Subway Railcar Decontamination with Methyl Bromide

March 15, 2017

Decontamination of a Subway Railcar using Methyl Bromide Fumigant on *Bacillus anthracis* Sterne Strain Spores

Homeland Security
Science and Technology

Sandia National Laboratories

Lawrence Livermore National Laboratory

Questions concerning this document or its application should be addressed to the following:

Shannon D. Serre, EPA
Co-Program Manager
serre.shannon@epa.gov

Leroy Mickelsen, EPA
Co-Program Manager
mickelsen.leroy@epa.gov

Disclaimer

This report has been peer- and administratively reviewed and has been approved for publication as an EPA document. It does not necessarily reflect the views of the EPA. No official endorsement should be inferred. The EPA does not endorse the purchase or sale of any commercial products or services. This report includes photographs of commercially available products. The photographs are included for purposes of illustration only and are not intended to imply that the EPA approves or endorses any product or its manufacturer.

Acknowledgements

This study required the collaboration of Federal government, academia, and contractor personnel for planning and successful execution. The project could not have been successfully accomplished without the collective commitment and contributions of all involved.

The following are acknowledged for their project planning and execution leadership:

Leroy Mickelsen, CBRN Consequence Management Advisory Division, EPA
Shannon Serre, CBRN Consequence Management Advisory Division, EPA

The following are acknowledged for scientific planning, coordination, and execution:

Larry Kaelin, CBRN Consequence Management Advisory Division, EPA
Leroy Mickelsen, CBRN Consequence Management Advisory Division, EPA
Michael Nalipinski, CBRN Consequence Management Advisory Division, EPA
Elise Jakabhazy, CBRN Consequence Management Advisory Division, EPA
Francisco J. Cruz, CBRN Consequence Management Advisory Division, EPA
Chris Gallo, Environmental Response Team, EPA
Worth Calfee, National Homeland Security Research Center, EPA
Marshall Gray, National Homeland Security Research Center, EPA
Shannon Serre, CBRN Consequence Management Advisory Division, EPA
John Archer, National Exposure Research Laboratory, EPA
Nicole Griffin, Arcadis US
Neil Daniell, CSS-Dynamac
Bill Kern, University of Florida
Renny Perez, University of Florida (Fumigation School Director)
Rudi Scheffrahn, University of Florida
Don Bansleben, Department of Homeland Security
Andrea Allen, Contract Support to the Department of Homeland Security
Mark Tucker, Sandia National Laboratories
Jasper Hardesty, Sandia National Laboratories
Veronica Lopez, Sandia National Laboratories
John Smith, Sandia National Laboratories
Kenneth Black, Sandia National Laboratories
Ellen Raber, Lawrence Livermore National Laboratory
Sav Mancieri, Lawrence Livermore National Laboratory
Hank Khan, Lawrence Livermore National Laboratory
Staci Kane, Lawrence Livermore National Laboratory

The following are acknowledged for their role in the primary data analysis and authorship of this report:

Shannon Serre, CBRN Consequence Management Advisory Division, EPA
Leroy Mickelsen, CBRN Consequence Management Advisory Division, EPA
Worth Calfee, National Homeland Security Research Center, EPA
Marshall Gray, National Homeland Security Research Center, EPA
Bill Kern, University of Florida
Rudi Scheffrahn, University of Florida

Table of Contents

Appendix

Acronyms and Abbreviations

AAMP	Ambient Air Monitoring Plan
ACGIH	American Conference of Governmental Industrial Hygienists
B	*Bacillus*
Ba	*Bacillus anthracis*
BI	biological indicator
CAA	Clean Air Act
CBRN	Chemical, Biological, Radiological, and Nuclear
CDC	Centers for Disease Control and Prevention
CFM	cubic feet per minute
CFU	colony forming unit
ClO_2	chlorine dioxide
CMAD	Consequence Management and Advisory Division
CRZ	Contaminant Reduction Zone (“warm zone”)
DHS	Department of Homeland Security
EPA	United States Environmental Protection Agency
ERT	Environmental Response Team
EtO	ethylene oxide
EVOH	polyethylene vinyl alcohol
EZ	Exclusion Zone (“hot zone”)
ft^3	cubic feet
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HDPE	high-density polyethylene
IC	Incident Commander
ID	inner diameter
IDLH	immediately dangerous to life or health
LLNL	Lawrence Livermore National Laboratory
LR	log reduction
MB	methyl bromide
mg/L	milligram per liter
mm	millimeter
MOP	method of procedure
NHSRC	National Homeland Security Research Center
NIOSH	National Institute for Occupational Safety and Health
OEL	occupational exposure limit
OSHA	Occupational Safety and Health Administration
PBST	phosphate buffered saline with Tween20
PEL	permissible exposure limit
PHILIS	Portable High-throughput Integrated Laboratory Identification System (EPA mobile on-site analytic laboratory)
PID	photoionization detector

PPE	personal protective equipment
ppm	part per million
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
RAP	Remediation Action Plan
REL	recommended exposure limit
RH	relative humidity
RTP	Research Triangle Park
SO	Safety Officer
Sandia	Sandia National Laboratories
SAP	Sampling and Analysis Plan
SCBA	self-contained breathing apparatus
SERAS	Scientific, Engineering, Response & Analytical Services
SZ	Support Zone (“cold zone”)
tarp	tarpaulin
TLV	threshold limit value
TSA	tryptic soy agar
TWA	time-weighted average
UTR	Underground Transport Restoration
VHP	vaporized hydrogen peroxide
VOC	Volatile organic chemical

Executive Summary

As part of the Department of Homeland Security's (DHS) Underground Transport Restoration (UTR) project, several federal agencies conducted a scientific study to evaluate methyl bromide (MB) as a fumigant for decontaminating subway railcars contaminated with *Bacillus anthracis* (*Ba*) using *Ba* Sterne strain spores. In conjunction with the DHS, the United States Environmental Protection Agency (EPA), Sandia National Laboratories (Sandia), and Lawrence Livermore National Laboratory (LLNL) participated in the fumigation of a subway railcar using MB in July 2015. The study was designed to evaluate the operational aspects and the efficacy of MB for inactivating surrogate *Ba* spores on the subway railcar. The study was conducted to gain large-scale information on the use of MB for the decontamination of *Ba* spores and to develop site-specific plans and guidance that could be modified and used during a real-world incident. The fumigant MB was selected because it has shown to be efficacious in the inactivation of *Ba* spores during laboratory testing, is less corrosive than most other fumigants, and can be captured on activated carbon.

A 1980s-era subway railcar was used in this study to examine the efficacy of MB for inactivating *Ba* Sterne strain spores. Spores of *Ba* Sterne 34F2, the vaccine strain, were used as surrogates in lieu of virulent *Ba* spores and placed on test coupon materials. The MB fumigation parameters were 212 milligrams of MB per liter of air (mg/L) at 75 °F, greater than 75% relative humidity (RH), maintained for 36 hours. Timed-series *Ba* coupons also were placed inside the fumigation envelope and were extracted at 6, 12, 18, 24, and 30 hours after the start of fumigation. At the conclusion of the 36-hour fumigation, the railcar was aerated and the test coupons were collected and sent to a laboratory for analysis.

The subway railcar was transported to the Sandia campus in Livermore, California, on a transport trailer and placed on a concrete pad. Before placement of the trailer and subway car on the concrete pad, a 6-millimeter (mm)-thick, high-diffusion-resistant polyethylene vinyl alcohol (EVOH) tarpaulin (tarp) was placed on the pad over which the chassis of the trailer was parked. Another section of EVOH tarp was placed over the top of the railcar, and both tarps were joined together. Before the EVOH tarp was placed over the top of the railcar, 4-inch-diameter, perforated, high-density polyethylene (HDPE) tubing was draped over the top and sides of the railcar, at multiple locations, to provide air space between the railcar and the tarp. This tented area allowed simultaneous fumigation of the interior and exterior of the railcar while also reducing the potential for condensation of MB at locations where the tarp and railcar would be in contact. The area inside the tented volume contained four fans (operating at 3,000 cubic feet per minute [cfm] each), ten 1,500-watt radiant heaters, and four humidifiers to help maintain temperature and RH equilibrium throughout the tented volume during the duration of the study.

