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Project Summary

Long-Term Performance of EPA-Certified Phase 2 Woodstoves, Klamath Falls and Portland, Oregon: 1998/1999

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Wood stoves have been identified as a major source of particulate and polycyclic organic matter (POM) emissions. For this reason, new source performance standards (NSPS) were promulgated for wood heaters. Wood heaters sold after July 1, 1992, had to be certified for low emissions, meet the most stringent requirements of NSPS, and are referred to as phase 2 certified. Of concern has been the fact that laboratory and field studies have shown that certified wood heaters can physically degrade with use and their air emissions commensurately increase. The objective of this study was to evaluate the condition and air emissions from old phase 2 certified wood heaters installed in homes and used regularly for home heating since the 1992/1993 heating season or earlier. Sixteen stoves were evaluated in the study, eight each in Klamath Falls and Portland, Oregon. An extensive data base from 43 week-long test runs was developed. The particulate emission factors of the certified phase 2 stoves evaluated in this study appear to have increased with use but, on average, after about 7 years still have lower emissions than uncertified conventional stoves. In addition, it was clear from the results that emission rates for phase 2 stove models reported as part of the NSPS certification process do not represent emission levels of the same stove models in homes after extended use.

This Project Summary was developed by the National Risk Management Research Laboratory's Air Pollution Prevention and Control Division, 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).

Introduction

Residential wood combustion (RWC) has been identified as a major source of particulate matter (PM) and POM air emissions. During 1997, RWC contributed an estimated 12% of the sum of the total PM with aerodynamic diameters < 10 μm (PM_{10}) emissions attributed to all fuel combustion, industrial processes, and transportation sources combined. RWC was also identified as the largest single source of POM during 1990. Approximately 72% of the cordwood burned annually in the U.S. in the category of residential wood combustion was burned in wood stoves. (The remaining 28% was burned mostly in fireplaces.) An estimated 9.3 million wood stoves were used in homes during the 1997-1998 heating season.

Due to the level of emissions attributed to wood stoves, standards of performance were promulgated for new residential wood heaters. All wood heaters sold after July 1, 1992, have to meet the most stringent phase 2 particulate emission limits of the standards. These particulate emission limits are 4.1 g/hr for catalytic stoves and 7.5 g/hr for noncatalytic stoves. The limits for catalytic stoves are lower than for noncatalytic stoves since the presumed deterioration of the catalyst over time was estimated to result in emissions from catalytic wood heaters over their use-

ful lifetimes, approximately equal to those for noncatalytic wood heaters.

Furthermore, there has been concern about the overall physical deterioration of wood stoves with use and the commensurate increase in air emissions. This concern has been confirmed in both laboratory and in-home studies: physical degradation coupled with higher PM emissions has been documented for some stoves. Not only are accurate airshed inventories of PM and POM fundamentally important for health and environmental assessments, state and local agencies in areas of PM_{10} nonattainment have been directed to consider performance degradation in their State Implementation Plans (SIPs) when calculating credits from replacing noncertified stoves with certified stoves. The replacement of noncertified stoves with phase 2 certified stoves remains a viable option for reducing airshed pollutant levels and obtaining PM_{10} SIP credits because, as of 1997, more than 80% of the wood stoves in use were still older non-certified units. In addition, because over 90% of the PM_{10} emissions from residential wood combustion are also PM with aerodynamic diameters < 2.5 μm ($PM_{2.5}$), emission credits may be very important for possible future $PM_{2.5}$ nonattainment areas.

Experimental Procedures

The basis of the experimental study was the use of the Automated Woodstove Emission Sampler (AWES), which was developed to quantify emissions of particles for residential wood-burning appliances while they are in normal in-home use. The AWES is small and operates unattended in home settings. Due to the temporal variability in emissions from wood-burning appliances, the AWES is also designed to collect long-term integrated samples necessary to provide mean values. Studies conducted with the AWES have provided the majority of the data base used for particulate emission factor development by EPA for residential wood combustion. The AWES has been used to quantify emissions from wood stoves, masonry heaters, pellet stoves, and fireplaces. Due to its extensive use, the AWES has undergone EPA-supported quality assurance evaluation.

For sampling purposes, the AWES is placed adjacent to the wood-burning appliance in study homes. For wood-stove applications, a stainless steel inlet probe is typically attached to the chimney (stove pipe) 30 cm above the flue collar of the stove. The sample is withdrawn at a rate of approximately 1 L/min. The flow rate is maintained by a calibrated orifice. Particulate samples, including condensible particles, are captured with a heated filter followed by an XAD-2® resin cartridge. All interconnecting tubing, holders, and hardware exposed to the sample are made of either stainless steel or Teflon® to maintain sample integrity. After sample collection, the chimney gas is passed through silica gel to protect downstream components from condensate. The oxygen content of the chimney gas is measured with an electrochemical cell. The sample flow is then returned to the wood-burning appliance chimney above the point where the sample was withdrawn. Room temperature and chimney gas temperature are measured with Type K thermocouples. The chimney gas temperature is measured within the chimney at the same location as the sample is withdrawn.

