Title Page

Top-down and Bottom-up Lead Emission Assessment at the Grand Forks, North Dakota Airport

Applicant:
Principal Investigator (PI): Dr. David Delene
Department of Atmospheric Sciences
John D. Odegard School of Aerospace
david.delene@und.edu

Undergraduate Researcher: Jenna Post
Department of Atmospheric Sciences
John D. Odegard School of Aerospace
jenna.post@und.edu

Undergraduate Researcher: Jacob Halmos
Department of Atmospheric Sciences and Department of Aviation (Dual Major)
John D. Odegard School of Aerospace
jacob.halmos@und.edu

Funding Requested: $10,000
Topic Area: Atmospheric Chemistry

Relevant Previous Research Funding: No previous seed research funding in this topic area. Previously, Research Experience for Undergraduate Student (REU – National Science Foundation) researcher Alex Mendes worked on this project.

Period of Performance: 16 May 2025 – 15 May 2026

Abstract

Lead (Pb) is a highly toxic metal that has significant negative effects on human health. Once exposed, it is very difficult to remove lead from the blood. General aviation (GA) aircraft continue to use lead in their fuel as an octane booster to prevent engine damage. Therefore, it is important to qualify aircraft lead emission to determine environmental and human health impacts. At the University of North Dakota, we have the opportunity to determine lead emissions from GA aircraft due to the University's large fleet. A top-down and bottom-up emission analysis will be started to determine the amount of lead emitted by the University of North Dakota's fleet of aircraft. The top-down analysis will determine the actual amount of lead in the atmosphere, while the bottom-up analysis will estimate the amount of lead that the fleet of aircraft emits.

III. Proposal

Introduction

Lead (Pb) is a highly toxic metal pollutant (Collin et al. 2022) that has a sufficient economic cost (Grosse et al. 2002) and impacts human health due to accumulation in the blood, which reduces full-scale intelligence quotient (IQ) scores (Galiciolli et al. 2022). Due to lead's environmental impacts, vehicles have been engineered to no longer require tetraethyl lead (TEL) as a gasoline additive. The unleaded gasoline transition started in the 1970s with new vehicles engineered to run on unleaded gasoline, and by the mid-1980s most gasoline used in the United States was unleaded. A similar transition is now occurring in general aviation (Kessler 2013), with newer built aircraft able to operate with currently available, unleaded aviation fuel; however, older (legacy) aircraft generally have engine systems that develop maintenance issues if operated with unleaded fuels. To promote adaptation of unleaded fuel usage by general aviation, a fundamental understanding of lead emissions at airports is necessary. General aviation contributes a large amount of lead to its surrounding atmosphere.

There is a need to study and understand the amount of lead in the atmosphere to determine human health and environmental impacts. According to the Texas Commission on Environmental Quality, lead can have long term negative health effects. "Depending on the level of exposure, lead can adversely affect the nervous system, kidney function, immune system, reproductive and developmental systems, and the cardiovascular system." (TCOEQ pg 1.) The significance of this study is to understand the level of lead emissions in Grand Forks from the UND fleet and apply that information to future studies on its overall impact.

The University of North Dakota is one of the top Aviation Universities in the world. With a high number of Aviation major enrollment, UND burns a lot of fuel for general aviation. With a population of 59,000 in 2023, Grand Forks has a large ratio of aviation fuel consumption compared to its population. Grand Forks is a good place for this study because of its high fuel consumption, and localized area.

Objective

The overall research objective is to qualify lead emissions using both a top-down (atmospheric measurement) assessment and a bottom-up (aircraft based) assessment. The specific purposes of this seed money project are to 1.) prove that we can obtain lead free filter blanks that would be used for atmospheric measurements, and 2.) obtain and process the necessary aircraft data that would be used for a bottom-up assessment. The project's research team will be split into two groups. One team will work on the top-down approach and the other team on the bottom-up approach.

Methods: Top-down Assessment

The purpose of the top-down method is to measure the actual amount of lead in the atmosphere around Grand Forks airport. The objective for the top-down approach is to get a zero-lead measurement on the filters to be able to accurately measure the backgrounds. From previous projects, we have obtained filter samples from the top of the Clifford Hall building at UND and at the airport that are currently available for analysis. These samples can be analyzed by methods to determine lead levels of the different types of filters. Once analyzed, the team will determine the best filters for this project and proceed with conducting additional atmospheric sampling.

Methods: Bottom-up Assessment

The purpose of the bottom-up method is to estimate the amount of lead emitted by the UND aircraft within a circle surrounding the Grand Forks International Airport. The sample area is defined by a circle with a radius of 5 nautical miles, centered at the Grand Forks VOR (Figure 1). The vertical dimensions of the sample volume will be based on the boundary layer height. Underneath the boundary layer, we assume that the air is well mixed. We will determine this height from High Resolution Rapid Refresh (HRRR) model data. Since the boundary height changes frequently, the height of our circle will be re-calculated hourly.

