PanCeria: Catalytic NO and CO Emission Control Unit for Small Off-Road Engines

John Williams, Michelle Lau, Marisol Reveles Trujillo,
Charles Elliott, Sergio Gomez Beltran
Advisors: David Cocker, PhD; Amanda Rupiper, PhD

Chemical and Environmental Engineering – Senior Design Project 2023

Background and Motivation

What are small off road engines and why are they an issue?

- Small Off Road Engines (SOREs) are typically equipment used to maintain lawns and gardens, classified as a spark ignition engine running under 25 horsepower [1]. They are not as regulated as motor vehicles, resulting in them becoming a huge contributor of nitrogen oxide (NO) and carbon monoxide (CO)

Why are NO and CO a problem?

- Nitrogen oxides react with sunlight, forming ozone which is a criteria air pollutant. NO also causes irritation of the eyes, nose, throat, lungs, as well as coughing and nausea [2].
- Carbon monoxide indirectly affects climate change due to its participation in the formation of ozone. For humans, CO causes blood to lessen its ability to carry oxygen, leading to symptoms such as headache, fatigue, confusion, and dizziness due to less oxygen reaching the brain [3].

Motivation for the project?

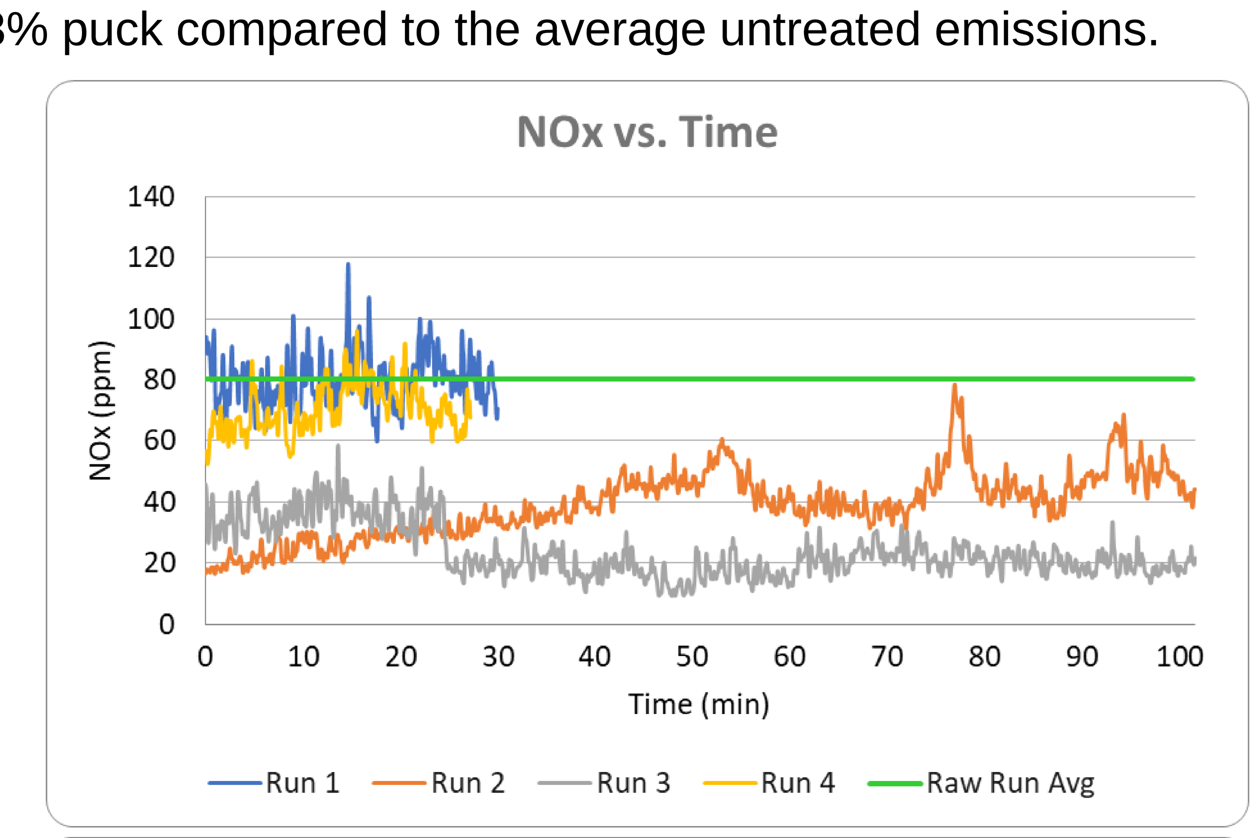
- Because there are less regulations on SOREs, they are on track to becoming the worst air polluters in California. PanCeria aims to develop a catalytic converter using non-precious metals to reduce NO and CO emissions.

