Supplementary Materials

Seasonal and Spatial Variations of Atmospheric Ammonia in the Urban and Suburban Environments of Seoul, Korea

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Sources of Ammonia

Figure S1. Schematic Diagram of Ammonia passive sampler-based ammonia collection process for its concentration measurement.
Figure S2. Real-time installation of the NH₃ passive sampler with Temperature (℃) and RH (%) sensor inverted in Rain shelter at the studied sites.

Figure S3. Portable sensor (EasyLog USB) for measuring the temperature (℃) and relative humidity (%).
Figure S4. Schematic Diagram of Annular denuder setup in the laboratory at HUFS.
Figure S5. Comparison of ammonia concentrations measured by replicates passive samples. The error bars represent the relative standard deviation of 3.8% calculated from all 212 pooled replicate samples.

Table S1. Quality Assurance & Quality Control (QC/QA) Using Ion Chromatography During Sample Analysis.

| QC/QA Measurement Parameters | Measured Values |
|------------------------------|-----------------|
| Relative Error (%)          | 0.10            |
| Absolute Error (ppb)        | 0.20            |
| Analytical Precision, CV (%)| 0.95            |
| Measurement Precision, RSD (%) | 3.80        |
| Minimum Detection Limit, MDL (ppb) | 0.07 |

Dionex calibration check measurements were used to evaluate the accuracy in terms of Absolute Error and Relative Error using Equation S1 and S2 respectively [1].

\[ E = X_i - X_t \]
\[ E_r(\%) = \frac{X_i - X_t}{X_t} \times 100\% \] \hspace{1cm} (S2)

Where \( X_i \) is the measurement of the quantity and \( X_t \) is the true value and it was found that the system shown a relative error of 0.10\% and an absolute error of 0.20 ppb. Analytical precision was evaluated using the data obtained by periodic analyses of the calibration standards and was calculated using Equation. S3 [56] and was found to be 0.95\%.

\[ CV(\%) = \frac{\text{Std. Dev.}}{\bar{x}} \times 100\% \] \hspace{1cm} (S1)

where \( \bar{x} \) is the average of all the replicate samples while measurement precision was found to be 3.8\% and was evaluated using Equation. S4 and S5 (Skoog et al. 2016).

\[ \text{RSD}(\%) = \frac{S_{\text{pooled}}}{\bar{x}} \times 100\% \] \hspace{1cm} (S4)

Where \( S_{\text{pooled}} = \frac{\sum_{i=1}^{N_1}(x_i - \bar{x})^2 + \sum_{i=1}^{N_2}(x_i - \bar{x})^2 + \cdots}{N_1 + N_2 + \cdots + N_S} \)

\( N_i \) represents the number of replicated data samples in set ‘I’ and 1, 2, …\( S \) represent the \( S \)th set.

Field and laboratory blanks were collected throughout the sampling period of 1 year to determine the Method Detection Limit (MDL) using the Equation. S6 [56].

\[ \text{MDL} \geq t \times S_b \times \sqrt{\frac{N_1 + N_2}{N_1 \times N_2}} \] \hspace{1cm} (S5)

where MDL was calculated to be 0.07 ppb for a 1-week Radiello passive NH\(_3\) sampler. In the Equation S5, \( t \) represents a value of 95\% confidence level, \( S_b \) is the blank standard deviation, \( (N_1 = 1) \) and \( (N_2 = 47) \) are the number of sample measurements and the number of analyzed blanks, respectively.
Figure S6. Sample Analysis for Accuracy, Precision and Minimum Detection Limit (MDL) Concentration of ammonia (ppb) at studied sites.

Table S2. Average Concentration and Standard Deviation of ammonia (ppb) at studied sites.

| Season | Sites       | Spring    | Summer    | Autumn    | Winter    |
|--------|-------------|-----------|-----------|-----------|-----------|
|        | Livestock 1 | 60.2 ± 14.5 | 74.7 ± 14.8 | 94.2 ± 26.4 | 47.9 ± 22.6 |
|        | Livestock 2 | 40.0 ± 9.2  | 55.9 ± 8.8  | 62.6 ± 13.7 | 34.6 ± 16.5 |
|        | Seoul Station| 17.2 ± 3.7  | 23.2 ± 2.9  | 18.6 ± 3.3  | 13.7 ± 2.4  |
|        | Roadside    | 16.8 ± 3.1  | 19.1 ± 3.5  | 15.0 ± 4.4  | 12.2 ± 3.2  |

Figure S7. Regional Distribution of Temperature (°C) and relative humidity (%) information over the period of 1 year on weekly average basis.
Habitation 1  7.2 ± 2.1  12.6 ± 3.0  7.9 ± 2.2  5.0 ± 2.0
Habitation 2  7.4 ± 1.9  13.5 ± 2.9  7.2 ± 1.8  5.1 ± 2.0
Industry     8.4 ± 2.4  11.1 ± 2.3  8.9 ± 1.9  6.2 ± 2.6
Background (HUFS)  4.6 ± 1.2  3.9 ± 0.7  3.2 ± 0.4  3.7 ± 2.4

Figure S8. Passive NH₃ concentration time series for all eight sites in the Northeastern region of Scheme 2020. All samples were measured every Monday for sampling on a weekly basis.

References
56. Skoog, D.A.; Holler, F.J.; Nieman Crouch, S.R. Appendix I: Evaluation of Analytical Data. In Principles of Instrumental Analysis, 7th ed.; CENGAGE, Seoul, South Korea, 2016.