Long-Term Trends in Gas-Particle Partitioning of Reduced Reactive Nitrogen Species, as Analyzed by Annular Denuders and Ion Chromatography

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The following is an excerpt from a longer piece. For full text, please visit https://scholar.colorado.edu/concern/undergraduate_honors_theses/9306t067v

Abstract

Reduced reactive nitrogen species, which primarily consist of ammonia and low-mass amines, occur in the gas-phase and the particle-phase of the atmosphere. Despite being present at trace concentrations, these species can have severe effects on eutrophication, biodiversity, human pulmonary and cardiac health, and deposition. Long-term sampling of these species is infrequent, and such sampling that has taken place is focused around agricultural sources rather than urban environments. A greater understanding of the gas-particle partitioning of these species elucidates our understanding of the roles they play in the aforementioned environmental effects.

I adapted the EPA's procedure for the sampling of ambient air using annular denuders and performed troubleshooting techniques on an ion chromatograph to develop a method to collect and analyze reduced nitrogen species; with this method, phases can be examined separately, thus allowing for a greater understanding of the magnitude of each risk associated with the gas and particle-phases rather than conflating the total concentration together. Method development is a crucial step in initiating long-term sampling, because consistency is the foundation of accuracy. I began preliminary ambient sampling with a focus on ensuring the procedure works and exploring potential trends.

While further sampling over the course of years will be necessary to confirm trends, some trends are beginning to emerge: gas-phase ammonia is present in higher concentrations when the average temperature is greater. The total concentration and the ratio of gas-to-particle concentrations are still being considered, as are these apparent trends. For the future, focus should be directed towards identifying the dominant source of analyte in the second annular denuder, observing effects of different filters, refining the gradient method, and considering the maximum collectable concentration on the denuders and filter.

Lay Summary

All living things from plants to animals to humans require nitrogen to perform a variety of essential chemical processes. While ~78% of the atmosphere is made up of nitrogen, the vast majority of this exists in an unreactive, and therefore unusable, form. This is due to a strong triple bond between two nitrogen atoms in the nitrogen gas molecule (N_2). Reactive nitrogen, on the other hand, is also present in the atmosphere but its lack of a triple bond makes it usable for living things.

In small concentrations, reactive nitrogen can deposit onto ecosystems, providing plants and animals with a vital, and often limited, nutrient. In larger concentrations, atmospheric reactive nitrogen forms particulate matter; particulate matter is tiny solids or liquids suspended in the air. Of most interest is particulate matter with a diameter of less than 2.5 micrometers ($PM_{2.5}$); for reference the width of a human hair is around 70 micrometers. Particulate matter of this size penetrates deeply into the lungs and causes pulmonary, respiratory, and cardiac diseases. Furthermore, the World Health Organization says that $PM_{2.5}$ is the greatest risk to human health associated with air pollution. Due to the high risk of these species along with projected increases in emissions and limited study in urban environments, there is a lot to be gained from analyzing trends in the concentration of reactive nitrogen over time.

In this paper, I developed a method to collect several compounds of reactive nitrogen from the atmosphere and then determine the concentration that those species are present in at the University of Colorado, Boulder. The compounds were collected using a vacuum pump that pulls air through a cylindrical tube and filter. The tube was coated with phosphorous acid which causes basic gasses to stick to the inner walls. The filter collected particulate matter of the desired diameter. Ion chromatography was the method used to determine the concentrations of the compounds that were collected. The chromatography instrument first separated the compounds by their polarity and then measured their conductivity, which is linearly related to the concentration. The results of interest are total concentrations of compounds and the relative amount of a compound in the gas-phase and the particle-phase. Comparing these results to the weather conditions at the time of sampling allows people to better recognize high-risk locations and circumstances.

This paper demonstrates the feasibility of long-term sampling of reactive nitrogen in an urban environment and provides a framework for such analysis to continue in the future. It is too early in the sampling process to fully understand the trends and fluctuations as a result of weather conditions, but a proven method is a vital first step.