Before fumigation, 40 coupons were made from each of the following materials previously removed from a similar railcar: nylon loop-pile carpet, fiberglass wall paneling, aluminum, rubber flooring, Mylar® on polycarbonate, and vinyl seating. The test coupons were inoculated with a known amount (about 10^6 colony forming units [CFU]) of *Ba* Sterne strain spores. Two

coupons of each material were placed at 20 locations inside and outside the railcar, including behind closed panels and confined spaces within mechanical and electrical equipment.

At the conclusion of the 36-hour fumigation period, the railcar was aerated and the coupons were collected and sent to a laboratory for analysis. Results showed that none of the 40 fiberglass or 40 aluminum test coupons contained viable spores after fumigation. Out of the 40 coupons of each material type, the following numbers of coupons were positive after fumigation: 2 nylon carpet coupons, 1 rubber flooring coupon, 1 Mylar® coupon, and 8 vinyl seating coupons. No growth on any of the procedural blank (60 total) coupons suggests that contamination did not occur during field or laboratory procedures. All 39 positive-control coupons (inoculated but not exposed) were positive for growth. None of the 31 negative control coupons (not inoculated and not exposed) were positive for growth.

Timed-series coupons removed from the fumigation envelope at 6, 12, 18, and 24 hours after the start of fumigation all contained viable spores on some materials. Analysis of the time-series coupons exposed for 30 hours showed viable spores (10 CFUs) were recovered from only one (fiberglass coupon) of the twelve coupons, resulting in an average recovery of 5 CFUs for fiberglass and zero recovered viable spores for all other materials. Log reductions (LR) for the quantitative temporal assessment portion at 30 hours after exposure were greater than or equal to 6 LR for all coupons except for the fiberglass coupon, which had an LR value of 5.5. At the 24-hour exposure time, efficacy was greater than or equal to 2.5 LR for all coupons, with all material types having recoverable spores.

An activated carbon scrubber system was used to capture the MB after the fumigation. The system consisted of two scrubber vessels (each containing approximately 900 pounds of activated carbon), a blower, flexible ducting, a vent stack, and fittings. The activated carbon scrubber was effectively deployed and used to reduce the MB concentration inside the tented volume from approximately 55,000 parts per million (ppm) to less than 20 ppm in 5 hours after active fumigation was complete.

Ambient air monitoring was achieved by placing photoionization monitors at four stationary locations around the tented railcar. In addition, hand-held monitors of similar technology were used to leak test the perimeter of the tented railcar and to provide monitoring of those locations not covered by the stationary monitors.

Based on several positive test coupon results from this study, it is recommended that the fumigation of a railcar for *Ba* be extended from 36 to 48 hours and that the temperature, RH, and MB concentration be maintained above the set points of 75 °F, 75% RH, and 212 mg/L, respectively, during the 48-hour fumigation period. In addition, based on the result of eight positive results for the vinyl seat covering coupons, it is recommended that railcar seating material be sprayed down with pH-adjusted bleach before fumigation to aid in the inactivation of *Ba* spores.

This operational study and update of the operational documents improves the capacity of U.S. agencies to respond to and recover from a biological incident in a subway system.

1 Introduction

As part of the Department of Homeland Security's (DHS) Underground Transport Restoration (UTR) project, several federal agencies conducted a scientific study to evaluate methyl bromide (MB) as a fumigant for decontaminating subway railcars contaminated with *Bacillus anthracis* (*Ba*) using non-pathogenic *Ba* Sterne strain spores. In conjunction with the DHS, the United States Environmental Protection Agency (EPA), Sandia National Laboratories (Sandia), and Lawrence Livermore National Laboratory (LLNL) participated in the fumigation of a subway railcar using MB. The study was designed to evaluate the operational aspects and the efficacy of MB for inactivating of *Ba* Sterne spores on a full-scale subway railcar. The site-specific plans and guidance developed for this study could be modified and used for a real-world incident. The fumigant MB (also known as bromomethane, CH_3Br) was selected because it has shown to be efficacious in the inactivation of *Ba* spores during laboratory testing, is less corrosive than most other fumigants, and can be captured on activated carbon.

The fumigation study was conducted from July 6 through 15, 2015, at the Sandia campus in Livermore, California. Project planning, coordination, and execution involved members from the following agencies and organizations: EPA's Chemical, Biological, Radiological, and Nuclear (CBRN) Consequence Management and Advisory Division (CMAD), DHS, Sandia, LLNL, EPA's National Homeland Security Research Center (NHSRC), EPA's Environmental Response Team (ERT), the University of Florida, and several contractors.

This report discusses the study materials and methods (Section 2), the results of the fumigation study (Section 3), and provides conclusions and recommendations based on the study findings (Section 4). Section 5 lists references used to prepare this report. In addition, this report includes the following draft documents that can be used and modified during a real-world response for subway railcars requiring MB fumigation:

- Appendix A: Lessons Learned
- Appendix B: Health and Safety Plan (HASP)
- Appendix C: Ambient Air Monitoring Plan (AAMP)

The following sections discuss previous MB fumigation studies, MB usage and properties, health and safety, and study objectives.

1.1 Previous MB Fumigation Studies

In the event of the release of a biological agent such as *Ba* in a subway system, the areas impacted will require decontamination, including subway tunnels and railcars. The railcars contain many electrical components sensitive and subject to damage if exposed to harsh chemicals. Corrosion and discoloration of materials in these railcars could also occur with the use of some fumigants that are efficacious against *Ba*. In the case of sensitive or historic infrastructure, corrosive methods (relying on oxidation) are not desirable remediation techniques. Studies have been conducted to examine fumigant efficacy against *Ba* and the corrosion caused by some fumigants. The studies summarized below highlight findings for MB fumigation against *Ba*.

- The EPA has conducted the studies discussed below to examine the compatibility of decontamination agents with electronics and items of historical value (EPA, 2013).

- An unpublished EPA study[1] examined the impact of chlorine dioxide (ClO_2) gas, vaporized hydrogen peroxide (VHP), ethylene oxide (EtO), and MB on several types of historical materials. This study provided insight into the risk for damage from a decontamination scenario using different fumigants. Based on the study findings, VHP, EtO, and MB are the most compatible (of the fumigants and materials tested) with museum-quality objects. MB is a viable alternative for a whole-building decontamination scenario when materials such as books, documents, and photographs are present.
- In another study (EPA, 2012), personal computers were exposed to MB fumigation under the same conditions necessary to inactivate spore-forming bacteria. The fumigant included 2% chloropicrin mixed in with the MB (standard use for olfactory detection). The chloropicrin appeared to oxidize some components in the computer system, but the MB appeared to not negatively impact materials.

- The EPA conducted a laboratory study (EPA, 2011) on seven different indoor building materials. The study found that MB fumigation was efficacious for the decontamination of *Ba* Ames (a virulent strain of *Ba* spores) on the indoor building materials tested.
- Corsi et al. (2007) concluded that MB does not engage appreciably in sorptive interactions with indoor materials, although some diffusion can occur into porous materials and desorb. Desorption of adsorbed MB from indoor materials appears to be rapid. It also appears that exposure of some building materials to elevated concentrations of MB increases the desorption rate of carbonyls and several methylated aliphatic compounds. However, the absolute increases appear to be small and likely are not a major concern for either disinfection workers or those who reoccupy a building after disinfection.
- Juergensmeyer et al. (2007) established that a minimum effective dose of MB of 80 milligrams per liter (mg/L) was lethal to a concentration of 10^7 spores of *Ba* for nine different strains (including Ames and Sterne) on glass slides after a 48-hour period exposure at 37 °C. In addition, under the same exposure conditions, 9 other strains of *Ba* (ATCC 10, ATCC 937, ATCC 4728, ATCC 9660, ATCC 11966, ATCC 14187, AMES-1-RIID, AMES-RIID, and ANR-1) were equally susceptible to MB and were not dependent upon virulence factors. The study showed that *Bacillus (B.) atrophaeus* and *B. thuringiensis* were more resistant than *Ba* to MB when tested at similar conditions. All *B. thuringiensis* and *B. atrophaeus* spores tested showed a dose-dependent reduction in spore numbers, but the spores were not reduced to below detection level by any of the MB concentrations tested. The study concludes that MB has several advantages as a fumigant. First, because MB is a registered structural fumigant, personnel trained in its use are available nationally. Additional training in decontamination procedures would be minimal for these professionals. Second, decontamination is rapid, occurring within 48 hours. Extensive preparation of the contaminated item is not required, and all furnishings or other internal structures or items may remain in place. Third, MB leaves no residue and is a noncorrosive alkylating agent that does not damage commodities (such as food supplies), furnishings, documents, or even sensitive electronic equipment.
- Weinberg and Scheffrahn (2004a, 2004b) conducted an MB field trial within a 30,000-cubic-foot structure. Filter-paper coupons containing 10^6 spores of one of three species (*Geobacillus stearothermophilus*, *B. atrophaeus,* and *B. thuringiensis*) and stainless-steel coupons containing 10^6 spores of *B. atrophaeus* were placed in 50 locations within the structure. Fumigation was

[1] Point of Contact: Dr. Shannon Serre, EPA

conducted using 312 mg/L of MB for 48 hours at 35.5 °C with an overall mean relative humidity (RH) of 76%. The study results found that only one location, a sealed refrigerator, contained viable spores of *B. atrophaeus* on a single coupon. It was noted that the performance of sensitive electronics and electronic media placed in the structure were unaffected by MB fumigation.

