Reduction of Surface Distributed Composition-B Particles by Prescribed Burns

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Abstract: Low-order detonations and blow-in-place procedures of surface unexploded ordnances (UXO) can leave explosive residue on the soil surface of military training ranges. These residues are deposited during live-fire training, generally as particles, fibers, and slivers. Composition-B (Comp-B) is a high explosive used in hand grenades and artillery and mortar warheads. Comp-B is a source for TNT, RDX, HMX, and their degradation products in various migration pathways such as leaching, surface runoff, and biological exposure. Many of these training ranges have prescribed burn management plans to improve military training, reduce fuel load, and maintain fire-dependant plant communities that serve as crucial habitats. However, minimum research has been conducted to measure the effects these prescribed burns have on the persistence of these materials used in training activities. This study was conducted to determine if the occurrence of incidental and prescribed burning of training land vegetation would provide a remedial effect on the fate of residual Comp-B particles on the soil surface. Demonstration plots were set up at a local field site to mimic these prescribed burns using two different fuel types, *Paspalum notatum (*bahiagrass) and pine straw. Temperature probes and Comp-B were placed on the soil surface throughout the plots, and the vegetation was then burned under various but ideal weather and moisture conditions. Comp-B reduction was determined by particle recovery and chemical analysis of the surface soil. The bahiagrass burn resulted in an average 62% particle reduction, whereas the pine straw burned under more favorable conditions and resulted in an average 92% particle reduction. Chemical analysis confirmed residual Comp-B compounds were less than 3% of original mass. Field evaluations at four different U. S. Army installations later verified the initial data from the demonstration plots, with an overall average of 94% Comp-B reduction. These results conclude that with optimum biomass, weather conditions, and direct flame exposure, Comp-B particles combust during prescribed and incidental burns.

Keywords: Composition-B, explosives, prescribed burn, RDX, TNT

Introduction: Though training ranges are imperative to the readiness of our Armed Forces, there are high concerns of environmental effects training activities present. The United States has an estimated 50 million acres of military training ranges that are contaminated with energetic residues (Armstrong, 1999a, b). Military high explosives containing energetic compounds such as 2,4,6-trinitrotoluene (TNT), 1,3,5-hexahydro-1,3,5-trinitrotriazine (RDX), and 1,3,5,7-tetrahydro-1,3,5,7-tetranitrotetrazocine (HMX) are scattered onto the soil surface as particles, fibers, and slivers during live-fire training (Jenkins, 2006). High explosive particles found on the soil surface at an artillery range from a single shot can weigh from 1.0 g to 50 g (Jenkins, 2006). Low-order detonations and blow-in-place procedures of unexploded ordnances (UXO) are considered to be a primary source of the chunks and soil-sized particles of Composition-B (Comp-B) found on the soil surface (Jenkins, 2006, and Dontsova, 2006).

Comp-B has been a primary explosive frequently used post-World War II (Clausen, 2004) in M67 and C-13 fragmentation grenades and a variety of artillery and mortar warheads (Jenkins, 2006), which consists of 60% military grade RDX (composed of 90% RDX and 10% HMX), 39% military grade TNT, and 1% wax or plasticizer. In addition to property damage and physical injury by detonation, these components can have detrimental health effects. Humans can be exposed to these components by drinking water, breathing air, and contacting contaminated soil (Lynch, 2002). Liver and blood damage, anorexia, anemia, and systemic poisoning affecting bone marrow and the liver are a few of the known health effects associated with Comp-B exposure (Atsdr, 1996; Lynch, 2002). In addition, TNT and RDX are considered possible human carcinogens (Atsdr, 1996; Lynch, 2002).

A variety of Comp-B remedial studies have been conducted to find a solution for military training ranges; however, there has been minimal research done measuring the effects that burns, prescribed or incidental, have on the persistence of these particles. Prescribed burns are common land management practices executed by many military installations to not only enhance troop training, but to promote sustainability of ecosystems as well. Routine burning controls undergrowth of forest stands, and therefore, improves timber management and access for military training. Burning also reduces the fuel load that could possibly contribute to incidental burns, or wildfires, caused during training activities, and they also help maintain habitats for threatened and endangered species (Garten, 2006).

