

A. COVER PAGE

Project Title: Alternative Fuel Use to Reduce Diesel Emissions Exposure and Toxicity in Mining	
Grant Number: 5 R01 OH011410-03	Project/Grant Period: 9/1/2018 - 8/31/2023
Reporting Period:	Requested Budget Period:
Report Term Frequency: Final	Date Submitted: 6/21/2024
Principal Investigator Information: Jefferey Burgess Email:	Recipient Organization: University of Arizona



RPPR Checklist: 5R01OH011410-03 (UA Account #3029610)

PI: Jefferey L. Burgess

Reporting Period: 09/01/2018 – 02/28/2023

Business Office Contact: Cathy Gamez

Formatting Guidelines:

- **Font size:** Must be 11 points or larger. Smaller text in figures, graphs, diagrams and charts is acceptable, as long as it is legible when the page is viewed at 100%. Arial, Georgia, Helvetica, Palatino Linotype fonts are recommended by NIH.
- **Type density:** Must be no more than 15 characters per linear inch (including characters and spaces).
- **Line spacing:** Must be no more than six lines per vertical inch.
- **Margins:** 0.5 inch margins.

Section B. Accomplishments

B.1. What are the major goals of the project? (8,000 character limit including spaces)

The purpose of this project is to determine the extent to which use of alternative fuel mixtures can reduce exposure to hazardous components of diesel engine exhaust in underground mines and thereby reduce adverse health effects resulting from emissions exposures. Diesel particulate matter (DPM) is a known human carcinogen with exposure associated with increased lung and bladder cancer rates, as well as a number of other respiratory and cardiovascular effects. Although for regulatory purposes diesel emissions monitoring is limited to DPM, other components (e.g., nitrogen dioxide (NO₂), nitric oxide (NO), aldehydes, polycyclic aromatic hydrocarbons (PAHs), and carbon monoxide (CO)) have known toxicity. In an effort to reduce underground mine exposures to DPM, some operators have implemented the use of alternative fuels, particularly biodiesel/diesel blends with ratios typically ranging from 20/80 (B20) to 75/25 (B75). In general, biodiesel use appears to decrease respirable DPM, but increased formaldehyde, other aldehydes, and NO₂ have been reported. In addition, other alternative fuels have been developed, including but not limited to renewable diesel. The effect of alternative fuels varies by the vehicle engine and pollution control configuration in place, so it will be important to work with our industry partner to test if alternative fuels are effective in reducing exposures within their mine, and to measure any associated changes in health effects through evaluation of biomarkers.

Aim 1. Evaluate working underground mine exposures and health effects associated with use of diesel (D) and alternative diesel fuels. GDiesel (GD), an alternative fuel proposed for testing during the initial application, was not available by the time the proposal was funded. Renewable Diesel (RD), a drop-in replacement for regular petroleum diesel, was available and used for testing. Due to difficulties finding an underground mine partner (details provided in section F.2), we evaluated the tail-pipe emissions of a 793B Caterpillar haul truck using D and RD at Freeport-McMoRan's Tyrone surface metal mine. Emissions were monitored using a portable emissions monitoring system for six hours a day while the truck performed a typical, controlled cycle using D for three days, and RD for three days.

Aim 2. Assess and compare exposures associated with use of D, RD, and GD in an LHD vehicle. Using a late-model LHD typical of underground coal operations and running D and RD, we evaluated underground area and personal exposures by measuring respirable carbon, elemental carbon, organic carbon; aldehydes, NO₂, NO, CO, PAHs, and particle size/surface area/mass distributions. Vehicle operation parameters and the study location (University of Arizona (UA) San Xavier Underground Mining Laboratory) were the same as those of the previous D/B75 study.

Aim 3. Assess and compare acute health effects associated with use of D, RD and GD in a vehicle with DPF. In conjunction with the exposure monitoring in Aim 2, using D and RD in the aforementioned LHD, we measured respiratory, cardiovascular, and exposure effects pre- and post-exposure for D and RD.

Our outputs and outcomes will include measurement of DPM and other emission components in both working and research mines comparing diesel and alternative fuel blends, and evaluation of the health effects of exposure to these emissions, including measurement of biomarkers of both respiratory and cardiovascular effects. In addition, our study will provide some insight into the relationship vehicle-fuel pairings may have with vehicle emissions.