- Field studies by the EPA (2015) and Serre et al. (2016) evaluated operational MB fumigation to inactivate *Ba* Sterne strain spores within a structure. The structure was covered with polyethylene vinyl alcohol (EVOH) tarpaulins (tarp). The MB concentration, temperature, and relative humidity of 212 mg/L, 27 °C, and 75%, respectively, were maintained for 48 hours. Spores of *Ba* Sterne 34F2, the vaccine strain, were inoculated onto wood and glass coupons with approximately 10^6 colony forming units (CFU) and placed at 22 separate locations throughout the structure. After fumigation, all 174 coupons were negative for growth. An activated carbon scrubber system was effectively deployed to reduce the concentration of MB inside the structure from approximately 55,000 parts per million (ppm) to below 150 ppm in 4 hours.

1.2 MB Usage and Properties

MB, also known as bromomethane (CH_3Br), is a colorless, odorless (at low concentrations), and nonflammable gas classified as an alkyl bromide. MB is containerized as a liquid under a modest pressure of approximately 2 atmospheres. The EPA originally registered MB for applications that included soil fumigation (injected into soil before crop planting to effectively sterilize the soil of nematodes, weed seeds, and plant pathogens); commodity treatment (post-harvest pest control); and structural pest control (to fumigate buildings for termites and warehouses and food processing facilities for insects and rodents) (EPA, 2006). Current domestic use of MB is as a quarantine fumigant to treat exported and imported commodities such as wood and fresh fruits and vegetables.

MB fumigant concentrations and contact times vary depending on the commodity or structure being treated, the target pest, temperature, and RH. MB is an effective pesticide because it acts as a methylating agent that disrupts an organism's internal enzymatic protein chemistry. However, the production of MB was reduced in 2005 under an international treaty called the Montreal Protocol and by the EPA under the Clean Air Act (CAA) (http://www.epa.gov/ozone/mbr/) due to its stratospheric ozone-depleting potential. Use now requires an exemption by the EPA under appropriate provisions in the CAA. MB currently is used in the U.S. only under these exemptions and is manufactured in the U.S. by Chemtura Corp., with label provisions developed by Great Lakes Corp. Allowable exemptions include the Quarantine and Pre-Shipment exemption to eliminate quarantined pests and the Critical Use Exemption designed for agricultural users with no technically or economically feasible alternatives. Under these exemptions, approximately 7 million pounds of MB is used annually in the U.S. In addition, MB has a Section 18 exemption under EPA authority. Due to the need to find an effective fumigant or method to inactivate *Ba* spores, the EPA continues to research decontamination technologies, including MB use at relatively low temperatures and RH levels (EPA, 2014).

Before phase-out of MB as an ozone-depleting substance began in 2005, MB fumigation was widely used for 60 years against soil and structural pests. Today, most major U.S. seaports and some airports have facilities regulated by the United States Department of Agriculture for MB fumigations of imported fruits, vegetables, and other regulated commodities. These facilities have crews trained in MB fumigation using much of the same equipment and methods as those used in structural fumigations. Although the crews have the technical expertise to conduct lawful fumigations, only a small percentage of fumigation crews currently working in the industry meet the requirements for

entering a biological agent remediation site. Such requirements include Occupational Safety and Health Administration (OSHA) Hazardous Waste Operations and Emergency Response (HAZWOPER) certification, medical clearance to wear respiratory protection, and annual respiratory protection training. (Medical clearance, self-contained breathing apparatus (SCBA) use, and respirator training already are requirements for licensed fumigators.) In addition, fumigation workers at biological agent remediation sites need site-specific training with a focus on the hazards of *Ba* and on conducting fumigation tasks in Level C personal protective equipment (PPE) protective gear, most likely including powered air-purifying respirators. Initial HAZWOPER technician training is a one-time, 24-hour event with subsequent 8-hour refresher training required annually. To overcome this deficiency, fumigation industry workers without the required HAZWOPER training could be prepared with minimal training to meet these requirements as needed for emergency response remediation work.

Most of the structural fumigation industry in the U.S. (mostly non-MB usage) is located in Florida, the Gulf Coast, the Southwest, and Hawaii. The quarantine fumigation industry (MB usage) mainly is located at large sea ports and airports where international cargo is imported. These locations largely coincide with the locations of major subway systems in the US. During a national emergency involving the release of *Ba* in a subway system, this industry could be used to increase the remediation capacity.

MB penetrates quickly and deeply into sorptive materials at normal atmospheric pressure. Also, at the end of a fumigation treatment, MB vapors dissipate rapidly from the materials (Corsi et al., 2007). MB gas is non-explosive under ordinary circumstances and may be used without special precautions against combustion.

In the absence of oxygen, liquid-phase MB reacts with aluminum to form methyl aluminum bromide. Methyl aluminum bromide ignites spontaneously in the presence of oxygen. **Liquid MB should never be stored in cylinders containing any appreciable amount of the metal aluminum, and aluminum tubing should not be used for applying the liquid phase of the fumigant.** Vapor-phase MB will not react with aluminum. Table 1 summarizes the chemical properties of MB.

Table 1. MB Chemical Properties

Chemical formula	CH_3Br
Boiling point	3.6 °C
Freezing point	-93 °C
Molecular weight	94.95
Specific gravity gas (air = 1)	3.27 at 0 °C
Liquid (water at 4 °C = 1)	1.732 at 0 °C
Vapor pressure	1,400 millimeters (mm) of mercury at 20°C
Latent heat of vaporization	61.52 calories per gram
Flammability limits in air	Flammable between 10 to 15% (some say 20%) in air
Solubility in water	1.34 grams per 100 milliliters at 25 °C
Odor	Odorless at low concentrations; strong musty or sickly sweet odor at high concentrations (greater than 1,000 ppm)
Pertinent chemical properties (liquid-phase only)	Powerful solvent of organic materials, especially natural rubber; liquid MB reacts with aluminum and its alloys to form methylated aluminum compounds that are spontaneously flammable in air; reacts with zinc, magnesium, tin, and iron surfaces in the presence of impurities such as water or alcohol; avoid the presence of acetylenic compounds, ammonia, dimethylsulfoxide, EtO, oxidizers, and hot metal surfaces

1.3 Health and Safety

With all fumigants, human exposure is a concern because of the toxic nature and inhalation hazard associated with fumigants, including MB. MB is a toxic chemical. Because MB dissipates so rapidly to the atmosphere, it is most dangerous at the fumigation site itself. Human exposure to high concentrations of MB can result in central nervous system and respiratory system failure as well as specific and severe deleterious reactions affecting the lungs, eyes, skin, kidneys, and liver.

The risk of exposure to MB without sufficient warning is significant because MB is a colorless and odorless (at working concentrations) gas. To address this significant risk, a detailed HASP (Appendix B) and AAMP (Appendix C) were developed to protect workers during this study. MB has a history of industrial use, and it is fairly well characterized in terms of human toxicity, including recommended and regulatory occupational exposure limits (OEL). For the purposes of this study, a detailed HASP was developed that integrates personnel and area monitoring, emergency response, medical monitoring, PPE requirements, clearance thresholds, and other related issues.

