Characteristics of aminiums in PM2.5 during winter clean and polluted episodes in China: aminium outbreak and its constraint

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Table S1. Mean values (± SD) of the main parameters observed in different periods and locations.

Parameters	Lanzhou (LZ) Dec. 2–30, 2017 (n = 17)[a]			Taiyuan (TY) Dec. 2–30, 2017 (n = 15)[a]			Haerbin (HEB) Dec. 18, 2017 to Jan. 15, 2018 (n = 17)[a]			Beijing (BJ) Dec. 22, 2017 to Jan. 21, 2018 (n = 18)[a]		
	Clean day	Polluted day	Full period	Clean day	Polluted day	Full period	Clean day	Polluted day	Full period	Clean day	Polluted day	Full period
$PM_{2.5}$ (μg m^{-3})	52.33 ± 13.40	111.75 ± 19.17	80.29 ± 33.87	32.50 ± 11.37	135.43 ± 44.91	80.53 ± 60.39	41.60 ± 17.35	133.00 ± 45.60	106.12 ± 57.36	34.00 ± 13.90	115.40 ± 32.40	56.61 ± 41.90
T (°C)	–5.25 ± 1.72	–4.99 ± 1.10	–5.13 ± 1.47	–4.14 ± 3.77	–3.82 ± 4.70	–3.99 ± 4.23	–12.63 ± 3.27	–15.43 ± 3.10	–14.61 ± 3.40	–6.68 ± 2.51	–2.68 ± 3.83	–3.79 ± 3.94
RH (%)	52.69 ± 4.87	53.58 ± 8.34	53.11 ± 6.74	35.45 ± 2.46	54.86 ± 13.53	44.51 ± 13.50	65.78 ± 4.06	69.56 ± 6.16	68.45 ± 5.88	40.43 ± 5.78	70.58 ± 14.07	48.80 ± 16.17
Wind speed (m s^{-1})	1.64 ± 0.33	1.63 ± 0.52	1.63 ± 0.43	2.64 ± 0.62	1.57 ± 0.71	2.14 ± 0.85	2.68 ± 0.56	2.36 ± 0.68	2.45 ± 0.67	2.35 ± 0.94	1.65 ± 0.50	2.16 ± 0.90
VC[b] (m^2 s^{-1})	434. 06 ± 270.98	337.49 ± 201.57	388.61 ± 245.60	1632.49 ± 951.06	352.14 ± 247.19	1034.99 ± 958.60	1253.71 ± 581.83	553.49 ± 268.89	759.44 ± 502.39	760.26 ± 960.35	394.85 ± 367.63	658.76 ± 854.64
PBLH (m)	250.25 ± 105.49	193.81 ± 63.06	223.69 ± 92.50	571.91 ± 238.95	212.74 ± 80.36	404.29 ± 256.07	452.36 ± 180.19	225.09 ± 75.03	291.94 ± 155.71	268.58 ± 157.05	205.93 ± 119.69	251.18 ± 150.27
Amount of rainfall (mm)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.07 ± 0.17 (n = 1)[c]	0.03 ± 0.12 (n = 1)[c]	0.04 ± 0.08 (n = 1)[c]	0.00 ± 0.00	0.01 ± 0.05 (n = 1)[c]	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
SO_2 (μg m^{-3})	44.56 ± 11.27	68.38 ± 26.58	55.76 ± 23.26	33.75 ± 23.36	100.43 ± 18.31	64.87 ± 39.42	38.00 ± 8.29	62.25 ± 13.91	55.12 ± 16.70	9.08 ± 3.69	10.00 ± 3.90	9.33 ± 3.77
NO_2 (μg m^{-3})	72.56 ± 16.67	100.63 ± 22.64	85.76 ± 24.18	38.00 ± 11.65	86.43 ± 11.10	60.60 ± 26.71	34.80 ± 7.98	60.42 ± 11.77	52.88 ± 15.90	49.62 ± 14.45	73.60 ± 8.21	56.83 ± 17.25
O_3 (μg m^{-3})	55.44 ± 11.53	50.00 ± 8.66	52.88 ± 10.63	64.63 ± 12.19	23.43 ± 10.63	45.40 ± 23.55	54.80 ± 1.94	39.08 ± 8.72	43.71 ± 10.30	37.92 ± 15.31	22.80 ± 14.84	33.72 ± 16.63
O_x (μg m^{-3})	128.00 ± 12.56	150.63 ± 25.31	138.65 ± 22.64	102.63 ± 7.31	109.86 ± 11.01	106.00 ± 9.91	89.60 ± 7.36	99.50 ± 8.27	96.59 ± 9.20	87.54 ± 11.47	96.40 ± 9.73	90.56 ± 11.55
NO_3^- (μg m^{-3})	12.93 ± 6.45	24.73 ± 12.78	18.48 ± 11.56	6.46 ± 1.83	26.72 ± 11.53	15.92 ± 12.89	3.05 ± 1.78	10.72 ± 4.48	8.47 ± 5.23	6.64 ± 3.87	27.80 ± 13.74	12.52 ± 12.37