B.1.a Have the major goals changed since the initial competing award or previous report? (8,000 character limit including spaces)

No.

B.2. What was accomplished under these goals? (2 page limit)

For this reporting period describe: 1) major activities; 2) specific objectives; 3) significant results, including major findings, developments, or conclusions (both positive and negative); and 4) key outcomes or other achievements. Include a discussion of stated goals not met. As the project progresses, the emphasis in reporting in this section should shift from reporting activities to reporting accomplishments.

Aim 1. Evaluate working underground mine exposures and health effects associated with use of diesel (D) and two alternative diesel fuels.

Introduction: The proposal was submitted on 09/29/2016 and not funded until 09/01/2018, almost two years later. During this time the originally proposed GDiesel (GD) fuel stopped being commercially produced. However, Renewable Diesel (RD) continued to be used extensively as a drop-in replacement for petroleum diesel fuel. Our initial underground mining partner for the study was on strike for almost three years (from March 2017 through January 2020 and eventually chose not to participate in the study. The COVID-19 pandemic increased the difficulty in finding an alternate industry underground mine site, and the University of Arizona only allowed essential (pandemic-related) research until March of 2021 when on-campus in-person research resumed. After extensive outreach and in-depth discussions with a number of potential underground mining partners which did not come to fruition, our work eventually resulted in a collaboration with Freeport-McMoRan (FMI) at their Tyrone surface metal mine. FMI has aggressive goals to reduce their CO₂ and other tailpipe emissions over time and was very interested in the potential to partner on a pilot study. However, given the surface rather than underground mine location, it was not possible to evaluate underground mining health effects from the use of the use of D and RD fuels.

Methods: The test was conducted with a 793B Caterpillar (CAT) haul truck with rear-wheel drivetrain, 6-speed auto transmission, and 69,000 cc 3516 CAT engine. The portable emissions monitoring system (PEMS) included a SEMTECH-LDV (Sensors, Inc; Saline, Michigan) that was installed on the truck and used to measure real-time gaseous emissions (CO, CO₂, NO, NO₂), as well as a Pegasor Mi3 Particle Sensor (Tampere, Finland) used to monitor real-time particle mass (PM) data.

The haul truck began each cycle at the top of the mine, drove to the bottom unladen, was then loaded with ore, and returned to the top laden, where ore was dumped. Span and zero calibrations of the gaseous monitor were conducted at the start and end of, as well as every two hours during, the cycle (to prevent analyzer drift). The PEMS calibration process occurred at the shift swap bay, where the vehicle remained stationary for 45 minutes to allow for a battery change, quality assessment of the data, and check of the analyzers. This cycle was repeated for a total of six hours each day. At the end of the third day, the mine team derigged the truck, switched to RD, changed the fuel filter, and operated the truck for two days to allow for burnout or residual D. The same evaluation cycle was repeated once more with RD. Because the truck typically operates for >=20 hours per day, the requirement for data on cold starts was not deemed necessary.

Mass flow was determined using the carbon balance method. Engine load data provided by FMI were used to calculate power by treating 100% engine load as equivalent to the max rated power of the engine (2160 hp ≈ 1590 kW), with which emissions per kilowatt per hour (kWh) were calculated.

Results: With use of the RD fuel, the emissions (g/kWh) of oxides of nitrogen (NO_x) were statistically significantly ($p < 0.05$) greater (108% unladen, 107% laden), compared to D. Emissions (g/kWh) of carbon dioxide (CO₂) were also significantly increased (13.7% laden only) with RD use. Small reductions in fuel consumption (gal/kWh) were observed for both laden (-0.4%) and unladen (-2.0%) tests, but these were not statistically significant. There was a slight decrease in particle mass (g/kWh) during unladen (-1.4%) tests, but a small increase during laden (2.2%) tests.

Discussion: Results are mostly consistent with our team's past investigation of alternative diesel fuels – with an increase in emissions of or exposures to some contaminants (NO_x). However, we anticipated a greater reduction in particulate emissions. This work underscores the importance of performing such trials to ensure that specific vehicle-fuel pairings result in desired emission, exposure, and health effect outcomes. The use of RD also failed to improve the outcome of most interest to the mining partner, that of tailpipe CO₂ emissions.