Although this study was a research project, the fumigation site was managed as if it were an emergency response site, with the designation of an Exclusion Zone (EZ) or "hot zone," a Contaminant Reduction Zone (CRZ) or "warm zone," and a Support Zone (SZ) or "cold zone." The three zones were delineated based on the most conservative airborne OELs for MB provided by OSHA, the National Institute for Occupational Safety and Health (NIOSH), and the American Conference of Governmental Industrial Hygienists (ACGIH). The ACGIH threshold limit value (TLV) is 1 ppm as an 8-hour time-weighted average (TWA), and the OSHA permissible exposure limit (PEL) is 20 ppm as a ceiling value that cannot be exceeded in any part of the workday. NIOSH's immediately dangerous to life or health (IDLH) value is listed as 250 ppm (NIOSH, 2012). MB has no NIOSH recommended exposure limit (REL) because NIOSH considers MB a potential occupational carcinogen. Other organizations, such as the International Agency for Research on Cancer (1986), the National Toxicology Program (1992), and the EPA (1988) do not classify MB as a potential human carcinogen.

In addition to inhalation exposure limits, the OELs annotate a skin notation for MB, which suggests potential adverse effects to the skin and/or absorption through the skin. The reports of Jordi (1953) and Hezemans-Boer et al. (1988) suggest that sweating increases human vulnerability to skin absorption of MB. Yamomoto et al. (2000) studied cutaneous exposure of rats to MB, but it is not clear whether the exposure was to MB in liquid or vapor form. This study found an immediate rise in plasma bromide ion, with a plasma clearance half-life of 5.0 to 6.5 days.

For purposes of this MB fumigation study, the zones were established based on MB concentrations as follows: EZ greater than 0.5 ppm, CRZ between 0.5 ppm and non-detect, and SZ at non-detect. Wind directional flags were used throughout the fumigation area, and the SZ was maintained upwind from the fumigation area. PPE including SCBAs and foot and hand protection were prescribed based on work task. SCBAs were required for entry into an area with airborne concentrations consistently exceeding the action level of 0.5 ppm (a level of MB concentration that requires mitigative actions). Two Certified Industrial Hygienists (American Board of Industrial Hygiene) served as the site Safety Officers (SOs) and provided 24-hour oversight of the project during all fumigation activities. The SOs also collected personal breathing zone samples from EPA and contract personnel during tasks identified as having the potential for MB exposure, including coupon extraction and carbon scrubber operations conducted during aeration of the railcar.

The HASP restricted entry into the railcar from the time fumigation began until the fumigation was complete and airborne MB concentrations were measured to be below 5 ppm. Coupons were not

collected until MB concentrations were below 1 ppm. When dispensing MB from cylinders, workers wore no gloves and loose-fitting clothing (as required by the MB labeling) to reduce the risk of trapping liquid MB under clothing next to the skin. Engineering controls, work practices, and required PPE all are detailed in the site-specific HASP. This HASP can serve as an example HASP to be modified and used at other sites requiring MB fumigation.

1.4 Study Objectives

The overall goal of this study was to conduct and evaluate the operational aspects and efficacy of MB fumigation for inactivating non-pathogenic *Ba* Sterne spores in a full-scale subway railcar. The five objectives summarized below were developed to achieve this overall goal. Achieving these objectives will result in greater resiliency and capacity to respond to and recover from a *Ba* release or other biological incident using MB fumigation.

1.4.1 Objective 1

Under this objective, a Quality Assurance Project Plan (QAPP) was developed for the fumigation of a subway railcar using MB for inactivating the chosen non-pathogenic surrogate spores. As part of the QAPP, this study included the development of a site-specific HASP, and an AAMP. With minor changes, the site-specific HASP, and AAMP, can be easily modified and used for fumigation of one or more railcars using MB.

1.4.2 Objective 2

This objective was to conduct the fumigation process safely, economically, and effectively. MB concentration, temperature, and RH were monitored and maintained during the study to ensure that the following requirements were achieved inside the railcar fumigation envelope during the 36-hour fumigation period: MB concentration greater than or equal to 212 mg/L, temperature at greater than or equal to 75 °F, and relative humidity at greater than or equal to 75%. Furthermore, MB concentration, temperature, and RH were monitored outside the railcar before, during, and after the same 36-hour fumigation and aeration period.

1.4.3 Objective 3

Under this objective, the efficacy of the fumigation was evaluated by measuring the post-fumigation viability of *Ba* Sterne strain spores. This objective was accomplished by inoculating *Ba* Sterne strain spores onto six types of material test coupons (materials obtained from a railcar) and placing the coupons in 20 locations inside and outside the railcar before fumigation, followed by laboratory analysis of spore viability after the fumigation.

1.4.4 Objective 4

This objective required evaluating the effectiveness of activated carbon for capturing the MB fumigant during the aeration portion of the fumigation cycle and monitoring MB breakthrough status of the activated carbon during aeration of the railcar.

1.4.5 Objective 5

The objective was to monitor the effectiveness of MB containment and provide for the health and safety of workers during the entire fumigation process. The HASP, and AAMP, provide detailed

procedures for air monitoring and for handling elevated levels (exceeding 0.5 ppm) of MB in ambient air during all aspects of the fumigation process.

2 Study Materials and Methods

This section discusses the study materials and methods, including subway railcar preparation, the MB fumigation process, temperature and RH monitoring, test coupon preparation and analysis, pre-and post-fumigation sponge stick sampling, activated carbon scrubber system deployment, ambient air monitoring, and leak detection.

2.1 Subway Railcar Preparation

A 1980s-era subway car (Figure 1) undergoing a retrofit process was transported to Sandia's campus in Livermore, California, on a transport trailer, where it was tented and fumigated with MB.

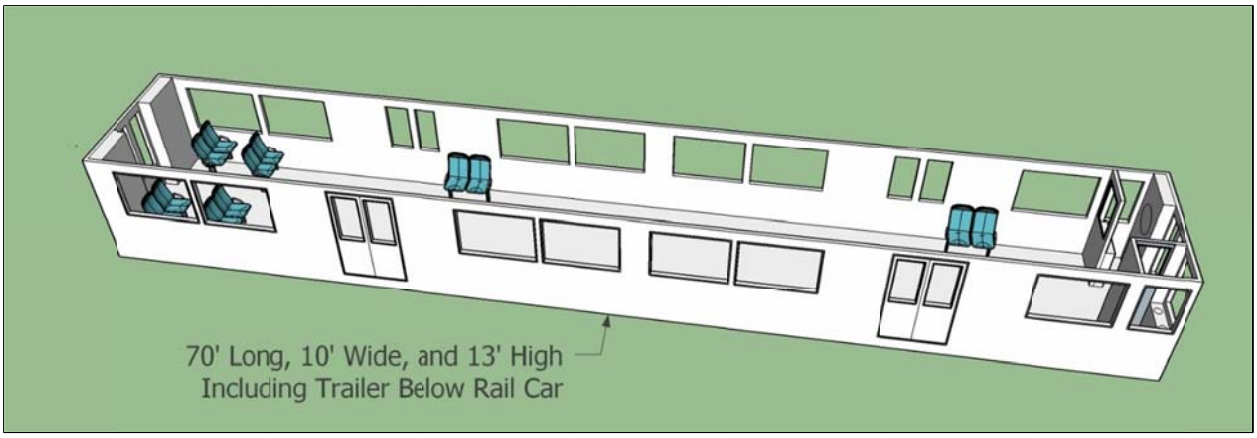


Figure 1. Schematic diagram of subway railcar, with dimensions

As discussed in Section 1.4.2, the MB fumigation parameters were 212 mg/L, 75 °F, greater than 75% RH, and 36 hours. The railcar site contained a chain-link fence used to cordon off the fumigation area and keep unauthorized personnel away from the fumigation site. An operations center was located in a building directly adjacent to the fumigation site, with an on-site operations station located just outside the fence between the site and the operations center.

The railcar was tented, and circulation fans, heaters, humidifiers, and displacement bladders were installed in the railcar as discussed below.

2.1.1 Tenting of the Railcar

The railcar and transport trailer were placed on a concrete pad at Sandia's campus in Livermore, California. Before placement of the trailer and subway car, a 6-mm-thick, high-diffusion-resistant EVOH tarp with polyester scrim reinforcement (GeoCHEM Inc., Renton, Washington) was placed on the concrete pad under the chassis of the trailer. On Friday, July 10, 2015, site personnel placed another section of EVOH tarp over the top of the railcar, and both tarps were joined together. Before the EVOH tarp was placed over the top of the railcar, 4-inch-diameter, perforated, high-density polyethylene (HDPE) tubing was draped over the top and sides of the railcar, at multiple location, to provide air space between the railcar and the tarp. This tented area allowed simultaneous fumigation of the interior and exterior of the railcar while also reducing the potential for condensation of MB at locations where the tarp and railcar would be in contact.

