Statement of Work

Ammonia Emission Assessment from Diesel and Gasoline Engines under Utah Specific Conditions

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Project Duration: October 1, 2018 – September 30, 2019 (Year 1)
October 1, 2019 – September 30, 2020 (Year 2)

This Statement of Work (SOW) summarizes the initial planned tailpipe ammonia (NH_3) measurements in laboratory and on-road settings on a sample set of diesel and gasoline vehicles representative of Utah's vehicle fleet. The specific work plan and tasks for the initial phases of the proposed project are discussed below. Additionally, suggested subsequent years' continuation projects are summarized.

Background

The importance of ambient ammonia (NH_3) to the formation of wintertime particulate in northern Utah has been well documented in the last few years (see UWFPS, 2017, https://documents.deq.utah.gov/air-quality/planning/technical-analysis/research/northern-utah-airpollution/utah-winter-fine-particulate-study/DAQ-2018-004037.pdf). Recent emissions inventories have estimated 3,884 tons/year of ammonia emissions are emitted into the relevant airsheds, and approximately 22% is estimated to be derived from mobile sources. However, attempts by UDAQ to model atmospheric NH_3 concentrations and subsequent photochemical reactions, as well as limited actual ambient NH_3 observations, have suggested that current NH_3 emissions inventory may be too low by a factor averaging about 6x (C. Pinnell, UDAQ, personal communication). Inadequate mobile source emission factors have been speculated as a likely source of at least some of these deficiencies.

Utah has traditionally focused on reducing emissions from gasoline engines as a key strategy to improve the state's air quality. However, diesel vehicles are believed to account for nearly half of the on-road mobile source nitrogen oxides (NOx), fine particulate exhaust ($PM_{2.5}$) and NH_3 emissions in the non-attainment areas. National and international studies are revealing that diesel and gasoline vehicles may be contributing more ammonia emissions than previously accepted. As an example, Sun et al. (2016) estimated vehicular NH_3 emissions in the US are

likely more than twice those given in the US National Emissions Inventory. Very little information, however, exists on the true emissions from diesel and gasoline vehicles under Utah-specific conditions. Evaluating emissions, including ammonia emissions, from vehicles under Utah-specific conditions and examining how ammonia emissions are distributed in Utah valleys will help in understanding the true emissions impact from diesel and gasoline engines on Utah's air quality. This will help UDAQ develop more targeted and effective controls to bring non-attainment areas into compliance with federal regulations.

Specific Project Objectives

The overarching objectives of the work proposed herein are the direct tailpipe characterizations of ammonia emissions from a representative sample of Utah's on-road, passenger vehicles, including both diesel and gasoline engines. As in outlined in the four (4) tasks below, these will include (1) Numerical delineation of Utah's diesel and gasoline vehicle passenger vehicle categories, (2) Laboratory (dynamometer) comparison of base station NH_3 analyzer and Portable Emissions Monitoring System (PEMS), (3) Laboratory (dynamometer) measurement of diesel and gasoline vehicle NH_3 emissions, and (4) Task 4: Quantification of Real Driving Emissions (RDEs) of NH_3 from diesel and gasoline vehicles.

Project planning meetings will be conducted in early fall of 2018, protocol development, initial instrument calibrations/comparisons, and vehicle identifications will start in the fall of 2018, and laboratory and on-road vehicle testing will proceed in the winter and spring of 2019. Owing to the likely number of vehicles, and the replicate and seasonal emissions testing, for both dynamometer and on-road testing, the testing will continue through the summer and fall of 2019 and into the winter of 2020. Although data compilation and analysis will be an on-going process, final data preparation will extend into the fall of 2020.

Dr. Randal S. Martin from Utah State University (USU) will serve as the overall project PI, while Dr. John Sohl from Weber State University (WSU) and Joe Thomas from WSU's National Center for Automobile Science and Technology (NCAST) will serve as Co-PIs. Dr. Sohl will work with WSU undergraduate students in data collection and management and Mr. Thomas will manage the usage of NCAST facilities and personnel.

Task 1: Numerical delineation of Utah's diesel and gasoline vehicle passenger vehicle categories and update literature search

The first task will be to identify test vehicle populations representative of northern Utah's diesel and gasoline passenger fleet. Total numbers of registered passenger vehicles in the counties along the northern Wasatch Front, including Cache County, will be obtained for the State of Utah Department of Motor Vehicles. Although the final bins will be determined after team

discussions, the vehicles will be categorized based on fuel type (gasoline vs. diesel) and age or Tier class. Additionally, attempts will be made to identify the local population of diesel passenger vehicles that have been modified or "chipped" to optimize for performance at the cost of emissions. If possible, a representative population of such vehicles will be included as part of this study. NCAST personnel will lead the data compilation. Team discussions between NCAST and USU personnel will decide the ultimate numbers and distributions to be targeted for lab (dynamometer) and on-road (RDE) testing.