Aims 2 and 3. Assess and compare exposures associated with use of diesel, renewable diesel and G-Diesel in a vehicle with DPF; and assess and compare acute health effects associated with use of diesel (D), renewable diesel (RD) and G-Diesel (GD) in a vehicle with DPF. Our team recruited and consented 22 subjects, predominantly students, from the University of Arizona during fall 2021 and spring 2022. Subjects visited the San Xavier (SX) underground mine twice during the semester. Baseline biological monitoring was conducted immediately preceding subjects' exposure sessions in the mine, which included: exhaled nitric oxide (NO), exhaled carbon monoxide (CO), exhaled breath condensate (EBC), urine collection, and blood draw. Subjects donned heart rate variability monitors to be worn for the duration of the exposure session.

Each exposure session lasted 90 minutes and was conducted at the recently developed heading of an unventilated decline, approximately 100 meters from the portal. Subjects observed and operated a (2018) Caterpillar (289D) Skid Steer with 73 HP, C3.3B DIT engine while personal diesel particulate matter (DPM) and nitrogen dioxide (NO₂) exposures were measured, as well as area diesel particulate matter (DPM), NO₂ and NO concentrations. Each subject operated the skid steer for 45 minutes and observed operation, from approximately 10 meters, for 45 minutes. Biological monitoring occurred immediately after each exposure session, beginning with exhaled CO and exhaled NO.

During fall 2021 subjects were first exposed to D and then RD exhaust. Subjects of spring 2022 were exposed to RD and then D exhaust. During fuel changeout the previous fuel was drained, the new fuel was added, and then the skid steer was operated for 15 minutes to burn the remainder of the previous fuel.

Collectively, the average D to RD change for personal DPM and NO₂ exposure concentrations were -30% and -13%, respectively. The average D to RD change for area DPM, NO, and NO₂ concentrations were -18%, +17%, and -12%, respectively. With use of D, subjects experienced a decrease of 13% in exhaled CO, but a 10% increase with RD. Use of D was associated with a 3.1% increase in NO, while subjects saw an increase of 6.7% after exposure to RD.

Analysis of additional health effects monitoring is being finalized. We will include these data in publications currently in preparation.

In addition, we measured health exposures during operation of a 2005 Wagner B10-203 LHD vehicle with diesel oxidation catalyst, but no diesel particulate filter, at the SX. This is a vehicle we have used in the past to evaluate multiple alternative diesel fuels. This work was completed in a minimally ventilated section of an older rubber-tire decline, where the gate and adit door to the decline were closed and tarped, and the mine fan was turned off. The LHD was operated in a manner similar to previous studies, with in-cabin exposures measured. A total of 10 90-minute sessions were evaluated, per fuel. Use of RD was associated with a 5.6% (886 $\mu\text{g}/\text{m}^3$ to 836 $\mu\text{g}/\text{m}^3$) reduction in respirable DPM, on average. The average NO concentrations were reduced by 23.9% with use of RD (4.68 ppm to 3.56 ppm), and the average NO₂ concentrations were reduced by 59.9% (4.51 ppm to 1.81 ppm).

Institutional Review Board Approval. We received approval for human subjects research from the University of Arizona Institutional Review Board.

B.4. What opportunities for training and professional development has the project provided?

Timothy Gustafson was an undergraduate student enrolled in the Environmental and Occupational Health track of the Public Health program. He engaged in the project from August 2019 – May 2021 and contributed to the field work at the SX. His skills as an Emergency Medical Technician were helpful for the health effects portion of our study. He is currently employed as an industrial hygienist with Freeport-McMoRan Copper and Gold.

Nic Reed is a graduate student enrolled in the Environmental and Occupational Health track of the MPH program. Nic completed an internship at one of Freeport-McMoRan's surface metal mines in 2020 and engaged in the project.

B.5. How have the results been disseminated to communities of interest? (8,000 character limit including spaces)

We are currently preparing two scholarly articles for publication:

- Reed, R., Littau, S., & Burgess, J.L. Occupational Exposures and Acute Health Effects Associated with Renewable and Regular Diesel in Two Vehicles in an Underground Mining Laboratory. Journal of Occupational and Environmental Medicine. (In preparation).
- Reed, R., & Burgess, J.L. Portable Emissions Associated with Renewable and Regular Diesel in an Operating 793F Caterpillar Haul Truck at a Surface Metal Mine. Journal of Occupational and Environmental Medicine. (In preparation).