The bottom and top tarp layers were joined using spray-on glue and by overlapping and rolling adjacent edges together and binding them with plastic-tipped, metal-spring fumigation clamps. The lower edge of the tent envelope was held down on the ground with overlapping 40-pound sandbag "snakes." This process took approximately 2 hours. Figures 2 and 3 show the tented railcar.

Figure 2. Tented railcar with HDPE tubing draped between the tarp and railcar visible as "ribs" under the tarp; MB scale and heater unit shown in foreground

Figure 3. Skirt of EVOH tarp dropped to the ground and weighed down with sandbag "snakes"

Several penetrations into the tented volume were needed to supply electrical power for the fans, heaters, and humidifiers (see Section 2.1.2) through 4-inch-diameter polyvinyl chloride (PVC) pipes. Another penetration was necessary for the scrubber duct inlet, and two 4-inch-diameter PVC pipes also

were used for coupon removal at timed intervals. PVC pipes also were used as conduits for MB introduction from "shooting" hoses (3/4-inch braided, chemical-resistant, high-temperature [149 °C rating], and high-pressure [greater than 200 pounds per square inch] rating) with MB monitoring lines (6.4-mm outer diameter, nylon). After the shooting and monitoring lines were routed through the PVC pipes, voids in the PVC piping and pipe chases were filled and sealed with expanding polyurethane foam.

Timed-series coupons also were placed inside the fumigation envelope for extraction and analysis to determine the number of colony-forming spores recovered from these test coupons for comparison to positive control coupons. The timed-series test coupon holder (PVC-pipe construction) was sealed at its exterior terminus with threaded PVC caps (Figure 4).

Figure 4. Termini of PVC piping used for timed-series coupon extractions

2.1.2 Circulation Fans, Heaters, Humidifiers, and Displacement Bladders

Fans were strategically placed inside the railcar for mixing and to ensure uniform concentration, temperature, and RH conditions throughout the railcar. The area inside the tented volume contained four fans (operating at 3,000 cubic feet per minute [cfm] each), ten 1,500-watt radiant heaters, and four humidifiers (Delonghi, Model EW7707CM, Woodridge, New Jersey). Figure 5 shows a diagram of the fans, heaters, and humidifiers located in the railcar.

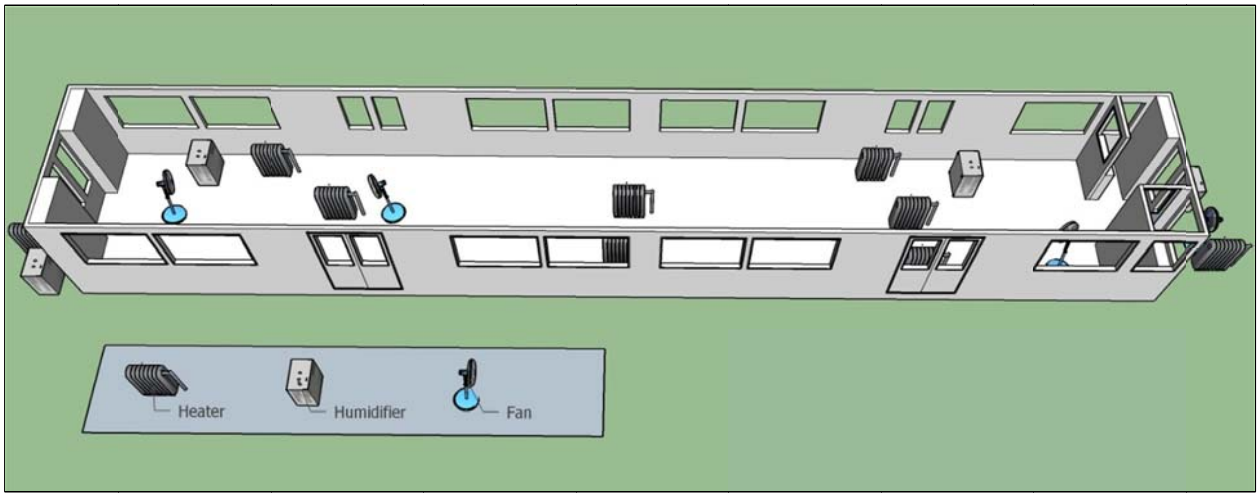


Figure 5. Schematic diagram of railcar showing locations of fans, heaters, and humidifiers

The fans ran continuously during the fumigation process (including during scrubbing and aeration) to maintain temperature and RH equilibrium throughout the railcar and to disperse the MB gas when it was introduced into the fumigation envelope. The power supply for the radiant heaters and humidifiers was on continuously throughout the fumigation process. The heaters, fans, and humidifiers were turned on immediately after the tarp was placed over the railcar and allowed to pre-condition the environment before the introduction of MB. The humidifiers were refilled before the final sealing of the tarp envelope and before fumigation.

The contents within a volume to be fumigated should be factored into the fumigation decision process and may adversely impact the efficacy of the fumigation. Specific contents at a significant quantity, may act as sinks for fumigants, water vapor (humidity), and heat. Fumigant adsorption may be followed by latent desorption (off-gassing) for extended periods of time after fumigation. For example, large amounts of foam may act as a sink for a fumigant, requiring the foam to be removed or additional fumigant to be used to overcome the loss of fumigant to the foam. The interactions between the contents with the fumigant and fumigation parameters dictate actions that may be needed. However, interactions are not always known in advance, and fumigation parameters must be monitored during fumigation to ensure that the parameters necessary for an efficacious decontamination are met and that safe levels are reached after fumigation before reoccupation of the railcar.

Three inflatable Mylar® tubes (IMPAK Corp., Los Angeles, California) were installed along the length of the railcar ceiling (Figure 6) as bladders to displace a portion of the fumigated airspace so that less MB would be needed to reach the target concentration.

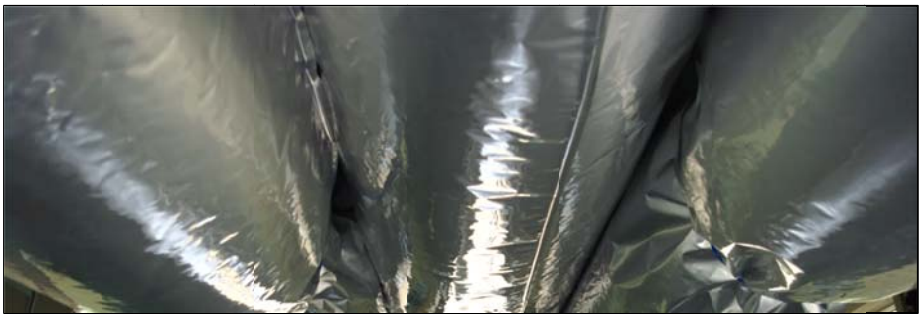


Figure 6. Three displacement bladders suspended from ceiling of the railcar

The 5.6-mm-thick displacement bladders consisted of four layers (Mylar® film, polyethylene, aluminum foil, and polyethylene) designed for food packaging. One end of each bladder was sealed with tape and the other end tape-fitted with a 2-inch-diameter PVC pipe. The pipe was attached to an electric leaf blower, and each bladder was filled with ambient air to near capacity. The PVC pipes were immediately capped. The initial volume displaced by the filled bladders was approximately 920 cubic feet (ft^3) at the beginning of the fumigation.

For this study all interior cabinets and panels were left in the closed position to intentionally challenge the process. However, the standard practice for fumigation is to open as many doors, cabinets, enclosures, etc., to accelerate fumigant movement into these areas. The fumigation envelope was sealed up at around 1500 on Friday, July 10, 2015.

2.2 MB Fumigation Process

The MB used in this study (100%, Meth-O-Gas 100®, Great Lakes Chemical Co., West Lafayette, Indiana) was contained as a liquid in commercial, 100-pound metal cylinders. MB without chloropicrin was used to avoid potential corrosive damage caused by chloropicrin. Because MB has a boiling point of 38.5 °F, heat was added during introduction to ensure that only gaseous MB was released from the end of the shooting hose. Heat was added by using a hose to affix the cylinder valve to a 5-gallon-capacity heat exchanger. The heat exchanger contained a coiled metal tube through which the MB passed. The coil was surrounded by a water/radiator coolant mixture (60:40) heated by a propane burner to 195 °F. The gaseous MB exited the heat exchanger through the shooting hose at about 160 °F and then traveled as a gas through the shooting hose and exited into the shooting bucket inside the railcar. The certified applicator (Clark Pest Control, Concord, California) placed the MB cylinder on a balance and donned a full-face-shield and air-purifying respirator before opening the MB cylinder. All MB released was measured gravimetrically.

