atmosphere

MDPI

Supplementary Materials

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

Rahul Singh [1], Kyunghoon Kim [1], Gyutae Park [2], Seokwon Kang [1], Taehyun Park [1], Jihee Ban [1], Siyoung Choi [1], Jeongin Song [1], Dong-Gil Yu [1], Jung-Hun Woo [3], Yuri Choi [4] and Taehyoung Lee [1,*]

[1] Department of Environmental Science, Hankuk University of Foreign Studies, Yongin 17035, Korea; korsrahul@hufs.ac.kr (R.S.); khkim159@hufs.ac.kr (K.K.); gang0701@hufs.ac.kr (S.K.); tpark@hufs.ac.kr (T.P.); jhban@hufs.ac.kr (J.B.); siyoung@hufs.ac.kr (S.C.); sji980115@hufs.ac.kr (J.S.); envigreen@keiti.re.kr (D.-G.Y.)
[2] Air Pollution Engineering Division, Climate and Air Quality Research Department, National Institute of Environmental Research, Incheon 22689, Korea; gt0303@korea.kr
[3] Department of Civil and Environmental Engineering, Konkuk University, Seoul 05029, Korea; jwoo@konkuk.ac.kr
[4] Public Health and Environment, Seoul Research Institute of Public Health and Environment, Seoul 04524, Korea; cyuri@seoul.go.kr
* Correspondence: thlee@hufs.ac.kr; Tel.: +82-31-330-4039