SO_4^{2-} (μg m^{-3})	10.99 ± 4.84	22.09 ± 11.76	16.21 ± 10.40	9.12 ± 3.85	30.38 ± 15.57	19.04 ± 15.28	5.52 ± 2.08	12.67 ± 5.14	10.56 ± 5.52	3.97 ± 1.48	16.00 ± 7.14	7.31 ± 6.69
NH_4^+ (μg m^{-3})	6.93 ± 2.81	11.58 ± 6.01	9.11 ± 5.15	6.33 ± 1.68	22.80 ± 13.83	14.02 ± 12.58	3.51 ± 2.09	9.73 ± 3.61	7.90 ± 4.31	4.28 ± 2.85	13.75 ± 10.48	6.91 ± 7.37
K^+ (μg m^{-3})	0.54 ± 0.23	0.98 ± 0.40	0.75 ± 0.39	0.85 ± 0.27	2.15 ± 0.74	1.46 ± 0.84	0.80 ± 0.52	2.28 ± 0.83	1.85 ± 1.01	0.66 ± 0.44	0.90 ± 0.47	0.73 ± 0.46
ALW (μg m^{-3})	10.84 ± 7.00	26.29 ± 15.97	18.11 ± 14.33	6.94 ± 5.86	70.33 ± 87.02	36.52 ± 67.47	11.94 ± 7.67	41.46 ± 17.28	32.78 ± 20.22	7.69 ± 3.29	109.91 ± 149.35	36.09 ± 91.10
Total org. acids[d] (μg m^{-3})	0.28 ± 0.37	0.43 ± 0.47	0.35 ± 0.43	0.32 ± 0.29	1.06 ± 0.49	0.67 ± 0.54	0.73 ± 0.17	1.32 ± 0.48	1.15 ± 0.49	0.28 ± 0.16	0.85 ± 0.46	0.43 ± 0.38
(NO_3^- + 2SO_4^{2-}) – NH_4^+ (μg m^{-3})	27.97 ± 13.30	57.34 ± 24.40	47.79 ± 24.26	18.37 ± 7.67	64.70 ± 28.15	3.99 ± 30.58	10.58 ± 3.95	26.33 ± 10.21	21.69 ± 11.58	10.30 ± 4.93	46.06 ± 18.74	20.23 ± 19.28
pH	5.01 ± 0.17	5.39 ± 1.01	5.19 ± 0.73	6.09 ± 0.34	5.23 ± 0.41	5.69 ± 0.57	3.61 ± 1.21	4.62 ± 0.85	4.32 ± 1.07	5.86 ± 1.09	4.03 ± 0.79	5.35 ± 1.30
$DMAH^+$ (μg m^{-3})	5.70 ± 1.69	10.42 ± 5.70	7.92 ± 4.73	5.15 ± 1.44	19.16 ± 10.44	11.69 ± 10.04	4.19 ± 2.10	11.73 ± 6.33	9.52 ± 6.43	1.97 ± 2.01	2.91 ± 1.60	2.23 ± 1.95
$MMAH^+$ (μg m^{-3})	7.49 ± 4.37	12.18 ± 5.01	9.70 ± 5.23	7.90 ± 2.56	28.04 ± 14.44	17.30 ± 14.21	6.23 ± 3.77	23.37 ± 11.85	18.33 ± 12.82	3.66 ± 3.09	5.18 ± 3.14	4.08 ± 3.18
EAH^+ (μg m^{-3})	1.46 ± 1.28	2.80 ± 1.42	2.09 ± 1.50	1.25 ± 0.95	4.66 ± 2.29	2.84 ± 2.41	1.21 ± 0.87	2.87 ± 1.05	2.38 ± 1.26	1.36 ± 0.64	1.35 ± 0.64	1.36 ± 0.86
$DEAH^+$ (μg m^{-3})	1.70 ± 0.73	2.37 ± 1.29	2.01 ± 1.09	15.05 ± 9.38	31.27 ± 20.60	22.62 ± 17.62	0.14 ± 0.19	1.04 ± 0.90	0.77 ± 0.87	0.35 ± 0.40	1.18 ± 0.64	0.58 ± 0.61
PAH^+ (μg m^{-3})	0.27 ± 0.52	0.74 ± 0.59	0.49 ± 0.60	0.00 ± 0.00	0.34 ± 0.26	0.16 ± 0.25	0.62 ± 0.32	0.85 ± 0.30	0.78 ± 0.32	0.13 ± 0.27	0.54 ± 0.59	0.43 ± 0.55
BAH^+ (μg m^{-3})	0.40 ± 0.53	1.05 ± 0.73	0.71 ± 0.71	0.16 ± 0.10	0.62 ± 0.23	0.38 ± 0.29	1.11 ± 0.35	0.94 ± 0.33	1.19 ± 0.33	0.83 ± 0.78	0.60 ± 0.42	0.77 ± 0.71
$PYRH^+$ (μg m^{-3})	0.72 ± 0.57	1.40 ± 0.65	1.04 ± 0.70	0.65 ± 0.48	3.34 ± 1.23	1.91 ± 1.62	0.58 ± 0.22	1.49 ± 0.45	1.22 ± 0.58	0.60 ± 0.58	0.27 ± 0.36	0.51 ± 0.55
Total aminiums (μg m^{-3})	17.75 ± 8.06	30.96 ± 12.52	23.97 ± 12.32	30.17 ± 12.87	87.45 ± 42.52	56.90 ± 41.81	13.90 ± 6.83	42.53 ± 19.92	34.11 ± 21.54	9.31 ± 8.01	11.62 ± 6.50	9.95 ± 7.69
TA/NH_4^+	2.55 ± 0.53	3.48 ± 2.97	2.99 ± 2.12	4.19 ± 2.09	4.33 ± 1.69	4.64 ± 1.94	4.48 ± 1.10	4.53 ± 2.07	4.51 ± 1.84	2.31 ± 2.15	1.65 ± 2.18	2.13 ± 2.18