Thermal treatment of Comp-B particles was initially studied in a field series of wind tunnel experiments. These tests were conducted with various controlled wind speeds and fuel loads on different soil types. Though elevated temperatures of 320-330 °F result in combustion of Comp-B, these temperatures were often not reached at the soil surface in the wind tunnel; therefore, direct flame exposure from burning vegetation was necessary for combustion of Comp-B particles. Chemical analysis revealed TNT, RDX, and HMX were present in the soil where Comp-B particles were exposed to heat only and slightly melted. Soil samples where Comp-B combusted 100%, TNT, RDX, HMX, and degradation products were present during analysis. The total net loss of solid Comp-B was 72% with simulated wildfire burning in the wind tunnel. Wind speed, fuel moisture, and density of vegetation affected the burn patterns. It was then recognized that these variables alone may not be used dependably for effective field application criteria (Price, 2011).

The purpose of this study was to determine if the occurrence of prescribed or incidental burning of training ranges would provide a remedial effect on the fate of residual Comp-B particles located on the soil surface with optimum biomass and weather conditions. A series of individual burns was conducted in the field with demonstration plots simulating two fuel types commonly burned at U. S. Army installations under varying weather conditions. After the demonstration study was deemed a successful remediation technique, this technique was applied at four U.S. Army installations with various geographical locations, weather conditions, fuel types, and fuel loads.

Materials and Methods

Demonstration Plots

Plot setup. In a field of bahiagrass (*Paspalum notatum)* vegetation, three 40-foot by 40-foot plots were measured out and flagged at our offsite field testing location. To represent dormant vegetation, a sufficient dose of Roundup was applied to the grass of each plot and was allowed to rest for two weeks before burning. Three additional plots were prepared as previously mentioned. In addition, bales of pine straw were purchased from a local garden center and applied to each plot. Prior to application of pine straw, biomass data were collected and calculated from five different mature pine stands in the DeSoto National Forest of Mississippi and were used to determine that 265 kg/m^2 of fuel per plot would be an efficient replicate. The plots were left to settle and weather for approximately two months before burning.

Equipment setup. The Omega Data Logging System (OMP-MODL) was placed on the windward side approximately three feet outside of the plot to be burned. Eight Omega thermocouple wires (XT-K-24-500), ranging in length from 15-40 ft, were connected to the data logger and randomly laid on the ground throughout the test plot. The tip of each thermocouple was staked down to ensure the recorded temperature was taken at the soil surface. Three, 2-inch diameter, numbered metal rings were tamped into the ground surrounding each probe tip, and the ring identification numbers and corresponding probe numbers were recorded. To ease locating all of the rings, a 2-foot piece of flagged rebar was driven in the ground in the center of each set of three rings. In the center of the plot, two 8-foot pieces of rebar were driven into the ground about 4 ft apart, and string was tied at 1-foot increments, up to 6 ft, connecting the two pieces of rebar, to be used to determine flame height. For safety purposes, a 5-foot buffer zone was saturated with water around the entire plot to ensure the flames stayed within the test plot. Figure 1 shows the complete setup of a demonstration plot with a bahiagrass fuel source.

Figure 1. Complete demonstration plot setup.

Comp-B preparation. Comp-B cylinders, weighing approximately 2.5 lb each, were obtained as Hexolite, reclaimed Grade B, from a military demilitarization facility. Using non-sparking tools, the cylinders were reduced down to 0.5-1.0 gram pieces. One piece of Comp-B was placed on top of the soil, under the vegetation, within each ring. The bahiagrass plots had two 0.5 g pieces and one 1.0 g piece of Comp-B per each set of three rings; in contrast, only 0.5 g pieces were used in the pine straw plots. Figure 2 shows three pieces of Comp-B (circled in yellow) after being placed in a tampered ring prior to burning.

Figure 2. Three pieces of Comp-B placed in tampered rings in a demonstration plot.

Data collection. The morning of each burn, weather data was collected online from National Oceanic Atmospheric Administration (NOAA) to confirm if conditions were ideal for burning. Prior to each burn, weather data was physically collected from the burn site using a Kestrel 4000 pocket weather meter (manufactured by Nielsen-Kellerman, in Boothwyn, PA).

Temperature (°C), relative humidity (% moisture), and surface wind speed (mph) were determined and recorded. The duff moisture (%) was also determined and recorded at random points throughout the plot using a DMM600 Duff Moisture Meter (manufactured by Campbell Scientific, in Logan, UT). Biomass was also collected by cutting and clearing vegetation from a randomly selected square meter, placed in a large Ziploc bag, and later calculated as kg/m^2.

