

Collection of Nitrate in a Denuder

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Abstract. Data are given for aerosol nitrate (NO_3) size distributions in the atmosphere as recorded by a cascade impactor and by an annular denuder. Using this data, our goal is to find the percent of nitrate in the atmosphere that the denuder is able to detect. This requires that we find the size distribution of nitrate that enters the denuder. From these data and calculations, we find that 32.8% of nitrate in the atmosphere can be detected by the denuder. Nitrate was measured to study its effects on seagrass in the Tampa Bay and to compare nitrate levels with seagrass growth and decline. Using a denuder for routine measurements will not allow scientists to accurately compare nitrate data to seagrass levels.

Keywords. Denuder, Atmosphere, Aerosol Nitrate

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Motivation

In the Tampa Bay, dying seagrass has been attributed to many different factors. Stormwater runoff containing nutrients and chemicals such as fertilizer cause algae to grow in the Bay. When algae forms, it can block the sun and inhibit the growth of sea grasses.

Seagrass is important to the Tampa Bay area for many reasons, according to the Hillsborough County Water Atlas. It provides habitat and food for many species of sea life and also holds down sand and prevents erosion, especially during strong storms and tides.

Periodically, the Southwest Florida Water Management District takes measurements of seagrass acreage and the Tampa Bay Estuary Program has reported that conservation efforts since the mid-1990s have increased the amount of grass in the Bay and have offset the previous decline. Though recovery has been slow in recent years, it has had an upward trend in most areas. "Gains were documented in every bay segment except Old Tampa Bay, where seagrasses declined by 636 acres, or 12 percent, during this two-year

period [2002-04]. This segment has experienced a steady loss of seagrass since 1982” (TBEP).

Seagrass Acreage Variation within Middle Tampa Bay								
1988	1990	1992	1994	1996	1999	2001	2004	2006
5145	5248	5207	5717	5466	5573	5581	6240	5078

Source: Hillsborough County and City of Tampa Water Atlas, Southwest Florida Water Management District

One of the chemicals affecting the seagrass seems to be aerosol nitrate (NO_3^-). Nitrate can be measured in several different ways. One of the most effective ways is to use an instrument called a cascade impactor, which can effectively measure particles of many different sizes. However, more routine measurements are made by an annular denuder, which can only detect particles with a diameter equal to, or less than, about 2.5 microns.

The objective of this paper is to take data provided by both the cascade impactor and the denuder, and to determine what percentage of nitrate the denuder is able to account for.

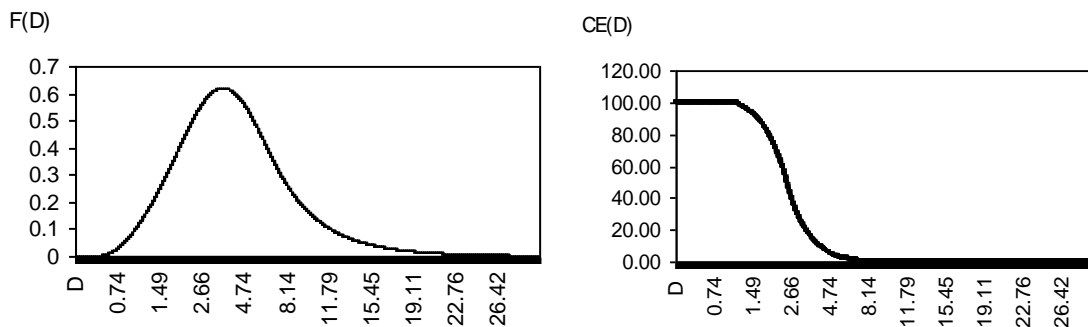
Measuring the amount of sea grass over time and the amount of nitrate in the atmosphere can help scientists understand the impact of aerosol nitrate on seagrasses. Also, comparing data from the denuder and the impactor can help engineers develop better methods of measurement and assess the reliability of the tools used in relation to the data being collected.

Mathematical Description and Solution Approach

Data for this paper was given as a series of just over 2,000 entries in Microsoft Excel, the denuder and impactor measurements (See Appendix B for a sample.)

