FIRE AND PESTICIDES: AIR QUALITY CONSIDERATIONS.

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ABSTRACT

The classes of primary chemical products naturally produced by the combustion of forest fuels include: carbon dioxide, water, carbon monoxide, particulate matter, methane and non-methane hydrocarbons, polynuclear aromatic hyrocarbons, nitrogen and sulfur oxides, aldehydes, free radicals, and inorganic elements. Pesticides are a class of secondary chemical by-products of fires that have been of some public concern with the extensive use of herbicides for site preparation and release in some forest ecosystems and insecticides for insect control in others. Studies conducted on herbicides and insecticides indicate that hot fires (>500˚C) thermally degrade most pesticides. Smoldering fires (<500˚C) have the potential to volatilize significant amounts of some pesticides. Exposure analyses indicate that, even under conditions of smoldering fires, no significant human health risks occur from pesticides incorporated into or on forest fuels. Naturally occurring chemical by-products of combustion are a far greater risk to human health.

keywords: air quality, herbicides, insecticides, pesticides, prescribed burn

INTRODUCTION

Fire has continued to be a management tool used by public and private land managers in the southeastern United States to sustain production of natural resources, preserve and maintain wildlife habitat, and improve grazing conditions. The use of fire in timber management has raised concerns such as:

1. particulate matter emissions or inorganic and organic gaseous emissions presenting a threat to public health, along with nuisance concerns,
2. visibility impairment in areas of high humidity, and
3. decrease in recreational aesthetic appeal.

Based on recent health studies, the Environmental Protection Agency (EPA) proposed air quality standards of particulate matter and ground-level ozone in July 1997. Consequently, land managers must minimize prescribed fire emissions and the adverse impact of smoke on public health and the environment. In addition, land managers have to re-evaluate alternatives such as mechanical site preparation, whole tree harvesting, and yarding of unmerchantable material. Mechanical site preparation in the Piedmont region, however, often leads to accentuated erosion and soil

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compaction. Use of herbicides in combination with other site preparation techniques minimizes soil disturbance. In the absence of fire, however, herbicides may result in accumulation of dead vegetation, as well as insect and disease vectors. A movement away from burning as part of site preparation has the additional disadvantage of on-site slash/fuel buildup and increased potential for intense wildfire.

Pesticide use patterns in forest management are governed by a number of factors such as economics, sensitivity of the ecosystem, potential liability for off-site impacts, etc. Insecticides and fungicides are extensively used in seed orchards and nurseries, where small acreages are treated to protect highly valued seed sources and seedlings for out-planting. The use of insecticides over extensive forested areas, however, is generally restricted to cases where trees with high commercial or aesthetic value are threatened or where epidemic pest outbreaks occur (e.g. gypsy moth, tussock moth, spruce budworm, and pine bark beetle). In such cases, entire watersheds may be treated. In young pine stands, herbicides are used extensively to assist in site preparation, while insecticides may be applied for insect control. Thus the incidents when timber stands treated with pesticides might be subject to a fire are limited to times of site regeneration and cleanup of epidemic pest outbreaks.

Prescribed burns routinely used in forest management include: 1) slash burns in harvested stands, 2) “brown and burn” for site preparation, 3) under-story burns for wildlife habitat improvement and weed/brush control, and 4) grassland burns. Site preparation slash burns and “brown and burn” burns are used once in a regeneration cycle (20-80 years) to facilitate planting and early regeneration management practices. The “brown and burn” site preparation removes unwanted competing vegetation by burning 30-180 days following herbicide application. The browning of hardwood foliage and herbaceous plants increases the fuel source, making late summer burns effective for further reduction of smaller residual hardwoods that may have been missed by application or were resistant to the herbicide. Also, burning the area greatly facilitates planting operations by removing logging debris. Under-story burns and grassland burns can be used every 1-7 years to control weed competition and improve wildlife habitat, but usually do not consume fuels treated with pesticides and/or herbicides.

The “brown and burn treatment” management practice has raised forest worker and public concern about possible exposure to herbicide residues in smoke from the fire or from burning herbicide-treated hardwoods in fireplaces or stoves. The roots of this concern can be traced back to the warning statement found on herbicide labels, as well as material data safety sheets. These statements referring to fire hazards and toxic decomposition products urge the user to “wear a mask” or, “if burned, stay out of the smoke.” While these cautions are appropriate in connection with fires near herbicide concentrates and containers found at mixing and storage sites, they were not intended to apply to the diluted forms following an application to forested sites. In these cases, on a given acre, only a few ounces or pounds of herbicide are spread over many thousand pounds of ground litter and vegetation. The latter material constitutes the predominant fuel in the prescribed fire and the principal smoke risk factor to the worker or the public.

FIELD STUDIES

In a forest fuel combustion study (McMahon et al. 1985), wood treated with five herbicides and two common insecticides was burned under controlled combustion conditions (Table 1). Over 95% pesticide decomposition occurred when wood was burned under conditions of rapid (flaming) combustion, while variable amounts of pesticide residues were recovered from the smoke stream in the case of smoldering combustion. Relatively stable compounds such as lindane (insecticide) and dicamba (herbicide), as well as compounds with significant vapor pressures, can be expected to be released under smoldering or slow heating conditions. For example, the insecticides lindane and dicamba and the herbicide 2,4-D were extensively recovered intact in the smoke stream (43, 92, and 92%, respectively), while the insecticide chlorpyrifos and the herbicides hexazinone and picloram were extensively decomposed (>75% decomposition).

