**Appendix**

**Electrostatically assisted air coarse filtration for energy efficient ambient particles removal: long-term performance in real environment and influencing factors**

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This supporting information (12 pages) includes 5 figures and 9 tables.

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|  |
| (a) Air temperature and moisture content |
|  |
| (b) Particle number concentration for 0.3 ~ 0.5 μm, 1 ~ 3 μm, and 5~ 10 μm particles |
|  |
| (c) Particle number concentration for 0.5 ~ 1 μm and 3 ~ 5 μm particles |

Fig. A1. Environmental parameters during the operation period of EAA coarse filter.

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| --- |
|  |
| (a) Charging voltage and charging current |
|  |
| (b) Polarizing voltage and polarizing current |

Fig. A2. Operation parameters during the operation period of EAA coarse filter.

|  |  |
| --- | --- |
|  |  |
| (a) Efficiencies for 0.5 ~ 1 μm particles | (b) Efficiencies for 1 ~ 3 μm particles |
|  |  |
| (c) Efficiencies for 3 ~ 5 μm particles | (d) Efficiencies for 5 ~ 10 μm particles |

Fig. A3. Long-term single pass filtration efficiencies of the EAA coarse filter for 0.3 ~ 10 μm particles

|  |  |
| --- | --- |
|  |  |
| (a) New (the 1st day) | (b) Before cleaning (the 27th day) |
|  |  |
| (c) After cleaning (the 28th day) | (d) At end (the 51st day) |

Fig. A4. Morphology changes of a charging pin along the long-term experiment for EAA coarse filter.



Fig. A5. Long-term single pass filtration efficiency for 0.3 ~ 0.5 μm ambient particles and pressure drop of the conventional electret filter at face air velocity of 1 m/s.



Fig. A6. 0.3 ~ 0.5 μm ambient particle concentrations at downstream of EAA coarse filter and conventional electret filter.

**Description for Tables A1 ~ A3** *(in order to obtain the key factors influencing the* ***charging stability*** *by PCA method)***:**

We obtained the correlation coefficients among the 9 influencing factors in Table A1. The factors with high correlation coefficient will be categorized in one principal component. We decided to extract 3 principal components from the 9 influencing factors according to the explained total variance shown in Table A2. Generally, the total variance up to certain number of the principal components should exceed 80% to ensure most of the data to be explained. Then, the correlation coefficients between the 9 influencing factors and the 3 principal components were shown in Table A3.

When several influencing factors dominates in one principal component, we can use the principal component to represent most characteristic of these influencing factors. At the same time, if these influencing factors have strong correlation among themselves, we can use the characteristic of one of them to represent the others. For example, the correlation coefficients of *C*n,up(0.3 ~ 0.5), *C*n,up(0.5 ~ 1), *C*n,up(1 ~ 3), *C*m(PM2.5), and *d*air were beyond 0.75 as shown in Table A1 and they dominated in principal component 1 as shown in Table A3. We used *C*n,up(0.5 ~ 1) to represent the characteristics of *C*n,up(0.3 ~ 0.5), *C*n,up(1 ~ 3), and *C*m(PM2.5). Since *d*air was a totally different parameter from *C*n,up, we would discuss its influence separately. Similarly, we used *C*n,up(3 ~ 5) to represent the characteristics of *C*n,up(5 ~ 10), while discuss the influence of *T*air and *CA*acc(PM2.5) separately. Therefore, we had 5 key parameters to discuss their influence on *P*c of the EAA coarse filter, including *T*air, *d*air, *C*n,up(0.5 ~ 1), *C*n,up(3 ~ 5) and *CA*acc(PM2.5).