[a]The numbers in parentheses indicate the number of samples.

[b]The ventilation coefficient (VC) can be used to characterize the state of atmospheric dilution in pollutant concentrations(Gani et al., 2019). The VC value can be expressed as a product of wind speed and planetary boundary layer height (PBLH).

[c]The numbers in parentheses indicate the days of rainfall.

[d]It represents the total concentrations of six organic acids including formic acid ($HCOO^-$), acetic acid (CH_3COO^-), oxalic acid ($C_2O_4^{2-}$), succinic acid ($C_4H_4O_4^{2-}$), methanesulfonic acid ($CH_3SO_3^-$), and glutaric acid ($C_5H_6O_4^{2-}$).

Table S2. Mean values (± SD) of the main parameters observed in different periods and locations.

Parameters	Xi'an (XA) Dec. 22, 2017 to Jan. 20, 2018 (*n* = 29)[a]			Wulumuqi (WLMQ) Mar. 3–28, 2018 (*n* = 14)[a]	Chengdu (CD) Dec. 1–31, 2017 (*n* = 17)[a]			Wuhan (WH) Dec. 6–29, 2017 (*n* = 15)[a]		
	Clean day	Polluted day	Full period	Clean day	Clean day	Polluted day	Full period	Clean day	Polluted day	Full period
$PM_{2.5}$ (μg m^{-3})	51.00 ± 12.98	159.40 ± 60.09	144.45 ± 67.33	34.07 ± 18.29	56.86 ± 12.06	138.70 ± 29.99	105.00 ± 47.03	56.83 ± 8.59	114.89 ± 21.98	91.67 ± 33.59
T (°C)	–2.02 ± 2.59	–4.17 ± 1.40	–1.68 ± 2.57	6.81 ± 4.14	7.26 ± 3.18	7.78 ± 2.35	7.56 ± 2.73	3.65 ± 2.75	5.21 ± 4.60	4.59 ± 4.04
RH (%)	47.08 ± 9.54	70.98 ± 14.45	67.68 ± 16.14	64.08 ± 12.87	74.30 ± 6.20	78.95 ± 6.25	77.04 ± 6.64	61.67 ± 19.52	64.23 ± 12.08	63.21 ± 15.54
Wind speed (m s^{-1})	10.14 ± 2.05	5.14 ± 2.35	5.83 ± 2.89	1.72 ± 0.48	1.28 ± 0.45	1.09 ± 0.21	1.17 ± 0.34	2.40 ± 0.61	1.94 ± 0.63	2.12 ± 0.66
VC[b] (m^2 s^{-1})	1489.30 ± 553.62	826.75 ± 571.42	918.14 ± 613.15	396.77 ± 164.14	483.56 ± 156.03	296.32 ± 71.82	373.42 ± 146.80	764.58 ± 384.17	437.39 ± 244.80	568.27 ± 347.40
PBLH (m)	159.45 ± 73.12	171.29 ± 82.64	169.65 ± 81.49	230.12 ± 66.52	385.03 ± 61.64	272.50 ± 42.69	318.84 ± 75.52	315.71 ± 116.95	214.63 ± 79.69	255.06 ± 108.32
Amount of rainfall (mm)	0.00 ± 0.00	1.26 ± 3.07 (*n* = 5)[c]	1.09 ± 2.89 (*n* = 5)[c]	0.29 ± 0.80 (*n* = 2)[c]	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
SO_2 (μg m^{-3})	19.75 ± 1.79	31.84 ± 8.83	30.17 ± 9.22	10.71 ± 2.86	11.14 ± 2.17	13.10 ± 2.07	12.29 ± 2.32	12.83 ± 7.31	18.44 ± 4.72	16.20 ± 6.50
NO_2 (μg m^{-3})	79.24 ± 23.93	55.25 ± 6.91	83.08 ± 23.45	35.07 ± 8.77	112.14 ± 9.45	133.50 ± 28.38	124.71 ± 24.92	57.83 ± 17.94	84.00 ± 12.52	73.53 ± 19.67
O_3 (μg m^{-3})	38.55 ± 17.38	66.75 ± 6.30	34.04 ± 14.02	52.29 ± 9.26	50.86 ± 12.14	47.60 ± 19.88	48.94 ± 17.19	40.83 ± 18.90	34.56 ± 19.56	37.07 ± 19.54
O_x (μg m^{-3})	122.00 ± 7.04	117.12 ± 22.66	117.79 ± 21.26	87.36 ± 12.20	112.14 ± 9.45	133.50 ± 28.38	124.71 ± 24.92	98.67 ± 34.73	118.56 ± 21.92	110.60 ± 29.42
NO_3^- (μg m^{-3})	40.39 ± 24.31	9.72 ± 3.20	36.16 ± 24.95	6.68 ± 4.63	11.82 ± 4.37	33.64 ± 14.85	24.65 ± 15.90	15.72 ± 8.16	27.88 ± 10.78	23.02 ± 11.48
SO_4^{2-} (μg m^{-3})	15.56 ± 12.13	25.13 ± 12.54	23.81 ± 12.91	6.13 ± 3.26	6.45 ± 1.82	16.26 ± 6.47	12.22 ± 7.02	8.59 ± 2.74	10.39 ± 3.68	9.67 ± 3.45
NH_4^+ (μg m^{-3})	5.18 ± 1.30	21.42 ± 14.12	19.18 ± 14.27	3.54 ± 1.71	5.71 ± 1.96	15.70 ± 8.80	11.59 ± 8.44	7.16 ± 2.04	9.95 ± 3.49	8.83 ± 3.29
K^+ (μg m^{-3})	0.91 ± 0.56	2.13 ± 1.70	1.96 ± 1.65	0.16 ± 0.13	0.92 ± 0.31	1.67 ± 0.39	1.36 ± 0.51	0.74 ± 0.29	1.47 ± 0.53	1.18 ± 0.57
ALW (μg m^{-3})	12.80 ± 10.66	94.99 ± 76.11	83.25 ± 76.21	10.22 ± 6.25	25.21 ± 19.67	107.37 ± 87.24	73.54 ± 79.19	34.36 ± 42.74	37.24 ± 33.06	36.09 ± 37.26
Total org. acids[d] (μg m^{-3})	0.87 ± 0.59	1.15 ± 1.23	1.11 ± 1.17	0.04 ± 0.03	0.66 ± 0.33	1.99 ± 0.86	1.45 ± 0.95	0.85 ± 0.24	1.10 ± 0.22	1.04 ± 0.29
(NO_3^- + $2SO_4^{2-}$) – NH_4^+ (μg m^{-3})	69.22 ± 33.07	35.66 ± 26.06	64.59 ± 34.21	15.34 ± 8.45	19.01 ± 5.95	50.46 ± 17.27	37.51 ± 20.73	25.73 ± 10.18	38.71 ± 13.72	33.52 ± 13.96
pH	5.07 ± 0.28	4.37 ± 0.69	4.46 ± 0.69	4.31 ± 1.63	3.45 ± 0.22	3.31 ± 0.39	3.37 ± 0.34	3.85 ± 0.99	3.68 ± 0.62	3.75 ± 0.79
$DMAH^+$ (μg m^{-3})	3.59 ± 1.54	6.75 ± 4.35	6.31 ± 4.22	1.92 ± 0.74	7.75 ± 4.38	15.37 ± 5.23	12.23 ± 6.16	5.43 ± 1.42	8.01 ± 2.95	6.98 ± 2.76
$MMAH^+$ (μg m^{-3})	8.74 ± 3.19	16.06 ± 9.53	15.05 ± 9.28	1.07 ± 0.55	10.37 ± 5.79	23.71 ± 8.02	18.22 ± 9.73	8.80 ± 3.11	15.35 ± 8.27	12.73 ± 7.43
EAH^+ (μg m^{-3})	3.44 ± 3.01	1.91 ± 1.39	2.12 ± 1.79	0.45 ± 0.06	6.54 ± 4.87	17.00 ± 12.69	12.70 ± 11.45	1.99 ± 1.36	2.03 ± 1.24	2.01 ± 1.29
$DEAH^+$ (μg m^{-3})	0.84 ± 0.93	1.97 ± 1.54	1.82 ± 1.52	0.65 ± 0.21	3.58 ± 2.66	5.56 ± 1.91	4.75 ± 2.45	1.08 ± 0.25	1.68 ± 0.73	1.44 ± 0.65
PAH^+ (μg m^{-3})	0.48 ± 0.28	0.28 ± 0.37	0.31 ± 0.37	0.00 ± 0.00	0.04 ± 0.07	0.21 ± 0.20	0.14 ± 0.18	0.04 ± 0.07	0.02 ± 0.04	0.03 ± 0.06
BAH^+ (μg m^{-3})	1.16 ± 0.21	0.86 ± 0.50	0.90 ± 0.48	0.07 ± 0.05	0.25 ± 0.11	0.40 ± 0.16	0.34 ± 0.16	0.20 ± 0.07	0.25 ± 0.09	0.23 ± 0.09
$PYRH^+$ (μg m^{-3})	1.05 ± 0.08	1.11 ± 0.08	1.11 ± 0.74	0.00 ± 0.00	1.29 ± 0.82	2.49 ± 1.12	1.99 ± 1.16	0.64 ± 0.25	1.29 ± 0.62	1.03 ± 0.60
Total aminiums (μg m^{-3})	19.31 ± 8.31	28.95 ± 16.75	27.62 ± 16.20	4.16 ± 1.24	29.83 ± 16.75	64.73 ± 20.57	50.36 ± 25.68	18.18 ± 4.86	28.62 ± 13.09	24.44 ± 11.77
TA/NH_4^+	4.07 ± 2.19	1.94 ± 1.56	2.24 ± 1.82	1.34 ± 0.54	4.93 ± 1.44	4.72 ± 1.36	4.81 ± 1.40	3.01 ± 1.15	2.62 ± 0.61	2.85 ± 0.99