The working concentrations of MB during the fumigation were monitored at four locations using a Fumiscope® thermal conductivity detector as shown in Figure 7 (Key Chemical Co., Clearwater, Florida) with an accuracy of approximately ±1 gram per cubic meter of MB.

Figure 7. Fumiscope® used to monitor fumigation MB concentrations

Key Chemical Co. calibrated the monitor with MB in November 2013. Fumiscope® monitoring locations included two locations inside the railcar and two outside the railcar (inside the enclosure). The Fumiscope® was fitted with an air pump to pull the interior MB-laden air through a monitoring line into the instrument, which then gave a near real-time reading of MB concentration. At the conclusion of the 36-hour fumigation, the railcar was aerated. During fumigation and aeration, authorized personnel (licensed California applicators) monitored the MB concentration 24 hours per day.

2.3 Temperature and Relative Humidity Monitoring

Temperature and RH inside the railcar were monitored in real time during the fumigation process, including the aeration phase, using a HOBO temperature and RH monitoring system (Model ZW-03, Onset Computer Corporation, Bourne, Massachusetts). The monitoring system included four wireless sensor nodes spaced throughout the railcar and a router placed on the outside skin of the railcar under the tarp. The wireless system transmitted real-time data to the receiving station located approximately 50 feet from the railcar. Real-time temperature and RH data were collected and displayed on a laptop computer using HOBOware Pro software (Onset Computer Corporation, Bourne, Massachusetts). In addition to the four wireless sensors, HOBO temperature and RH loggers (Model U10, Onset Computer Corporation, Bourne, Massachusetts) were placed adjacent to the 20 test coupon locations inside the fumigation envelope.

2.4 Test Coupon Preparation and Analysis

Before fumigation, multiple test coupons were inoculated with a known amount (about 10^6 CFUs) of surrogate spores (*Ba* Sterne strain). The test coupons were placed in various locations throughout the railcar. The following sections discuss preparation and analysis of the test coupons.

2.4.1 Coupon Preparation

Materials were removed from a subway railcar undergoing renovation. The coupons were cut from those materials to a 10-mm diameter and included the following materials: nylon loop-pile carpet, fiberglass wall paneling, aluminum, rubber flooring, Mylar® on polycarbonate, and vinyl seating (Figure 8).

Figure 8. Material coupons (from left to right): nylon loop-pile carpet, fiberglass wall paneling, aluminum, rubber flooring, Mylar® on polycarbonate, and vinyl seating

The coupon materials were sterilized before inoculation using EtO (Andersen Products, Haw River, North Carolina). Spores of *Ba* Sterne 34F2, the vaccine strain (Colorado Serum Co., Denver, Colorado), were selected as inoculation surrogates for fully virulent *Ba* spores. Spore production procedures were conducted at Yakibou Labs, Inc. (Apex, North Carolina), using proprietary methods. Negative control coupons and field blank coupons (although not guaranteed to be sterile after packaging) remained un-inoculated.

After inoculation, test coupons were allowed to dry at room temperature on a bench and then packaged into custom-sized Tyvek® pouches (Figure 9).

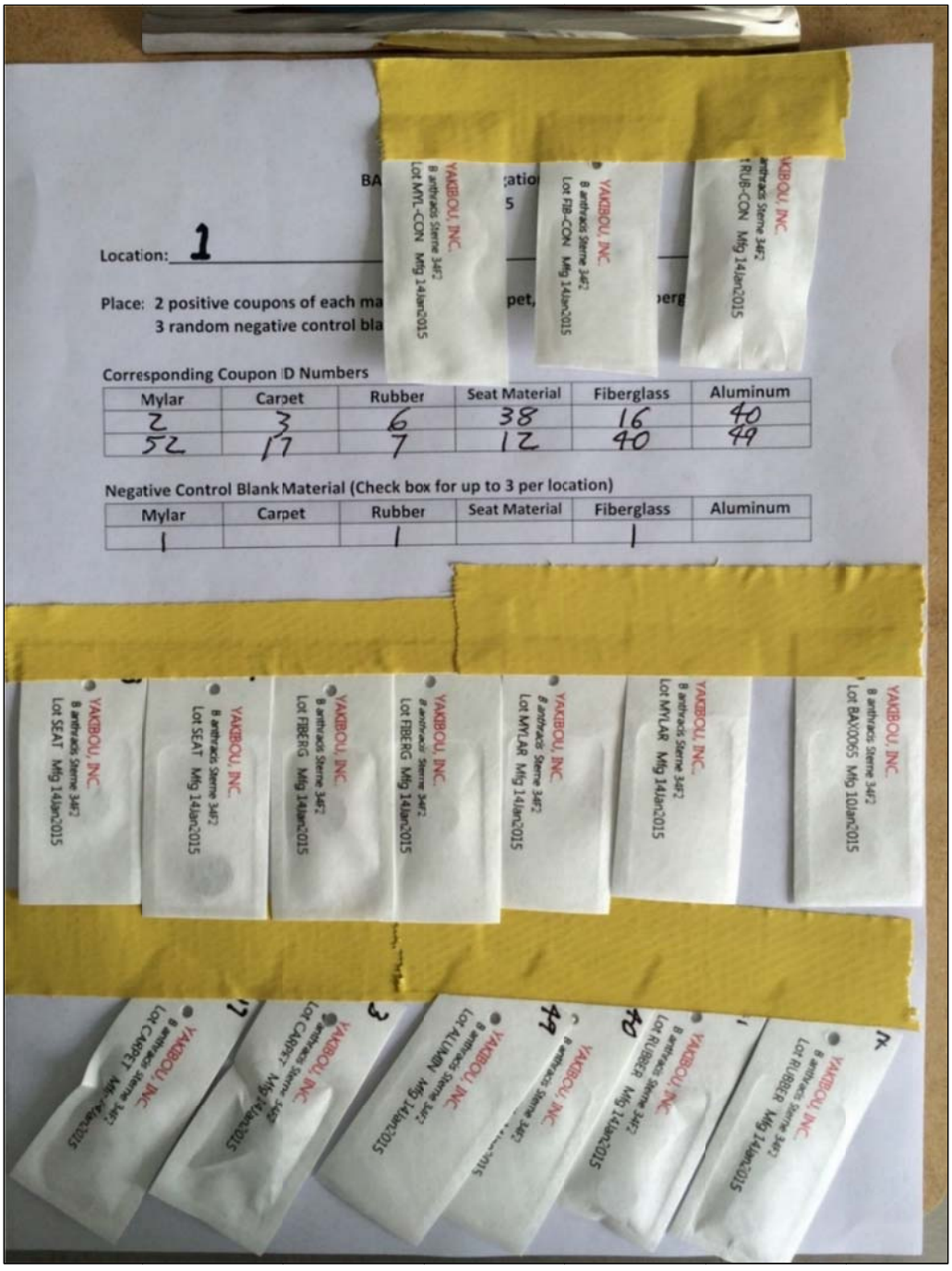


Figure 9. Tyvek® envelopes containing coupons and sample numbers used to track each coupon location and material type

The pouches were heat-sealed to prevent infiltration or exfiltration of spores or particulate contaminants, thereby preventing escape of the spores and maintaining the integrity of the biological indicators (BI) from the surrounding environment. Tyvek® pouches were pre-labeled with an identifier unique to each product type.

Pre- and post-fumigation testing of coupon spore population densities was performed at EPA's NHSRC Research Triangle Park (RTP) Microbiology Laboratory in accordance with methods of procedure (MOP) 6535a, 6565, and 6566 as summarized in Table 2.

