B-56 Study on Evaluation of Deep Ocean Storage Method of Recovered Carbon Dioxide

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The deep ocean CO_2 storage, in which liquid CO_2 is stored in a dented ocean floor deeper than 3500 m where liquid CO_2 is heavier than ambient seawater, is a promising measure to mitigate the global warming In order to get the necessary data for the evaluation of this method, the properties of CO_2 hydrate, dissolution and diffusion process of stored CO_2 and the biological influence of dissolved CO_2 were investigated through the land-based experiments, the numerical simulation and the *in situ* experiments. On the properties of CO_2 hydrates, the hydrate membrane strength was measured by a modified Du-Nouy type surface tension meter, in fresh water, in saline water and in CO_2 rich water. On the CO_2 dissolution and diffusion process, the numerical simulations for two and three dimensional systems around CO_2 storage site were conducted as a research to the Sojo University. As another trust research, the Tokyo University of Fisheries conducted several *in situ* surveys in Suruga Trough and a deep seafloor depression south east of Haha Island, potential sites of CO_2 storage. A preliminary study on the lowering effect of pH on a deep-sea Copepod (*Neocalanus cristatus*) was also conducted to show an equivalent tolerance range with oceanic zooplankton in shallow waters.

A new ocean disposal scenario of anthropogenic CO_2 was proposed, namely, "*Disposal process of CO_2 in the form of CO_2 hydrate formed in a submerged crystallizer*". Basic data for the process design of the crystallizer are obtained with laboratory scale experiments. A simulation experiment on the injection process of CO_2 liquid into pressurized water was conducted, and the mass transfer process from CO_2 hydrate particles into water was studied. Based on the experimental results, the energy consumption for the disposal process was evaluated.

The following results were obtained ;

1) The membrane strength increases about 10 times just below the dissociation temperature and in CO_2-saturated water. And the membrane deforms a lot under stress in sub-saturated water but it shows almost no deformation in saturated water. These unexpected phenomena are to be considered for the evaluation of CO_2 ocean sequestration. "Free water molecule model" can well explain the above phenomena and made clear that the deformation is a kind of rebuilding process of hydrate membrane. Another experiment succeeded in simulating the overflow phenomenon discovered by Dr. Brewer et al. in their *in situ* experiment at Monterey Bay. The stratified layer formed above stored liquid CO_2 well suppresses the dissolution rate of CO_2 from the storage site and the pH lowering is only 0.2 above stratified layer, which implies the sequestration term longer than 2000 years can be expected. The deep seafloor depression south east of Haha Island seems to be suitable from the scanty biomass. An investigation on the possibility of the endemic fauna, however, must be done from the point of conserving biodiversity. Considering long-term effect of low pH and topographical character of the site, it is necessary to have intensive investigation around the site before considering storage experiments. From the joint *in situ* experiment with the Monterey Bay Aquarium Research Institute, it was suggested that sea animals such as hagfish might be insensitive to the dissolved CO_2.

2) The crystallization or hydrate formation process strongly depended on the stirring conditions in the crystallizer. The mass transfer rate was greatly retarded by the hydrate film. Experimental correlations were obtained for the mass transfer coefficient as a function of the ambient flow conditions. In addition, mass transfer mechanism was elucidated. The total energy consumption for the proposed process was comparable with those for the previous scenario for the ocean disposal of CO_2.