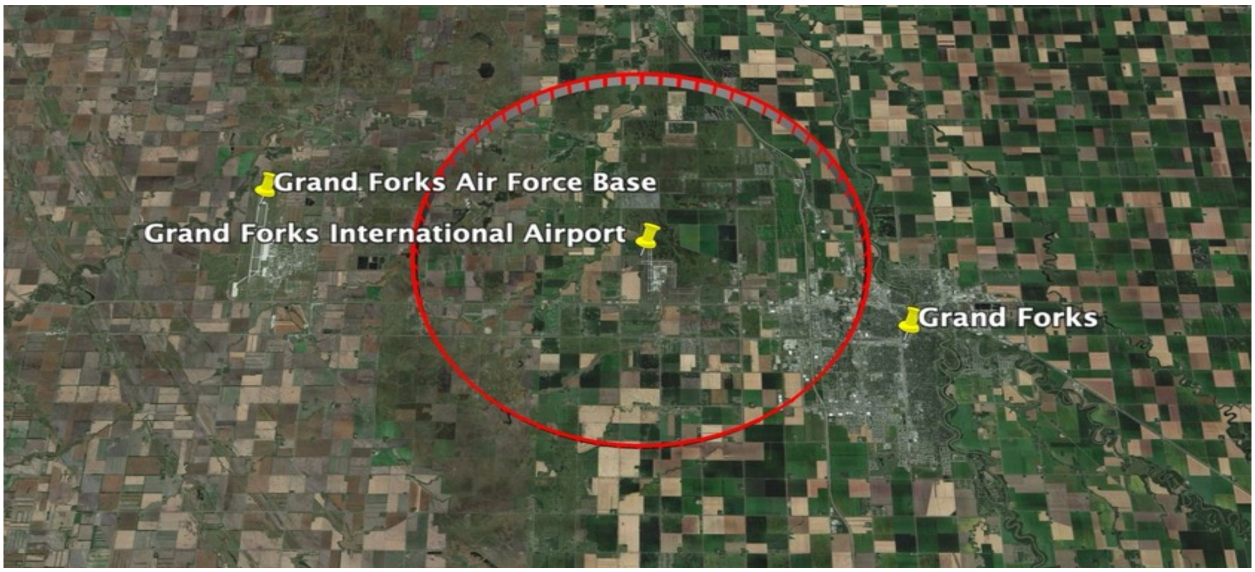


Figure 1: A top-down view of the Grand Forks, ND area. Circled in red is the area in which the study will be conducted. The pin at the Grand Forks airport is placed over the VOR.

At UND, we have the unique opportunity to measure specific lead outputs from individual aircraft due to the large amount of data that is collected and stored from each airplane's advanced Garmin Avionics System. Prior research from the Environmental Protection Agency (EPA) has attempted to measure the amount of lead emitted each year from general aviation (GA), however they did not have access to the specific engine parameters we have today. (EPA, 2008) According to the American Society for Testing and Materials (ASTM) the maximum amount of lead in 100 low-lead fuel (100LL) is approximately 2.12 grams per gallon. (ATSM, 1982) The EPA historically estimated that the retention rate of lead (the amount of lead that remains in the engine) in a car engine was approximately 25%. In newer studies focusing on aviation engines, that number is estimated to be approximately 5%. (EPA, 2008). In our research, we are approximating lead emitted through the following equation:

$$lead\ emitted = (gallons)\left(2.12\ \frac{g\ Pb}{gal}\right)(.95)$$

Data Analysis

The top-down approach data analysis will be performed by the following steps. First, analyzing the blank filter and the filters previously obtained from summer 2023. Any newly obtained filters will also be examined, and all filters will be analyzed to determine the lead percentage of the total. Weights of the filters will be obtained to find what's accumulated by comparing the weights with the blank filter. Then x-ray fluorescents will be taken for further analysis.

Coordination with the Aerospace Analytics team is a key component of the bottom-up analysis. A Python script will be written to retrieve and sort various variables from the data provided by the Aerospace Analytics team. Some of the variables we will be analyzing are gallons per hour, latitude and longitude, altitude, and RPM settings. The script will proceed to take this data from each individual aircraft and calculate the total lead emitted in our specified area using the equation stated previously. For the last step of this project, both groups of the research team will compare and contrast the data gathered to determine a conclusion on the lead emissions to come to a conclusion on the lead emissions from the UND fleet.

Possible External Funding Opportunity

The National Science Foundation (NSF) is a possible external funding opportunity. The PI has sent a White Paper about this project to Mamadou Diallo in the Environment Engineering Division of NSF. Dr. Diallo indicated that the project fits within the scope of the Division and encourages submission of a proposal. The PI plan to submit a proposal once filter blanks are successfully obtained and the aircraft data set created.