[a]The numbers in parentheses indicate the number of samples.

[b]The ventilation coefficient (VC) can be used to characterize the state of atmospheric dilution in pollutant concentrations (Gani et al., 2019). The VC value can be expressed as a product of wind speed and planetary boundary layer height (PBLH).

[c]The numbers in parentheses indicate the days of rainfall.

[d]It represents the total concentrations of six organic acids including formic acid ($HCOO^-$), acetic acid (CH_3COO^-), oxalic acid ($C_2O_4^{2-}$), succinic acid ($C_4H_4O_4^{2-}$), methanesulfonic acid ($CH_3SO_3^-$), and glutaric acid ($C_5H_6O_4^{2-}$).

Table S3. Mean values (± SD) of the main parameters observed in different periods and locations.

Parameters	Hangzhou (HZ) Dec. 4–31, 2017 (*n* = 17)[a]			Guangzhou (GZ) Dec. 1–30, 2017 (*n* = 17)[a]			Guiyang (GY) Dec. 10, 2017 to Jan. 11, 2018 (*n* = 17)[a]		
	Clean day	Polluted day	Full period	Clean day	Polluted day	Full period	Clean day	Polluted day	Full period
$PM_{2.5}$ (μg m^{-3})	46.38 ± 13.48	105.11 ± 30.01	77.47 ± 37.71	45.33 ± 19.01	83.60 ± 5.31	56.59 ± 23.82	41.47 ± 14.44	100.50 ± 13.50	48.41 ± 23.82
T (℃)	7.38 ± 3.17	8.00 ± 5.43	7.71 ± 4.52	15.06 ± 4.28	18.41 ± 4.59	16.04 ± 4.63	4.09 ± 3.22	8.80 ± 0.30	4.65 ± 3.39
RH (%)	64.17 ± 19.25	69.33 ± 15.09	66.90 ± 17.36	63.21 ± 13.12	69.53 ± 6.87	65.07 ± 11.99	79.95 ± 13.27	60.90 ± 2.60	77.71 ± 13.92
Wind speed (m s^{-1})	2.46 ± 0.70	2.19 ± 0.96	2.32 ± 0.86	3.69 ± 1.35	2.13 ± 0.62	3.23 ± 1.38	2.64 ± 0.53	1.58 ± 0.04	2.52 ± 0.60
VC[b] (m^2 s^{-1})	970.49 ± 568.32	817.49 ± 776.37	889.49 ± 690.60	1703.32 ± 1018.18	470.35 ± 281.24	1340.69 ± 1034.73	1041.78 ± 512.05	656.11 ± 158.86	996.40 ± 499.76
PBLH (m)	310.78 ± 182.84	377.66 ± 128.87	342.26 ± 163.18	420.39 ± 141.33	205.03 ± 81.28	357.05 ± 160.22	390.80 ± 167.15	417.31 ± 111.32	393.92 ± 161.81
Amount of rainfall (mm)	4.50 ± 7.31 (*n* = 3)[c]	0.98 ± 2.59 (*n* = 2)[c]	2.64 ± 5.64 (*n* = 5)[c]	0.00 ± 0.00	0.14 ± 0.28 (*n* = 1)[c]	0.04 ± 0.16 (*n* = 1)[c]	2.01 ± 5.36 (*n* = 6)[c]	0.00 ± 0.00	1.77 ± 5.08 (*n* = 6)[c]
SO_2 (μg m^{-3})	12.13 ± 3.26	14.56 ± 2.99	13.41 ± 3.34	15.17 ± 4.49	23.60 ± 1.02	17.65 ± 5.41	30.73 ± 10.30	35.50 ± 0.50	31.29 ± 9.80
NO_2 (μg m^{-3})	59.50 ± 5.48	73.78 ± 15.50	67.06 ± 13.86	64.75 ± 25.49	103.80 ± 15.89	76.24 ± 29.15	36.93 ± 17.94	79.50 ± 5.50	41.94 ± 21.81
O_3 (μg m^{-3})	45.63 ± 19.33	49.78 ± 24.69	47.82 ± 22.43	71.25 ± 21.74	67.40 ± 31.66	70.12 ± 25.13	28.53 ± 17.91	36.00 ± 13.00	29.41 ± 17.57
O_x (μg m^{-3})	105.13 ± 19.61	123.56 ± 19.72	114.88 ± 21.71	136.00 ± 39.08	171.20 ± 32.83	146.35 ± 40.65	65.47 ± 24.87	115.50 ± 18.50	71.35 ± 29.09
NO_3^- (μg m^{-3})	12.56 ± 2.37	30.94 ± 9.81	22.29 ± 11.73	4.39 ± 2.20	9.29 ± 2.87	5.83 ± 3.29	4.44 ± 3.05	9.21 ± 3.47	5.00 ± 3.46
SO_4^{2-} (μg m^{-3})	5.37 ± 1.49	10.86 ± 4.12	8.28 ± 4.19	7.67 ± 2.73	12.09 ± 1.89	8.97 ± 3.22	7.35 ± 2.64	17.22 ± 4.60	8.51 ± 4.33
NH_4^+ (μg m^{-3})	5.55 ± 0.83	13.95 ± 8.36	10.00 ± 7.41	3.51 ± 1.27	6.03 ± 1.02	4.25 ± 1.66	3.25 ± 1.33	7.65 ± 2.55	3.77 ± 2.09
K^+ (μg m^{-3})	0.63 ± 0.22	1.20 ± 0.23	0.93 ± 0.36	0.57 ± 0.28	1.13 ± 0.15	0.73 ± 0.36	0.38 ± 0.24	1.14 ± 0.18	0.47 ± 0.34
ALW (μg m^{-3})	45.58 ± 65.02	78.22 ± 89.59	62.86 ± 80.65	7.34 ± 5.73	18.40 ± 9.42	10.59 ± 8.64	39.83 ± 76.00	16.77 ±	37.12 ± 71.86
Total org. acids[d] (μg m^{-3})	0.17 ± 0.10	0.58 ± 0.44	0.39 ± 0.39	0.38 ± 0.42	1.11 ± 0.39	0.59 ± 0.53	0.46 ± 0.32	1.55 ± 0.59	0.59 ± 0.51
(NO_3^- + $2SO_4^{2-}$) – NH_4^+ (μg m^{-3})	17.76 ± 2.11	38.70 ± 9.83	28.84 ± 12.75	16.23 ± 5.41	27.45 ± 4.45	19.53 ± 7.25	15.89 ± 7.18	35.99 ± 10.11	18.25 ± 9.97
pH	3.76 ± 0.45	3.67 ± 0.68	3.71 ± 0.59	2.44 ± 0.47	2.35 ± 0.36	2.41 ± 0.44	3.22 ± 0.52	3.02 ± 0.37	3.20 ± 0.51
$DMAH^+$ (μg m^{-3})	6.71 ± 5.82	16.49 ± 7.39	11.89 ± 8.29	2.36 ± 0.94	6.47 ± 3.71	3.57 ± 2.87	6.67 ± 4.09	16.10 ± 11.30	7.78 ± 6.25
$MMAH^+$ (μg m^{-3})	7.85 ± 3.30	26.62 ± 11.81	17.79 ± 12.91	4.94 ± 2.34	10.55 ± 1.80	6.59 ± 3.37	14.36 ± 10.99	45.75 ± 29.35	18.06 ± 17.61
EAH^+ (μg m^{-3})	2.17 ± 1.95	5.93 ± 2.60	4.16 ± 2.98	0.71 ± 0.42	0.94 ± 0.65	0.78 ± 0.51	2.20 ± 1.77	6.45 ± 3.75	2.70 ± 2.51
$DEAH^+$ (μg m^{-3})	2.48 ± 2.49	5.79 ± 2.74	4.23 ± 3.10	6.86 ± 4.23	11.28 ± 4.09	8.16 ± 4.65	0.33 ± 0.47	0.35 ± 0.35	0.33 ± 0.46
PAH^+ (μg m^{-3})	0.16 ± 0.28	0.51 ± 0.46	0.35 ± 0.42	0.29 ± 0.30	0.16 ± 0.32	0.25 ± 0.31	0.54 ± 0.53	1.55 ± 0.65	0.66 ± 0.63
BAH^+ (μg m^{-3})	0.39 ± 0.40	0.94 ± 0.53	0.68 ± 0.54	0.47 ± 0.39	0.34 ± 0.34	0.43 ± 0.38	0.88 ± 0.44	1.40 ± 0.30	0.94 ± 0.46
$PYRH^+$ (μg m^{-3})	0.45 ± 0.35	1.48 ± 0.53	0.99 ± 0.69	0.36 ± 0.39	0.84 ± 0.40	0.50 ± 0.45	1.72 ± 1.23	4.65 ± 3.05	2.06 ± 1.82
Total aminiums (μg m^{-3})	20.22 ± 11.75	57.75 ± 23.86	40.09 ± 26.78	16.00 ± 6.37	30.57 ± 9.22	20.29 ± 9.89	26.71 ± 18.36	76.25 ± 48.75	32.53 ± 28.84
TA/NH_4^+	3.52 ± 1.62	4.54 ± 1.66	4.06 ± 1.72	5.07 ± 2.60	5.12 ± 1.42	5.09 ± 2.32	8.37 ± 4.12	8.82 ± 3.43	8.43 ± 4.04