Ignition and sampling. Nomex suits, leather gloves, and leather boots were worn by all the participants during burn demonstrations. Depending on weather conditions, the fire was lit with a backing fire or head fire along the border using drip torches fueled with a 50:50 gas/diesel mixture. Once a flame temperature of ≥32 °C reached any thermocouple tip, the data logger began recording soil surface temperature from all eight thermocouples at 0.5- second intervals. The data logger was manually stopped and turned off once there were no visual flames within the plot. Once the smoke cleared, physical measurements of the changes of the Comp-B particles were recorded by determining presence or no presence. Some particles melted, making it impossible to calculate weight loss because plant tissue and soil were bound to the melted masses. Using a hand-held garden shovel, the metal rings were removed from the plot along with the inner soil plug and any remaining Comp-B particle and placed in a labeled Ziploc sample bag for transport. In the lab, samples were transferred to 120 ml wide-mouth amber jars to prevent photodegradation of TNT. Figure 3 exhibits a burn that resulted in two of three pieces of Comp-B combusting, leaving one slightly melted.

Analytical methods. A total of 72 soil samples from the three bahiagrass plots were analyzed for explosive residue by Engineer Research and Development Center's (ERDC) Environmental Chemistry Branch in Vicksburg, MS, using USEPA Method 8330, Nitroaromatics and Nitroamines using High Performance Liquid Chromatography (HPLC, 1100

Series, Agilent Technologies, Englewood, CO). Based on the observed reduction of Comp-B in the pine straw plots, analysis was not performed; however, the samples were properly stored at 4°C for reference if needed at a later time.

Figure 3. Comp-B after a complete burn of a demonstration plot, two pieces combusted (circled red) and one remained (circled yellow).

Field Plots

After coordinating with personnel at the following US Army installations: Fort McCoy, WI; Camp Shelby, MS; Fort Pickett, VA; and Fort Stewart, GA, field evaluations were scheduled during the installations' prescribed burning season, as weather permitted. Prior to burning, the plot was prepared as previously mentioned, and initial field data were collected.

After the prescribed burn was complete and the smoke cleared, data, samples, and equipment were retrieved as done with the demonstration plots.

Project Note: Changes in Department of Transportation (DOT) regulations made transporting explosive materials nearly impossible and forced the team to consider an alternate energetic material to Comp-B that was not classed as an explosive for DOT purposes. After evaluating and testing several military propellants, M10 propellant exhibited the same burning response to temperature and exposure to fire as Comp-B, and was used as a substitute in field tests at Fort Stewart, GA, Fort Pickett, VA, and Camp Shelby, MS.

Results and Discussion:

Demonstration Plots. Prescribed burning of *Paspalum notatum* (bahiagrass) typically generated lower peak temperatures compared to those produced from the burning of pine straw. The three *Paspalum* burns peaked at 232, 468, and 357 °C, respectively, as shown in Figure 4. The three pine straw burns peaked at 538, 566, and 427 °C, respectively, as demonstrated in Figure 5. Hotter, longer-burning fire generally ensured complete burning of vegetation and exposure of Comp-B to heat, flame, and embers. The average combustion of each of the six burns is listed in Table 1, including three *Paspalum* replicates and three pine straw replicates. The overall average results from the three burns are 62% and 92% combustion of Comp-B in *Paspalum* and pine straw test plots, respectively. The averages indicate that under field conditions, effective reduction can be achieved.

Field Plots. Table 2 displays the results of the field tests at Fort McCoy, WI, Camp Shelby, MS, Fort Pickett, VA, and Fort Stewart, GA. These four locations provided various vegetative cover types, densities, and biomass, indicating the variety that can be expected in most Army training lands where fire-managed ecosystems occur. Low biomass did not

178 **Figure 4.** ***Paspalum notatu*** **demonstration plot burn temperatures.**

