WET AND DRY DEPOSITION STUDY: TEXAS COASTAL BEND BAYS AND ESTUARIES PROGRAM

Terry L. Wade [1], Stephen T. Sweet [1], and Clyde W. Sweet (retired) [2]

[1]Geochemical and Environmental Research Group Texas A&M University, 833 Graham Rd., College Station, TX 77845

[2]Illinois State Water Survey, 2204 Griffith Dr., Champaign, IL 61820-7495

GERG — GEOCHEMICAL & ENVIRONMENTAL RESEARCH GROUP, College of Geosciences, Texas A&M University

Abstract

The National Atmospheric Deposition Program (NADP) was established in 1977 to investigate the effects of atmospheric deposition. Atmospheric deposition studies were instituted at sampling sites on Corpus Christi Bay in 1997 as part of CBBEP. In 2002 the Texas A&M University, Corpus Christi (TAMUCC) site became an official NADP site (TX39), the first located in close proximity to an urban/industrialized/estuarine area, and operated thru 2006. The flux of inorganic nitrogen via wet and dry atmospheric deposition was estimated from data collection that began in the late spring of 1997 and continued through September 1999 at the two sampling sites. Wet only rain samples were collected with an AeroChemetric rain sampler. Dry deposition (1997 to 1999) was estimated from analytes deposited to "clean water" in the dry side bucket of the AeroChemetric rain sampler. This study was the first attempt to characterize atmospheric loading rates of nitrogen in both wet and dry deposition to the Coastal Bend Bays estuaries. Dry deposition is dominated by ammonium at both the Texas A&M University Corpus Christi Station (TAMUCC) and at Whites Point Station (WP). Wet deposition of nitrogen directly to the coastal bend bays and estuaries ranges from 3.6 to 4.4 x 10^5 kg and dry deposition ranges from 5.6 to 7.6 x 10^5 kg based on rates from these two stations. The wet depositional rate of nitrate and ammonium at TAMUCC and at WP for 1998 was 1.15 and 1.36 kg N/ha-yr; 1.60 and 1.50 kg N/ha-yr, respectively. Wet deposition rates of nitrate at the two sites in Corpus Christi are similar to the NADP/NTN site located in Beeville, Texas (1.2 kg N ha-1 yr -1) and at the TAMUCC NADP (TX39) in latter years; however, the ammonium flux is higher at Beeville TX (2.0 kg N/ha-yr) for 1998. Coupled studies (n = 8) of dry deposition to an empty AeroChemetric rain sampler bucket compared to one with clean water indicated similar collection efficiency for nitrate, but enhanced efficiency for ammonium. Based on these studies NADP wet only nitrogen deposition for Coastal Bends Estuaries is underestimated by a factor of 2.3 to 5.5. The atmospheric depositional inputs of N to the Bay may result in increased phytoplankton productivity and eutrophication.

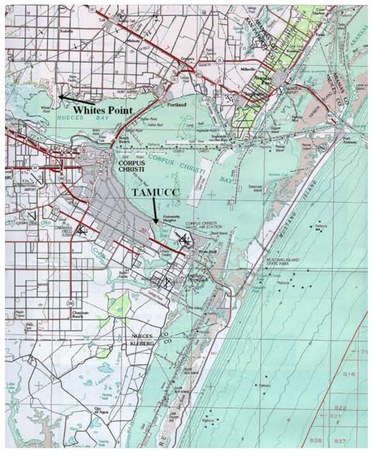


Figure 1. Atmospheric stations located in Corpus Christi, TX.

Introduction

The atmosphere plays an important role in the transport, deposition, and cycling of inorganic nitrogen. Atmospheric nitrogenous compounds can have both beneficial (e.g., soil fertility, plant nutrient) and deleterious effects.

Two monitoring stations were established on the edges of the Nueces estuary (Figure 1). The first station was situated on the Texas A&M University Corpus Christi (TAMUCC) campus (Figure 2) located at the western edge of Corpus Christi Bay. Data collection began on April 22, 1997 and the station was operated continuously until January 2007. The TAMU-CC station is down-wind of the Corpus Christi Naval Air Station and up-wind of most of the urbanized areas during the dominant southeasterly wind. This station is down-wind of the petrochemical plants along the Corpus Christi ship channel, the City of Corpus Christi, and the industries located on the north shore of Corpus Christi Bay during periods of northerly winds. The Port of Corpus Christi is a major shipping and transportation center with heavily industrialized areas (e.g., petroleum refining and metal processing). Corpus Christi Bay has a limited exchange with the Gulf of Mexico.

Figure 2. TAMUCC Station, note AeroChemetrics wet-dry samplers and the Belfort rain gauge in the foreground and the meterological sensors in the background.

Figure 3. Whites Point Station, note the meterological sensors and the Belfort rain gauge in the foreground, the AeroChemetrics wet-dry samplers in the background, industrial complex on the horizon.