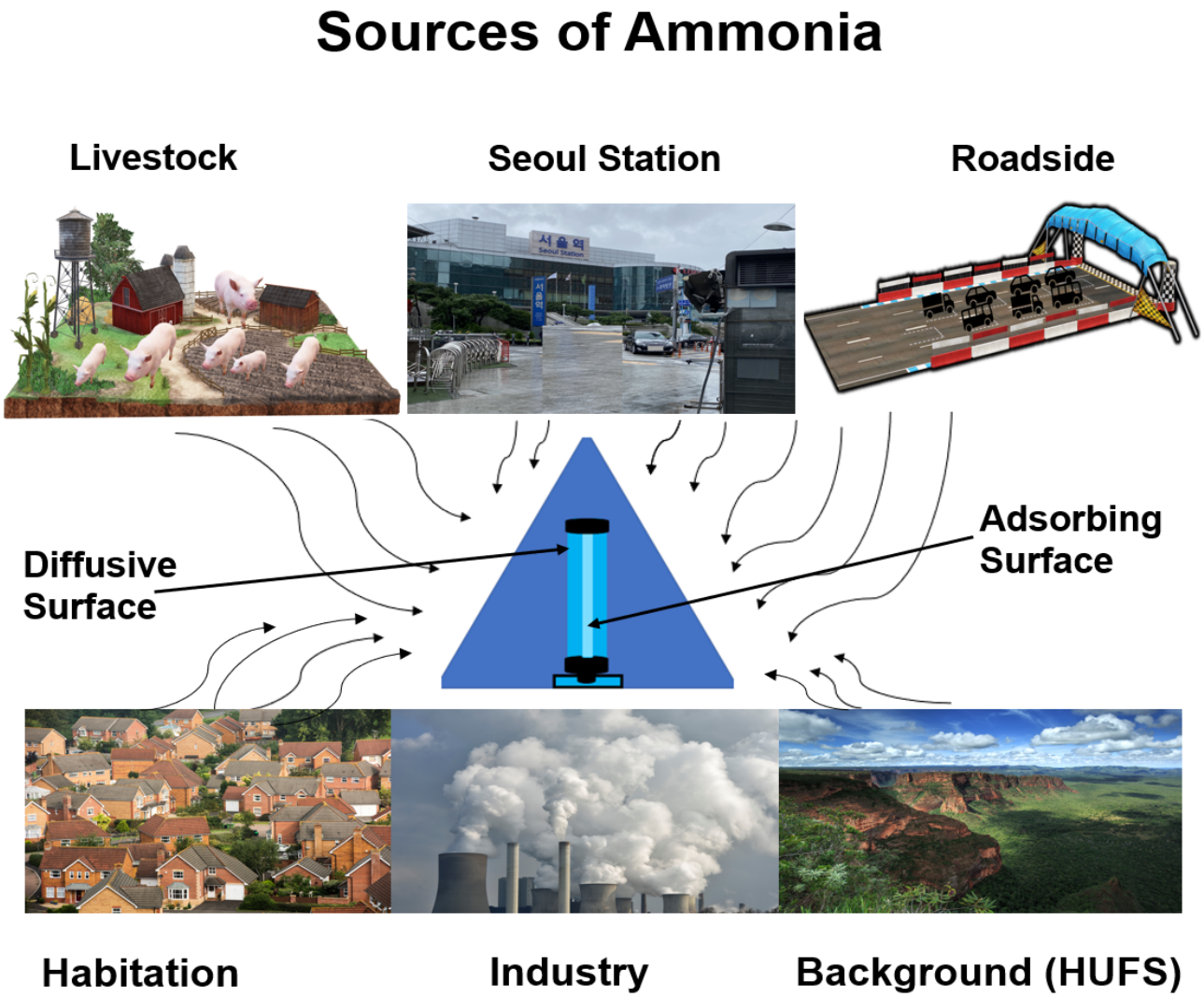

Figure S1. Schematic Diagram of Ammonia passive sampler-based ammonia collection process for its concentration measurement.