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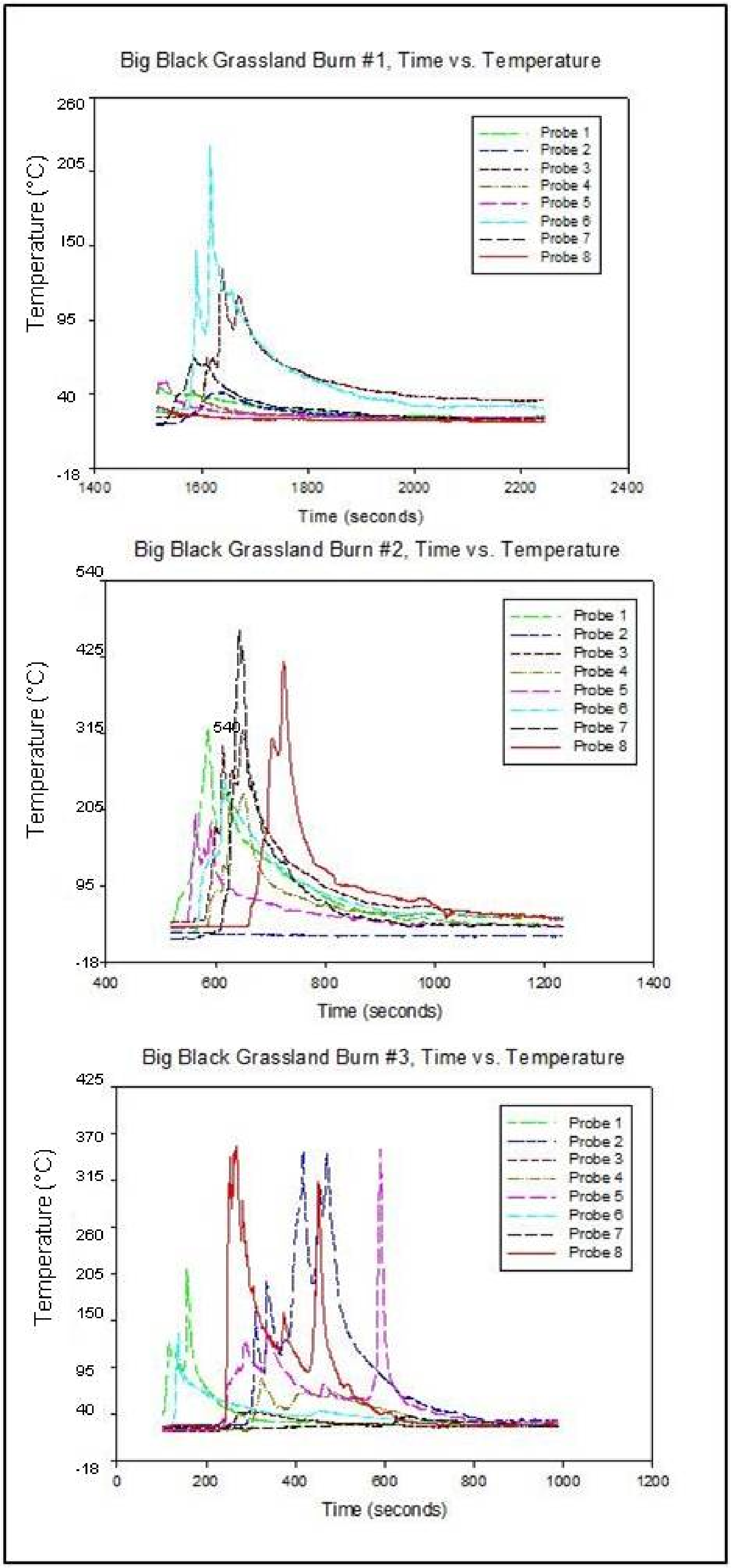

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Figure 5. Pine straw demonstration plot burn temperatures.