[a]The numbers in parentheses indicate the number of samples.

[b]The ventilation coefficient (VC) can be used to characterize the state of atmospheric dilution in pollutant concentrations (Gani et al., 2019). The VC value can be expressed as a product of wind speed and planetary boundary layer height (PBLH).

[c]The numbers in parentheses indicate the days of rainfall.

[d]It represents the total concentrations of six organic acids including formic acid ($HCOO^-$), acetic acid (CH_3COO^-), oxalic acid ($C_2O_4^{2-}$), succinic acid ($C_4H_4O_4^{2-}$), methanesulfonic acid ($CH_3SO_3^-$), and glutaric acid ($C_5H_6O_4^{2-}$).

Table S4. Mean mass concentrations of various aminiums in $PM_{2.5}$ or cloud water in different seasons and locations.

Type of site	Research area	Year	Period	$DMAH^+$ (ng m^{-3})	$MMAH^+$ (ng m^{-3})	EAH^+ (ng m^{-3})	$DEAH^+$ (ng m^{-3})	Other aminiums[a] (ng m^{-3})	Total aminiums (ng m^{-3})	Reference
Urban	Guangzhou (China)	2020	Summer	15.6	29.1	6.5	40.6	19.5	111.3	(Chen et al., 2022b)
	Guangzhou (China)	2018	Autumn	49.0	243.0	–	1.0	4.0	297.0	(Huang et al., 2022)
	Guangzhou (China)	2015–2016	Winter	28.6	40.4	2.7	7.0	41.3	120	(Liu et al., 2022a)
	Guangzhou (China)	2017–2018	Winter	3.4	6.3	1.3	10.2	2.2	23.4	(Liu et al., 2023)
	Xiamen (China)	2013	Winter	1.7	10.2	5.3	0.9	35.6	53.7	(Ho et al., 2016)
	Hong Kong (China)	2013	Winter	1.5	12.1	4.5	0.9	26.7	45.7	(Ho et al., 2016)
	Shanghai (China)	2013	Summer	15.7	8.9	11.5	38.8[c]	0	74.9	(Tao et al., 2016)
	Shanghai (China)	2013	Summer	–	2.4	0.2	–	2.2	4.8	(Huang et al., 2016)
			Winter	–	3.9	0.3	–	3.8	8.0	
	Shanghai (China)	2013	Spring	6.4	–	–	4.8	8.4	19.6	(Zhou et al., 2019)
			Summer	9.1	–	–	1.7	0.9	11.7	
			Autumn	15.5	–	–	2.8	12.7	31.0	
			Winter	27.3	–	–	7.3	35.2	69.8	
	Shanghai (China)	2017–2018	Winter	8.6	16.0	4.0	3.7	3.5	35.8	(Liu et al., 2023)
	Yangzhou (China)	2016	Summer	3.6	1.4	12.6	–	0	17.6	(Cheng et al., 2020)
	Yangzhou (China)	2015–2016	Winter	4.3	4.9	15.4	–	0	24.6	(Shen et al., 2017)
	Nanjing (China)	2017–2018	Winter	5.1	6.6	3.5	1.7	2.4	19.3	(Liu et al., 2023)
	Nanjing (China)	2016	Spring	4.2	7.6	21.7	–	0	33.5	
	Nanjing (China)	2001	Spring	–	12.5	6.7	–	4.0	23.2	(Yang et al., 2005)
			Autumn	–	5.5	3.7	–	1.7	10.9	
	Seoul (Korea)	2018	Spring	2.8	–	0.3	1.4	1.3	5.8	(Choi et al., 2020)
			Summer	3.4	–	0.4	1.2	0.8	5.8	
			Autumn	2.6	–	0.3	1.3	0.9	5.1	
			Winter	2.3	–	0.1	1.4	1.9	5.7	
			Annual	2.7	–	0.3	1.3	1.3	5.6	
	Beijing (China)	2013	Winter	4.3	31.0	14.8	2.1	81.0	133.2	(Ho et al., 2016)
	Xi’an (China)	2017–2018	Winter	5.0	13.2	2.4	1.2	3.6	25.4	(Liu et al., 2023)
	Xi’an (China)	2013	Winter	3.8	24.7	12.6	2.0	62.2	105.3	(Ho et al., 2016)