$F(D)$ = Particle size (0-30 microns) distribution in atmosphere (D represents diameter)

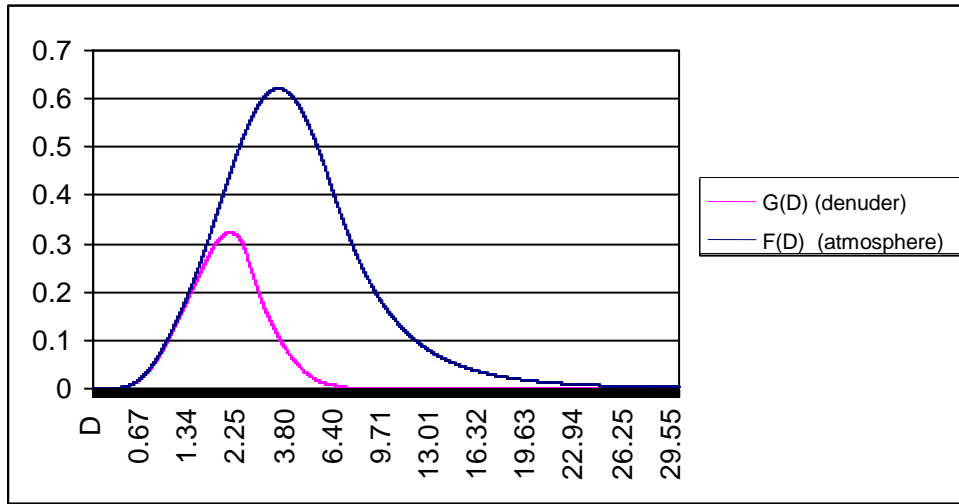
$CE(D)$ = Collection efficiency (0-100%) of denuder for given particle size



$G(D)$ = percent distribution of particles detected by the denuder:

$$G(D) = F(D) \times CE(D)$$

This gives the following graph:



To find the percent of nitrate in the atmosphere that the denuder is able to detect, we find the area under each curve and then the ratio of denuder to atmosphere amounts.

Atmosphere = F(D) (unknown equation)

Amount of nitrate in atmosphere = $\int F(D)dD$

Denuder = G(D) (unknown equation)

Amount of nitrate detected by denuder = $\int G(D)dD$

$$\frac{\int G(D)dD}{\int F(D)dD} = \text{percentage of nitrate detected by denuder}$$

Since we do not know the equation for either curve but must integrate, we use a numerical algorithm. (See Appendix C for Excel calculation formulas.)

$$\int_{x_0}^{x_1} F(D)dD \approx (x_1 - x_0) \times \frac{F(x_0) + F(x_1)}{2}$$

$$\int_{x_0}^{x_1} G(D)dD \approx (x_1 - x_0) \times \frac{G(x_0) + G(x_1)}{2}$$

Discussion

The area under the curve measuring the nitrate in the atmosphere was 4.25. The area under the curve measuring the nitrate detected by the denuder was 0.68. (See Appendices B and C.)

$$\frac{0.68}{4.25} \cdot 100 = 16.08\%$$

The objective of the paper, to find the percentage of nitrate in the atmosphere that is detected by the denuder, was met. This percentage is equal to 16.08%.

Only 16.08% of particles in the atmosphere can be detected by an annular denuder. Because most of the particles have a diameter of about 3-5 microns, and many fall into larger size ranges, it was not surprising that such a small percentage was detected by the denuder, which reaches about 50% efficiency for particles of 2.5 microns, and decreases with larger size. It does not detect any particles larger than 7.65 microns.

Because a denuder can only measure a small amount of particles, it does not seem like a very good tool for routine measurement if the whole amount is needed.

For the purpose of environmental protection of the Tampa Bay seagrasses, comparing consecutive denuder measurements could still help predict trends and gauge nitrate levels.

Conclusions and Recommendations

Annular denuders can measure nitrate particles, but not those larger than 2.5 microns in diameter. According to our calculations, this is 16.08% of the total nitrate in the atmosphere.