The data logging system is a key component of the AWES. The data logging system records date, time, oxygen content, room temperature, and chimney gas temperature at regular intervals. The oxygen content of the chimney gas, along with the mass of wood burned, allows for the calculation of total chimney gas flow during sampling which is needed for the subsequent calculation of emission rates and emission factors. The record of chimney gas temperatures allows for the total time of appliance operation over the course of the sampling duration to be determined. In addition to data recording, the system is programmed to control the sampling frequency, sampling duration, and sampling period. For this study, the AWES was programmed to sample for 2 minutes every 15 minutes for 1 week. The system is further programmed to turn on the sampling pump during the programmed 2-minute sampling time only if the wood stove is in operation (as determined by the chimney temperature), in order to avoid collection of sample material when the appliance is not in operation. A threshold chimney temperature of 100° F (38° C) was used as an indicator of wood stove operation.

Results and Discussion

The primary objective of the study was to select phase 2 stoves that were installed in homes prior to the fall of 1992 in order to assess the level of long-term degradation and potential increase in PM and POM air emissions of older phase 2 certified stoves under actual in-home usage. Wood stoves in homes in both Portland and Klamath Falls, Oregon, were selected for this study. The average heating degree day (HDD) value for Portland is 4109 and the average HDD for Klamath Falls is 6600. Stoves in the two climatologically dissimilar cities were selected to produce results more widely applicable to wood-stove usage in the nation as a whole than if homes in a single city were selected. In addition, nine phase 2 stoves installed in homes in Klamath Falls were previously studied during the 1989-1990 and 1991-1992 heating seasons. Therefore, a secondary objective of the study was to utilize as many of these homes as possible in the current study to help document phase 2 stove degradation and commensurate emission increase.

Sixteen homes were targeted for study during the 1998-1999 heating season. Two of the study group were homes in Klamath Falls that had phase 2 wood stoves that were part of the earlier studies. Emission samples were collected for three 1-week periods from wood stoves in each home using the AWES. The AWES was developed specifically for the in-home collection of air emission samples from residential wood burning appliances, and data developed from its use have previously been used to calculate particulate emission factors published in AP-42. Samples collected with the AWES were analyzed for particulate matter and organic compounds. The specific organic compounds analyzed included the seven and sixteen POM compounds needed to calculate the 7-Polycyclic Aromatic Hydrocarbon (PAH) and 16-PAH values, respectively, which are used as surrogate indicators for POM. The PM and POM surrogate emission factors (mass of pollutant emissions per unit mass of fuel) were compared against the emission factors tabulated in AP-42 for wood stoves. The PM emission rates (mass of pollutant emissions per time of stove operation) measured under actual in-home use for each wood-stove model were compared against their certified emission values listed by EPA.

The PM emissions from this study and from the previous studies were compared for the stoves in the Klamath Falls homes that were part of earlier studies. Cordwood tree species, cordwood moisture, the amount of cordwood burned, burn rates, ambient temperature during testing, a description of wood stove use in each home, chimney characteristics, and the condition of the stoves were also documented as part of the study.

Conclusions

Of the 16 stoves inspected, all showed the effects of use. However, only six stoves were degraded to the point that it was speculated that their condition would significantly affect air emissions. Routine maintenance or minor repairs could

have kept all units in good operating condition if the maintenance or repairs had been done.

An extensive data base was developed from the 43 week-long test runs on 16 homes in Klamath Falls and Portland. No direct statistical correlation between emissions and wood moisture, burn rate, or stove condition could be made due to the number of variables associated with real-world in-home use of wood stoves.

The particulate emissions for stoves in Portland homes were, on average, higher than for stoves in Klamath Falls homes. This result is consistent with the average higher fuel moisture content and burn rate characteristics of the Portland portion of the study as compared with the Klamath Falls portion of the study.

The particulate emission factors for the certified phase 2 stoves evaluated in this study appear to have become higher with use, but after about 7 years, on average, the certified phase 2 stoves still have lower emissions than uncertified conventional stoves (Table 1).

The emission rates for phase 2 stove models reported as part of the NSPS certification process do not represent emission levels of the same stove models in homes after extended use.

Particulate emissions cannot be used as a surrogate measure of POM emissions for wood stoves. POM emission factors, as based on the 7-PAH and 16-PAH surrogates, determined from the in-home use of wood stoves in this study, were lower than the POM emission factors tabulated in AP-42. This observation is significant because the AP-42 emission factors are the basis for the national emission inventory of POM for which residential wood combustion was identified as the single largest source.

Table 1. Comparison of average particulate emission factors (5H adjusted) to AP-42 values.

Stove Group	Method 5H Equivalent Emission Factor g/kg (Dry)
Catalytic Stoves (5 Stoves, 13 Runs)	10.8
Noncatalytic Stoves (11 Stoves, 30 Runs)	9.23
Catalytic	8.1
Noncatalytic	7.3
Conventional	15.3

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The complete report, entitled "Long-Term Performance of EPA-Certified Phase 2 Woodstoves, Klamath Falls and Portland, Oregon: 1998/1999," (Order No. PB2001-101921; Cost: $54.00, subject to change) will be available only from:

National Technical Information Service
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