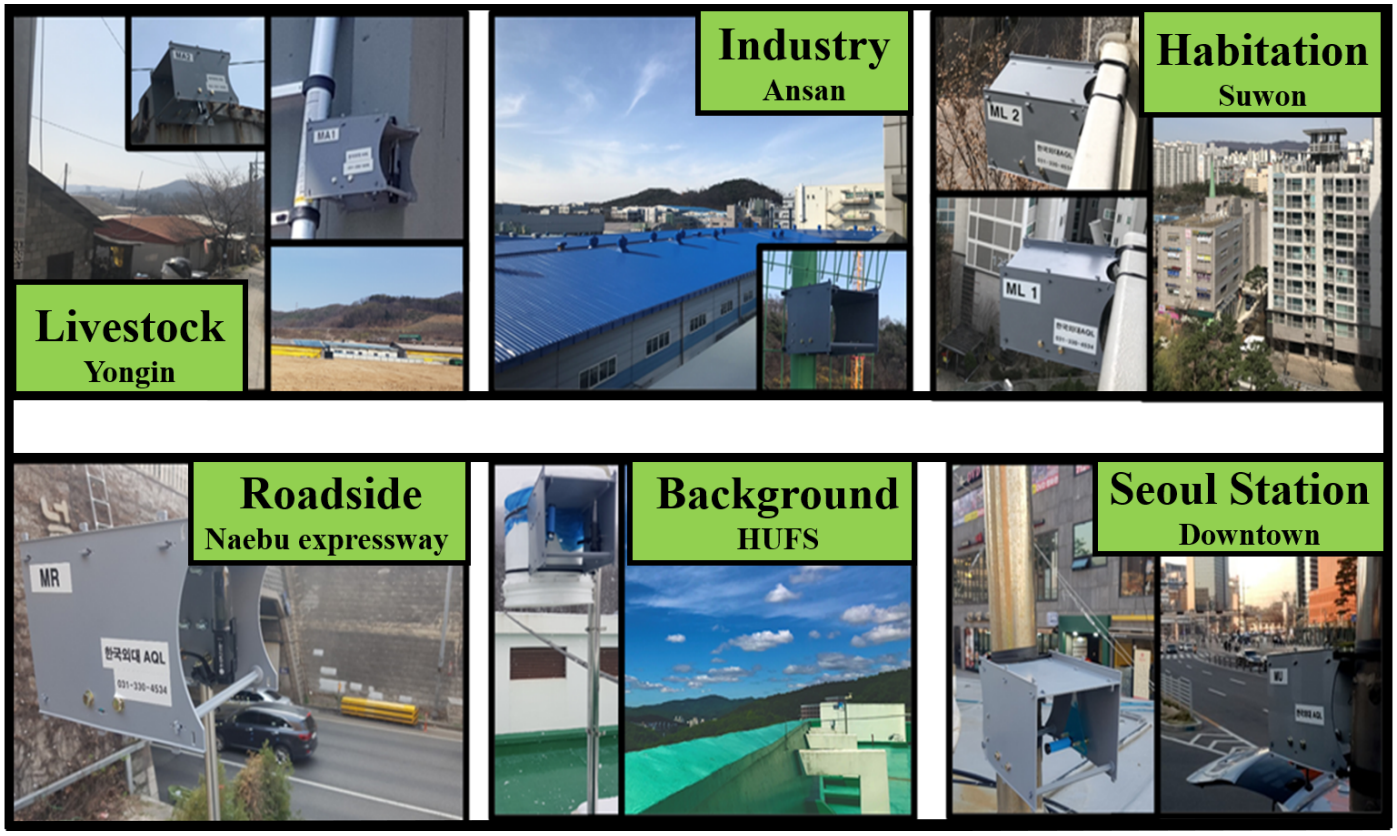

Figure S2. Real-time installation of the NH_3 passive sampler with Temperature (℃) and RH (%) sensor inverted in Rain shelter at the studied sites.

Figure S3. Portable sensor (EasyLog USB) for measuring the temperature (℃) and relative humidity (%).

