Alternative Fuels to Reduce Lead Emissions from Piston Engine Aviation

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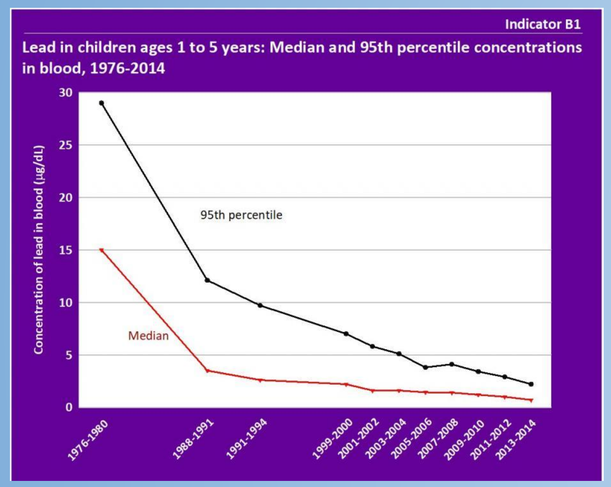
♦ Introduction

Lead is a toxic metal that poses many health risks if it enters the human body. The largest source of lead emissions in the United States is the burning of leaded aviation fuel, 100 Octane Low Lead (100LL/Avgas). Avgas has yet to be phased out because no alternative fuel with comparable or better performance has been identified to replace it. In this study, a variety of fuels were examined to determine a possible alternative.



♦ Purpose

The purpose of this investigation was to identify a potential replacement fuel for Avgas that does not contain lead, so as to significantly decrease the lead emissions from aviation

♦ Research Question

Are there alternative non-lead fuels that provide equivalent performance to Avgas, so as to be capable of replacing it as the primary fuel used in piston engine aviation?

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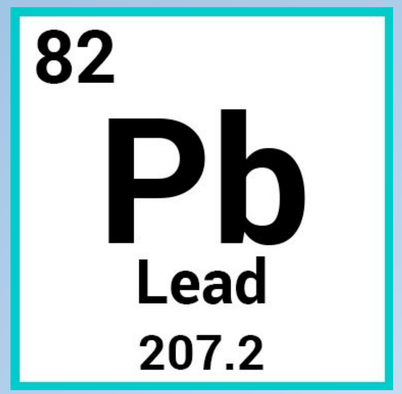
♦ Hypothesis

Alternative hypothesis: There are alternative non-lead fuels that provide an equivalent octane rating to Avgas.

Null hypothesis: There are no alternative non-lead fuels that provide an equivalent octane rating to Avgas.

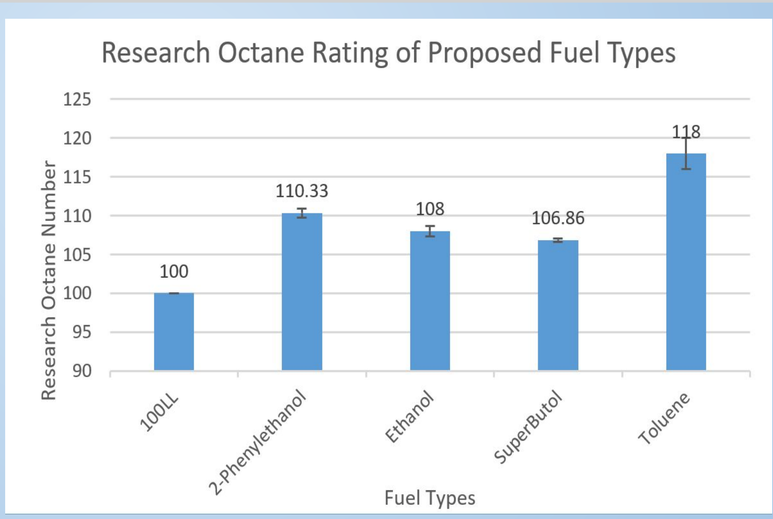


♦ Methods & Materials

This study was conducted through systematic literature review of many peer-reviewed journals and articles. The data was collected on the RON values for different fuels. These values indicate the octane rating of a particular fuel. Data was acquired through Thousand Oaks High School, mentors with PhDs in scientific disciplines, and the California State University Channel Islands library. The Literature review commenced from August 2017 to December 2017, while data collection and systemic analysis took place from February 2018 through March 2018. Data collected was obtained from previous scientists research. Data was entered into and analyzed using Excel.

♦ Results

The four fuels that were compared to Avgas are 2-Phenylethanol, Ethanol, Sueprbutol, and Toluene. When analyzed, 2-Phenylethanol's octane rating was reported at 111, and 110.These values returned a mean octane rating of 110.33 with a standard deviance of 0.577. Ethanol's octane rating was reported at 107, 109, and three times at 108. The mean octane rating came out to be 108 with a standard deviance of 0.707. Superbutol's octane rating was reported at 106.6 and 107 twice. Its mean octane rating was 106.86 with a standard deviance of 0.231. Toluene's octane rating was reported at 116, 118 and 120. These values gave Toluene a mean octane rating of 118 and a standard deviance of 2, the largest variance out of all the fuels.



♦ Discussion

The first thing that should be addressed is all the proposed fuels had higher RON values than Avgas. This can be attributed to the fuels that were chosen with higher performance than automotive gasoline. All the fuels considered had to be high performance because any low performance fuel would not have a high enough octane rating to compare with Avgas, and could be easily eliminated. Since all the fuels were high performance, there was a high probability that the selected fuels would have a high enough octane rating to replace Avgas.

Toluene and 2-Phenylethanol were found to have the highest octane ratings. Therefore, they are the two primary types of fuel that should move onto further testing. If in additional testing both Toluene and 2-Phenylethanol are found to have properties that prevent them from being suitable Avgas replacements, the other fuels studied can also be taken into additional testing. After 2-Phenylethanol, Ethanol would be the next fuel to be tested, then Superbutol.

♦ Conclusion

The results of the study indicate that Toluene and 2-Phenylethanol had the highest octane ratings of 118 and 110.33 respectively, both above the 100 octane rating of Avgas, making them the most promising fuels to move onto further testing to determine if they can replace Avgas.

♦ Further Work

- Fuel testing under complex conditions
- High altitude testing
- Low temperature testing
- Engine lubrication properties
- Possible use of fuel additives
- Fuel cost

♦ References

1. Bedon M., Milosavljevic M., Morel V., Solari J., Bourhis G., Dauphin. (2017). Design of a valuable fuel couple and engine compression ratio for an octane-on-demand SI engine concept: a simulation approach using experimental data. *Fuel 189*, 107-119. Doi: 10.1016/j.fuel.2016.10.060
2. Bourhis G., Morel V., Solari J., Dauphin. (2017). Using ethanol's double octane boosting effect with low RON naphtha based duel for an octane on demand SI engine. *SAE Int. J. Engines 9(3)*. doi:10.4271/2016-01-0666
3. Brochin R., Leone S., Phillips D., Shepard N., Zisa D., Angerio A. (2008). The cellular effect of lead poisoning and its clinical picture. *The Georgetown Undergraduate Journal Of Health Sciences 5(2)*. https://pdfs.semanticscholar.org/8d6c/28ad713fc2866a2196b0480848e24235e48.pdf
4. Czarnigowski, J., Jaklitski, P., Wendeker, M. (2010). Fueling of aircraft radial piston engines by ES95 and 100LL gasoline. *Fuel 89*, 3568-3578. Doi: 10.1016/j.fuel.2010.06.032

See academic paper for full references list

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