DIOXIN EMISSIONS FROM FOREST FIRES

Schaum. JL

U.S. Environmental protection Agency, Office of Research and Development, National Center for Environmental Assessment. 1200 Pennsylvania Ave. Washington, DC 20460

Introduction

Several lines of evidence indicate that forest fires release dioxins to the environment. Sediment core studies have shown that dioxins were found at measurable levels prior to the industrial revolution [1,2]. The most likely source for these residues is natural fires. Gullet et al. [3,4] used chamber tests to show that more dioxins are emitted than contained in the biomass being burned. Finally, multiple chamber studies and one large field study have now measured dioxins in forest fire emissions. Therefore, it is reasonably well established that dioxin are both formed and released from forest fires. However, it is still controversial whether these emissions are sufficiently well understood to make reliable emission estimates for use in national inventories. In 2006, EPA concluded that the data were insufficient for this purpose[5]. Several new studies have now been published that were not available for consideration in the 2006 document. Combining the old and new studies creates a relatively large data base on emission factors. Six chamber studies have been conducted with a variety of wood types and a cumulative *n* of 46 (Table 1). Additionally, one large field study was conducted in Australia involving various types of forests with an *n* of 18. This paper proposes a way to use this expanded dataset to derive an emission factor and make national emission estimates.

Approach

The chamber studies have shown a wide range of results (means across tests vary from 0.37 to 25 ng TEQ/kg) suggesting that emissions are highly variable across fuel types and fire conditions. The Australian field measurements suggest emission factors near the low end of the chamber results. Meyer et al. [6] believe that the chamber tests have overestimated dioxin emissions due to longer residence time in the formation temperatures than occurs in the field. They also support their belief that forest fires have low dioxin emissions on the basis of ambient air monitoring in southern Victoria during the large forest fires in northeast Victoria in January 2003. The monitor showed clear impacts of the plume during the fire based on sharp increases in particulate and potassium salts (a biomass combustion tracer) but no increases in dioxins.

Using the available data to develop a forest fire emission factor for the U.S. involved considering how representative the test data are of the types of wood and fires that occur in North America:

- Wood types - Over 20 different types of forests exist in the U.S. with a variety of wood types, biomass density, moisture content, height, etc. The chamber tests did not represent all wood types found in North America but did include some common types such as pine and oak. All of the field tests were conducted in Australia; some included pines, but others were primarily eucalyptus and jarrah trees, which are uncommon in the U.S.
- Fire types - A number of different types of fires can occur such as ground fires, which burn the humus layer of the forest floor but do not burn appreciably above the surface; surface fires, which burn forest undergrowth and surface litter; and crown fires, which advance through the tops of trees or shrubs. It is not uncommon for two or three of the types to occur simultaneously. The ground level monitors cannot directly sample the high smoke plume generated near the tops of trees during a crown fire. Some of the smoke generated during a crown fire is present at ground level, but it is uncertain how representative this smoke is of the main plume. Ground/surface fires create a smoke plume, which starts near ground level, and the monitors are much more likely to collect samples, which are representative of these emissions. Similarly, the chamber tests cannot mimic the intensity and scale of crown fires but may be representative of the conditions associated with the smaller ground/surface fires.

In summary, the forest fire data appear to represent some but not all of the wood types and fire types that occur in North America. The large database of emission tests suggest a wide range of emission factors, but this is reasonable considering that they cover a wide variety of wood types, fire types and burn conditions. The size of the database

and wide range of results increases the confidence that the full range of emission factors have been characterized and that the midpoint of the range provides a reasonable central point estimate. The *n*-weighted average for the field tests is 0.8 ng TEQ/kg and for the chamber tests is 5.9 ng TEQ/kg. The midpoint of this range (3 ng TEQ/kg) was selected as a reasonable assumption for a central value emission factor. This value is lower than the UNEP[7] recommended emission factor of 5 ng TEQ/kg of biomass burned for forest fires. UNEP based their recommendation primarily on the chamber study by Ikeguchi and Tanaka[8].

Results

Forest fires in the U.S. consumed 243.8 million MT of biomass in 2000[9] . Multiplying this biomass burned by the emission factor of 3 ng TEQ/kg, the dioxin emissions from forest fires can be estimated as 730 g TEQ. The uncertainty in this estimate can be evaluated by considering the range of possible results. The field data suggest an emission factor of 0.95 ng TEQ/kg, and the chamber data suggest an emission factor of 7.5 ng TEQ/kg. If the lower emission factor is used, the forest fires would have a release of 230 g TEQ (70% less than the central estimate), and if the higher emission factor is used, the forest fires would have a release of 1,800 TEQ (150% higher than the central estimate). By comparison, the largest single source of dioxin emissions to the atmosphere reported in the USEPA's national inventory for the year 2000 was backyard burning, and was estimated to be 500 g TEQ[5].

References

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Table 1. CDD/CDF Emission factors for forest fires

Biomass Description and Location	Wood Type	Test Device	*n*	ng TEQ_{DF}/kg of biomass Mean (Range)*	Reference
Tree from Central North Carolina	Loblolly pine	Chamber	7	0.86	Gullet et al. [4]
Pile – Central North Carolina	Loblolly pine	Chamber	10	0.615	Gullet et al. [4]
Supplement – Central North Carolina	Loblolly pine	Chamber	2	0.93	Gullet et al. [4]
Supplement – Western North Carolina	White pine	Chamber	2	1.225	Gullet et al. [4]
Supplement – Oregon	Hemlock/Pine	Chamber	2	1.64	Gullet et al. [4]
Shrub – California	Titi, pine straw, gallberry	Chamber	2	8.36	Gullet et al. [4]
Shrub – Florida	Maritime chaparral	Chamber	2	2.62	Gullet et al. [4]
Central North Carolina	White pine	Chamber	4	25 (14-47)	Gullet and Touati [3]
Oregon	Hemlock/Pine	Chamber	3	15 (1-56)	Gullet and Touati[3]
Tree and leaves from Japan	Unspecified	Chamber	1	4.7	Ikeguchi and Tanaka[8]
Wood, leaves, and grass from Sweden	Unspecified	Hood over fire on plate	1	27	Gonczi et al.[10]
Litters, mosses, heathers, brackens, conifer needles, pine cones, shrubs, barks, and branches from France	Pine and oak	Chamber	5	10 (1-26)	Collet and Fiani [11]
Forest leaf litter from three locations in Australia	Eucalyptus, box, ironback	Chamber	5	0.37 (0.09-0.79)	Meyer et al. [6]
Prescribed forest fires in Queensland, Victoria, and Western Australia	Eucalyptus	Field	10	0.5 (0.07-1.4)	Meyer et al. [6,12]
Tropical savanna - Australia	Unspecified	Field	3	1.1 (0.2-2.8)	Meyer et al. [6,12]
Wildfires in Victoria	Eucalyptus	Field	2	0.7 (0.6-0.8)	Meyer et al. [6,12]
Woodlands in Australia	Unspecified	Field	3	1.5 (0.9-2.5)	Meyer et al. [6,12]

* All TEQs based on WHO-98.