# Estimation of vertical profile of dissolved CO2 concentration in Cameroonian volcanic lakes using sound velocity of lake water

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Limnic eruptions in 1984 and 1986 at Lakes Monoun and Nyos in Cameroon were caused by sudden degassing of magmatic CO2 dissolved in the lake water. The disasters killed about 1800 residents around the lakes. To prevent further disasters, monitoring of CO2 in the lake waters is essential. Until today CO2 measurement has been done only once or twice a year because the methods of CO2 measurement require chemical analysis of water samples, and are not suitable for more frequent measurement. For this reason, we are trying to develop a simple and convenient method of CO2 monitoring as part of SATREPS project supported by JICA and JST. In the field of engineering sound velocity (SV) has been proposed to measure salt concentration (Kleis and Sanchez, 1990). We applied the method to dissolved CO2 (CO2(aq)) assuming the following formula

v+ =k1[CO2(aq)]+k2[HCO3-], where v+ is a term additional to SV due to dissolved ions, and k1 and k2 are the empirical coefficients that we should determine by experiments.

**Laboratory experiments**

To determine k1, a SV profiler (Minos X) with a SV sensor, thermometer, and pressure sensor were placed in a cylindrical stainless vessel filled with pure water. Then, high-pressure CO2 gas was injected into the vessel to produce carbonated water. Additional term v+ was defined as the difference of SV between carbonated water and pure water under the same temperature and pressure. CO2(aq) concentration was calculated using Henry's law. The result indicated that v+ [m/s] was proportional to CO2(aq) concentration [mmol/kg], and the coefficient k1 was found temperature (T) dependent with a regression equation of k1 = 0.033-0.0005*T [m kg/s/mmol].

**Field survey**

Depth profiles of SV, pressure, T, and electric conductivity of Lakes Nyos and Monoun were measured in March 2012 using the SV profiler. The profiles of total CO2 concentration was determined by the syringe method (Kusakabe et al., 2008). Using these data and the correlation between [HCO3-] and electric conductivity proposed by Kusakabe et al. (2008), k2 was determined to be 0.091 at Lake Nyos and 0.067 at Lake Monoun. Then, CO2(aq) concentration was calculated using the k1, k2, SV, T, and electric conductivity. Comparison of the CO2(aq) profiles between the SV method and the syringe method indicated the accuracy of the SV method was better than +-10 mmol/kg. The accuracy is good enough for practical CO2 monitoring. We confirmed that the SV method is applicable to detect an abrupt change of the CO2(aq) profile that may be caused by sudden CO2 injection to the lakes. Concerning the set of SV, pressure, and T, we measured at 19 points at Lake Nyos and 14 points at Lake Monoun. All the SV profiles at Nyos were almost identical suggesting that lake water was stably stratified. On the other hand, the SV profiles at Monoun can be grouped into two patterns. It suggests that lake water in the west basin contains higher CO2(aq) than water in the east basin.