Noise Suppression in Beta Attenuation Monitors through Array-Type Sampling System

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Abstract

The Beta Attenuation Monitor (BAM) is widely used for real-time ambient $PM_{2.5}$ monitoring, but its typical detection limit (4–4.8 μg/m³) is close to the WHO guideline of 5 μg/m³. Additionally, fluctuations in the number of beta particles emitted by the source often lead to significant variability in BAM data. This study aimed to develop an array-type BAM that reduces particle loss, increases the number of detection units to suppress noise, and simultaneously enhances signal strength—thereby improving overall performance.

A homemade array-type BAM system was fabricated using 3D printing technology. A controlled particle generation system was used to evaluate the performance of the array-type BAM. Signal attenuation was converted to mass concentration using the Lambert-Beer law, and data smoothing was applied via a moving average method. Key performance metrics—including response time, signal-to-noise ratio (S/N), and detection limit—were assessed and compared with those of a commercial BAM.

The array-type sampling system achieved 97% penetration efficiency for particles smaller than 3.625 μm. Compared to a single-unit BAM, the four-unit array effectively reduced measurement variability by 50%, and significantly improved performance by reducing data fluctuations, response time, and detection limit under an S/N ratio of 10.

The array-type sampling BAM successfully reduced the detection limit from 10 μg/m³ to 3 μg/m³, while maintaining uniform sampling and particle integrity. It also effectively suppressed the signal variability typically observed in conventional BAM systems. These improvements in response time, sensitivity, and measurement stability enhance the system's applicability for accurate and real-time $PM_{2.5}$ monitoring.

Keywords: Particulate Matter; Atmospheric Monitoring; Radiation; Detection Limit; Signal-to-Noise Ratio