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Strontium isotope and major ion chemistry of the rainwaters from Guiyang, Guizhou Province, China

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Abstract

Twenty-two rainwater samples from Guiyang city, southwestern China, have been analyzed for their chemical compositions and $^{87}Sr/^{86}Sr$ ratios, with a main purpose to get a better understanding of the general features of rainwater in Guiyang city and their correspondences to human activities. The rainwaters studied are almost acidic (pH=4.53) and show big changes in major ion composition. Ca^{2+} and Mg^{2+} are the principal cations in the rainwaters and their mean values are 56.6 μmol/L (12.5–163.8 μmol/L) and 12.8 μmol/L (4.5–47.3 μmol/L), respectively. The sum of Ca^{2+} and Mg^{2+} accounts for 78%–96% of the total cations in the studied rainwaters. Na^+ was the least abundant of the major cations with a mean content of 4 μmol/L (0.9–7.8 μmol/L). SO_4^{2-} is the predominant anion, with a mean content of 94 μmol/L (33.5–279.4 μmol/L), coming next is NO_3^- with a mean content of 48 μmol/L (2.1–251.8 μmol/L). SO_4^{2-} and NO_3^- together account for 77%–99% of the total anions.

Ca^{2+} and Mg^{2+} in the rainwater are most likely from dissolution of carbonate minerals in dust or aerosol, unlike K^+ that shows more contribution of anthropogenic sources to the rainwater. Na^+ does not vary in concentration with Cl^-. Significant enrichment of Cl^- relative to Na^+ as compared with sea water indicates negligible contribution of marine source, which is supported by the evidence that the total rainwater samples show lower $^{87}Sr/^{86}Sr$ ratios (ranging from 0.707934 to 0.709080) than sea water. The rainwater samples are characterized by high contents of NO_3^-, SO_4^{2-}, and Cl^- relative to Na^+, as compared to the rainwater from other areas in the world, suggesting that the anions (NO_3^-, SO_4^{2-}, and Cl^-) have mainly of anthropogenic sources. Sr isotope shows potential to trace sources of contaminants when combined with other chemical factors: covariation of $^{87}Sr/^{86}Sr$ ratio with Cl^-/Na^+ in the rainwater suggest presence of at least two anthropogenic sources for the rainwater samples studied. The coal-combustion industries are probably the major atmospheric contaminant sources in Guiyang city.

Keywords: Rainwater; Strontium isotope; Ionic composition

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1. Introduction

Land-use and industrial activities are considered the most important driving forces in the ongoing processes of atmospheric chemistry alteration. Most of these anthropogenic influences on the atmospheric chemistry are due to emissions of nitrogen and sulfur compounds. Therefore, the increasing worldwide industrialization has let the problem of acidic deposition receive more and more attention because of its notable direct adverse effects on ecosystem and indirect effects on human health (Lara et al., 2001; Hu et al., 2003).

With a fast economic development, energy consumption has increased significantly in the last two decades in Guizhou Province, China. This has given rise to widespread coal-fired power plants and heating systems built-up at an astonishing speed. Acid rain, therefore, has been a serious atmospheric environment problem especially for several big cities in Guizhou Province for many years. As early as late 1970s, acid rain has already been recognized as a potential environmental problem in southwestern China (Zhao and Seip, 1991; Zhao et al., 1988, 1994; Seip et al., 1995, 1999). However, studies on the chemistry and Sr isotopic composition of rainwater are few. Strontium isotope ratios in rainwater from several areas in the world have been reported by several authors (Graustein and Armstrong, 1983; Gosz and Moore, 1989; Aberg et al., 1989; Andersson et al., 1994; Dupre et al., 1994; Negrel and Roy, 1998). Strontium from different sources has a very distinct isotopic signature, and hence can be used to distinguish various aerosol sources (Herut et al., 1993; Aberg, 1995). Sr isotopes are expected to provide insights into the source of base cations in rainwater, particularly Ca, which is not well constrained from concentration data alone. In order to identify the contaminant sources and quantify their fluxes to the catchments, we have conducted a study on variations in chemical and Sr isotopic composition of the rainwater of Guiyang, a capital city of Guizhou Province.

2. Sampling site

Acid rain has been observed particularly in the middle northern part of the Guizhou Province. Guizhou Province has a mountainous topography and cities there are often located in basins surrounded by high mountains. The soil is mainly acidic yellow earth and red earth, which cover 39% and 11% of the total area of the province, respectively. More than 70% of the whole area is composed of calcareous (Zhao and Seip, 1991). Guiyang (26.34 N, 106.43 E) is a capital city of Guizhou Province, with more than 1.34 million urban population. The city lies in a wide karst valley basin with an elevation of around 1000 m. The lithological characteristic of Guiyang city is dominated by sedimentary strata, most of which are carbonate and clastic rocks (Fig. 1).

The climate is sub-tropical and the average temperatures range from −1 °C in the winter to 30 °C in the summer. The dry season lasts from November to April and the wet season from May to October. Seventy-five percent of the total annual rainfall occurs in the wet season. Rainwater samples were collected on the roof of the building 28 in the Institute of Geochemistry, Chinese Academy of Sciences (CAS). Sampling was carried out at least 150 cm above the local roof level. This sampling site is located at the east-north part of Guiyang city and is at an elevation of 1080 m. No specific pollution sources or point sources are adjacent to the sampling site. Because the wind direction is usually east-north, the sampling site actually is located at the windward of the industrial districts of Guiyang city. It hence had avoided the direct industrial emission. Therefore, the sampling site has the atmosphere–environment characteristics of residential uptown.

3. Sampling and analytical procedures

The samplers were 2L polyethylene bottles, which were cleaned with acid (2–3 N HCl) and finally rinsed with Milli-Q water and dried. In order to minimize contributions from dry fallout, special attention was paid to opening the sampler as quickly as possible after the onset of rainfall. Since rainwater has very different pH value and chemical composition within first 20 min of each rain event (Dupre et al., 1994; Tuncel and Ungör, 1996), we collected bulk rainwater samples after ~30 min from start of each rain event. There were several months during which the sampling failed due to inadequate amount of precipitation.