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Project Summary

Effects of Burn Rate, Wood Species, Moisture Content, and Weight of Wood Loaded on Woodstove Emissions

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Four woodstove operating parameters (burn rate, wood moisture, wood load, and wood species) were tested at two levels each using a half factorial experimental test design to determine statistically significant effects on the emission components CO, CO_2, particulate matter, total extractable organics (TEOs), polycyclic aromatic hydrocarbons (PAHs), C_1-C_7 hydrocarbons, metals, and the Ames plate incorporation bioassay mutagenic potential.

Results showed that increasing burn rate lowered CO, particulate matter, TEO and C_1-C_7 hydrocarbon emission rates. Increasing burn rate raised emission rates of individual PAHs and several metals, and also the mutagenic potential of the emissions. All of these effects were significant at the 90% or better confidence interval.

At the 90% or better confidence interval, reducing wood moisture increased the particulate emission factor while concentrations of several PAHs in the stack gas were lowered.

Changing from pine to oak increased potassium emissions at the 90% confidence interval. Effects just under the 90% confidence interval included reductions in emission factors for several PAHs and a decrease in mutagenic activity.

Increasing the weight of the initial wood load increased particulate emissions, significant at the 90% confidence interval. A decrease in mutagenic activity was significant at slightly below the 90% confidence interval.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Test Conditions

This project is one of a number of studies to characterize toxic/mutagenic compounds emitted by residential wood combustion units such as woodstoves. The Integrated Air Cancer Project (IACP) will use the information gained from this and other such studies to determine the contribution of toxic/mutagenic substances by residential woodburning units to ambient air.

Specifically, this project studied the effect of stove operating variables on organic emissions such as polycyclic aromatic hydrocarbons (PAHs), total extractable organics (TEOs), particulates, and CO. Other emissions studied included C_1-C_7 hydrocarbons.

A half factorial experimental test design was used to evaluate statistically the effects of four stove operating variables: burn rate, wood moisture, wood load, and fuel type on the measured woodstove emissions. Ranges were established according to high and low values and used in the half factorial test matrix. Burn rate target values were previously determined to be approximately 2 kg/hr for low burn

rate and 6 kg/hr for high burn rate. The experimental averages for the low and high burn rates were used. Wood moisture contents were determined gravimetrically for cure and uncured woods which were procured prior to test implementation. Uncured wood remained in log form and was cut 1 day prior to testing to preserve the wood moisture content. Wood loads were determined according to the volume of the firebox. High wood loads filled the stove to capacity initially, and low wood loads filled the stove approximately half full. Two wood types were tested, oak and pine. Test variables with actual experimental values are:

Variables	*High +*	*Low –*
Fuel	*Oak*	*Pine*
Moisture	*Cured 16.9%*	*Uncured 33.2%*
Load	*High 15.2 kg*	*Low 8.0 kg*
Burn Rate	*High 6.56 kg/hr*	*Low 1.75 kg/hr*

Results

For this discussion, three types of emissions are defined: concentrations are mass of component per cubic meter of stack gas (STP) wet (g/m^3), emission factors are mass of component per mass of wet wood burned (g/kg), and emission rates are mass of component emitted per hour (g/hr). All reported effects are the result of the analyses of variance performed by the half factorial statistical test design.

Burn Rate

A. The effects of increasing burn rate (kg wood burned/hr) at a 90% or better confidence limit are:
   1. The stove and stack gas temperatures increase significantly, as much as 140 and 170°C, respectively. Maintaining higher temperatures may contribute to better combustion efficiency, and thus, lower total extractable organic, particulate, and CO emissions.
   2. CO_2 emissions are increased while CO emissions are decreased.
   3. Particulate matter (probe and filter catch) concentration and emission factors decrease. At high burn rates, particulate concentrations and emission factors are lower, but the stack flow rate is higher; at low burn rates, particulate concentrations and emission rates are higher, but the stack flow is lower. These effects tend to cancel, such that wood load has the most significant effect on particulate emission rates.
   4. Gravimetric compounds (>300°C b.p.) emissions decrease.
   5. TCO compounds (100-300°C b.p.) emissions decrease.
   6. TEO emissions decrease.
   7. C_1-C_7 concentration and emission factors decrease.
   8. H_2O emission rates increase but H_2O emission factors decrease.
   9. Benzo(b)fluoranthene emission factor (mg/kg wet wood) increases.
   10. Potassium emission increases.
   11. Manganese concentration and emission rate increase.
   12. Sulfur emission increase.
   13. Zinc concentration increases.
   14. Mutagenic activity as measured by TA98 + S9 increases.

B. The effects of increasing burn rate (kg wood burned/hr) at just under a 90% confidence limit are:
   1. Naphthalene, phenanthrene, fluoranthene, pyrene, chrysene, benzo(b)fluoranthene, and benzo(a)pyrene emission rates all increase.
   2. Naphthalene and fluorene emission factors (mg/kg wood) decrease.
   3. Chrysene emission factor increases.
   4. Benzo(a)pyrene concentration increases.
   5. TA98-S9 mutagenic activity increases.

Wood Moisture

The effects of decreasing wood moisture percent at a 90% or better confidence limit are:

1. Lower stack gas moisture concentration, but particulate and CO_2 emission factors increase.
2. Naphthalene concentration decreases.
3. Pyrene emission factor decreases.
4. Cadmium emissions decrease.
5. The weight percent of barium in the ash decreases while the weight percent of aluminum, iron, magnesium, and strontium increases.
6. The iron to potassium rati the ash increases.

Wood Type

A. The effects of changing from pin oak at a 90% or better confide limit are:
   1. Potassium emissions increa
   2. Manganese emissic decrease.
   3. Zinc emission factor decreas
   4. The weight percent in ash barium, calcium, and stront increases.
   5. The weight percent in ash aluminum, manganese, m nesium, and zinc decreases.
   6. The iron to potassium ra decreases.

B. Effects of changing from pine to just under a 90% or better c fidence limit are:
   1. Acenaphthylene, phenanthre anthracene, and pyre emission factors decrease.
   2. Particulate emission fac increases.
   3. Gravimetric and TCO conc trations and emission ra decrease.
   4. TEO concentration decreases
   5. Mutagenic activity as measur by TA98 + S9 and - decreases.

Wood Load

A. The effects of increasing wood lo at 90% or better confidence lir are:
   1. Stack flow increases.
   2. Particulate emission ra increases.

B. The effect of increasing wood lo just under a 90% confidence limit
   1. Mutagenic activity (TA98-S decreases.

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The complete report, entitled "Effects of Burn Rate, Wood Species, Moisture Content, and Weight of Wood Loaded on Woodstove Emissions," (Order No. PB 89-196 828/AS; Cost: $36.95, subject to change) will be available only from:
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