	Xi'an (China)	2008–2009	Spring	–[b]	16.9	9.7	–	6.0	32.6	(Ho et al., 2015)
			Summer	–	6.2	3.8	–	1.6	11.6	
			Autumn	–	14.7	8.4	–	4.5	27.6	
			Winter	–	22.3	11.5	–	6.8	40.6	
Suburban	Shanghai (China)	2018	Summer	6.3	15.0	–	20.4	3.9	45.6	(Du et al., 2021)
	Guangzhou (China)	2021	Winter	4.8	11.3	6.2	7.4	22.7	52.4	(Shu et al., 2023)
	Xuzhou (China)	2015–2016	Winter	12.7	111.0	112.0	8.5[c]	4.8	249.0	(Yang et al., 2023)
			Spring	15.2	109.0	41.0	10.5[c]	16.7	192.4	
			Summer	16.2	49.7	14.7	11.3[c]	22.8	114.7	
			Autumn	13.9	53.0	14.3	6.9[c]	15.6	103.7	
			Annual	14.6	80.8	52.0	9.7[c]	14.9	172.0	
	Beijing (China)	2017	Winter	1.2	23.3	11.1	0.4	8.9	44.9	(Wang et al., 2022)
Rural	Guiyang, puding (China)	2017–2018	Winter	8.8	20.6	3.2	0.1	4.5	37.2	(Liu et al., 2023)
	Baoding (China)	2019–2020	Winter	59.6	20.4	–	79.1	170.7	329.8	(Feng et al., 2022)
	Egbert (Canada)	2010	Autumn	0.1	–	–	1.0[c]	0	1.1	(Vandenboer et al., 2012)
Forest	Nanling (China)	2016–2017	Summer	5.0	11.9	–	1.7	2.1	20.7	(Liu et al., 2018)
			Autumn	2.4	8.8	–	1.1	0.1	12.4	
Coastal, Marine, or polar areas	Qingdao (China)	2018	Winter	58.7	8.5	2.7	8.4	52.4	130.7	(Liu et al., 2022b)
		2019	Winter	86.3	6.9	2.4	8.7	28.6	132.9	
	Zonguldak (Turkey)	2006–2007	Winter	4.6	4.5	4.4	4.2	102.1	119.8	(Akyüz, 2008)
			Summer	2.8	2.3	2.2	2.8	66.6	76.7	
	Huaniao Island (China)	2016	Summer	4.0	–	–	8.7[c]	0	12.7	(Zhou et al., 2019)
	The coastline of the East China Sea, South China Sea, and Yellow Sea	2018	Spring	30.1	–	–	–	–	–	(Chen et al., 2022a)
	Northwest Atlantic	2020	Winter (non-cold)	3.91	–	–	–	–	–	(Corral et al., 2022)
		2020	Winter (cold)	7.39	–	–	–	–	–	
		2020	Summer	0.63	–	–	–	–	–	
	South of the southern boundary of the Antarctic Circumpolar Current	2015	Winter	2.02	0.34	0.12	3.84	0.81	7.13	(Dall'osto et al., 2019)
	North of the southern	2015	Winter	0.7	0.05	0.01	0.61	0.12	1.49	(Dall'osto et al., 2019)

	boundary of the Antarctic Circumpolar Current									

[a]It indicates the total concentrations of other aminiums including triethylaminium ($TEAH^+$), PAH^+, BAH^+, $PYRH^+$, morpholine ($MORH^+$), or monoethanolaminium ($MEOH^+$).

[b]The symbol "–" indicates no data.

[c]It indicates the sum of $TMAH^+$ and $DEAH^+$ concentrations.