In a second study (McMahon and Bush 1992), 14 prescribed burning operations ("brown and burn") were monitored to determine possible worker exposure. Field worker breathing zone concentrations of smoke suspended particulate matter (SPM), herbicide residues, and carbon monoxide (CO) were monitored on sites treated with labeled rates of forestry herbicides containing the active ingredients imazapyr, triclopyr, hexazinone, and picloram. The sites were burned 30-169 days after herbicide application. No herbicide residues (sensitivity 0.1-4 ugm/m^3) were detected in 140 smoke samples from the 14 fires. These detection levels are several hundred to several thousand times less than any occupational exposure limit for these herbicides.

The SPM and CO levels monitored on these fires were highly variable, depending on fire conditions, size of tract, and worker assignment. The toxicology of combustion products (polynuclear aromatic hydrocarbons, SPM, CO, etc.) and the larger issue of the EPA Air Quality Standards proposed in 1997 are beyond the intended scope of this presentation.

In follow-up laboratory studies (McMahon and Bush 1986), herbicide recoveries in the smoke stream were compared. As expected, the upslope fires where herbicide distillation is likely resulted in low combustion efficiency (high smoke production) and recovery of 2,4-D and picloram (5% and 0.04%, respectively). Herbicide recoveries from downslope fires were <0.02% and 0.08% for picloram and 2,4-D, respectively. Thus, fire intensity directly impacts the extent of herbicide combustion and volatilization.

Bark beetles, especially the southern pine beetle *(Dendroctonus frontalis)*, are a serious threat to forest stands and individual high value trees throughout the South. Insecticidal control of bark beetle infestations is effective but disposal of insecticide-treated trees could present a problem. In a fourth study (Bush et al. 1987b), wood samples collected 4 month post-treatment for pine bark beetle control were found to contain lindane and chlorpyrifos residues ranging from 0.32 to 35.8 mg/kg for lindane and <0.1 to 76.1 mg/kg for chlorpyrifos. Combustion of these samples under smoldering fire conditions resulted in 43% and 28% recovery of lindane and chlorpyrifos, respectively, in the smoke stream. With rapid combustion in a well developed fire, all lindane and chlorpyrifos residues were thermally degraded.

WORKER AND PUBLIC EXPOSURE ASSESSMENT

Worker exposure to herbicide residues released from burning treated vegetation was estimated in the U.S. Department of Agriculture Forest Service Southern Region Environmental Impact Statement (Weeks et al. 1988). This analysis assumed that: 1) $3.0x10^7 m^3$/ha smoke is produced, 2) herbicides are applied at maximum labeled application rates, 3) herbicides degrade with time at published dissipation rates, and 4) no thermal decomposition of the parent compound occurs in the burning process. Margins of safety (MOS's) were estimated for all registered herbicides, comparing predicted smoke residue levels to threshold limit values. All MOS's were found to be >150 except for triclopyr ester, which had a MOS of 84. For the scenario where wildfire occurs on the day of application, the MOS's were all >50 except for imazapyr applied by the aerial foliar method, which was 46. The estimated MOS's were undoubtedly higher than those likely to occur in an actual fire, where a large fraction of the herbicide residues would be destroyed during combustion (McMahon et al. 1985, Bush et al. 1987a). Herbicide concentrations in the air dissipate with distance from the burn site; thus the public would be expected to have lower exposures than on-site workers.

Forestry-use herbicides have been detected in the air at short ranges (<1 km) after aerial applications (spray drift) but generally not after prescribed fires in herbicide-treated stands. Forestry herbicides also have not been detected in regional air mass samples or rainfall during nationwide air quality studies (Majewski and Cadel 1995). However, agricultural herbicides have been detected in these studies.

Risk analysis concerning the use of herbicide-treated wood in home fireplaces conducted in the Southern United States (Bush et al. 1987a) clearly demonstrated that under assumptions that unrealistically produced complete volatilization of pesticide residues, exposures resulting from burning herbicide-treated wood in a fireplace resulted in household air concentrations >100 times lower than the acceptable daily intake. Thus, the safety factor is high and the exposure risk from burning herbicide-treated wood in fireplaces is very low.

MANAGEMENT IMPLICATIONS

Worker exposure assessments and field studies have shown that risk from herbicide exposure to forest workers under "brown and burn" conditions is small (MOS >50), even if the fire occurs immediately after herbicide application, as might occur in a wildfire. Thus, use of herbicides in combination with fire in site preparation, under-story vegetation management, or creating wildlife habitat/openings does not increase human exposure over risks associated with fire alone. Likewise, human exposure to insecticides from wildfires in recently-treated stands is not likely due to the rapid, flaming combustion associated with these fires.

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Table I. Parent pesticide (%) and particulate emissions (%) recovered from burning herbicide-treated (Study 1) and insecticide-treated (Study 3) wood under slow and rapid burning conditions (adapted from McMahon et al. 1985)

	Pesticide	**Slow burn**		**Rapid burn**	
		Pesticide recovered %	**Particulate emissions[a]**	**Pesticide recovered %**	**Particulate emissions[a]**
Study 1	2,4-D	92	11.2	1.6	1.3
	picloram	0[b]	11.2	0[b]	1.3
	hexazinone	11	9.2	0	<1.0
	dicamba	92	10.8	32	3.4
	dichloroprop	>100[c]	10.8	6.5	3.4
Study 3	lindane	43	10.8	0	<1.0
	chlorpyrifos	28	10.8	0	<1.0

[a] % of dry fuel
[b] 98 and 64%, respectively, was recovered as picloram decomposition product 2, 3, 5 trichloro-4-amino-pyridine.
[c] High recovery reflects an enhanced instrument response in the presence of smoke condensate.