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Emissions from prescribed burning of timber slash piles in Oregon

Johanna Aurell [a], Brian K. Gullett [b,*], Dennis Tabor [b], Nick Yonker [c]

[a] University of Dayton Research Institute, 300 College Park, Dayton, OH, 45469, USA
[b] U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Research Triangle Park, NC, 27711, USA
[c] Oregon Department of Forestry Fire Protection, 2600 State St., Salem, OR, 97310, USA

HIGHLIGHTS

- Dry biomass piles burned with higher combustion efficiency than wet piles.
- Piles that had been covered with polyethylene had lower emissions than wet piles.
- Burning the polyethylene cover on the pile had no distinctive effect on emissions.

GRAPHICAL ABSTRACT

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ABSTRACT

Emissions from burning piles of post-harvest timber slash (Douglas-fir) in Grande Ronde, Oregon were sampled using an instrument platform lofted into the plume using a tether-controlled aerostat or balloon. Emissions of carbon monoxide, carbon dioxide, methane, particulate matter ($PM_{2.5}$), black carbon, ultraviolet absorbing PM, elemental/organic carbon, filter-based metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzodioxins/dibenzofurans (PCDD/PCDF), and volatile organic compounds (VOCs) were sampled to determine emission factors, the amount of pollutant formed per amount of biomass burned. The effect on emissions from covering the piles with polyethylene (PE) sheets to prevent fuel wetting versus uncovered piles was also determined. Results showed that the uncovered ("wet") piles burned with lower combustion efficiency and higher emission factors for VOCs, $PM_{2.5}$, PCDD/PCDF, and PAHs. Removal of the PE prior to ignition, variation of PE size, and changing PE thickness resulted in no statistical distinction between emissions. Results suggest that dry piles, whether covered with PE or not, exhibited statistically significant lower emissions than wet piles due to better combustion efficiency.

1. Introduction

To reduce wildfire risk and to improve timber forest productivity and health, woody biomass fuels from selective thinning and timber harvests are mechanically treated and piled for burning (Cross et al., 2013; Trofymow et al., 2014). This practice is becoming more prevalent, particularly in the Pacific Northwest, as prescribed fire complexity and risk associated with elevated fuel levels

* Corresponding author.
E-mail addresses: aurell.johanna@epa.gov (J. Aurell), gullett.brian@epa.gov (B.K. Gullett), tabor.dennis@epa.gov (D. Tabor), Nick.J.Yonker@oregon.gov (N. Yonker).

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(proximity to the wildland/urban interface, smoke effects on air quality and respiratory health) limit the use of broadcast prescribed burning (Wright et al., 2010). Pile burning mitigates concerns about fire safety and air quality as it allows managers to burn under optimal weather conditions and with reduced staffing levels (Wright et al., 2010). Biomass pile burns are often the most economical way to dispose or utilize the biomass due to collection, transportation, and end-product processing costs (Springsteen et al., 2011). Depending on the season and rainfall history, burn piles can smolder for days after they are lit resulting in significant quantities of air pollution (Springsteen et al., 2011). To promote pile combustion, the biomass is preferably dry, resulting in faster, hotter, and more efficient burns, presumably with less pollutants. Common practice involves covering these large piles with polyethylene (PE) film until burn conditions are optimal to prevent moisture saturation during the rainy season. This has raised some questions about emissions from the burning plastic film. The Oregon Department of Forestry (ODF) has used small amounts of PE film sheeting (9.3 m^2) per pile through administrative rulemaking (OAR 629-048-0210) (Oregon Department of Forestry (2014)). Often this is not enough to keep piles dry for efficient consumption after significant rainfall. Because of this limitation, ODF is seeking data to determine whether or not larger and thicker coverings of PE have deleterious effects on burn emissions.