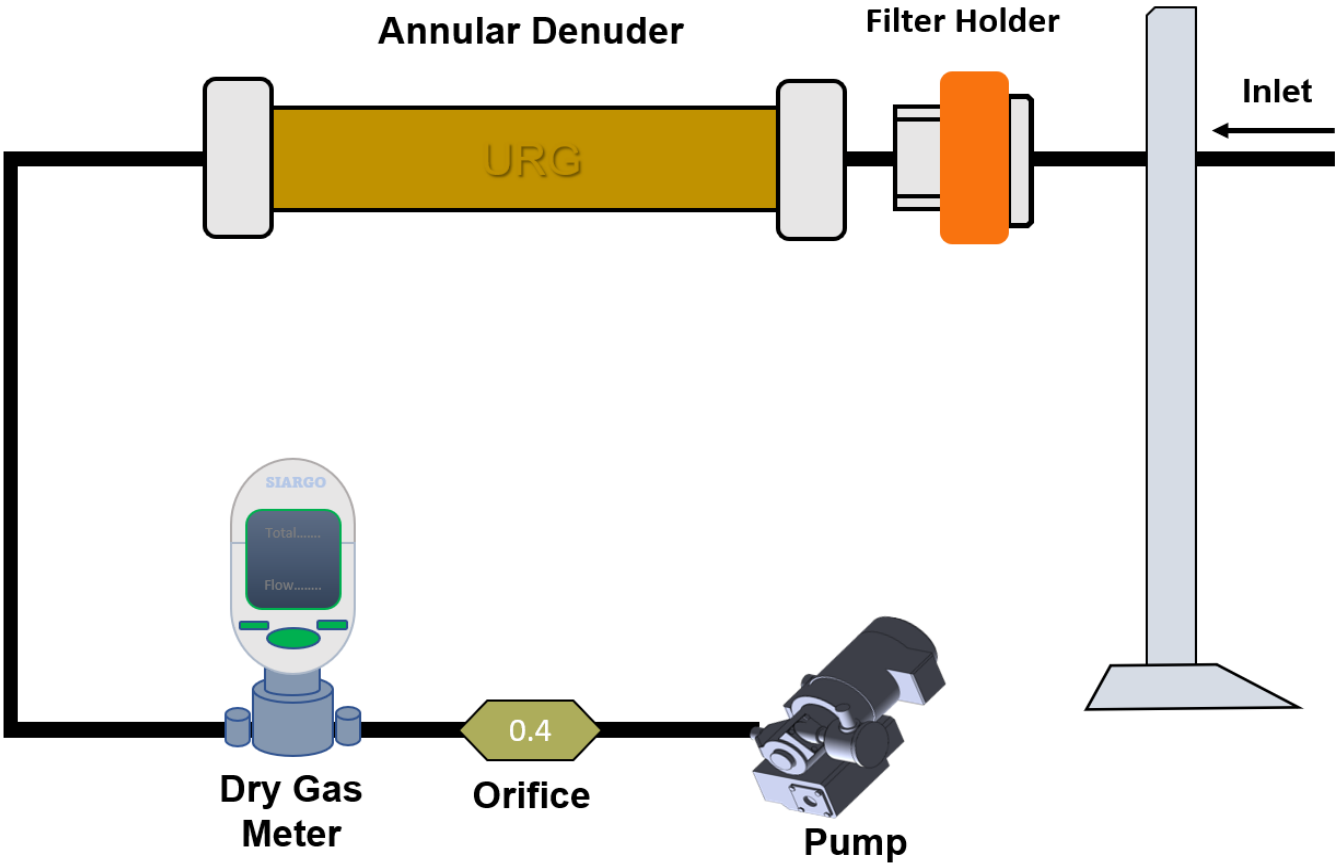

Figure S4. Schematic Diagram of Annular denuder setup in the laboratory at HUFS.

