Pilot-Scale Combustion of Building Decontamination Residue

Paul M. Lemieux
U.S. EPA
Office of Research and Development
Research Triangle Park, NC 27711

ABSTRACT

Building decontamination and cleanup efforts from a biological warfare (BW) or chemical warfare (CW) agent terrorist attack typically result in a significant quantity of building decontamination residue (BDR). This BDR consists mainly of porous materials, such as carpeting or ceiling tiles, which were removed from the building either before or, after decontamination efforts. The BDR is likely to have been decontaminated but due to its porous nature and the limitations of sampling methodologies, the possibility exists of the presence of trace quantities of agents, as well as the likelihood of the presence of varying quantities of decontamination chemicals (e.g., bleach solutions). One likely disposal technique for the BDR is high temperature thermal incineration. This paper describes preliminary experiments that were performed in a pilot-scale rotary kiln incinerator simulator to evaluate the combustion characteristics of BDR in an effort to aid in the selection of appropriate disposal facilities and to aid facilities in maintaining permit compliance while processing potentially contaminated BDR.

INTRODUCTION

After a building has gone through decontamination activities following a terrorist attack with chemical warfare (CW) agents, biological warfare (BW) agents, or toxic industrial chemicals (TICs), there will be a significant amount of residual material and waste to be disposed. This material is termed “building decontamination residue” (BDR). Although it is likely that the BDR to be disposed of will have already been decontaminated, the possibility exists for trace levels of the toxic contaminants to be present in absorbent and/or porous material such as carpet, fabric, ceiling tiles, office partitions, furniture, and personal protective equipment (PPE) and other materials used during cleanup activities. It is likely that much of this material will be disposed of in high-temperature thermal incineration facilities, such as medical/pathological waste incinerators, municipal waste combustors, and hazardous waste combustors.

Although pathogens such as *Bacillus anthracis* (anthrax) present in BDR are killed at typical incineration temperatures (> 800 °C), gas-phase residence times (> 2 s), and solid-phase residence times (> 30 min), it is possible for some of the pathogens to escape the incinerator due to bypassing the flame zones, cold spots, and incomplete penetration of heat through the bed. Wood et al., (2004) reported on EPA testing of commercial hospital waste incinerators by doping large quantities of *Geobacillus stearothermophilus* (an anthrax surrogate) spores into the combustors and measuring the number leaving in the stack emissions and in the incinerator bottom ash, in terms of Log reduction in spore concentration. It was found that, in certain cases, only a 3-Log reduction in spore

destruction was found, in spite of acceptably high operating temperatures and sufficiently long residence times.

The EPA instituted a pilot-scale test program to investigate issues related to the thermal destruction of contaminated BDR (Lemieux, 2004) including carpeting, ceiling tile, and wallboard. Contaminants to be tested will include BW simulants (Geobacillus stearothermophilus) and CW simulants (dimethyl methylphosphonate). These tests would examine time/temperature requirements for spore destruction, issues related to facility compliance with relevant permits (e.g., emissions of nitrogen oxides), and understanding which facilities may or may not be appropriate to handle certain types of BDR.

EXPERIMENTAL

Testing was performed at the EPA's Rotary Kiln Incinerator Simulator (RKIS) facility located in Research Triangle Park, NC. The RKIS has been used in the past to test a wide variety of solid and liquid wastes (Stewart and Lemieux, 2003; Lemieux and Stewart, 2004; Lemieux et al., 2004). The RKIS (shown in Figure 1) consists of a 73 kW (250,000 Btu/hr) natural gas-fired rotary kiln section and a 73 kW (250,000 Btu/hr) natural gas-fired secondary combustion chamber (SCC). Following the SCC is a long duct that leads into a dedicated flue gas cleaning system (FGCS) consisting of another afterburner, baghouse, and wet scrubber. The RKIS is equipped with continuous emission monitors (CEMs) for oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), and total hydrocarbons (THCs). A series of Type-K thermocouples monitor the temperature throughout the system. For the initial tests, the rotary kiln combustion air was flowing at a rate of 85.0 sm^3/hr (3000 scfh) and the burner natural gas fuel was flowing at a rate of 5.66 sm^3/hr (200 scfh). The static pressure in the rotary kiln section was maintained at -0.05 in. w.c..