Plan for Dissemination of Knowledge to the Professional Community

The undergraduate researchers on the project team will write an article for the journal of undergraduate research to communicate project results.

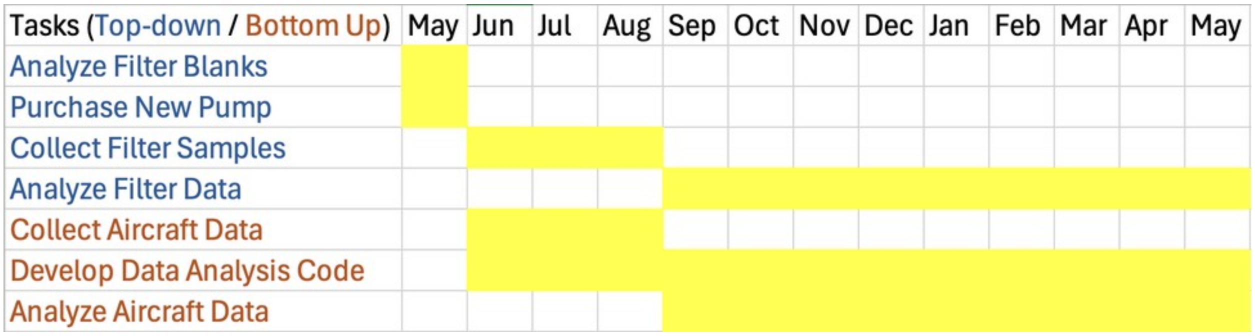
Budget

Description			
Salary Detail			Per Hour:
Undergraduate Student Hours	500.00	9,000	$18
Fringe Benefits	1.00%	90	
Total Salary/Fringe		**$9,090**	
Direct Costs			
Travel		0	
Supplies (Pump, Filters)		910	
Shipping		0	
Total Direct Costs		**$910**	
Total Salary/Direct Costs		**$10,000**	
Total Budget		**$10,000**	

Budget Justification

The budget includes support for two undergraduate researchers to work on the project for a total of 500 hours at the Department of Atmospheric Sciences rate of $18 per hour. Supplies include $700 for a replacement plume for the air sampling system and $210 for filters.

Timetable



VI. Evidence of Regulatory Compliance

No regulatory compliance is required for our project.

VII. References

1. Bendtsen, K. M., E. Bengtsen, A. T. Saber, and U. Vogel, 2021: A review of health effects associated with exposure to jet engine emissions in and around airports. *Environmental Health*, **20**, 10, https://doi.org/10.1186/s12940-020-00690-y.
2. Carr, E., M. Lee, K. Marin, C. Holder, M. Hoyer, M. Pedde, R. Cook, and J. Touma, 2011: Development and evaluation of an air quality modeling approach to assess near-field impacts of lead emissions from piston-engine aircraft operating on leaded aviation gasoline. *Atmospheric Environment*, **45**, 5795–5804, https://doi.org/10.1016/j.atmosenv.2011.07.017.
3. Collin, M. S., and Coauthors, 2022: Bioaccumulation of lead (Pb) and its effects on human: A review. *Journal of Hazardous Materials Advances*, **7**, 100094, https://doi.org/10.1016/j.hazadv.2022.100094.
4. Galiciolli, M. E. A., L. S. Lima, N. de S. da Costa, D. P. de Andrade, A. C. Irioda, and C. S. Oliveira, 2022: IQ alteration induced by lead in developed and underdeveloped/developing countries: A systematic review and a meta-analysis. *Environmental Pollution*, **292**, 118316, https://doi.org/10.1016/j.envpol.2021.118316.
5. Grosse, S. D., T. D. Matte, J. Schwartz, and R. J. Jackson, 2002: Economic gains resulting from the reduction in children's exposure to lead in the United States. *Environmental Health Perspectives*, **110**, 563–569, https://doi.org/10.1289/ehp.02110563.
6. Kessler, R., 2013: Sunset for Leaded Aviation Gasoline? *Environmental Health Perspectives*, **121**, a54–a57, https://doi.org/10.1289/ehp.121-a54.
7. American Society for Testing and Materials. "Annual Book of ASTM Standards. Section 5, Petroleum Products, Lubricants, and Fossil Fuels." *Annual Book of ASTM Standards. Section 5, Petroleum Products, Lubricants, and Fossil Fuels*, Annual book of ASTM

standards; sect. 5, 1983.
8. Chen, Lilia. “Exposures to Lead and Other Metals at an Aircraft Repair and Flight School Facility.” U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, July 1, 2013. https://doi.org/10.26616/NIOSHHETA201201153186.
9. Haby, Jeff. “Planetary Boundary Layer.” Accessed March 21, 2025. https://www.weather.gov/source/zhu/ZHU_Training_Page/clouds/planetary_boundary_layer/PBL.html.