A related study, that grew from our previous work, was recently accepted for publication and presentation at the Mine Ventilation Symposium 2023 in June 2023:

- Reed, R., Burgess, J.L., Lutz, E. Pilot Study Comparing Diesel and GDiesel® Exhaust Exposures in an Underground Mining Laboratory. Mine Ventilation. (Accepted).

We plan to present our findings at SME 2024, AIHce 2024, and MSHC 2024.

B.6. What do you plan to do during the next reporting period to accomplish the goals? (8,000 character limit including spaces)

Describe briefly what you plan to do during the next reporting period to accomplish the goals and objectives.

Discuss efforts to ensure that the approach is scientifically rigorous and results are robust and unbiased. Remember that significant changes in objectives and scope require prior approval of the agency (e.g., NIH Grants Policy Statement, 8.1.2.).

Include any important modifications to the original plans. Provide a scientific justification for any changes involving research with human subjects or vertebrate animals. A detailed description of such changes must be provided under Changes.

We are working to finalize analysis of some exposure and health effects results. We plan to publish at least two manuscripts in preparation during 2023. An alternative to Journal of Occupational and Environmental Medicine would be the Journal of Occupational and Environmental Hygiene. We also plan to present our findings at SME 2024, AIHce 2024, and MSHC 2024.

- Reed, R., Littau, S., & Burgess, J.L. Occupational Exposures and Acute Health Effects Associated with Renewable and Regular Diesel in Two Vehicles in an Underground Mining Laboratory. Journal of Occupational and Environmental Medicine. (In preparation).
- Reed, R., & Burgess, J.L. Portable Emissions Associated with Renewable and Regular Diesel in an Operating 793F Caterpillar Haul Truck at a Surface Metal Mine. Journal of Occupational and Environmental Medicine. (In preparation).

Section C. Products

C.1. Are there publications or manuscripts accepted for publication in a journal or other publication (e.g., book, one-time publication and monograph) during the reporting period resulting directly from this award?

None.

C.2. Website(s) or other internet site(s). (2,000 character limit including spaces)

None.

C.3. Technologies or techniques. (2,000 character limit including spaces)

None.

C.4. Inventions, patent applications, and/or licenses. (2,000 character limit including spaces)

Have inventions, patent applications and/or licenses resulted from the award during this reporting period?

None.

C.5. Other products and resource sharing. (2,000 character limit including spaces)

None.

Section D. Participants

D.1. What individuals have worked on the project?

Provide or update the following information for: (1) program director(s)/principal investigator(s) (PDs/Pis); and (2) each person who has worked at least one person month per year on the project during the reporting period, regardless of the source of compensation (a person month equals approximately 160 hours or 8.3% of annualized effort).

Provide the name and identify the role the person played in the project. Indicate the nearest whole person month (Calendar, Academic, Summer) that the individual worked on the project. Show the most senior role in which the person has worked on the project for any significant length of time. For example, if an undergraduate student graduates, enters graduate school, and continues to work on the project, show that person as a graduate student.

Instructions:

- An individual's Commons user ID may be used to partially populate his or her information.
- A Commons ID is required for all individuals with a postdoctoral role and/or supported by a Reentry or Diversity Supplement
- Individuals with a postdoctoral-like role should be identified as "Postdoctoral (scholar, fellow, or other postdoctoral position)."
- Do not include Other Significant Contributors who are not committing any specified measurable effort to this project.
- Do not report personnel for whom a PHS 2271 Appointment form has been submitted through xTRAIN.

****Please work with Lisa Granados to confirm/obtain this information****

Key Personnel

- Name: Jeff Burgess, MD, MS, MPH
Role: Principal Investigator
Months: 1.0 months
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- Name: Sally Littau, MT(ASCP)
Role: Lab Manager
Months: 4.5 months

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- Name: Rustin Reed, PhD, CIH, CSP
Role: Project Manager
Months: 7.0 months
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- Name: Samantha Castro
Role: Lab Coordinator
Months: 1.6 months
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D.2.a. Level of Effort (700 character limit including spaces)

Will there be, in the next budget period, either (1) a reduction of 25% or more in the level of effort from what was approved by the agency for the PD/PI(s) or other senior/key personnel designated in the Notice of Award, or (2) a reduction in the level of effort below the minimum amount of effort required by the Notice of Award?