Table 2. Pre- and Post-Fumigation BI Population Density Testing

Testing Type	Purpose	Frequency	Quantity	Analysis
Coupon enumeration pre- and post-fumigation	To determine spore population densities on coupons pre- and post-fumigation	one set each material before test and one set after test	23 total: 5 stainless-steel coupons and 3 coupons each of 6 materials tested (for a total of 18)	CFU enumeration

The testing included non-exposed control coupons. Spores were extracted from the coupons, serially diluted 10-fold, and then plated onto tryptic soy agar (TSA) plates. After incubation at 35 °C for 18 to 24 hours, the resulting CFUs were enumerated. The CFU abundance was used to estimate the total spore abundance on the coupons. Triplicate samples of each material type were analyzed for population density before and after the field fumigation. In addition, 10 replicate stainless-steel coupons that were inoculated (by Yakibou, Inc.) at the same time as the other coupons were tested for population density before and after the field fumigation. These stainless-steel coupons were expected to yield more accurate and repeatable estimates of pre- and post-fumigation viable spore population densities than other materials (Calfee et al., 2011) because recovery of spores from stainless-steel surfaces is highly efficient.

2.4.2 Coupon Analysis

Six types of coupons were used during the study to evaluate the efficacy of MB fumigation. These included two types of test coupons as summarized in Table 3: (1) spatial test coupons deployed throughout the fumigated area under the tarp to qualitatively assess spatial fumigant efficacy and (2) temporal (timed-series, collocated) coupons positioned inside the fumigation enclosure (at the extraction port) and collected at specified time intervals to quantitatively assess temporal fumigant efficacy.

Table 3. Test Coupon Types Used to Evaluate the Efficacy of MB Fumigation

Coupon Type	Location	Purpose	Frequency	Quantity	Analysis
Spatial Test Coupons	20 locations inside the fumigated area	To qualitatively assess spatial fumigant efficacy	Once per study	240 total: 40 of each material type	Qualitative (growth or no growth)
Timed-series Coupons	Inside the fumigation enclosure at extraction port	To quantitatively assess temporal fumigant efficacy	One set of samples at 6, 12, 18, 24, and 30 hours (five sets total)	60 total: 2 of each of 6 materials, 5 sets	Enumeration

In addition, four types of control coupons were used during the study: procedural blank, positive control, negative control, and laboratory-sterilized negative control coupons as summarized in Table 4.

Table 4. Control Coupon BI Types Used During the Study

Coupon Type	Location	Purpose	Frequency	Quantity	Analysis
Procedural Blank Coupons Collocated with Spatial Test Coupons	Same 20 locations as test coupons	To undergo fumigation and the determine extent of cross-contamination	Once per study	60 total: 3 coupons per location (20 locations)	Qualitative (growth or no growth)
Procedural Blank Coupons for Timed-Series Coupons	Same locations as timed-series coupons	To undergo fumigation and the determine extent of cross-contamination	One set of samples at 6, 12, 18, 24, and 30 hours (five sets total)	30 total: 1 of each of six materials, 5 sets	Enumeration
Positive Control Coupons	Traveled to study site but remained in sample coolers and were not fumigated	To determine the presence or non-presence of viable spores on non-fumigated coupons	Once per study	39 total: 6 Carpet 7 Fiberglass 5 Aluminum 7 Rubber 7 Mylar® 7 Seating	Qualitative (growth or no growth)
Negative Control Coupons	Traveled to study site but remained in sample coolers and were not fumigated	To determine the presence or non-presence of viable spores on non-fumigated coupons	Once per study	31 total: 6 Carpet 5 Fiberglass 5 Aluminum 5 Rubber 5 Mylar® 5 Seating	Qualitative (growth or no growth)
Laboratory-Sterilized Negative Control Coupons	Laboratory negative control (RTP Microbiology Laboratory only)	To demonstrate sterility of coupons and extraction materials and methods	Twice per study	23 total: 5 stainless-steel coupons and 3 coupons each of 6 materials tested (for a total of 18)	Qualitative (growth or no growth)

Procedural blank coupons were not inoculated but were collocated with the test coupons, both spatial and temporal, during fumigation and were used to determine the extent of cross-contamination from sample to sample during collection. Positive control coupons were inoculated in the same manner as the test coupons but were not exposed to MB. Positive control coupons traveled to the study site but remained in the sample shipment cooler for the duration of the study. Negative control coupons were not inoculated but were packaged in the same manner as the test coupons, traveled to the study site, remained in the sample shipment cooler, and were not exposed to MB. Because procedures required for packaging coupons into envelopes are not strictly aseptic, these coupons were not guaranteed to be sterile. Accordingly, positive growth results from these control coupons should not be interpreted to indicate a compromise in sample integrity through contamination. Lastly, laboratory-sterilized negative control coupons were received from Yakibou, Inc., and autoclaved (1 hour gravity cycle) upon

arrival at the RTP Microbiology Laboratory to sterilize them. These coupons were used to assess the handling technique of laboratory personnel during culturing procedures. Growth from these coupons would indicate compromised sample integrity through contamination within the laboratory.

Qualitative testing of the spatial assessment of efficacy and quantitative testing of the temporal assessment of efficacy are discussed in more detail in the following sections.

2.4.2.1 Spatial Assessment of Efficacy (Qualitative Test)

Two duplicate coupons of each material type (nylon loop pile carpet, fiberglass wall paneling, aluminum, rubber flooring, Mylar® on polycarbonate, and vinyl seating), along with three procedural blanks (non-inoculated coupons of three different materials) were positioned at 20 locations throughout the enclosed fumigation volume before fumigation as shown in Figure 10.

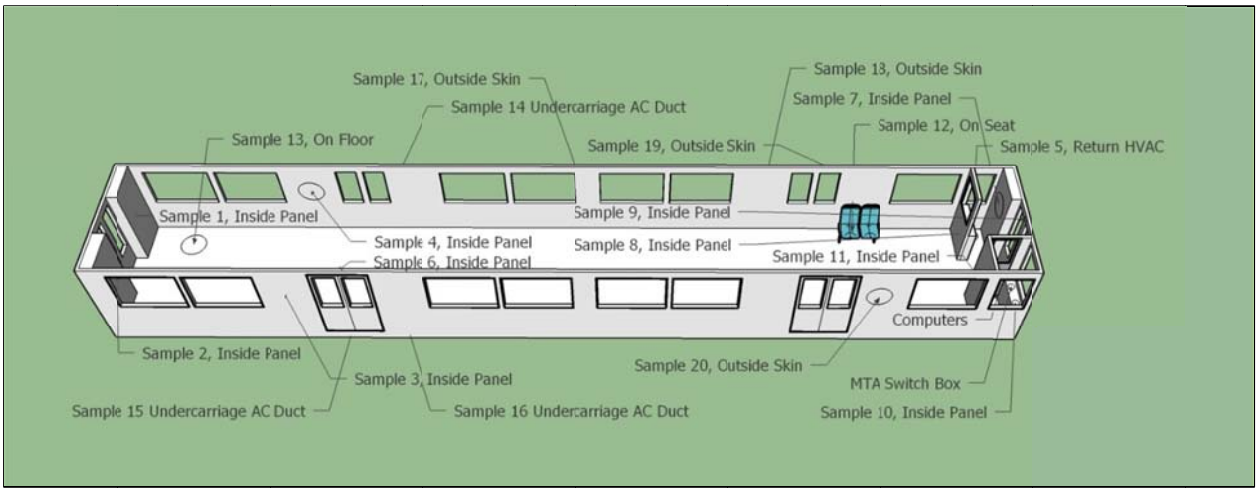


Figure 10. Schematic diagram of railcar showing locations of test coupons

Coupons were placed inside closed panels, outside on the skin of the railcar, and under the railcar. These coupons remained within the enclosed volume during fumigation and were retrieved after the MB air concentration within the fumigated volume was less than 1 ppm. After removal from the fumigated enclosure area, the coupons were aerated, cold-packed, and transported to the RTP Microbiology Laboratory, where they were qualitatively analyzed for surviving spores accordance with MOP 6566. Briefly, the coupons were stored in a biological safety cabinet, then carefully and aseptically removed from Tyvek® envelopes and placed into a bacterial growth medium of 10 milliliters of TSA. Culture tubes, 18- by 150-mm sterile borosilicate glass tubes (Fisherbrand Cat. No. 14-961-31), containing broth and the coupon then were incubated at 35 °C for 7 days. Periodically (on days 1, 3, and 7), the turbidity of the tubes was observed and the results recorded. Turbid media indicated the presence of bacterial growth and therefore incomplete decontamination. Figure 11 shows representative turbid and lucid culture tubes.

