Water Content and Dynamics in Antarctic Soils at Subfreezing Temperatures

Vugmeyster, L.; Clark, M.A. (U. of Alaska Anchorage, Chemistry); Hagedorn, B. (U. of Alaska Anchorage, ASET Laboratory)

Introduction

Survival of liquid water at subfreezing temperatures is crucial for formation of landscapes and maintenance of biological life. We investigated water content and dynamics in Antarctic soils from McMurdo Dry Valleys of Antarctica using static deuterium NMR measurements and impedance spectroscopy. We also probed the effect of an antifreeze peptide from Antarctic yeast organisms on water properties. Long-term goals of the study are to investigate i) the role of interfacial interactions in liquid water content and its molecular dynamics in frozen, ice rich ground; ii) how the effect of interfaces compares to freezing point depression by salts; iii) how the quantity and activity of unfrozen water affects the transport of solutes and water into frozen ground; and iv) the effects that antifreeze peptides from Antarctic yeast organisms have on liquid water content, molecular dynamics, and interfacial interactions.

Experimental

We utilized the 400 NMR spectrometer at the NHMFL for static deuteron NMR measurements (line shapes and longitudinal relaxation). In addition, we conducted impedance measurements at the same temperature conditions as NMR using equipment provided by Peter Gor'kov, Senior Research Associate at the NHMFL. All measurements were conducted on soil samples hydrated to 20% with D_2O in the range of temperatures between 25 to -50 ^oC.

Results and Discussion

Water content and hysteresis behavior of soils were probed for about 10 samples with a range of salt concentrations ranging from 2 x10^3 to 3 x10^6 ppm. All soil samples indicated presence of liquid water below the freezing point of D_2O and exhibited hysteresis behavior. The results from NMR analysis and impedance measurements were in agreement. (Figure 1). The results strongly suggest the importance of soil matrix on the mechanism of soil survival. Antifreeze peptide broadened the phase transition region and, interestingly, decreased the extent of hysteresis.

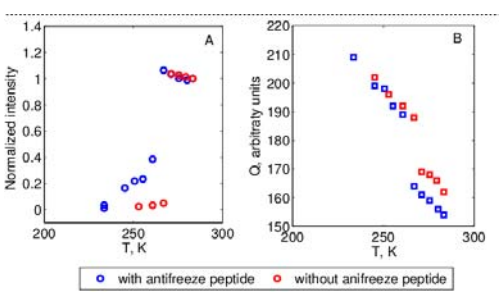

Fig.1 Characteristic plots of A) Normalized intensity of water from deuteron NMR and B) A measure of impedance given by the Q factor as a function of temperature. Results are shown with and without the presence of the antifreeze peptide.

Conclusions

Soil matrix plays an important role in determining the amount of water present in sub-freezing temperatures in Antarctic soils which have a very low percentage of organic matter. Deuteron line shape and relaxation measurement also point to the possible role of water dynamics at soil interfaces as a mechanism for liquid water survival.

Acknowledgements

A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-1157490,the State of Florida, and the U.S. Department of Energy. Additional funding is acknowledged from Environmental and Natural Resources Institute at University of Alaska Anchorage. We also acknowledge NHMFL scientists Riqiang Fu and Peter Gor'kov for technical assistance with the NMR and impedance measurements.

References

[1] Vugmeyster, *et al.,* Solid State NMR, **45-46**, 11-15 (2012).