Reductions are cumulative, i.e., the 25% threshold may be reached by two or more successive reductions that total 25% or more. Once agency approval has been given for a significant change in the level of effort, then all subsequent reductions are measured against the approved adjusted level. Selecting "yes" constitutes a prior approval request to the agency and the issuance of a subsequent year of funding constitutes agency approval of the request.

Please answer YES or NO.

If YES, provide an explanation.

No.

D.2.b. New Senior/Key Personnel

Are there, or will there be, new senior/key personnel?

Please answer YES or NO.

If YES, for all new training faculty, a biosketch and other support information will be required.

No.

D.2.c. Changes in Other Support

Has there been a change in the active other support of senior/key personnel since the last reporting period?

There have been changes, so we'll generate active other support for all senior/key personnel to review.

No.

D.2.d. New Other Significant Contributors

Are there, or will there be, new other significant contributors?

Other significant contributors are individuals who have committed to contribute to the scientific development or execution of the project, but are not committing any specified measurable effort (i.e., person months) to the project.

Please answer YES or NO.

If YES, for all new significant contributors, a Biosketch and current/pending other support information will be required.

No.

Section E. Impact

E.2 What is the impact on physical, institutional, or information resources that form infrastructure?

(8,000 characters including spaces)

Describe ways, if any, in which the project made an impact, or is likely to make an impact, on physical, institutional, and information resources that form infrastructure, including:

- physical resources (such as facilities, laboratories, or instruments);
- institutional resources (such as establishment or sustenance of societies or organizations); or
- information resources, electronic means for accessing such resources or for scientific communication, or the like.

If the award or award component(s) is not intended to support physical, institutional, or information resources that form infrastructure, select "Nothing to Report."

This study addresses the NIOSH NORA research priority area of new technologies, and the program focus on cancer and cardiovascular disease. It also addresses the NIOSH Mining Program strategic goal to reduce respiratory disease in miners through reducing health hazards in the workplace associated with diesel emissions. Our study provides useful and timely information regarding potential benefits that could be expected from more widespread use of alternative fuels.

In 2016, MSHA published a Request for Information regarding exposure of underground miners to diesel exhaust in order to better understand and characterize the current status of exposures, controls and best practices in the mining industry. Although forum for public comment has closed, MSHA also formed the Diesel Exhaust Health Effects Partnership, also in 2016. We intend to engage with this partnership with our results, published scholarly works, and in any other ways which might prove helpful. This work will contribute to the legislative process, resulting in policies designed to further protect the health of miners.

While this study focuses on the health and exposures of underground mine workers, it is relevant for multiple industries that struggle to control diesel exhaust exposures, including transportation, railroad, and construction. Should renewable diesel prove successful in reducing exposures and health effects and should more transportation companies transition to these alternative diesel fuels, secondary outcomes may include reduced diesel exhaust exposures and associated health effects in communities. These benefits are most likely to be observed in urban communities with proximity to heavy transportation corridors.

E.4. What dollar amount of the award's budget is being spent in foreign country(ies)?

For domestic awardees provide the dollar amount obligated to first-tier subawards to foreign entities for this reporting period. For foreign awardees provide the dollar amount of the award, excluding all first-tier subawards to U.S. entities, for this reporting period. Dollars provided should reflect total costs. If more than one foreign country, identify the distribution between the foreign countries.

If there is nothing significant to report during this reporting period, select "Nothing to Report."

None.

Section F. Changes

F.2 Actual or anticipated challenges or delays and actions or plans to resolve them (8,000 characters including spaces)

Describe challenges or delays encountered during the reporting period and actions or plans to resolve them. Describe only significant challenges that may impede the research (e.g., accrual of patients, hiring of personnel, need for resources or research tools) and emphasize their resolution.

Due to volatility typical of the mining industry, and challenges presented by COVID, finding underground mines willing to collaborate proved difficult (see Table 1). In addition, not long after the project proposal submission, the producer of GDiesel (a startup called Advanced Refining Concepts) paused operations indefinitely.

Table 1. Potential industry partnerships and their outcomes.