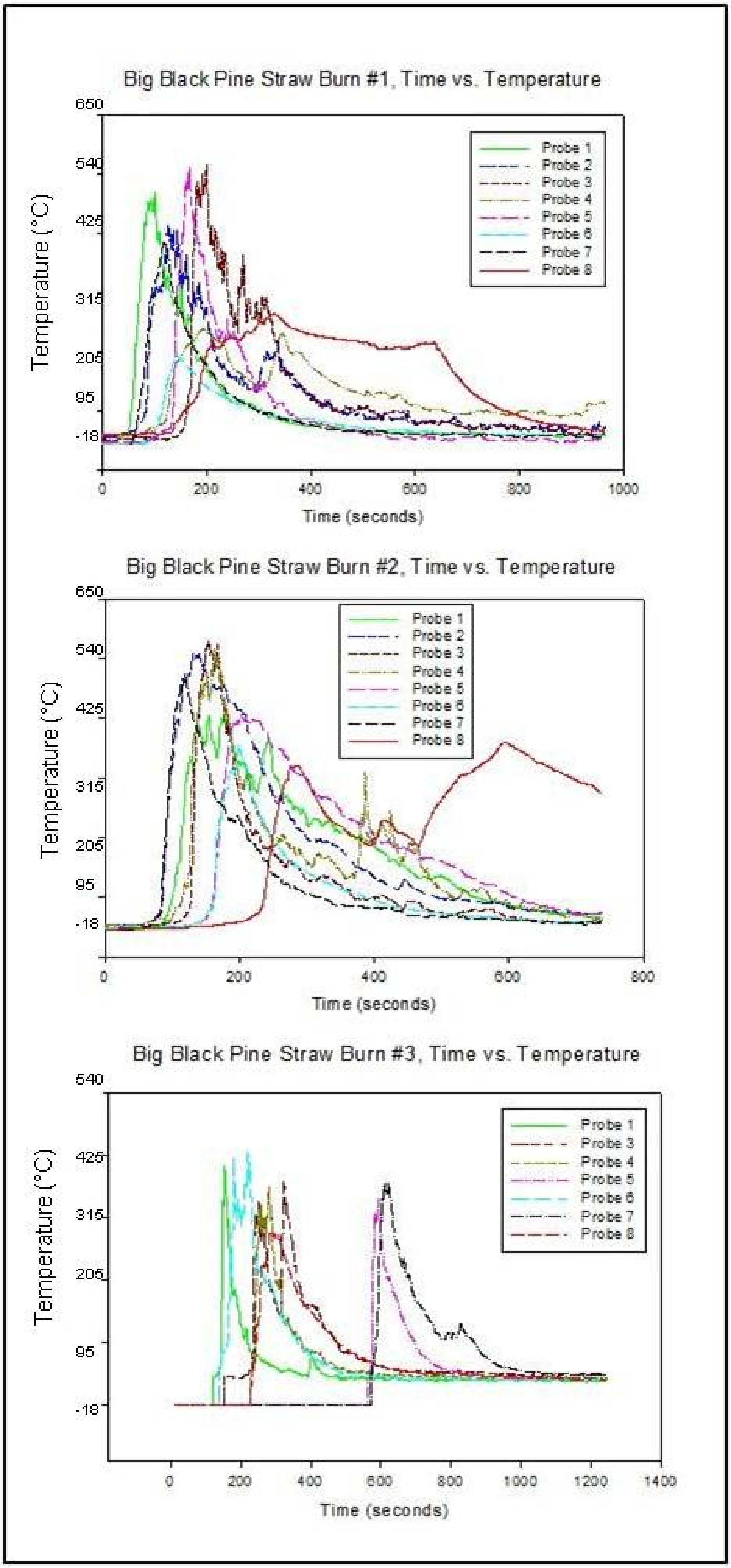


Table 1. Combustion of energetic material during burning of demonstration plots.