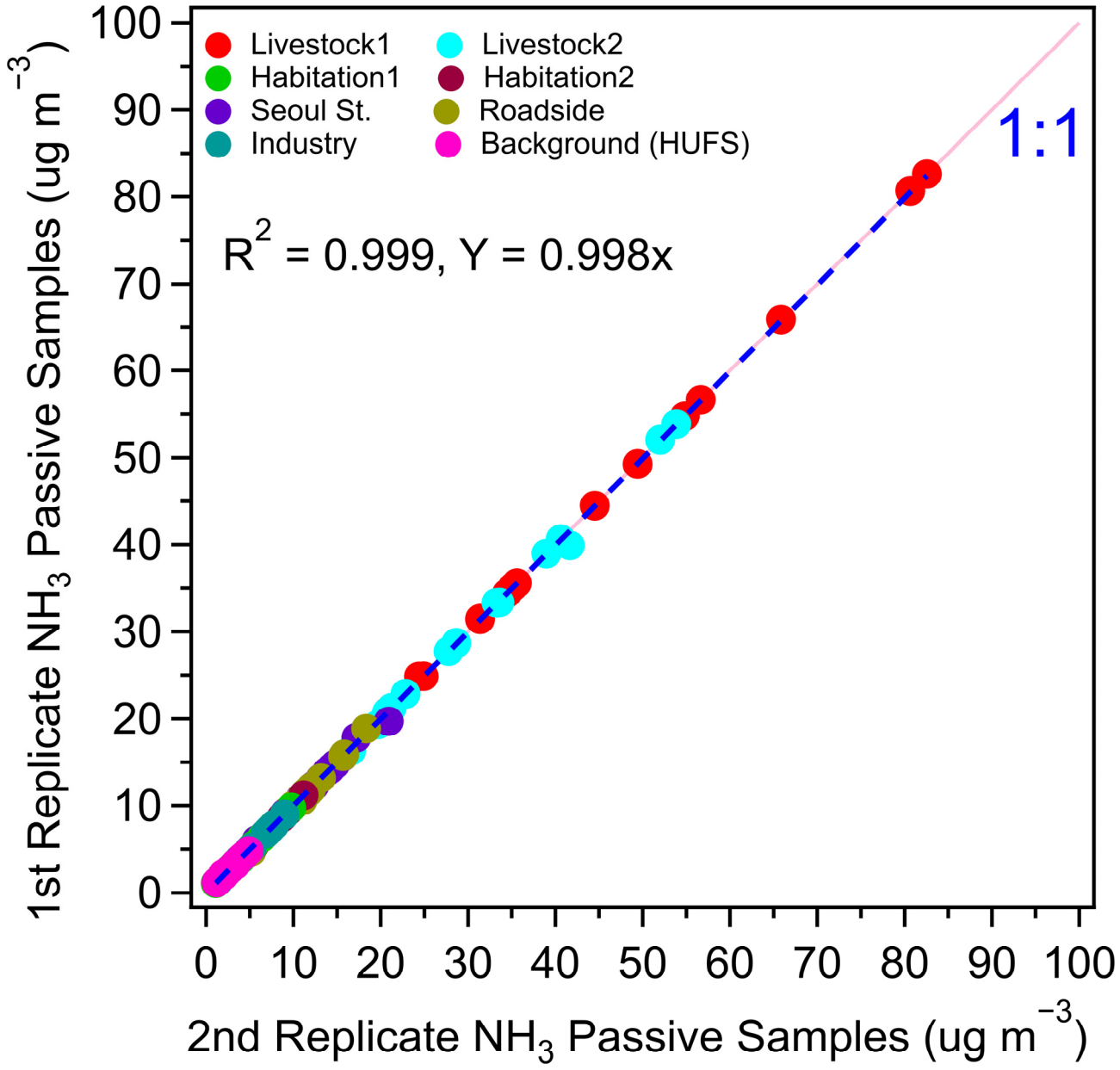

Figure S5. Comparison of ammonia concentrations measured by replicates passive samples. The error bars represent the relative standard deviation of 3.8 % calculated from all 212 pooled replicate samples.

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].

$$E = X_i - X_t \quad \text{S1}$$

$$E_r(\%) = \frac{X_i - X_t}{X_t} \times 100\% \quad \text{S2}$$

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%.

$$CV(\%) = \frac{\text{Std. Dev.}}{\bar{x}} \times 100\% \quad \text{S1}$$

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).

$$RSD(\%) = \frac{S_{pooled}}{\bar{x}} \times 100\% \quad \text{S4}$$

$$\text{Where } S_{pooled} = \frac{\sum_{i=1}^{N_1}(x_i - \bar{x}_1)^2 + \sum_{j=1}^{N_2}(x_j - \bar{x}_2)^2 + \cdots}{N_1 + N_2 + \cdots + N_s}$$

, 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].

$$MDL \geq t \times S_b \times \sqrt{\frac{N_1 + N_2}{N_1 \times N_2}} \quad \text{S5}$$

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, (N1 = 1) and (N2 = 47) are the number of sample measurements and the number of analyzed blanks, respectively.