The second station was situated near Whites Point (WP) located at the northwestern edge of Nueces Bay (Figure 3), with data collection from June 3, 1997 to September 1999. The White Point station is down-wind of the city Corpus Christi and refinery row during periods of southeast wind flow and receives deposition from agricultural land areas during periods of northerly winds. The location of these sites met as many of the criteria established by the EPA Great Waters Program for atmospheric deposition sampling sites as possible. The TAMUCC station became an official part of the NADP program (Site TX39) in 2002.

The entire estuarine system, includes Copano Bay, Aransas Bay, Nueces Bay, Corpus Christi Bay, and the upper Laguna Madre, has a surface area of 1.425 x 10^9 m^2 and a watershed of 6.95 x 10^{10} m^2. The prevailing winds are southeasterly throughout the year and the normal rainfall per year is about 77 cm (Baird et al., 1996).

Results and Discussion

This study provides atmospheric deposition fluxes of nutrients to Corpus Christi Bay (Figures 4 and 5), indicating the importance of atmospheric deposition of inorganic nitrogen. Spatial and temporal trends in wet deposition of inorganic nitrogen have been studied extensively at NADP sites and at other sites worldwide. The wet deposition data collected at TAMUCC and White Point are directly comparable to NADP generated data, at nearby NADP site at Beeville, TX (Table 1).

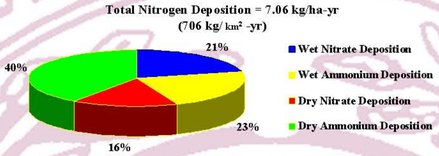


Figure 4. Whites Point Station total nitrogen deposition 1998.

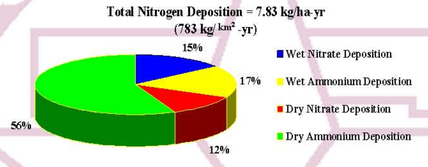


Figure 5. TAMUCC Station total nitrogen deposition 1998

The Illinois State Water Survey (ISWS) laboratory conducted analyses for all data reported. Only small-scale regional differences are seen for 1998 compared to 2002 sampling years.

Table 1. Wet and Dry Deposition Rates of Ammonium and Nitrate (Kg-N/Ha-yr).

	TAMUCC		White Point		Beeville
Year	Wet NH_4/NO_3	Dry NH_4/NO_3	Wet NH_4/NO_3	Dry NH_4/NO_3	Wet NH_4/NO_3
1997	1.57/1.24	4.76/0.49	0.71/0.79	2.33/0.65	2.0/1.50
1998	1.36/1.15	4.41/0.91	1.50/1.60	2.60/1.31	2.1/1.1
1999	1.40/0.50	8.07/0.59	1.24/0.75	3.17/0.80	1.46/0.89
2002	1.2/1.3				1.3/1.2

In 1998 the wet deposition of ammonia in the rain were within ten percent at both stations (1.36 and 1.50 kg N ha^{-1} yr^{-1}, for TAMUCC and WP respectively) while wet deposition of nitrate was 28% greater at WP (1.15 and 1.60 kg N ha^{-1} yr^{-1}, for TAMUCC and WP respectively). The precipitation pattern in 1998 was atypical (Figure 6) with drought conditions from early February through early August. The wet deposition during the same period is shown in Figure 7, note how the nitrogen depositional pattern mimics the precipitation distribution. Collection only during the spring or fall rains would give a radically different estimation of wet deposition. The wet deposition at Beeville in 1998 was dominated by ammonium by nearly a factor of two. During the same period, the wet deposition was evenly split between nitrate and ammonium in Corpus Christi. Dry deposition of ammonium at both sites were similar to the previous year while nitrate deposition was twice that found in 1997. During 1999 significantly less nitrate was present in the rain at both sites and wet ammonium deposition rates were similar. Dry deposition in 1999 was dominated by ammonium. Dry deposition generally was responsible for 50% or more (Table 2) of the total deposition to Corpus Christi Bay.