Table A1. Correlation matrix of influencing factors for charging power (*P*C).

|  | | *C*n,up  (0.3 ~ 0.5) | *C*n,up  (0.5 ~ 1) | *C*n,up  (1 ~ 3) | *C*n,up  (3 ~ 5) | *C*n,up  (5 ~ 10) | *T*air | *d*air | *C*m  (PM2.5) | *CA*acc  (PM2.5) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Corre-lation | *C*n,up(0.3 ~ 0.5) | 1.000 | 0.984 | 0.799 | 0.297 | 0.320 | 0.129 | 0.743 | 0.810 | 0.004 |
| *C*n,up(0.5 ~ 1) | 0.984 | 1.000 | 0.849 | 0.349 | 0.351 | 0.133 | 0.722 | 0.867 | 0.023 |
| *C*n,up(1 ~ 3) | 0.799 | 0.849 | 1.000 | 0.778 | 0.748 | 0.293 | 0.626 | 0.726 | 0.151 |
| *C*n,up(3 ~ 5) | 0.297 | 0.349 | 0.778 | 1.000 | 0.973 | 0.312 | 0.264 | 0.228 | 0.202 |
| *C*n,up(5 ~ 10) | 0.320 | 0.351 | 0.748 | 0.973 | 1.000 | 0.282 | 0.304 | 0.217 | 0.207 |
| *T*air | 0.129 | 0.133 | 0.293 | 0.312 | 0.282 | 1.000 | 0.449 | 0.055 | -0.132 |
| *d*air | 0.743 | 0.722 | 0.626 | 0.264 | 0.304 | 0.449 | 1.000 | 0.663 | -0.139 |
| *C*m(PM2.5) | 0.810 | 0.867 | 0.726 | 0.228 | 0.217 | 0.055 | 0.663 | 1.000 | 0.021 |
| *CA*acc(PM2.5) | 0.004 | 0.023 | 0.151 | 0.202 | 0.207 | -0.132 | -0.139 | 0.021 | 1.000 |
| Determinant = 1.56 × 10-7 | | | | | | | | | | |

Table A2. Total variance explained of influencing factors for charging power (*P*C).

| Comp-  onent | Initial eigenvalues | | | Extraction sums of squared loadings | | | Rotation sums of squared loadings | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Total | % of variance | cumulative % | Total | % of variance | cumulative % | Total | % of variance | cumulative % |
| 1 | 4.791 | 53.233 | 53.233 | 4.791 | 53.233 | 53.233 | 3.884 | 43.151 | 43.151 |
| 2 | 1.785 | 19.836 | 73.069 | 1.785 | 19.836 | 73.069 | 2.633 | 29.252 | 72.403 |
| 3 | 1.226 | 13.626 | 86.695 | 1.226 | 13.626 | 86.695 | 1.286 | 14.291 | 86.695 |
| 4 | 0.704 | 7.825 | 94.520 |  |  |  |  |  |  |
| 5 | 0.245 | 2.725 | 97.245 |  |  |  |  |  |  |
| 6 | 0.205 | 2.273 | 99.518 |  |  |  |  |  |  |
| 7 | 0.036 | 0.396 | 99.914 |  |  |  |  |  |  |
| 8 | 0.006 | 0.063 | 99.977 |  |  |  |  |  |  |
| 9 | 0.002 | 0.023 | 100.000 |  |  |  |  |  |  |
| Extraction method: principal component analysis | | | | | | | | | |

Table A3. Rotation component matrix of influencing factors for charging power (*P*C). Rotation converged in 4 iterations.

| Influencing factors | Principal component | | |
| --- | --- | --- | --- |
| 1 | 2 | 3 |
| *C*n,up(0.3 ~ 0.5) | 0.955 | 0.151 | 0.029 |
| *C*n,up(0.5 ~ 1) | 0.965 | 0.193 | 0.004 |
| *C*n,up(1 ~ 3) | 0.735 | 0.658 | 0.017 |
| *C*n,up(3 ~ 5) | 0.170 | 0.962 | 0.016 |
| *C*n,up(5 ~ 10) | 0.181 | 0.949 | 0.008 |
| *T*air | 0.045 | 0.399 | 0.766 |
| *d*air | 0.764 | 0.170 | 0.437 |
| *C*m(PM2.5) | 0.924 | 0.061 | -0.045 |
| *CA*acc(PM2.5) | -0.026 | 0.351 | -0.710 |
| Extraction method: principal component analysis.  Rotation method: varimax with Kaiser normalization component scores. | | | |

**Description for Tables A4 ~ A6** *(in order to obtain the key factors influencing the* ***filtration efficiency stability in early period*** *by PCA method):*

Similar to those in **Description for Tables 1 ~ 3**, we obtained the correlation coefficients among the 9 influencing factors in Table A4. We decided to extract 3 principal components from the 9 influencing factors according to the explained total variance shown in Table A5. And the correlation coefficients between the 9 influencing factors and the 3 principal components were shown in Table A6.