Industry Partner	Year	Outcome
Freeport-McMoRan Copper and Gold	2022-2023	Collaboration on 793B CAT haul truck emissions
Hecla Mining's Lucky Friday Mine	2020-2021	Failed due to mine policy regarding RD flash point
Waste Isolation Pilot Plant (WIPP)	2019-2020	MOU in review, failed due to COVID restrictions
Prairie State Generating Company Mine	2019-2020	MOU rejected by stakeholders citing liabilities
South32 Hermosa Mine	2018-2019	MOU in review, failed due to development setbacks
Energy Fuels Canyon Mine	2018-2023	Site buy-in but operations suspended
Hecla Mining's Lucky Friday Mine	2016-2018	Site buy-in, failed due to long-term employee strike

Our partnership with Freeport-McMoRan was delayed somewhat, due to logistics involved with the study parameters and coordination of multiple teams at the site. These issues, however, were resolved, and our field work was conducted in December 2022. We anticipate publishing two manuscripts this year and presenting our findings at three conferences in 2024.

F.3.a Human Subjects

If human subject protocols are or will be different from the previous submission, include a description and explanation of how the protocols differ and provide a new or revised Protection of Human Subjects Section as described in the competing application instructions.

If there are no significant changes to report during this reporting period, select "No Change."

No Change.

F.3.b Vertebrate Animals

If there are or will be significant changes to the uses of vertebrate animals from the previous submission, provide a description of the changes. Examples of changes considered to be significant include, but are not limited to, changing animal species, changing from noninvasive to invasive procedures, new project/performance site(s) where animals will be used, etc. If studies involving live vertebrate animals are planned and were not part of the originally proposed research design, provide a new or revised Vertebrate Animal Section as described in the competing application instructions.

If there are no significant changes to report during this reporting period, select "No Change."

Not applicable.

F.3.c Biohazards

If the use of biohazards is or will be different from the previous submission, provide a description and explanation of the difference(s).

If there are no significant changes to report during this reporting period, state "No Change."

No Change.

F.3.d Select Agents

If the possession, use, or transfer of Select Agents is or will be different from that proposed in the previous submission, including any change in the select agent research location and/or the required level of biocontainment, provide a description and explanation of the differences. If the use of Select Agents was proposed in the previous submission but has not been approved by regulatory authorities, provide an explanation. If studies involving Select Agents are planned and were not part of the originally proposed research design, provide a description of the proposed use, possession, transfer, and research location as described in the competing application instructions.

U.S. Select Agent Registry information: <http://www.selectagents.gov/SelectAgentsandToxins.html>

If there are no significant changes to report during this reporting period, select "No Change."

No Change.

Section G. Special Reporting Requirements

G.1. Special Notice of Award and Funding Opportunity Announcement Reporting Requirements

Address any special reporting requirements specified in the award terms and conditions in the Notice of Award (NoA) or Funding Opportunity Announcement (FOA).

Not applicable.

G.4.b Inclusion Enrollment Report

If conducting NIH-defined clinical research, reporting the cumulative enrollment of subjects and the distribution by sex/gender, race, and ethnicity is required, as defined in the competing application instructions. If there are details or concerns related to inclusion enrollment progress, or if the cumulative enrollment data does not reflect the planned enrollment by sex/gender, race, and/or ethnicity, the reasons for this should be addressed in Section F.3.a of the RPPR.

Update the inclusion enrollment with the total cumulative enrollment data collected to-date. Grantees can access the inclusion enrollment record(s) in Section G.4.b. by clicking the "Inclusion" link. The link will be available when inclusion monitoring is required.

Additional guidance: <https://www.nhlbi.nih.gov/alert-new-rppr-submission-procedures-inclusion-enrollment-data>

Note: In last year's RPPR, we had not yet submitted an IRB protocol and therefore did not submit any inclusion enrollment data. If there is now inclusion enrollment data to report, please enter this into the attached form. Otherwise, indicate "Nothing to Report."

Nothing to Report.

G.5 Human Subjects Education Requirement (Limit is 1300 characters or approximately 1/2 of a page) Are there personnel on this project who are or will be newly involved in the design or conduct of human subjects research?

Please answer YES or NO.

If YES, provide the following:

- names of individuals,
- title of the education program completed by each individual, and

- a one sentence description of the program

No.

G.6. Human Embryonic Stem Cells (hESCs)

Does this project involve human embryonic stem cells?

Please answer YES or NO.

If YES, enter hESC registration number. Only hESC lines listed as approved in the NIH [Registry](#) may be used in NIH funded research.

No.

G.9. Foreign Component (700 character limit including spaces)

Has significant scientific activity for this grant been performed outside of the United States, whether or not grant funds were expended?