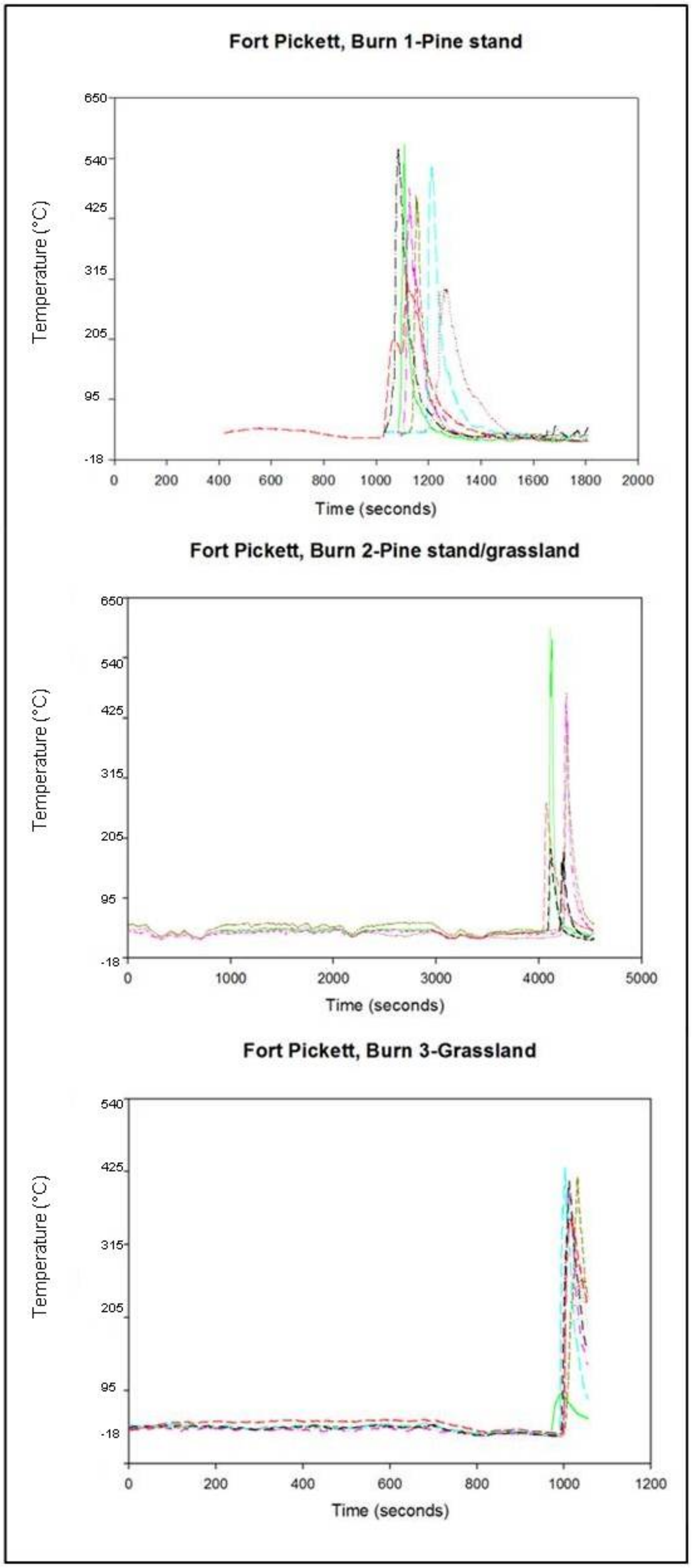
Fuel	Energetic Material	Average Combustion (%)
Bahiagrass	Comp-B	79
Bahiagrass	Comp-B	62
Bahiagrass	Comp-B	46
Final Results Average		**62**
Pine straw	Comp-B	100
Pine straw	Comp-B	100
Pine straw	Comp-B	75
Final Results Average		**92**

necessarily result in less combustion of Comp-B. Temperature profiles collected at Fort Pickett (Figure 6) show typical variation of peak temperatures at each location and maximum temperature yields observed previously in demonstration plot tests. As indicated previously, direct exposure to burning vegetation or embers generally results in combustion of Comp-B, despite low biomass or lower peak temperatures produced. Overall, field results from 10 prescribed fires resulted in an average reduction of 94% of the Comp-B and M10 placed on the soil surface, with a minimum of 79% and a maximum of 100%. Results indicate that under

Table 2. Combustion of energetic material during prescribed fire on training ranges.

Location	Fuel	Biomass (g/m^2)	Energetic Material	Average Combustion (%)
Fort McCoy	Grassland	50	Comp-B	79
	Hardwood litter	254	Comp-B	96
	Pine litter	462	Comp-B	92
Camp Shelby	Grassland	42	M10	88
Fort Pickett	Pine litter	88	M10	96
	Pine litter/Grassland	98	M10	88
	Grassland	51	M10	100
Fort Stewart	Pine litter/Palmetto	309	M10	100
	Pine litter/Hardwood litter	147	M10	100
	Pine litter/Grassland	104	M10	100
		Field Results Average		**94**

Figure 6. Fort Pickett burn temperatures using various fuel sources.



weather and vegetation conditions suitable for prescribed fire, the average reduction in Comp-B will exceed 90%.

Conclusions: There is evidence found in the flora and fauna that burns are taking place on military training ranges, whether prescribed or not. These prescribed and incidental burns of training land vegetation not only improve military training, enhance native plant ecosystems, and reduce fuel load but can also result in significant reduction of surface energetic materials. The reduction of Comp-B particles on the soil surface used in this study was related to the fire temperature and burn speed, which are directly related to vegetation type. In addition, it demonstrated that it is imperative for the flame to come in direct contact with the particle for complete combustion. In the demonstration plots, *Paspalum* burns resulted in an average 62% particle reduction; whereas, pine straw burns produced an average 92% reduction of Comp-B particles on the soil surface. These results vary drastically due to varying biomass and weather conditions at each site. Field validation was conducted at four different military installations and resulted in an overall average of 94% Comp-B reduction across ten different vegetation cover types. The results of this study conclude that under climatic and vegetative cover conditions suitable to support prescribed fire on training lands, 80% or greater of distributed particulate Comp-B canwill be consumed and pose no further threat to the environment.

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