Task 2: Laboratory (dynamometer) comparison of base station NH_3 analyzer and Portable Emissions Monitoring System (PEMS)

In order to solidify sampling protocols and develop instrument validations, a small subset of target vehicles (<5), combined gasoline and diesel, will be identified and tested for NH_3 emission concentrations using the bench-scale PIccaro G2013 NH_3 Analyzer and the more portable ECM miniPEMS (Portable Emissions Monitoring System). The primary goal of these tasks is to test for accuracy and precision of the two systems and develop protocols such that the miniPEMS may be reliably used for future on road studies (see Task 4 below). Within this task NH_3 calibration procedures will be developed and techniques for assessing tailpipe velocity/flowrate will also be validated (e.g. anemometers vs. averaging pitot tubes vs. OBD-related calculations. These studies will be conducted at a combination of the NCAST facilities and on the campus of Utah State University.

Task 3: Laboratory (dynamometer) measurement of diesel and gasoline vehicle NH_3 emissions

Laboratory-based NH_3 emissions, to be compared with available literature and model data, will be conducted at the dynamometer facility at WSU's NCAST center. The PIccaro 2013 will be used to measure the tailpipe NH_3 emissions of the representative diesel and gasoline vehicles. The exact number and classification of vehicles will be determined as described under Task 1. The vehicles will be tested in replicate samples under a simulated dynamometer drive cycle protocol to be determined. Additionally, it is planned that the same vehicles will be tested under differing seasonal emission scenarios. The tests and data compilation will be managed by a USU graduate student. NCAST personnel and undergraduate students from WSU will also assist in the testing, data, collection, and analysis.

Task 4: Quantification of Real Driving Emissions (RDEs) of NH_3 from diesel and gasoline vehicles

Upon verification of the suitability of the ECM miniPEMS, target vehicle populations will be solicited from local driving populations to participate in on-road or Real Driving Emissions (RDE) studies. These studies are planned to be conducted in both the Logan and Ogden airsheds. The

goal here is to quantify "real-world" emissions as result of normal, on-road drivers and driving practices and compare these to the dynamometer emissions and the currently suggested EPA-modeled emissions. A single drive route will be identified in each of the airsheds, and the test vehicles will be operated along the pathway for replicate and seasonal observations.

Deliverables

- Quarterly reports in a format to be specified by the Division of Air Quality
- Year 1 Interim Report (June 2019)
- Final Report (June 2020)
- Compiled and verified digital datasets for each of the above listed tasks in a format to be compatible with DAQ specifications, for ultimate public dissemination

Budget

As shown, in the proposed budget below, the total, 2-yr, budget request is $117,398.78 (see Table 1 below). The requested funds for Year 1 of the project total $59,957.58. As shown, personnel and associated fringe benefits costs for USU totaled $36,426.43.71. As per USU protocol, Dr. Martin's and the graduate student time is estimated in units of person-months (1.0 and 12.0 months, respectively) and charged at the appropriate rates. Although, budget out in terms of months, the graduate research assistantships are considered half-time appointments with the work expectation of of approximately 20 hours/week. Calculated fringe benefit rates at USU are based on a pool of actual administrative costs and are adjusted every six months to reflect potential changes. This procedure has been reviewed and approved by federal auditors who monitor these costs and the university's indirect costs. There are different pools for contract employees, like Dr. Martin, which is currently charged at a rate of 46.5%, increasing to 47.0% for the subsequent fiscal year, and another pool for students and hourly employees. Separately, employer-provided insurance ($1,750) is required for all graduate students and the USU administration has made it part of a rule that at least some graduate student tuition ($2,000) is required to be included separate from standard fringe benefits on all proposals. It should also be mentioned, that USU's Utah Water Research Laboratory typically charges an Environmental Quality Laboratory access (EQL) fee at a current rate of $4.50 per student/staff hour; however, following negotiations with the EQL manager, this cost has been waived. Materials and supply costs are estimated at $5,900.00. As previously mentioned, professor and student collaborators from Weber State and NCAST will aid in data collection and analysis and will be partially funded via a subcontract at $7,500.00. It should be noted that it is USU policy to charge the negotiated overhead rate on all subcontract awards up to $25,000,

above that level no F&A rates are charged. Travel by USU is assessed to require numerous trips from Logan to and around Ogden, as well as gas-card subsidies to volunteer vehicle participants and is estimated at $1,112.27. The F&A (indirect overhead) have been assessed at the agreed rate of 10% and is assessed at $5,268.88.