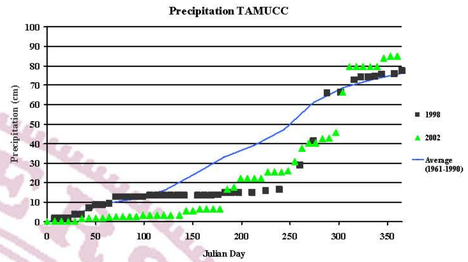


Figure 6. Precipitation at TAMUCC in 1998 and 2002

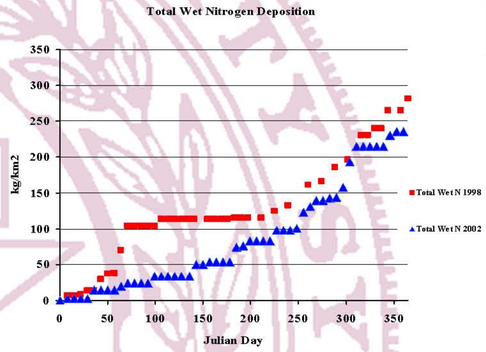


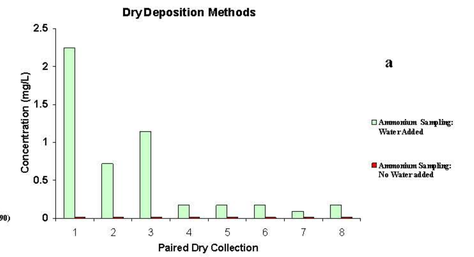
Figure 7. Wet-only Nitrogen Deposition at TAMUCC in 1998 and 2002

Table 2. Comparison of Nitrogen Wet, Dry, and Total Deposition (Kg/Ha-yr).

Site	TAMUCC			White Point			Beeville
Year	Wet	Dry	Total	Wet	Dry	Total	Wet
1997	2.8 (35)	5.3 (65)	8.1	1.5 (33)	3.0 (77)	4.5	3.5
1998	2.5 (32)	5.3 (68)	7.8	3.1 (44)	4.0 (56)	7.1	3.2
1999	1.9 (18)	8.5 (82)	10.4	2.0 (33)	4.0 (77)	6.0	2.4
2002	2.5						2.5

( ) = number in parentheses are % of total

Determination of dry deposition is not straight forward. However, dry deposition appears to be a very important process for nutrient nitrogen input to estuaries. For example, the annual dry deposition rate of ammonia plus nitrate was 5.3 and 4.0 Kg/Ha-yr at TAMUCC and Whites Point, respectively in 1998. The dry deposition rate is higher for nitrogen than the wet deposition rate. Figures 8a and 8b show the results from a dry deposition validation experiment. Two wet-dry samplers were co-located and the effects of a providing a water surface to the dry side bucket were determined over an eight week period. Similar results were obtained for dry deposition of nitrate with and without the addition of water, while ammonium is not detected in the dry bucket. A comparison of NADP data from the Tampa Bay area with this study shows that nitrogen-loading values are similar. Nitrate-nitrogen loading rates (wet deposition only) in our area are nearly as high as Tampa (1.36 vs. 1.45 Kg-N/Ha-Yr). A comparison with data from the Florida Acid Deposition Study (Zephyrhills site) shows that nitrate flux is 50% higher and the ammonium flux essentially equal (nitrate 1.36 vs. 2.07 Kg/Ha-Yr, ammonium 1.65 vs. 1.67 Kg/Ha-Yr).



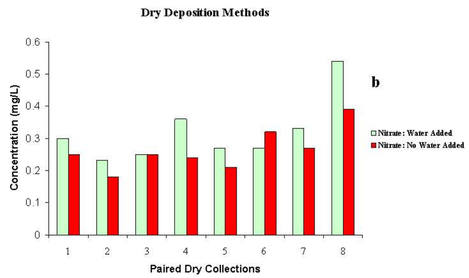


Figure 8. Paired collection of ammonium (a) and nitrate (b).

Figure 9 shows the wet deposition of inorganic nitrogen in 2002 from the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) with the data from the TAMUCC station value (2.5 Kg/Ha) in Corpus Christi plotted.

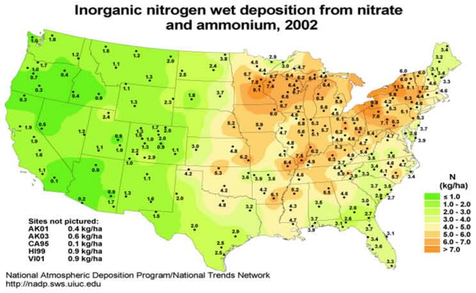


Figure 9. NADP wet-only nitrogen deposition for 2002.

Conclusions

- Total Nitrogen Deposition:
  Corpus Christi Bay: 7.1 (Whites Point) to 7.5 (TAMUCC) (Tampa Bay: 7.3 kg-N/ha-yr).
- 1998 Dry Deposition:
  Corpus Christi Bay: 56% to 68% of Total Nitrogen Deposition (44% Tampa Bay).
- 1998/2002 Wet Nitrogen Deposition:
  2.5/2.5 (TAMUCC) to 3.1 (Whites Point) kg-N/ha-yr (Beeville 3.2/2.5 kg-N/ha-yr).
- Deposition Directly to Corpus Christi Estuary in 1998 ranges from 1 x 10^6 kg-N/yr to 1.1 x 10^6 kg-N/yr (Tampa Bay 0.76 x 10^6 kg-N/yr).
- Accurate flux estimates require a complete year of data.
- Long-term monitoring is required to accurately determine depositional fluxes and to filter out interannual variability.