Redox status of hot springs in Taiwan and earthquake precursors

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Since the early scientific investigations by the Japanese scholars, hot springs of Taiwan have been studied for more than one hundred years. Although the basic of geology, occurrence, water temperature and chemistry of hot springs have been reported since the last century, however, the data of redox potential and important redox couples, e.g. sulfide and ammonium are quiet few. The purpose of this study is to explore the redox status of hot springs in Taiwan by measuring Eh in the field and to determine the concentrations of commonly found redox couples, i.e. O_2/H_2O, NO_3^-/NH_4^+, and HS^-/SO_4^{-2}.

Samples of water were collected at the point of discharge or head of water well through a pump. A total of 11 hot springs of 8 areas were surveyed. The measured values of Eh were all less than 0 mV and range from -23 to -277 mV, indicating a reducing condition of hot spring waters.

Most of the water samples from the hot spring sources contained sulfide and ammonium. In the Tatun Volcano Group, hot springs originated from mixing fumarolic gas and water contain high concentrations of hydrogen sulfide, which is the dominant reducing agent and caused the measured Eh values to be less than 0 mV. We also simulate the redox condition for Tien-Hsyang hot spring by the geochemical program PHREEQC and predict that As(III) is the dominant species while pe is less than 7.5 with pH 1.39. Ammonium is another important electron donor found in hot springs of Taiwan. However, there are disadvantages of using hot spring waters that contained ammonium since it interferes with chlorine disinfection and converts to ammonia gas at higher pH values.

The concentration change of hydrogen sulfide and its derivative species is found to be a good indicator of changes in the fumarolic activity in volcanic area. Ammonium may be used as another useful indicator for geochemical surveillance of volcanic activity. A good correlation between vertical soil movements and change of some geochemical parameters such as ammonium had been observed. Concentration changes of hydrogen sulfide and ammonium can give indications about the changes occurring in the deep hydrothermal system and possibly in the activity of the underlying magma chamber. In Taiwan, volcanic activity monitoring is still at its early stage, data on concentration change of hydrogen sulfide, ammonium and Eh values of thermal water and fumarolic gas are scarce and should be studied in the future.

In a nonvolcanic area, hot spring waters usually had been circulated to a great depth along a fault or fracture zone. Song et al. (2005) found that hot springs from deeper reservoirs are superior to shallow circulated springs and groundwater to show concentration anomalies correlated with earthquake events. Studies recommend that some of the geochemical items of hot springs, e.g. radon (Kuo et al. 2006, Yasuoka et al. 2006), chloride (Toutain et al. 1997, Toutain and Baubron 1999), calcium, sodium, sulfate, etc. (Biagi et al. 2001) would be capable of serving as earthquake precursors and fault activity indicators. However, case studies on ammonium and sulfide are rare. A study shows that ammonium concentrations in stream water from upper reaches of Guandaushi Creek in Nantou County increased by 20 to 40 times from August 1998 to September 1999 before the 921 Earthquake (Liu 2007). We suggest that the ammonium may come from deeper anoxic aquifers and discharged to the Guandaushi Creek through an unknown fault zone. Hot springs circulated from deeper part of fault zone contain dissolved reducing agents of hydrogen sulfide and ammonium, which will be the idea monitoring species.

References

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