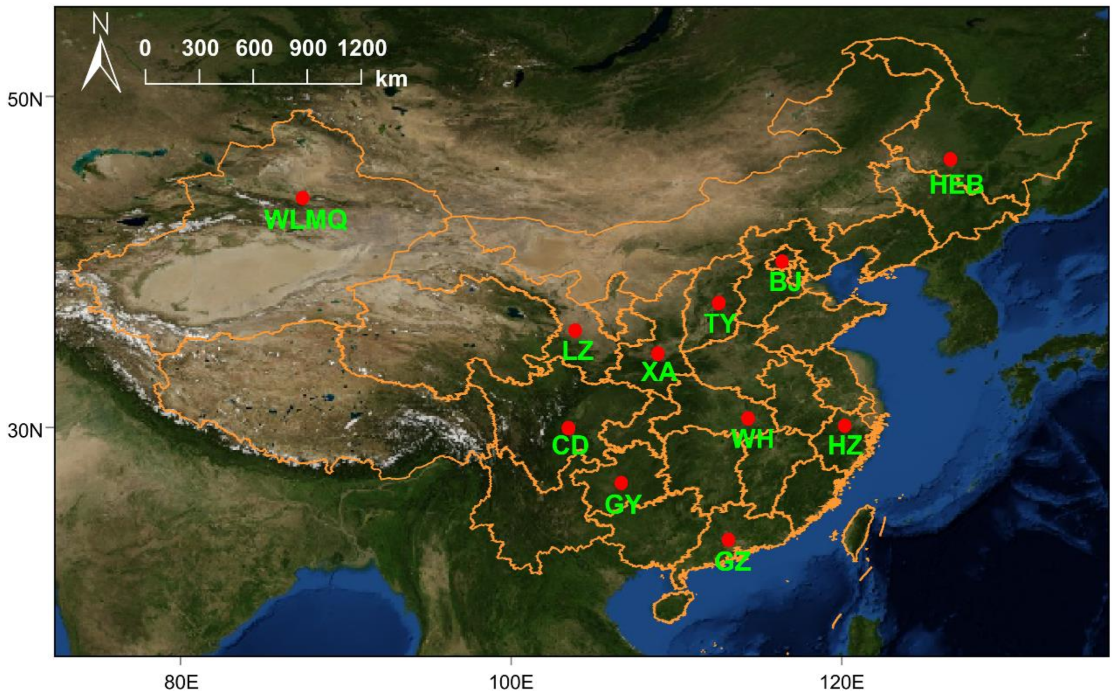

Figure S1. The locations of the sampling sites. The map was derived from ©MeteoInfoMap (version 3.3.0) (Chinese Academy of Meteorological Sciences, China).

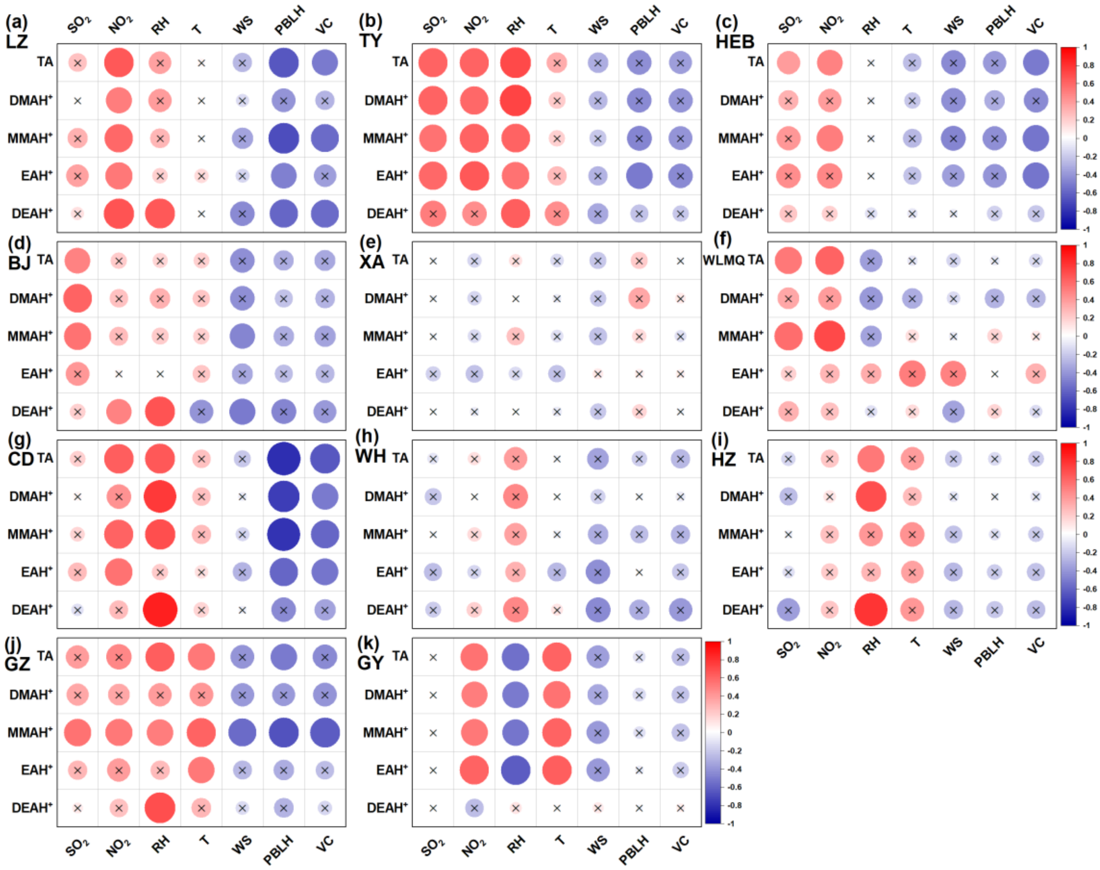

Figure S2. Diagrams presenting correlations between the concentrations of various aminiums and other parameters at (**a**–**k**) different sites. The colors of the different solid circles indicate different correlation coefficients *r*. The size of the solid circle indicates the significance of the correlation between the two corresponding parameters: the larger circle indicates that the correlation is more significant, whereas the symbol "×" indicates that the *P*-value is greater than 0.05.