Similar to those in **Description for Tables 1 ~ 3**, the correlation coefficients of *C*n,up(0.3 ~ 0.5), *C*n,up(0.5 ~ 1), *C*n,up(1 ~ 3), *C*m(PM2.5), and *d*air were beyond 0.5 as shown in Table A4 and they dominated in principal component 1 as shown in Table A6. We used *C*n,up(0.5 ~ 1) to represent the characteristics of *C*n,up(0.3 ~ 0.5), *C*n,up(1 ~ 3), and *C*m(PM2.5). Since *d*air was a totally different parameter from *C*n,up, we would discuss its influence separately. Similarly, we used *C*n,up(3 ~ 5) to represent the characteristics of *C*n,up(5 ~ 10), while discuss the influence of *T*air and *CA*acc(PM2.5) separately. Therefore, we had 5 key parameters to discuss their influence on *η*(0.3 ~ 0.5) in Group #3 of the EAA coarse filter, including *T*air, *d*air, *C*n,up(0.5 ~ 1), *C*n,up(3 ~ 5) and *CA*acc(PM2.5).

Table A4. Correlation matrix of influencing factors for 0.3 ~ 0.5 μm particle single pass filtration efficiency (*η*(0.3 ~ 0.5)) in Group #3.

|  | | *C*n,up  (0.3 ~ 0.5) | *C*n,up  (0.5 ~ 1) | *C*n,up  (1 ~ 3) | *C*n,up  (3 ~ 5) | *C*n,up  (5 ~ 10) | *T*air | *d*air | *C*m  (PM2.5) | *CA*acc  (PM2.5) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Corre-lation | *C*n,up(0.3 ~ 0.5) | 1.000 | 0.893 | 0.803 | 0.491 | 0.417 | -0.227 | 0.509 | 0.895 | 0.258 |
| *C*n,up(0.5 ~ 1) | 0.893 | 1.000 | 0.977 | 0.519 | 0.423 | -0.049 | 0.702 | 0.946 | 0.092 |
| *C*n,up(1 ~ 3) | 0.803 | 0.977 | 1.000 | 0.573 | 0.475 | 0.031 | 0.769 | 0.913 | 0.024 |
| *C*n,up(3 ~ 5) | 0.491 | 0.519 | 0.573 | 1.000 | 0.989 | 0.333 | 0.487 | 0.525 | 0.289 |
| *C*n,up(5 ~ 10) | 0.417 | 0.423 | 0.475 | 0.989 | 1.000 | 0.359 | 0.414 | 0.432 | 0.318 |
| *T*air | -0.227 | -0.049 | 0.031 | 0.333 | 0.359 | 1.000 | 0.163 | -0.064 | -0.021 |
| *d*air | 0.509 | 0.702 | 0.769 | 0.487 | 0.414 | 0.163 | 1.000 | 0.681 | -0.017 |
| *C*m(PM2.5) | 0.895 | 0.946 | 0.913 | 0.525 | 0.432 | -0.064 | 0.681 | 1.000 | 0.138 |
| *CA*acc(PM2.5) | 0.258 | 0.092 | 0.024 | 0.289 | 0.318 | -0.021 | -0.017 | 0.138 | 1.000 |
| Determinant = 2.03 × 10-7 | | | | | | | | | | |

Table A5. Total variance explained of influencing factors for 0.3 ~ 0.5 μm particle single pass filtration efficiency (*η*(0.3 ~ 0.5)) in Group #3.