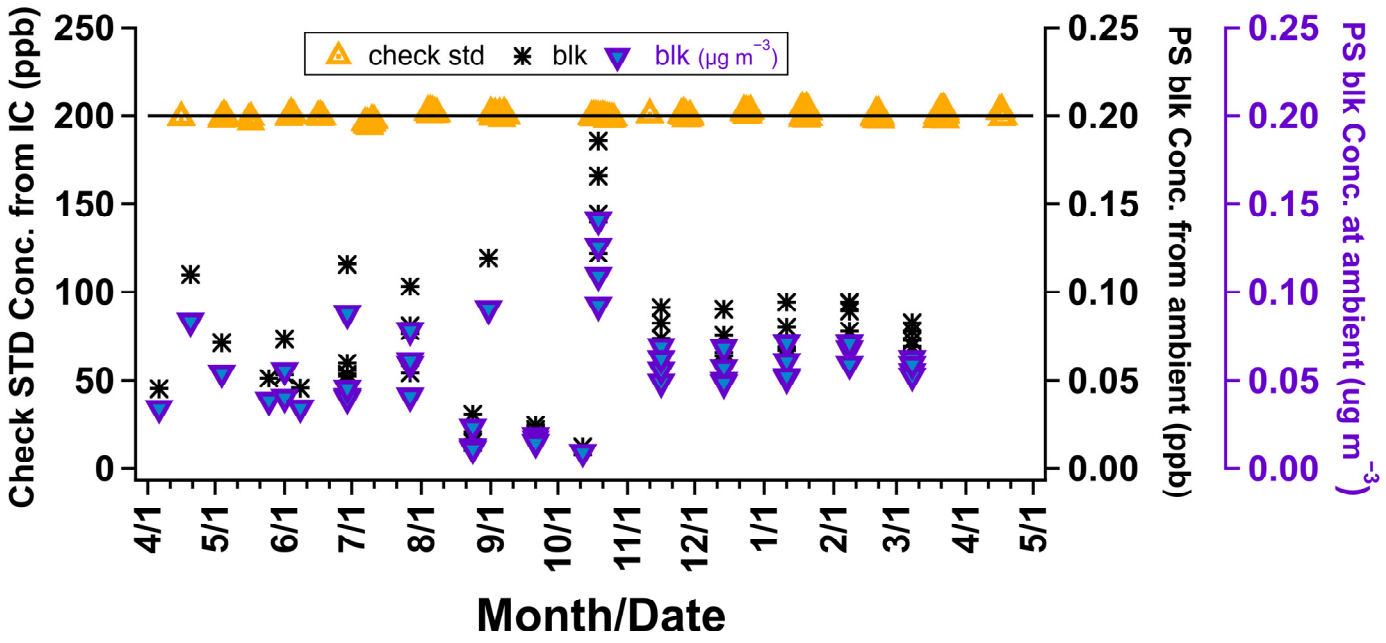

Figure S6. Sample Analysis for Accuracy, Precision and Minimum Detection Limit (MDL) ConcenTable S7. Regional Distribution of Temperature (℃) and relative humidity (%) information over the period of 1 year on weekly average basis.