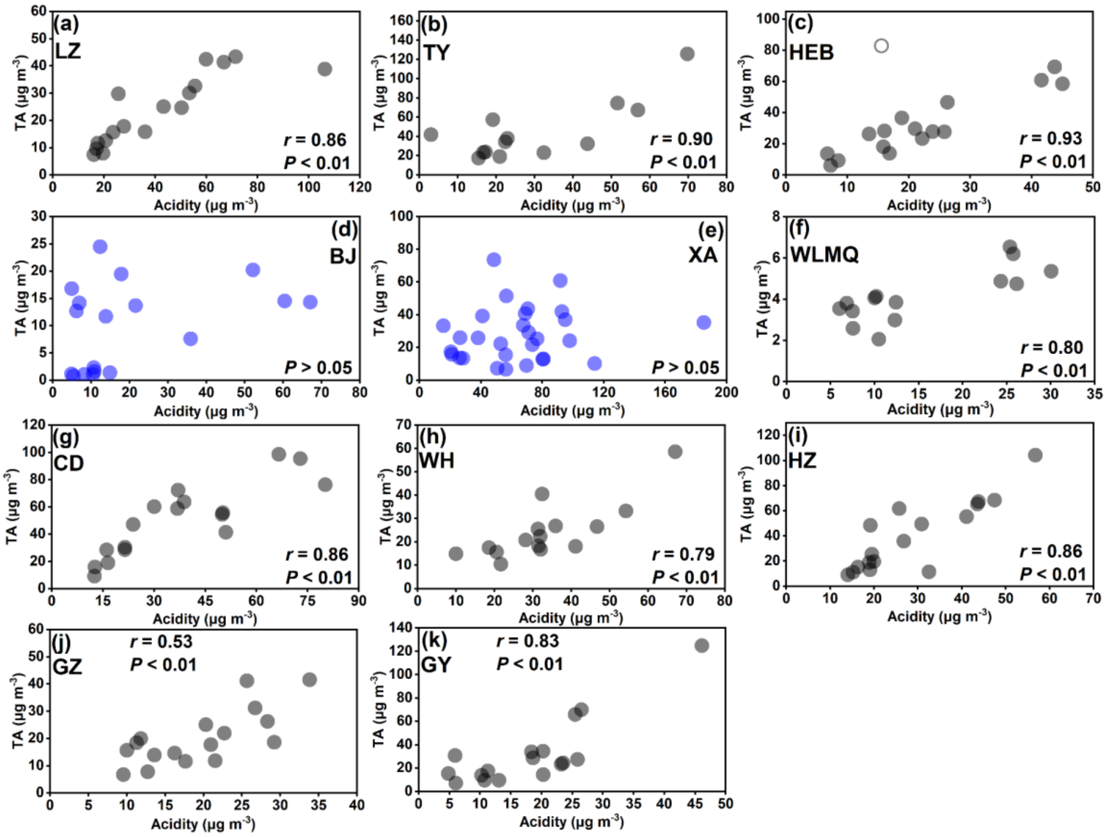

Figure S3. Concentration of TA as a function of acidity (expressed as (NO_3^- + 2SO_4^{2-}) – NH_4^+) at the (a) LZ, (b) TY, (c) HEB, (d) BJ, (e) XA, (f) WLMQ, (g) CD, (h) WH, (i) HZ, (j) GZ, and (k) GY sites. Open circles represent outliers.

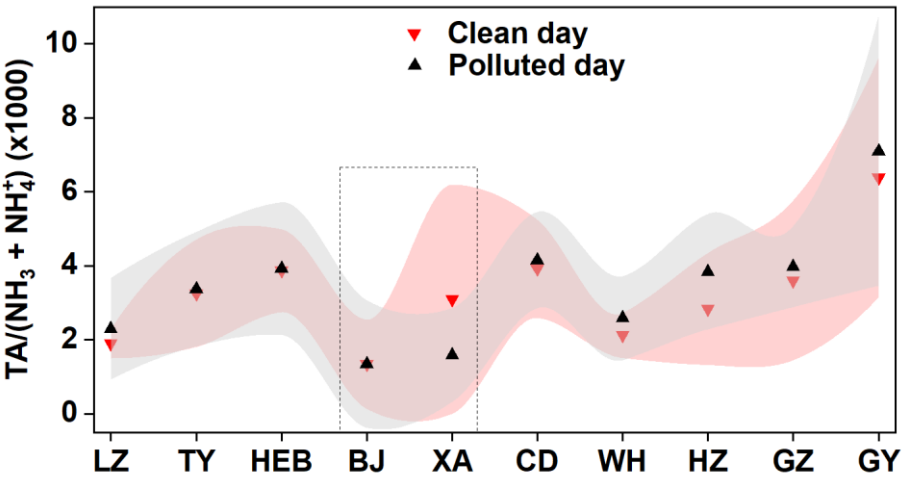

Figure S4. The averages of TA/(NH_3 + NH_4^+) ratios on clean and polluted days in different cities. The triangle and the shaded area represent the mean value and the associated standard deviation, respectively. The concentration of NH_3 was predicated using ISORROPIA-II (Guo et al., 2015).

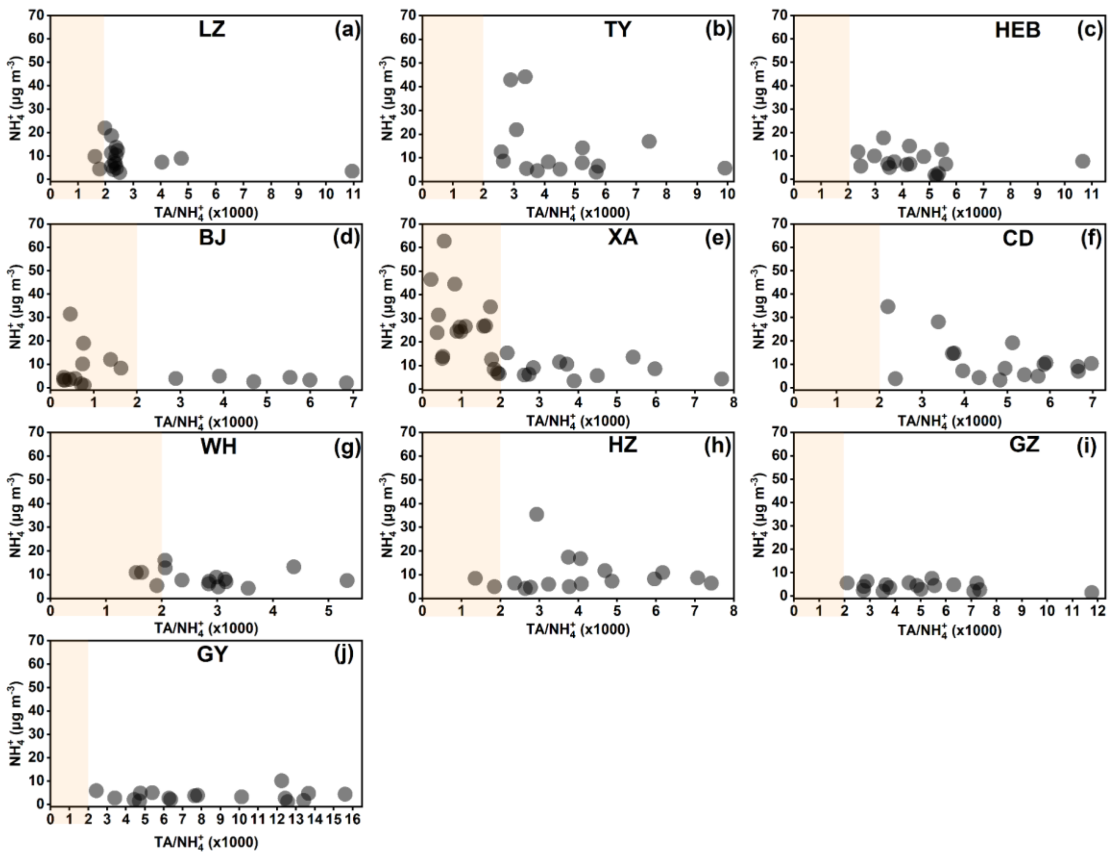

Figure S5. Scatterplots of the mass concentrations of NH_4^+ with the ratio of TA to NH_4^+ at the (a) LZ, (b) TY, (c) HEB, (d) BJ, (e) XA, (f) WLMQ, (g) CD, (h) WH, (i) HZ, (j) GZ, and (k) GY sites.

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