| Comp-  onent | Initial eigenvalues | | | Extraction sums of squared loadings | | | Rotation sums of squared loadings | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Total | % of variance | cumulative % | Total | % of variance | cumulative % | Total | % of variance | cumulative % |
| 1 | 5.057 | 56.194 | 56.194 | 5.057 | 56.194 | 56.194 | 4.539 | 50.431 | 50.431 |
| 2 | 1.689 | 18.771 | 74.966 | 1.689 | 18.771 | 74.966 | 1.971 | 21.901 | 72.332 |
| 3 | 1.153 | 12.807 | 87.772 | 1.153 | 12.807 | 87.772 | 1.390 | 15.440 | 87.772 |
| 4 | 0.546 | 6.068 | 93.840 |  |  |  |  |  |  |
| 5 | 0.376 | 4.179 | 98.019 |  |  |  |  |  |  |
| 6 | 0.106 | 1.173 | 99.192 |  |  |  |  |  |  |
| 7 | 0.065 | 0.721 | 99.913 |  |  |  |  |  |  |
| 8 | 0.005 | 0.054 | 99.966 |  |  |  |  |  |  |
| 9 | 0.003 | 0.034 | 100.000 |  |  |  |  |  |  |
| Extraction method: principal component analysis. | | | | | | | | | |

Table A6. Rotation component matrix of influencing factors for 0.3 ~ 0.5 μm particle single pass filtration efficiency (*η*(0.3 ~ 0.5)) in Group #3. Rotation converged in 4 iterations.

| Influencing factors | Principal component | | |
| --- | --- | --- | --- |
| 1 | 2 | 3 |
| *C*n,up(0.3 ~ 0.5) | 0.889 | -0.084 | 0.331 |
| *C*n,up(0.5 ~ 1) | 0.977 | 0.071 | 0.072 |
| *C*n,up(1 ~ 3) | 0.959 | 0.185 | -0.011 |
| *C*n,up(3 ~ 5) | 0.474 | 0.726 | 0.404 |
| *C*n,up(5 ~ 10) | 0.372 | 0.755 | 0.442 |
| *T*air | -0.152 | 0.844 | -0.209 |
| *d*air | 0.760 | 0.332 | -0.174 |
| *C*m(PM2.5) | 0.954 | 0.061 | 0.130 |
| *CA*acc(PM2.5) | 0.002 | 0.045 | 0.909 |
| Extraction method: principal component analysis.  Rotation method: varimax with Kaiser normalization component scores. | | | |

**Description for Tables A7 ~ A9** *(in order to obtain the key factors influencing the* ***filtration efficiency stability in late period*** *by PCA method):*

Similar to those in **Description for Tables 1 ~ 3**, we obtained the correlation coefficients among the 9 influencing factors in Table A7. We decided to extract 3 principal components from the 9 influencing factors according to the explained total variance shown in Table A8. And the correlation coefficients between the 9 influencing factors and the 3 principal components were shown in Table A9.

Similar to those in **Description for Tables 1 ~ 3**, the correlation coefficients of *C*n,up(0.3 ~ 0.5), *C*n,up(0.5 ~ 1), *C*n,up(1 ~ 3), *C*m(PM2.5), and *d*air were beyond 0.5 as shown in Table A7 and they dominated in principal component 1 as shown in Table A9. We used *C*n,up(0.5 ~ 1) to represent the characteristics of *C*n,up(0.3 ~ 0.5), *C*n,up(1 ~ 3), and *C*m(PM2.5). Since *d*air was a totally different parameter from *C*n,up, we would discuss its influence separately. Similarly, we used *C*n,up(3 ~ 5) to represent the characteristics of *C*n,up(5 ~ 10), while discuss the influence of *T*air and *CA*acc(PM2.5) separately. Therefore, we had 5 key parameters to discuss their influence on *η*(0.3 ~ 0.5) in Group #7 of the EAA coarse filter, including *T*air, *d*air, *C*n,up(0.5 ~ 1), *C*n,up(3 ~ 5) and *CA*acc(PM2.5).

