): fresh water, brackish water, saline water, and brine water(Fig. 1)[2]. The Cl concentration is approximately 50-60% of TDS, and the salinity of seawater is reported to be around 35‰[3]. Therefore, seawater belongs to the saline water group. Generally, groundwater exhibits TDS concentrations of less than 0.5g/L, with increasing salinity observed as a result of seawater intrusion.

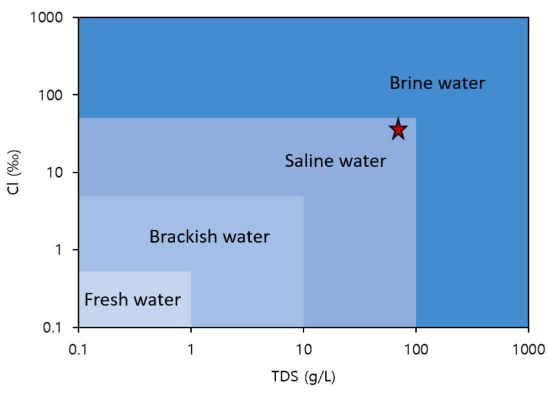

Fig. 1. Salinity classification of groundwater according to TDS and Cl concentration (red star indicates seawater)

2.2 Groundwater distribution in crystalline rock

Crystalline rock is preferred as a disposal site due to its high strength and stability, low thermal sensitivity, and low permeability[4].

2.2.1 The case of Fennoscandian and Canadian Shields

The saline water of the Fennoscandian and Canadian Shields have various origins and ages with several layers. In addition, the salinity and groundwater age increases as the depth increases, and it is reported that brine water with a higher salinity than seawater exists at depths of 1000 to 2000m.

2.2.2 The case of South Korea

Unlike Finland, Sweden, and Canada, there have been no reports of groundwater in South Korea exhibiting salinity exceeding that of seawater. Furthermore, groundwater showing salinity higher than freshwater is mostly influenced by seawater intrusion, particularly in coastal areas.

2.3 The origin of saline groundwater in Fennoscandian and Canadian Shields

The groundwater in the Fennoscandian Shield exhibits Na-Ca-Cl type, where the groundwater in the Canadian Shield shows Ca-Na-Cl type(Fig. 2)[5].

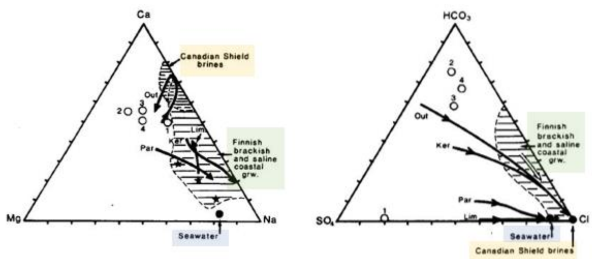

Fig. 2. Comparison of water quality types between Fennoscandian shield and Canadian Shield [taken from [5]].

Through δ18O, δD, δ34S analysis, the origins of saline groundwater in each shield were traced. Groundwater from both the Fennoscandian Shield and the Canadian Shield showed origins from the Paleozoic and Mesozoic seawaters. Groundwaters in the Canadian Shield also showed origins from water-rock interaction processes such as dolomitization and silicate dissolution [6].

2.4 The formation mechanism and characteristics of saline groundwater in Feenoscandian and Canadian Sshields

The saline groundwater in the Fennoscandian and Canadian Shield has been influenced by the ice sheets and geological changes during the ice ages. Seawater that infiltrated during the Paleozoic and Mesozoic became trapped due to permafrost formation during the glaciations, thus being unable to participate in meteoric water circulation, leading to salt concentration. As the ice sheets retreated after glaciations, the bedrock thawed, allowing meteoric water to recharge and reconnect with the North Sea. As a result of this process, infiltration of modern seawater intruded to the aquifers, leading to the differentiation of saline groundwater layers based on density differences. Consequently, groundwater layers with various origins and salinities were formed in shields.[3, 5].

2.5 The comparison of disposal safety between saline and freshwater environments

The deep, highly saline groundwater within the shields is considered stable geochemically and hydrogeologically, due to factors such as density effects and long residence times, making it potentially stable in response to changes in surface environments[7]. Therefore, Finland, Sweden, and Canada consider the deep brine regions within the shields as candidate sites for safe geological disposal.

However, high Cl concentrations can affect the corrosion of construction materials, equipment. Additionally, high Cl concentrations with high temperature and low pH conditions, it can reduce the corrosion resistance of copper[3]. Radionuclides retardation properties(solubility, diffusivity, sorption) also vary depending on salinity. In this regard, environments with high salinity may not be favorable. Therefore, if South Korea’s fresh water disposal environment is geologically stable and less influenced by other environments such as surface water, it may be considered more safe.

3. Conclusions

Finland, Sweden, Canada and South Korea all prefer crystalline rock as disposal sites for spent nuclear fuel. However, the distribution of groundwater salinity appears different. Finland, Sweden, and Canada have high-saline groundwater of various origins and residence times present in the deep underground. The origins of this saline groundwater are attributed to Paleozoic and Mesozoic seawater intrusion and water-rock interactions, influenced by glacial and interglacial periods’ ice sheets and geological changes. In contrast, the presence of groundwater exceeding seawater salinity has not been reported in Korea. This is due to differences in the geological location and topographical features during the Paleozoic and Mesozoic eras, as well as the effects of glacial/interglacial periods.

ACKNOWLEDGEMENTS

This work was supported by the Institute for Korea Spent Nuclear Fuel (iKSNF) and National Research Foundation of Korea(NRF) grant funded by the Korea government(Ministry of Science and ICT, MSIT)(No.2021M2E1A1085200)

REFERENCES

[1] R. Blomqvist, Hydrogeochemistry of deep groundwaters in the central part of the Fennoscandian Shield. Espo, Geological Survey of Finaland, Nuclear Waste Disposal Research, Report YST-101, 1999.

[2] S. N. Davis, The chemistry of saline waters, Groundwater, Vol.2, p.51, 1964

[3] POSIVA, Groundwater salinity at Olkiluoto and its effects on a spent fuel repository, POSIVA 2000-11, 2000

[4] NEA, 2011 NEA Annual Report, Nuclear Energy Agency, 2011

[5] P. A. Nurmi, I. T. Kukkonen, P. W. Lahermo, Geochemistry and origin of saline groundwaters in the Fennoscandian Shield, Applied Geochemistry, Vol.3, pp.185-303, 1998

[6] D. J. Bottomley, I. D. Clark, N. B. J. Battye, T. Kotzer, Geochemical and isotopic evidence for a genetic link between Canadian Shield brines, dolomitization in the Western Canada Sedimentary Basin, and Devonian calcium-chloridic seater, Canadian Journal of Earth Sciences, Vol.42, pp.2059-2017, 2011 et al., 2011

[7] Y. J. Park, E. A. Sudicky, J.F. Sykes, Effects of shield brine on the safe disposal of waste in deep geologic environments, Advances in Water Resources, Vol.32, pp.1352-1358, 2009.