For Year 2, the similarly grouped costs are estimated to be $37,289.54 (personnel and benefits), $2,000 (miscellaneous supplies), $3,950.00 (required student insurance and tuition), $7,725 (WSU subcontract), $1,442.00 (travel), and $5,034.66 (F&A), for a second-year total of $57,441.20. In general, costs were assumed to increase by 3% per year, unless specific increases are otherwise published (e.g. USU F&A rates at https://rgs.usu.edu/spo/benefit-rates/).

Although not required under the terms of this grant, partnership between investigators at USU and WSU has resulted in a substantial amount of in-kind contributions from the National Center for Automotive Science & Technology (NCAST) at Weber State University. NCAST is an education, industry and government partnership created to develop a better understanding of vehicle emissions, advanced emission control technology, fuels and transportation issues among academic, regulatory and private sectors. NCAST has been in the forefront nationally evaluating On-Board Diagnostics technology and the study of automotive emissions and emission control technologies. As the secondary institution on this research project, NCAST intends to provide in kind support to the funding equivalency of approximately $57,388 to meet the objectives outlined in this proposal (see Table 2 below).

Table 1. Requested Budget Detailed Breakout.

USU YEAR 1 BUDGET	
Personnel: Dr. Randy Martin, PI (1.0 months)	$ 9,823.93
Personnel: M.S. Student (12 months)	$ 21,459.75
Fringe Benefits	$ 5,142.75
Materials, and Supplies	$ 5,900.00
Other Op. Exp. (Student insurance & tuition)	$ 3,750.00
Subcontracts (Dr. John Sohl, Weber State University)	$ 7,500.00
Travel (numerous RTs to Weber State and test drives)	$ 1,112.27
Total Direct Costs	**$ 54,688.71**
F&A (Indirect) Costs (at 10%)	**$ 5,268.87**
TOTAL YEAR 1 COSTS	**$ 59,957.58**
USU YEAR 2 BUDGET	
Personnel: Dr. Randy Martin, PI (1.0 months)	$ 10,043.32
Personnel: M.S. Student (12 months)	$ 21,939.00
Fringe Benefits	$ 5,307.23

Materials, and Supplies	$ 2,000.00
Other Op. Exp. (Student insurance & tuition)	$ 3,950.00
Subcontracts (Dr. John Sohl, Weber State University)	$ 7,725.00
Travel (numerous RTs to Weber State and test drives)	$ 1,400.00
Total Direct Costs	**$ 52,406.55**
F&A (Indirect) Costs (at 10%)	**$ 5,034.65**
TOTAL YEAR 2 COSTS	**$ 57,441.20**
TOTAL 2-yr REQUESTED FUNDING: $ 117,398.78	

Table 2. NCAST In-Kind Support Detailed Breakout.

NCAST YEAR 1 In-Kind funding equivalency Support	
Personnel: Joe Thomas PI (12 months/part time)	$ 4,750
Personnel: 2 Automotive specialists (12 months/part-time)	$ 9,300
Fringe Benefits	$ 6,744
Equipment, Materials, and Supplies	$ 7,900
Total Direct Costs	**$ 28,694**
TOTAL YEAR 1 COSTS	**$ 28,694**
NCAST YEAR 2 In-Kind funding equivalency Support	
Personnel: Joe Thomas, PI (12 months/part time)	$ 4,750
Personnel: 2 Mobile Source specialists (12 months/part-time)	$ 9,300
Fringe Benefits	$ 6,744
Equipment, Materials, and Supplies	$ 7,900
Total Direct Costs	**$ 28,694**
TOTAL YEAR 2 COSTS	**$ 28,694**
Total In-Kind Support for Year 1 & 2	**$57,388**

Project Continuation

It is anticipated that the preliminary results from this study will lead to other emissions-related research questions for which additional funding will be sought through both in-state and external funding sources. At this point, these additional areas are expected to include further dynamometer and RDE testing of a wider a wider range of vehicle ages and types, additional investigation into differing seasonal behaviors, and examination of other pollutant emissions. Characterization of particulate matter (PM) counts, mass, and size distribution is of particular interest as many areas, nationally and internationally. Many government agencies are considering, or currently implementing, PM-based emission regulations, often times without adequate information on the variability of the mobile source emissions.