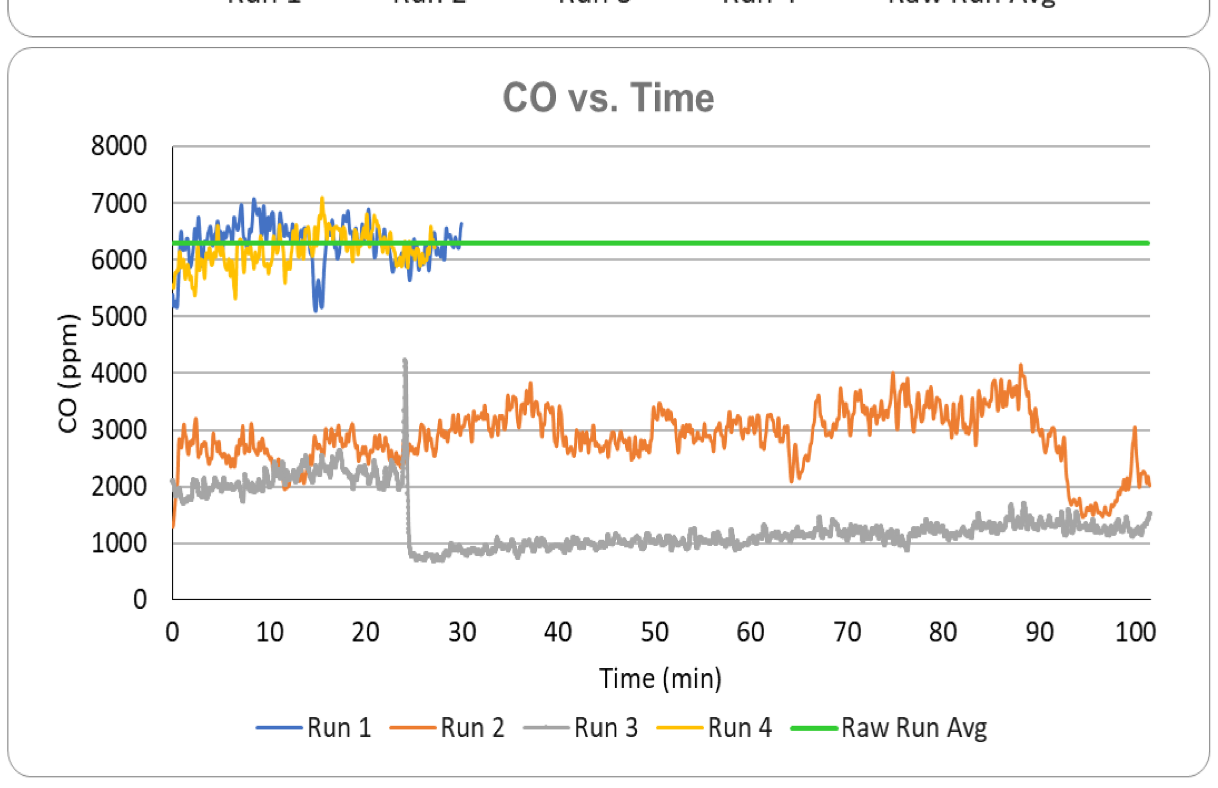
How will the catalyst reduce NO and CO emissions?

- PanCeria's catalyst consists of copper and cerium oxide on a cordierite monolith. The nitrogen oxides that are released from the engine's exhaust will come into contact with the catalyst and undergo carbon monoxide oxidation shown in this reaction: $2NO + 2CO + O_2 \rightarrow N_2 + 2CO_2$. The activation of the catalyst is only possible at exhaust temperatures of 200-350 degrees Celsius [4].