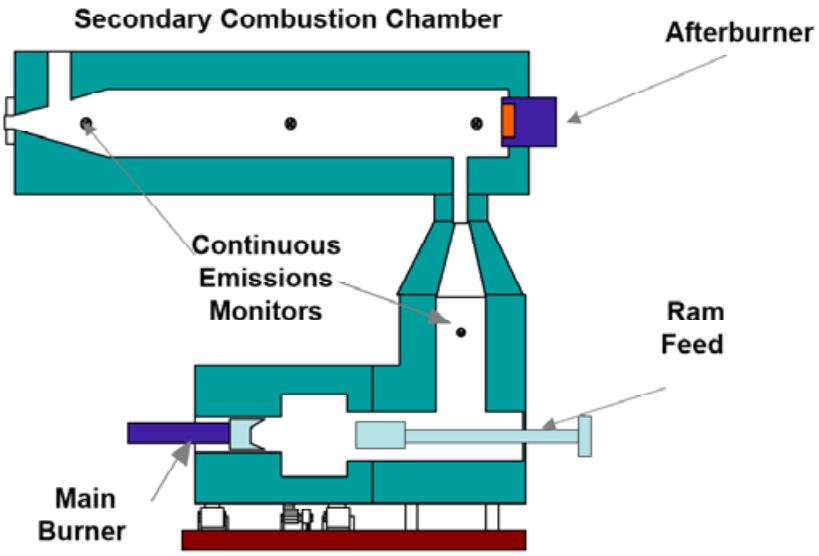

Figure 1. Rotary Kiln Incinerator Simulator.

The initial set of testing was performed with bundles of nylon 6 carpeting cut into 7.6 cm (3 in.) squares, enclosed in a titanium cage equipped with a wire loop. Embedded into the bundle was a small sealed metal tube containing a biological indicator spore strip containing $1x10^6$ spores of *Geobacillus stearothermophilus* and a Type-K thermocouple. The biological indicator carrier tube was autoclaved for 40 minutes at 121 °C prior to insertion of the spore strip. A diagram of the biological indicator tube is shown in Figure 2. A diagram of the carpet bundle with the biological indicator tube and thermocouple is shown in Figure 3.

A series of shakedown tests were performed where several different biological indicator carrier tube designs were tested. The criteria for a successful design was that it was 1) small, so as not to impose a large heat transfer resistance; 2) not leak when removed from the hot kiln and quenched in a bucket of water. The non-leaking provision was critical so that quantification of spore destruction could be performed and to prevent cross contamination of subsequent runs.