Table A7. Correlation matrix of influencing factors for 0.3 ~ 0.5 μm particle single pass filtration efficiency (*η*(0.3 ~ 0.5)) in Group #7.

|  | | *C*n,up  (0.3 ~ 0.5) | *C*n,up  (0.5 ~ 1) | *C*n,up  (1 ~ 3) | *C*n,up  (3 ~ 5) | *C*n,up  (5 ~ 10) | *T*air | *d*air | *C*m  (PM2.5) | *CA*acc  (PM2.5) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Corre-lation | *C*n,up(0.3 ~ 0.5) | 1.000 | 0.990 | 0.929 | 0.492 | 0.445 | -0.261 | 0.538 | 0.969 | -0.145 |
| *C*n,up(0.5 ~ 1) | 0.990 | 1.000 | 0.945 | 0.506 | 0.457 | -0.241 | 0.556 | 0.957 | -0.160 |
| *C*n,up(1 ~ 3) | 0.929 | 0.945 | 1.000 | 0.713 | 0.666 | -0.150 | 0.617 | 0.905 | -0.200 |
| *C*n,up(3 ~ 5) | 0.492 | 0.506 | 0.713 | 1.000 | 0.991 | 0.192 | 0.576 | 0.518 | -0.248 |
| *C*n,up(5 ~ 10) | 0.445 | 0.457 | 0.666 | 0.991 | 1.000 | 0.235 | 0.564 | 0.475 | -0.262 |
| *T*air | -0.261 | -0.241 | -0.150 | 0.192 | 0.235 | 1.000 | 0.292 | -0.203 | -0.499 |
| *d*air | 0.538 | 0.556 | 0.617 | 0.576 | 0.564 | 0.292 | 1.000 | 0.583 | -0.760 |
| *C*m(PM2.5) | 0.969 | 0.957 | 0.905 | 0.518 | 0.475 | -0.203 | 0.583 | 1.000 | -0.185 |
| *CA*acc(PM2.5) | -0.145 | -0.160 | -0.200 | -0.248 | -0.262 | -0.499 | -0.760 | -0.185 | 1.000 |
| Determinant = 3.37 × 10-8 | | | | | | | | | | |

Table A8. Total variance explained of influencing factors for 0.3 ~ 0.5 μm particle single pass filtration efficiency (*η*(0.3 ~ 0.5)) in Group #7.

| Comp-  onent | Initial eigenvalues | | | Extraction sums of squared loadings | | | Rotation sums of squared loadings | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Total | % of variance | cumulative % | Total | % of variance | cumulative % | Total | % of variance | cumulative % |
| 1 | 5.278 | 58.642 | 58.642 | 5.278 | 58.642 | 58.642 | 4.128 | 45.863 | 45.863 |
| 2 | 2.039 | 22.659 | 81.301 | 2.039 | 22.659 | 81.301 | 2.233 | 24.815 | 70.678 |
| 3 | 1.051 | 11.679 | 92.979 | 1.051 | 11.679 | 92.979 | 2.007 | 22.302 | 92.979 |
| 4 | 0.412 | 4.581 | 97.561 |  |  |  |  |  |  |
| 5 | 0.118 | 1.315 | 98.876 |  |  |  |  |  |  |
| 6 | 0.067 | 0.743 | 99.618 |  |  |  |  |  |  |
| 7 | 0.021 | 0.234 | 99.853 |  |  |  |  |  |  |
| 8 | 0.007 | 0.083 | 99.936 |  |  |  |  |  |  |
| 9 | 0.006 | 0.064 | 100.000 |  |  |  |  |  |  |
| Extraction method: principal component analysis | | | | | | | | | |

Table A9. Rotation component matrix of influencing factors for 0.3 ~ 0.5 μm particle single pass filtration efficiency (*η*(0.3 ~ 0.5)) in Group #7. Rotation converged in 5 iterations.

| Influencing factors | Principal component | | |
| --- | --- | --- | --- |
| 1 | 2 | 3 |
| *C*n,up(0.3 ~ 0.5) | .967 | .196 | .031 |
| *C*n,up(0.5 ~ 1) | .962 | .211 | .049 |
| *C*n,up(1 ~ 3) | .866 | .456 | .080 |
| *C*n,up(3 ~ 5) | .328 | .922 | .167 |
| *C*n,up(5 ~ 10) | .273 | .935 | .188 |
| *T*air | -.415 | .285 | .698 |
| *d*air | .508 | .295 | .738 |
| *C*m(PM2.5) | .941 | .223 | .087 |
| *CA*acc(PM2.5) | -.134 | -.021 | -.946 |
| Extraction method: principal component analysis.  Rotation method: varimax with Kaiser normalization component scores. | | | |