Data and Findings

The graphs below display the NOx and CO emissions obtained in each run (1-4) for a 1.3% puck compared to the average untreated emissions.





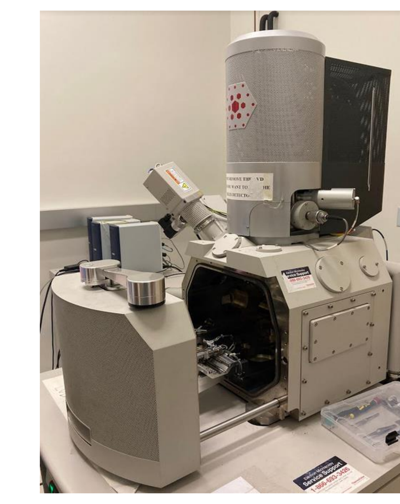
Runs 1 and 4 showed little to no reduction whereas Runs 2 and 4 removed upwards of 80% in emissions. We've concluded that there was not enough heat to complete a full reaction, therefore emissions increased for some samples.

Estimated Costs

Copper (II) nitrate is purchased at a price of $0.34 per gram and cerium (IV) oxide is $3.14 per gram. The cost of a cordierite ceramic monolith is $16 a piece and an SEM scan is $14. The catalyst requires a use of 0.5 g of copper (II) nitrate and 9.5 g of cerium (IV) oxide. The helium and hydrogen gas used total to $2.92 a puck. Thus bringing our estimated costs of a completed catalyst puck to a total of $62.91.

Equipment Used

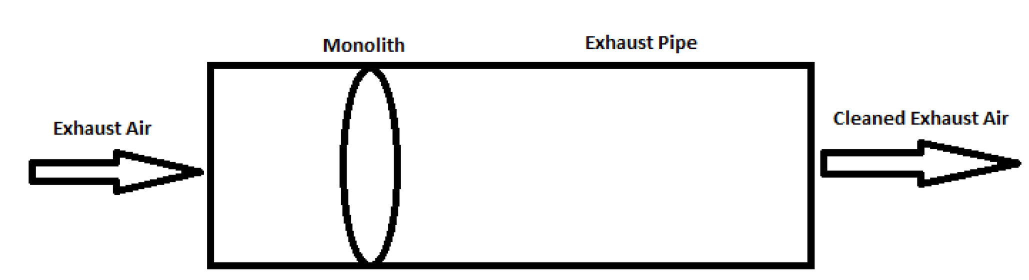
- Scanning Electron Microscope (SEM)
  - Used for finding the percent weight loading of copper
  - Can also scan for other elements and impurities
  - Help us determine if catalyst was synthesized properly



- Horiba PG-350 Gas Analyzer
  - NOx (ppm), CO (ppm), O_2 (% vol.), CO_2 (% vol.), and SOx (ppm)
  - 0.5 L/min sampling with 0 - 40℃ temperature range
  - Portable and high range

- Connected in-line rig
  - Catalyst chamber with cordierite puck
  - Lawnmower
  - Metal and copper tubing

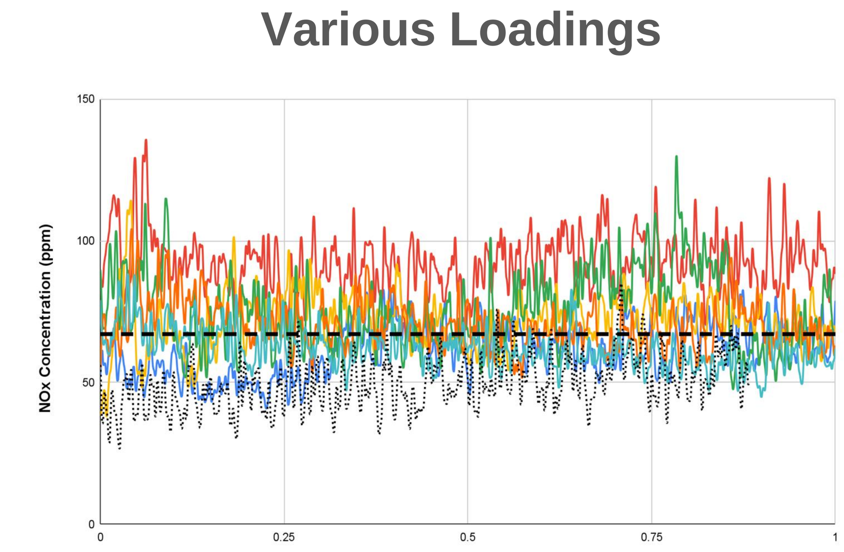
- Tube Furnace
  - Use to remove nitrates in catalyst powder
  - Can reach temperatures of 1,200℃
  - 90% Helium and 10% Hydrogen gas mixture at 100 mL/min
  - Can vary heating rate per minute