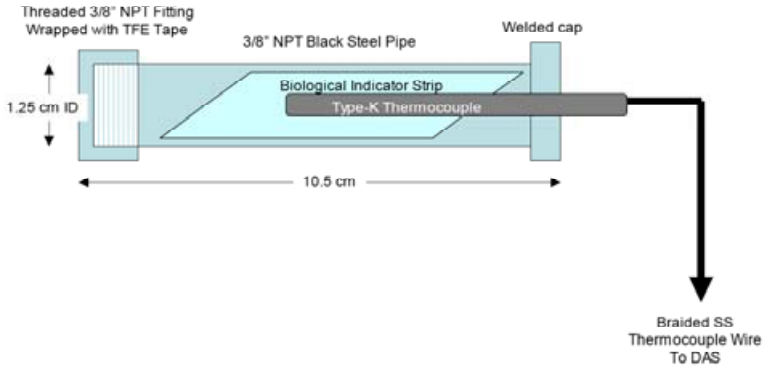

Figure 2. Biological Indicator Carrier Tube

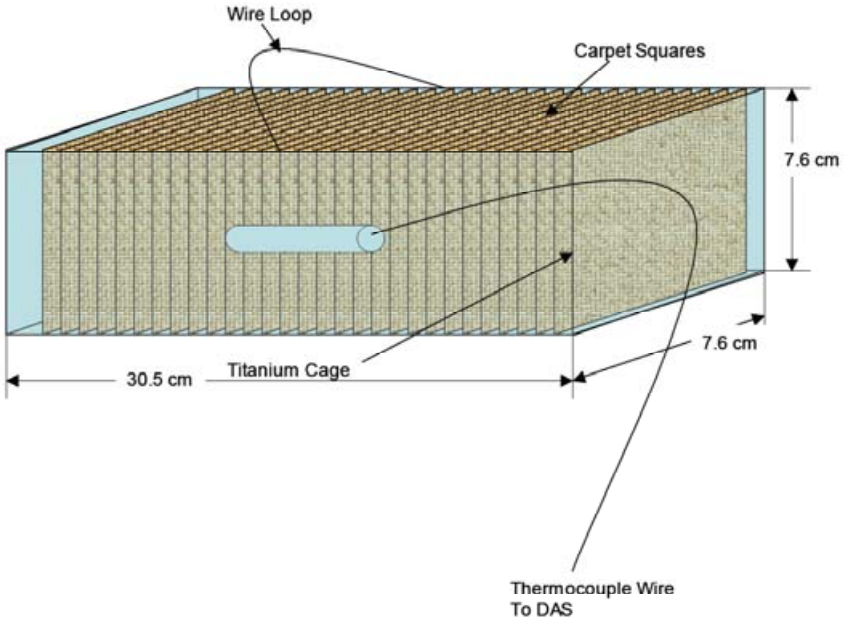

Figure 3. Carpet Bundle Illustration

The preliminary spore destruction experiments that are described in this paper are listed in Table 1. For each experiment, the carpet bundle was wetted in deionized water to simulate the decontamination process, drained until no more water dripped from the bundle, and then manually charged into the rotary kiln at a rate of 1 bundle every 10 minutes. The thermocouple in the bundle was connected to the RKIS data acquisition system (DAS) through a stainless steel braided umbilical that passed through the charging gate.

At predetermined intervals, a pole with a hook was inserted into the kiln, and the titanium cage containing the burning mass of carpet was removed from the kiln and quenched in a bucket of deionized water. The biological indicator carrier tube was removed and sent to the biocontaminant laboratory for analysis. For the analysis, the spore strip is aseptically transferred to 10 mL of sterile Nutrient Broth in sterile yellow cap tubes and incubated at 55 °C for seven days. No growth means that all spores were destroyed. Growth means that heat was not enough to completely kill the spores.

Table 1. Experimental Conditions

Run	**Carpet Mass (g)**	**Water Mass added to Carpet Prior to Feeding (g)**	**Time in Kiln Prior to Quench (min)**
1 (12/30/04)	390.5	605.8	2.0
2 (12/30/04)	390.6	640.5	3.0
3 (1/5/05)	405.4	578.3	4.0
4 (1/5/05)	402.6	666.2	5.0

RESULTS

At the time of the writing of this paper, only a limited number of tests have been performed. Only the presence or absence of spores has been determined, although future testing will quantify the Log reduction in spores due to the thermal treatment. Figure 4 shows the temperature of the thermocouple embedded in the bundle of carpet as the carpet was fed into the kiln and burnt. Of note when observing the temperature profiles are the time at which the bundle reaches approximately 100 °C, at which point the measured temperature holds steady; the time when the water is all evaporated and the temperature starts to rapidly climb; and the time at which the burning bundle was removed from the kiln and quenched in water. As more testing is performed, these parameters will be used to statistically analyze the data.