Understanding this percentage can help engineers develop devices to measure things like this more accurately. Since only a small percentage of nitrate is seen by the denuder, scientists could discontinue use of it if they need the whole amount, because using the denuder does not allow them to take measurements that are extremely accurate or complete.

To further this study, we could consider what sizes of aerosol nitrate particles might affect seagrass. For instance, if sizes only up to 2 microns have any effect on seagrass growth, it would not be necessary to use a cascade impactor for measurements; a denuder would suffice. On the other hand, if only sizes larger than 2 microns affected the grasses, a denuder would provide no useful measurements.

Another aspect to consider would be the comparison of data. If a denuder was used for continuous measurement, would it be accurate to only compare those measurements, without making more extensive measurements? If so, the denuder would be sufficient.

References

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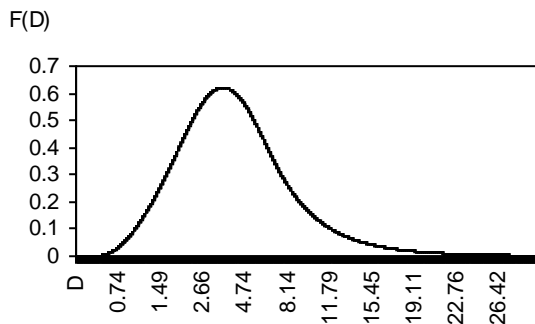
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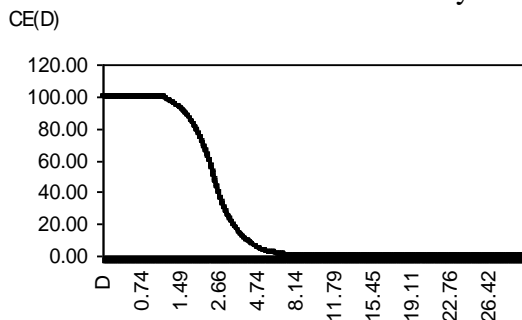
Appendices

Appendix A: Data Graphs

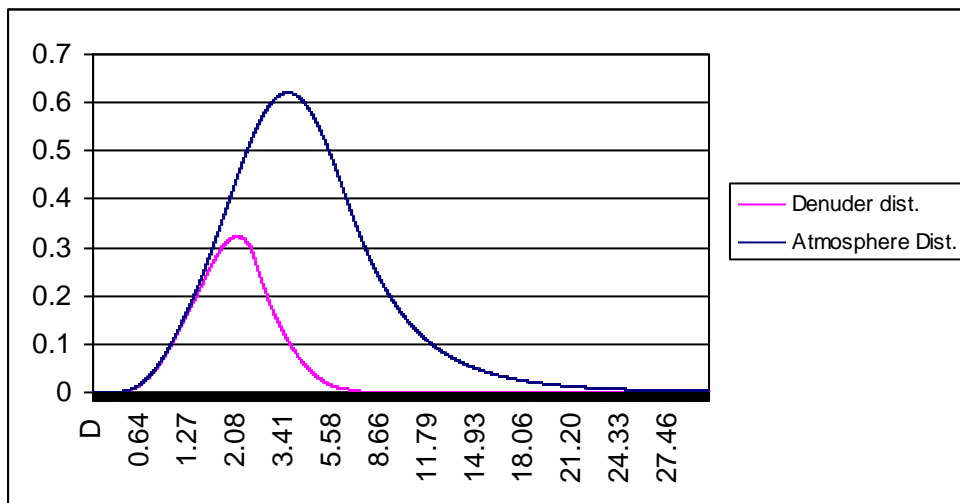
NO₃ Particle Size Distribution in the Atmosphere



Denuder Collection Efficiency



NO₃ Particle Size Distribution In Atmosphere and Denuder



Appendix B: Data Charts

Sample of data used:

A	B	C	D	E	F
D	CE(D)	f(D)	CE(D)*F(D)*0.01	Int. Denuder.	Int. Atmos.
0.0118	100.00	5.41E-18	5.41E-18		
0.0157	100.00	2.51E-16	2.51E-16	4.99E-19	4.99E-19
0.0196	100.00	4.31E-15	4.31E-15	9.40E-18	9.4E-18
0.0235	100.00	4.05E-14	4.05E-14	9.68E-17	9.68E-17
0.0274	100.00	2.53E-13	2.53E-13	6.70E-16	6.7E-16
0.0313	100.00	1.18E-12	1.18E-12	3.47E-15	3.47E-15
0.0352	100.00	4.46E-12	4.46E-12	1.45E-14	1.45E-14
0.0391	100.00	1.42E-11	1.42E-11	5.09E-14	5.09E-14
0.0430	100.00	3.96E-11	3.96E-11	1.56E-13	1.56E-13
0.0469	100.00	9.91E-11	9.91E-11	4.26E-13	4.26E-13
0.0508	100.00	2.27E-10	2.27E-10	1.06E-12	1.06E-12
0.0547	100.00	4.81E-10	4.81E-10	2.44E-12	2.44E-12
0.0586	100.00	9.58E-10	9.58E-10	5.25E-12	5.25E-12
0.0625	100.00	1.81E-09	1.81E-09	1.06E-11	1.06E-11
0.0664	100.00	3.25E-09	3.25E-09	2.05E-11	2.05E-11
0.0703	100.00	5.60E-09	5.60E-09	3.77E-11	3.77E-11

4.9420	4.53	5.38E-01	2.43E-02	6.61E-01	1.970022
4.9570	4.53	5.36E-01	2.43E-02	6.61E-01	1.978075
4.9720	4.53	5.35E-01	2.42E-02	6.61E-01	1.986131
4.9871	4.53	5.33E-01	2.42E-02	6.62E-01	1.994192
5.0022	4.53	5.32E-01	2.41E-02	6.62E-01	2.002255
5.0175	4.30	5.31E-01	2.28E-02	6.62E-01	2.010386
5.0328	4.30	5.29E-01	2.28E-02	6.63E-01	2.018455
5.0482	4.07	5.28E-01	2.15E-02	6.63E-01	2.026591
5.0635	4.07	5.26E-01	2.14E-02	6.63E-01	2.034667
5.0789	4.07	5.25E-01	2.14E-02	6.64E-01	2.042745

29.7672	0.00	2.39E-03	0.00E+00	6.83E-01	4.282935
29.7865	0.00	2.38E-03	0.00E+00	6.83E-01	4.282981
29.8058	0.00	2.38E-03	0.00E+00	6.83E-01	4.283027
29.8252	0.00	2.37E-03	0.00E+00	6.83E-01	4.283073
29.8445	0.00	2.36E-03	0.00E+00	6.83E-01	4.283118
29.8639	0.00	2.35E-03	0.00E+00	6.83E-01	4.283164
29.8832	0.00	2.34E-03	0.00E+00	6.83E-01	4.283209
29.9026	0.00	2.34E-03	0.00E+00	6.83E-01	4.283255
29.9219	0.00	2.33E-03	0.00E+00	6.83E-01	4.2833
29.9413	0.00	2.32E-03	0.00E+00	6.83E-01	4.283345
29.9606	0.00	2.31E-03	0.00E+00	6.83E-01	4.28339
29.9800	0.00	2.31E-03	0.00E+00	6.83E-01	4.283434
29.9993	0.00	2.30E-03	0.00E+00	6.83E-01	4.283479
				6.83E-01	4.24901

Appendix C: Excel Formulas

Excel calculations used:

CE(D)*F(D)*0.01	Integration - Denuder	Integration - Atmosphere
CE(D)*F(D)*0.01	$=((D3+D4)/2)*(A4-A3)+E3$ $=((D4+D5)/2)*(A5-A4)+E4$ $=((D5+D6)/2)*(A5-A4)+E5$ <p style="text-align: center;">.....</p>	$=((C3+C4)/2)*(A4-A3)+F3$ $=((C4+C5)/2)*(A5-A4)+F4$ $=((C5+C6)/2)*(A5-A4)+F5$ <p style="text-align: center;">.....</p>