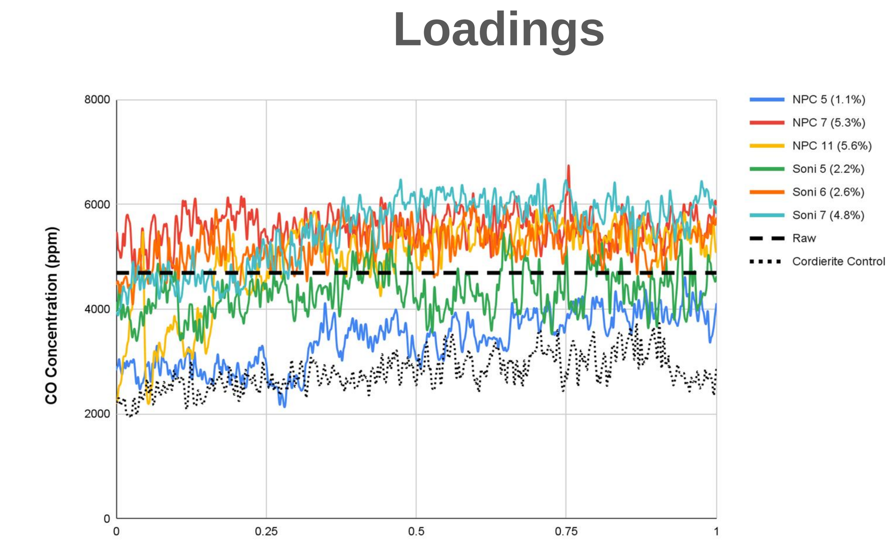
- Testing Device Schematic
  - Monolith housed in an exhaust pipe
  - Takes in polluted air and releases N2 and CO_2

Future Plans

NOx Emissions - Catalysts of Various Loadings



CO Emissions - Catalysts of Various Loadings



The graphs above display the relative emission levels for both NOx and CO from the tested catalysts of various copper to cerium oxide loading ratios.

Future work should be targeted towards obtaining more data and support on the variables influencing the emission reductions seen.

Acknowledgment

The current PanCeria team would like to acknowledge the previous phase I and II teams for their hard work and dedication to this project. Special thanks to Kyah Gracia for mentorship and direction on the project and Dr. Abdul-Aziz lab and graduate student Tu Nguyen for facilitating a space where we can do research and data collection. And most importantly thanks to our principal investigator Dr. Cocker and our professor Dr. Rupiper.

References

[1] "California Air Resources Board." Carbon Monoxide & Health | *California Air Resources Board*.ww2.arb.ca.gov/resources/carbon-monoxide-and-health. Accessed 23 May 2023.

[2] "Nitrogen oxides." *Agency for Toxic Substances and Disease Registry (ATSDR).* https://www.atsdr.cdc.gov/toxfaqs/tfacts175.pdf. Accessed 23 May 2023

[3] Snytnikov, P.V., Stadnichenko, A.I., Semin, G.L. (2007). et al. Copper-cerium oxide catalysts for the selective oxidation of carbon monoxide in hydrogen-containing mixtures: I. Catalytic activity. Kinet Catal 48, 439–447. Accessed 23 May 2023.

[4] "California Air Resources Board." Small Off-Road Engines (SORE) | *California Air Resources Board*. ww2.arb.ca.gov/our-work/programs/small-off-road-engines-sore. Accessed 23 May 2023.