"Foreign component" is defined as significant scientific activity that was performed outside of the United States, either by the grantee or by a researcher employed by a foreign organization, whether or not grant funds were expended. The following grant-related activities are significant and must be reported:

- involvement of human subjects or research with live vertebrate animals;
- extensive foreign travel by awardee project staff to collect data, or conduct surveys or sampling activities; or
- any awardee activity that may have an impact on U.S. foreign policy.

Examples of other award-related activities that may be significant are:

- collaborations with investigators at a foreign site anticipated to result in co-authorship;
- use of facilities or instrumentation at a foreign site; or
- receipt of financial support or resources from a foreign entity.

Foreign travel for consultation does not meet the definition of foreign component.

If NO, please select "No foreign component."

If YES, provide the organization name, country, and description of each foreign component.

No.

G.10.a Is it anticipated that an estimated unobligated balance (including prior year carryover) will be greater than 25% of the current year's total approved budget? (700 character limit including spaces)

The "total approved budget" equals the current fiscal year award authorization plus any approved carryover of funds from a prior year(s). The numerator equals the total amount available for carryover and the denominator equals the current year's total approved budget.

Please provide the following budget information for SPCS:

- Your current account balance.
- Total obligated expenditures for the remainder of the current budget period (does not need to be itemized).
- Detailed list of total unobligated (expected, but not expensed/encumbered) expenditures for the remainder of the current budget period.

Please answer YES or NO.

If YES, provide the estimated unobligated balance and an explanation for the unobligated balance.

YES.

Estimated unobligated balance: \$289,615.58.

The San Xavier Underground Mining Laboratory has not charged us their customary rate of \$1,650 per day rental fee for use of the mine, nor have they billed us for necessary repairs on equipment used during our field work. In addition, adjustments to our aims prevented us from collecting health effects data at our partner's mine site.

H. Budget

H.1 Budget Form

I will work with you to prepare the necessary budgets and budget justifications.

I. Outcomes of the Award

Project: Alternative Fuel Use to Reduce Diesel Emissions Exposure and Toxicity in Mining

Contact PI: Jefferey Burgess

Organization: Mel and Enid Zuckerman College of Public Health, University of Arizona

In collaboration with Freeport-McMoRan, we evaluated the tail-pipe emissions of a 793B Caterpillar haul truck using diesel (D) and renewable diesel (RD) fuels at the Tyrone surface metal mine. Emissions were monitored using a portable emissions monitoring system for six hours a day while the truck performed a typical, controlled cycle using D for three days, and RD for three days. With use of the RD fuel, the emissions (g/kWh) of oxides of nitrogen (NO_x) were statistically significantly ($p < 0.05$) greater (108% unladen, 107% laden), compared to D. Emissions (g/kWh) of carbon dioxide (CO₂) were also significantly increased (13.7% laden only) with RD use.

At the University of Arizona's San Xavier (SX) mine, we evaluated the health effects and personal exposures of 22 student subjects. Baseline biological monitoring was conducted immediately preceding subjects' exposure sessions in the mine, which included: exhaled nitric oxide (NO), exhaled carbon monoxide (CO), exhaled breath condensate (EBC), urine collection, and blood draw. Each exposure session lasted 90 minutes and was conducted at the recently developed heading of an unventilated decline, approximately 100 meters from the portal. Subjects observed and operated a (2018) Caterpillar (289D) Skid Steer with 73 HP, C3.3B DIT engine while personal diesel particulate matter (DPM) and nitrogen dioxide (NO₂) exposures were measured, as well as area diesel particulate matter (DPM), NO₂ and NO concentrations. Collectively, the average D to RD change for personal DPM and NO₂ exposure concentrations were -30% and -13%, respectively. With use of D, subjects experienced a decrease of 13% in exhaled CO, but a 10% increase with RD. Use of D was associated with a 3.1% increase in NO, while subjects saw an increase of 6.7% after exposure to RD.

Finally, we evaluated in-cabin exposures while operating the 2005 Wagner LHD from and in a manner similar to previous studies. Use of RD was associated with a 5.6% (886 $\mu\text{g}/\text{m}^3$ to 836 $\mu\text{g}/\text{m}^3$) reduction in respirable DPM, on average. The average NO concentrations were reduced by 23.9% with use of RD (4.68 ppm to 3.56 ppm), and the average NO₂ concentrations were reduced by 59.9% (4.51 ppm to 1.81 ppm).