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Comparative Study of Emission Factors and Mutagenicity of Biomass Smoke from Smoldering and Flaming Combustion

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Abstract

Wildfire events produce massive amounts of smoke and thus play an important role in local and regional air quality as well as public health. It is not well understood however if the impacts of wildfire smoke are influenced by fuel types or combustion conditions. Here we developed a novel combustion and sample-collection system that features an automated tube furnace to control combustion conditions, and a multi-stage cryo-trap system to efficiently collection particulate and semi-volatile phases of smoke emissions. Five different types of biomass fuels (red oak, peat, pine needles, pine, and eucalyptus) were tested at two different combustion conditions (flaming and smoldering) to represent western and eastern wildland fires in the United States. The furnace sustained stable flaming and smoldering biomass burning conditions consistently for ~60 min. The multi-stage cryo-trap system (-10°C followed by -47°C, and ending in -70°C sequential impingers) collected up to 90% (by mass) of the smoke. Condensates were extracted and assessed for mutagenicity (polycyclic aromatic hydrocarbons (PAHs)- and nitroarene-type activity) in Salmonella strains TA100 and TA98+/-S9. Carbon dioxide, carbon monoxide (CO), and particulate matter (PM) concentrations monitored continuously during the combustion process were used to calculate modified combustion efficiency (MCE) and emission factors (EFs). We found that the MCE of all the biomass fuels during smoldering conditions was in a range from 63% to 83%, and during flaming conditions, was in a range from 97% to 99%. In addition, all the biomass fuel smoldering EF for CO ranged from 158 g/kg to 299 g/kg, whereas flaming EF ranged from 16 g/kg to 29 g/kg. Smoldering EF for PM ranged from 55 g/kg to 174 g/kg, whereas flaming EF ranged from 0.6 g/kg to 1.6 g/kg. A preliminary assessment of the mutagenic potential of the biomass smoke showed that flaming emissions (e.g., eucalyptus flaming emission) were more mutagenic (up to ~6 times and ~19 times in TA100 and

TA98+S9, respectively) than smoldering emissions on an equal-mass smoke exposure basis. However, on an equal-mass fuel consumption basis, smoldering emissions (e.g., red oak smoldering emission) were more mutagenic (up to ~107 times and ~90 times in TA100 and TA98+S9, respectively) than flaming emissions. Most mutagenicity emission factors in strain TA100+S9 were greater than those in strain TA98+S9, indicating that the mutagenicity was associated with PAHs. The results demonstrate that 1) type of fuel and combustion conditions have dramatic differences in emission characteristics and mutagenicity; 2) the presented system can be useful for the health risk assessment from inhalation exposure to wildfire smoke; and 3) health impacts of wildfire smoke can be assessed on an equal-mass PM exposure basis or an equal-mass fuel consumption basis. [This study was funded through the Joint Fire Science Program (JFSP) project # 14-1-04-16. This abstract does not represent official USEPA policy.]