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The development of a digital gamma-gamma coincidence/anticoincidence spectrometer and its applications to monitor low-level atmospheric 22Na/7Be activity ratios in Resolute, Canada

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7Be (half-life, 53.2 d) and 22Na (half-life, 2.6 a) are naturally occurring radionuclides of cosmogenic origin. Intrusions of stratospheric air masses into the troposphere followed by dry or wet deposition are the main processes transferring 7Be and 22Na to the earth's surface. These two atmospheric cosmogenic nuclides are simultaneously generated in the upper atmosphere and have similar behaviors after production. They are interesting because their activities and activity ratio can be used as a tracer and radiochronometer for the stratosphere-to-troposphere downward air mass exchange if the current 22Na measurement limitations are overcome.

The analysis of 22Na and 7Be in air-filter samples collected on a daily basis has typically been based on a measurement done with a single HPGe detector using their respective 1274.5 keV and 477.6 keV gamma-rays. There are several practical problems associated with 22Na measurement by this method. In addition to very low 22Na activity concentration (about four orders of magnitude lower than that of 7Be), other important problems include the low measurement efficiency, the losses due to cascade summing and the background from Compton scatter from 208Tl and 40K. This decreases sensitivity and degrades the detection limit of the 1274.5 keV peak, restricting measurement of 22Na in particular.

To improve 22Na detection limit, a digital gamma-gamma coincidence/anticoincidence spectrometer was developed and examined for low-level cosmogenic 22Na and 7Be in air-filter sample monitoring. The spectrometer consists of two bismuth germinate scintillators (BGO) and an XIA LLC Digital Gamma Finder (DGF)/Pixie-4 software and card package. The spectrometer design allows a more selective measurement of 22Na with a significant background reduction by gamma-gamma coincidence events processing. It has been demonstrated that this improved spectrometer provides a more sensitive and effective way to quantify trace amounts of 22Na and 7Be with a critical limit of 3 mBq and 5 Bq respectively for a 20 h counting. The use of a list-mode data acquisition technique enabled simultaneous determination of 22Na and 7Be activity concentrations using a single measurement by coincidence and anticoincidence mode respectively.

Using the newly developed spectrometer, the aerosol samples collected at Resolute, NU, Canada (74.71°N, 94.97°W) airborne particulate monitoring station from 2016 to 2017 were counted. The activity concentrations of 22Na and 7Be were analysed. Based on the results from the Resolute station, the study confirms that the seasonal distribution of 22Na to 7Be activity concentration ratios has a significant peak in spring and winter, and it's relatively low in other seasons. It may indicate that the stratosphere-to-troposphere downward exchange events affect Northern Canada more frequently during spring and winter.

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