Only a few studies (Hardy, 1996) have investigated pile burn emissions in the field and often the number of pollutants characterized was limited (Hardy, 1996; Ward et al., 1989). Laboratory burns of *pinus ponderosa* slash (twigs, needles, and small branches) by Yokelson et al. (1996) characterized emissions from burn piles (1 m × 2 m) using FTIR analysis. Their work determined emission factors for smoldering/flaming phase as partitioned by modified combustion efficiency. Other work (Hosseini et al., 2014) examined emissions from 2 kg mixtures of manzanita wood (*Arctostaphylos* sp.) with 0, 5, and 50 g of shredded low density PE but found no statistical effect of increase PE content on over 190 compounds.

To complement the laboratory scale work previously done on assessing potential contribution of PE to biomass emissions, this work aimed to characterize and compare emissions from burning woody biomass piles, including dried PE-covered piles and wetted piles, in a large-scale field application.

2. Methods

2.1. Biomass piles

Tests were conducted during mid-October in western Oregon, on a timber-harvested Douglas fir (Pseudotsuga menziesii) stand (45° 0′ 44.14″ N, −123° 41′ 6.49″ W) located about 8 km southwest of Grand Ronde, Oregon and 30 km east of the Pacific coast. The site was at 880 m elevation on a ridge top with an about 10 m change in elevation in the test area. After timber harvesting, the piled material was primarily small branches and limbs of size less than 20 cm in diameter.

Biomass piles approximately 2.5 m high and 5 m in diameter and spaced at least 15 m apart were constructed by the landowner (Fig. 1). Three pile types were tested nominally: Dry, Wet, and Dry Polyethylene (PE) covered. Polyethylene sheeting covered eight of the piles throughout the summer to comprise the Dry and PE-covered test piles for the October tests. The PE was removed from four piles prior to testing and were designated Dry piles. The remaining four covered piles were left with the PE in place and were designated Dry PE piles. PE-covered piles had two film thicknesses, 0.10 mm (4 mil) and 0.15 mm (6 mil), and two area sizes, 3.0 m by 3.0 m (10 ft by 10 ft), and 6.1 m by 6.1 m (20 ft by 20 ft) (Table 1). The remaining four piles were uncovered throughout the summer and designated as Wet piles. Air emissions were only collected from three of these Wet piles, the fourth pile was used to check plume height for best collection efficiency prior to emission sampling.

Fig. 1. Typical burn pile, uncovered.

Table 1
Test order and type.

Test day	Test order, Type, PE size[a] (if applicable)
Day 1	Burn 1: WET 01
	Burn 2: DRY, PE 6.1 × 6.1 m, 0.15 mm
Day 2	Burn 3: WET 02
	Burn 4: DRY, uncovered
	Burn 5: DRY, PE 3 × 3 m, 0.15 mm
Day 3	Burn 6: WET 03
	Burn 7: DRY, uncovered
	Burn 8: DRY, PE 3 × 3 m, 0.10 mm
	Burn 9: DRY, uncovered
Day 4	Burn 10: DRY, PE 6.1 × 6.1 m, 0.15 mm
	Burn 11: DRY, PE 3 × 3 m, 0.15 mm
	Ambient background

[a] PE = Polyethylene, area in m x m, thickness in mm.

Terrain constraints to pile access, a desire to prevent the emissions from upwind smoldering fires from impinging on new burn piles, and effects of week-long meteorological conditions prohibited true random pile testing. The resultant "ordered" testing affects randomness and may have introduced bias into the measurements as a result of dynamic meteorological variables (conditions present at the end of the testing may be different than those at the beginning) confounding the comparisons. Four days of sampling were conducted in later October. Meteorological data for these dates are reported in Supporting Information (SI). The order and notation for the tests are presented in Table 1.

2.2. Sampling method

Fires were initiated by drip torch immediately after which emissions were sampled using an aerostat-lofted sampler system (Fig. 2) detailed more fully elsewhere (Aurell and Gullett, 2013; Aurell et al., 2011). Briefly, the system consists of a 5 m diameter, helium-filled aerostat, connected with two tethers to all-terrain vehicle (ATV)-mounted winches, upon which is mounted a sampler/sensor system termed the "Flyer". The Flyer was