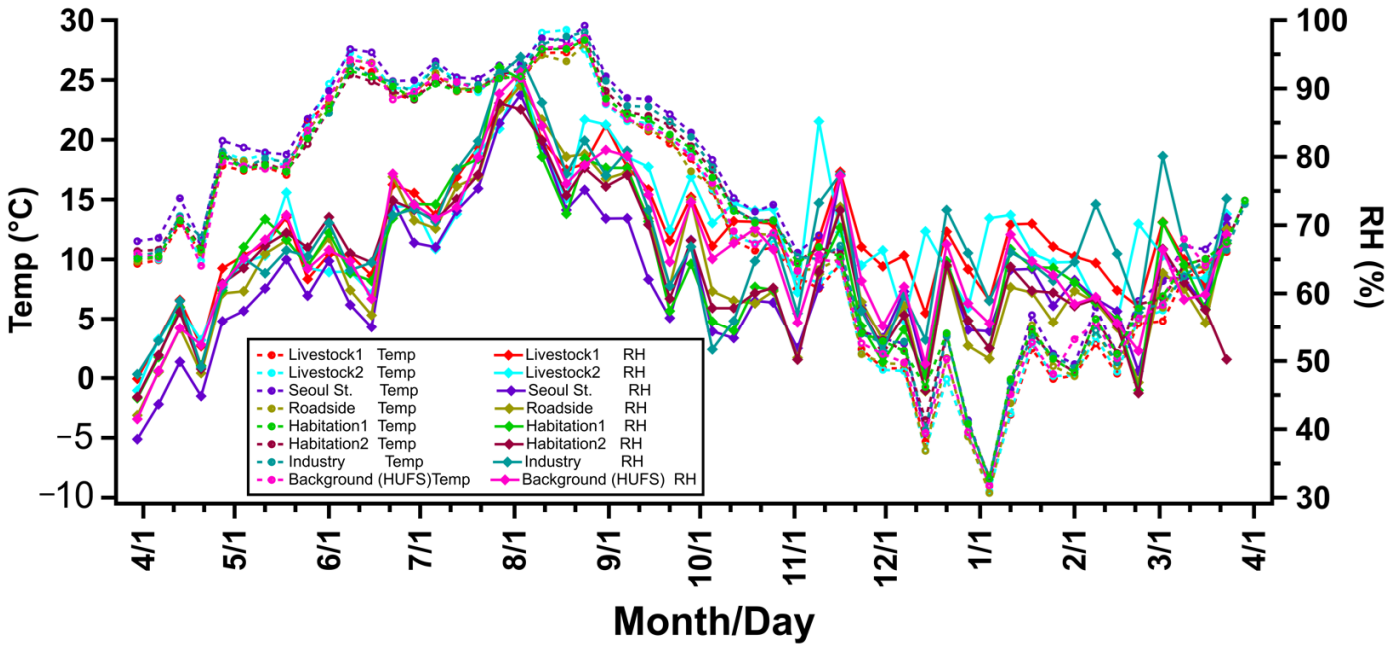

Figure S7. Regional Distribution of Temperature (℃) and relative humidity (%) information over the period of 1 year on weekly average basis.

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

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

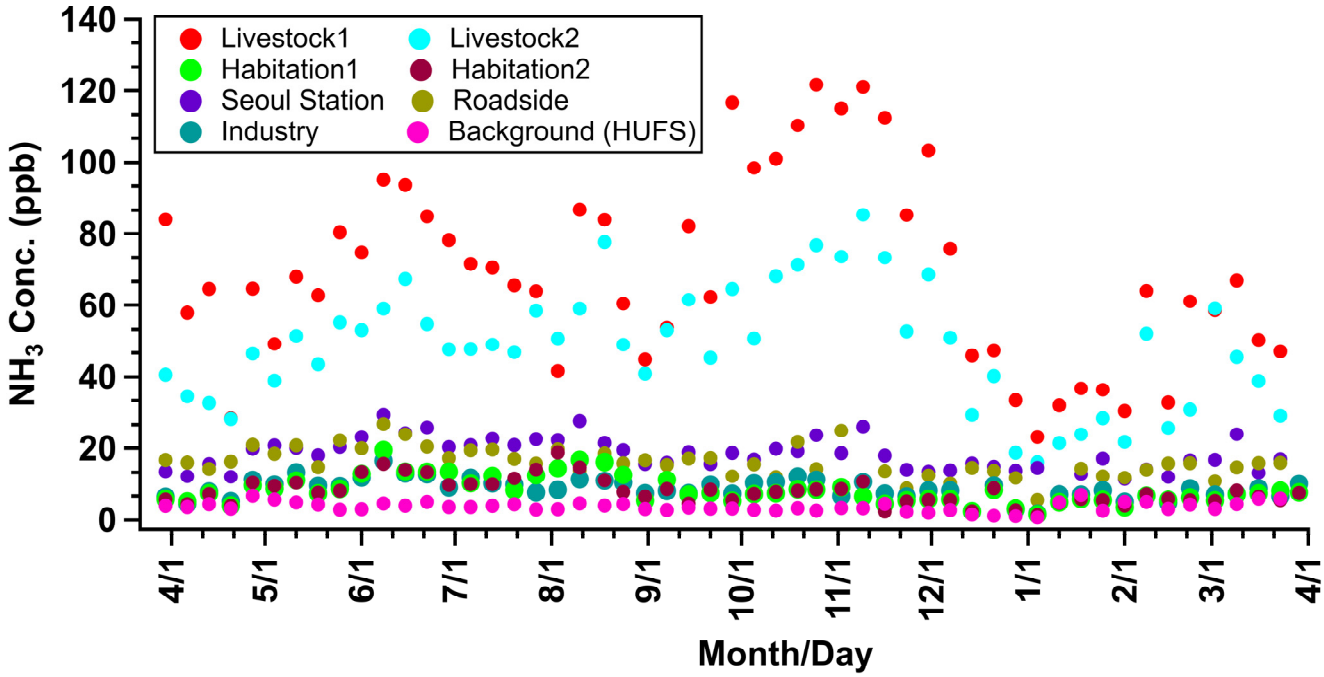

Figure S8. Passive NH_3 concentration time series for all eight sites in the Northeastern region of Scheme 2020. All samples were measured every Monday for sampling on a weekly basis.

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.