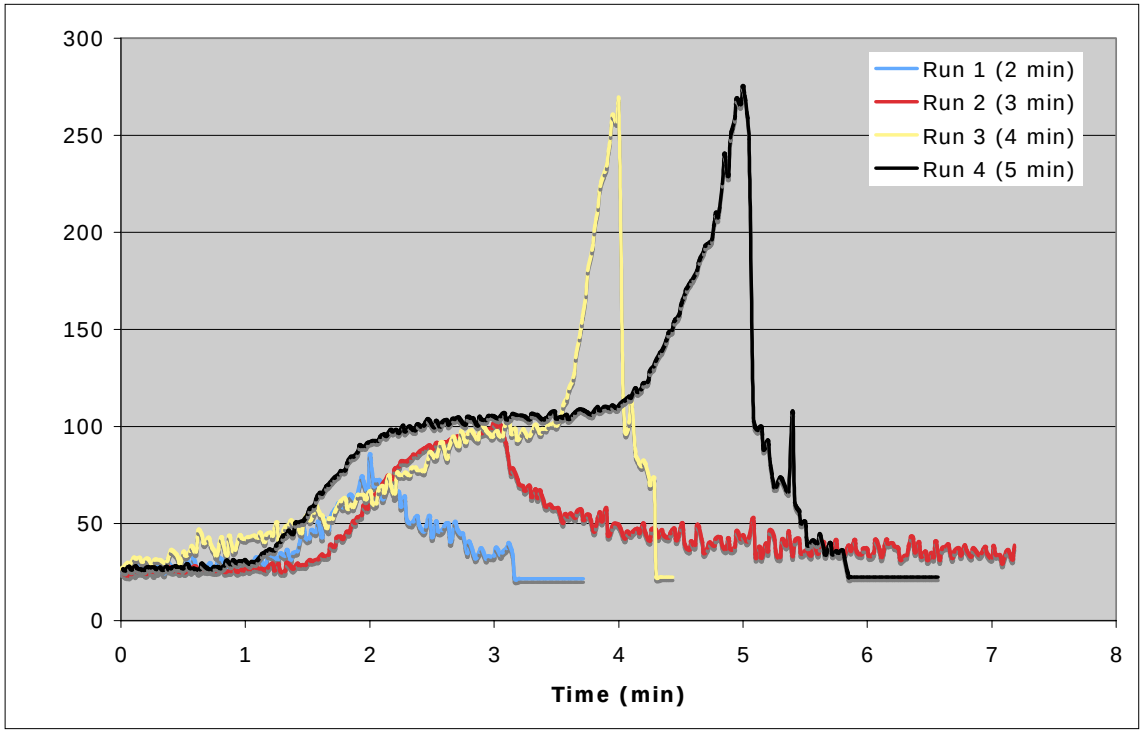

Figure 4. Temperature profiles

Table 2 shows the quantified spore destruction results from the initial tests, and the peak temperature measured in the carpet bundle. The samples removed at 2 and 3 min had not reached the point at which the water had boiled off. The samples removed at 4 and 5 minutes were removed from the kiln during the time period exhibiting rapid temperature rise. The variability in the amount of water that was absorbed onto the carpet bundles accounts for the slight offset between the 4 and 5 min traces. For these preliminary tests, only a presence/absence of viable spores was determined. Future experiments will quantify the number of remaining viable spores.

Table 2. Spore Destruction Results

Run	**Time Quenched (min)**	**Carpet Bundle Peak Temperature (°C)**	**Viable Spores Remaining**
1	2.0	85.9	Y
2	3.0	101.8	Y
3	4.0	268.6	Y
4	5.0	275.4	N

CONCLUSIONS

Preliminary experiments have been performed on the EPA's Rotary Kiln Incinerator Simulator to investigate destruction of *Geobacillus stearothermophilus* spores embedded in a bundle of carpeting. The investigators have been able to successfully recover the

biological indicator strips from inside the burning mass of carpet in order to examine the effects of time and temperature on spore destruction.

Initial tests show that the spores are apparently killed in the burning mass of carpet prior to the complete combustion of the carpet bundle. These tests suggest that if contaminated carpet were burned in such a way that sufficient oxygen is present to allow combustion of the carpet, then spores are destroyed in a few minutes, which is significantly less than the average solid-phase incinerator residence time.

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