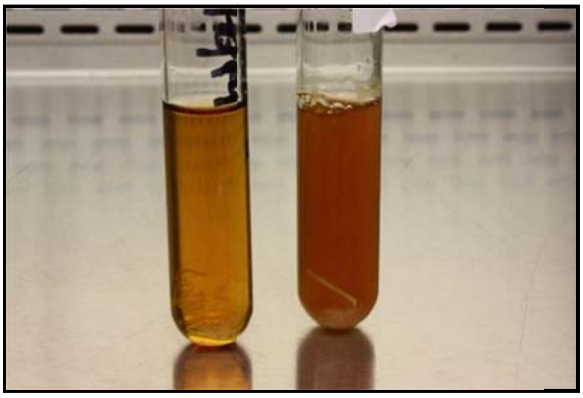


Figure 11. Lucid (left) and turbid (right) culture tubes representing negative and positive growth, respectively

2.4.2.2 Temporal Assessment of Efficacy (Quantitative Test)

To assess fumigation efficacy as a function of time, two replicates of each coupon type (nylon loop pile carpet, fiberglass wall paneling, aluminum, rubber flooring, Mylar® on polycarbonate, and vinyl seating), along with six procedural blanks, one of each material type (non-inoculated coupons), were retrieved from the tented enclosure at 6, 12, 18, 24, and 30 hours into the fumigation process. All coupons for a particular time-point were attached to a spring that held the set of coupons together. The spring was pulled from the extraction point using a string. Samples were allowed to aerate, then they were double-bagged, cold-packed, and transported to the RTP Microbiology Laboratory for extraction and analysis. The laboratory used an aseptic technique to place the coupons into 18- by 150-mm sterile borosilicate glass tubes containing 10 milliliters of phosphate-buffered saline with Tween20 (PBST). Each vial then was sonicated for 10 minutes at 42 kilohertz and 135 watts in accordance with MOP 6566. Then the tubes were continuously vortexed for 2 minutes to further dislodge spores from the coupons. Immediately before dilution or plating, each vial briefly was re-vortexed to homogenize the sample. The resulting extracts were subjected to five sequential 10-fold serial dilutions (MOP 6535a), and 0.1 milliliter of each dilution was inoculated onto TSA plates, spread with sterile beads (MOP 6555), and incubated at 35 ± 2 °C for 18 to 24 hours. After incubation, the CFUs were manually enumerated. Figure 12 shows the *Ba* Sterne strain spore colonies.

Figure 12. Representative dilution plates after incubation containing *Ba* Sterne strain spore colonies recovered from coupons

2.5 Pre- and Post-Fumigation Sponge Stick Sampling

The surrogate spores remained on the test coupons and inside Tyvek® envelops throughout the study (during transportation to the site; distribution, fumigation, and collection processes in the railcar; and transportation back to the laboratory). However, sponge stick samples were collected from surfaces in the railcar before the test coupons were deployed to gain an understanding of background contamination within the railcar and after the test coupons were retrieved at the end of the fumigation aeration cycle to determine if the test organism escaped the Tyvek® envelopes or if other contamination was present on surfaces after the fumigation. Sponge stick sampling was conducted in accordance with MOP 3144 and based on the Centers for Disease Control and Prevention (CDC) protocols (CDC, 2012). A total of 11 sponge stick samples were collected, 4 before and 7 after the fumigation process. Two blank sponge stick samples also were collected.

2.6 Activated Carbon Scrubber System Deployment

An activated carbon scrubber system was leased from General Carbon Corporation (Paterson, New Jersey) and was delivered to the study site on Monday morning, July 13, 2015. The system was unloaded from the truck and staged for subsequent placement and installation. Figure 13 shows the activated carbon scrubber system.

Figure 13. Activated carbon scrubber system installed on the railcar

The scrubber system consisted of two scrubber vessels (General Carbon TV-1000) with each vessel containing approximately 900 pounds of coconut-shell-based activated carbon (General Carbon 4x8S), one 2-horsepower centrifugal blower with damper (Model 00156ES1BD56CFL, Weg Electric Corp., Duluth, Georgia), 50 feet of 6-inch-inner-diameter (ID) flexible rubber ducting with spring steel-reinforced helix, a PVC exhaust stack (6-inch ID and 8 feet tall), various galvanized metal joint fittings, and a plastic ball valve. One extra vessel containing 700 pounds of activated carbon was ordered and placed on site in case of carbon breakthrough of the two vessels. However, the extra vessel never was

used. A WhisperWatt (MQ Power, Carson, California) 60-kilowatt diesel generator provided electrical power to the blower as well as other equipment at the site.

The inlet to the scrubber system was anchored to the floor near the railcar's rear door. The flexible duct dropped down to the concrete pad, where it penetrated the EVOH tarp. This open piece of flexible duct was connected to a ball valve operating in the closed position during fumigation and then opened during scrubbing. Approximately 10 feet of the flexible duct was used to connect the gate valve to the first scrubber, and then an additional 10 feet of flexible duct connected the two scrubbers. In addition, 10 feet of flexible duct connected the outlet of the second scrubber to the inlet of the blower. After traveling through both vessels, the scrubbed gas was exhausted to the atmosphere through an 8-foot-tall stack located on the positive side of the blower. The system air flow rate was 285 cfm. The entire system took two people approximately 6 hours to assemble and shakedown. A similar higher-capacity scrubber used by Serre et al. (2016) was shown to capture more than 99% of MB during aeration (Wood et al., 2015).

2.7 Ambient Air Monitoring

The study team monitored ambient conditions using both wireless air monitoring units and a weather station. Before fumigation began, personnel from the EPA ERT and the Scientific, Engineering, Response & Analytical Services (SERAS) contractor deployed four ambient air monitoring stations strategically around the railcar enclosure. Each station included a RAE System MultiRAE Pro, ERT's VIPER Data Management System for real-time access and analysis, and a SNAPPER air sampling collection system that included a sampling pump, Tedlar® bag, and software that can trigger air sample collection. The MultiRAE Pro used a 10.6-electrovolt lamp photoionization detector (PID) and a wireless radio frequency modem. The PID was calibrated to be responsive to MB using a 1.7 conversion factor[2] (additional information can be found at http://www.raesystems.com/products/multirae-family). The SNAPPER system, upon triggering by the operator, took a 1-minute Tedlar® bag sample. The Tedlar® bag sample then was retrieved and taken to EPA's on-site mobile laboratory, the Portable High-throughput Integrated Laboratory Identification System (PHILIS) laboratory, for MB analysis.

After deployment, the air monitoring units were calibrated at the study site. SERAS calibrated the MultiRAE Pro units using zero air and volatile organic chemical (VOC) standards, (isobutylene at 100 ppm). After unit calibration to the VOC standard, a bump test was conducted using MB gas at 5 ppm to ensure that the units were detecting MB in the 3- to 5-ppm range. If any drift occurred, the units were re-calibrated to ensure accuracy.

2.8 Leak Detection

In addition to the MultiRAE Pro units at the four stationary positions, another two MultiRAE Pro units were used as hand-held detectors for leak testing near the tented enclosure. A team of two or more walked the perimeter of the cordoned-off area around the railcar at least once per hour with a MultiRAE Pro and noted any non-zero readings. When the perimeter readings were below the action level of 0.5 ppm, the team entered the cordoned-off zone (15 feet around the perimeter of the railcar) and approached the enclosure while noting any non-zero readings. When a reading exceeded the action level (0.5 ppm) in the breathing zone of any team member, the team exited the area. To address leaks, SCBAs were donned and leak survey and leak mitigation activities were conducted by

[2] See RAE Systems TN-106 for the proper way to implement a conversion factor. For high concentration initial doses, it may be desirable to use a dilution fitting. See RAE Systems Technical Note TN-167.

personnel wearing appropriate PPE. Readings were taken all the way around the enclosure, including immediately adjacent to the tarp and at tarp penetrations at multiple locations. Elevated readings were reported to the tenting and fumigation contractor for potential leak mitigation.

3 Study Results

This section discusses the study results, including the results for the release and monitoring of MB, railcar temperature and RH, test coupons, sponge stick sampling, the activated carbon scrubber system, ambient air monitoring, leak detection, post-aeration air sampling, and displacement bladder observations.

3.1 Results from Release and Monitoring of the MB

The time and amount of MB released into the railcar is provided in Table 5. Initially, 150 lbs. of MB was introduced into the railcar over one and one-half hours. Two additional increments of MB were added, 20 lbs. (at 2.9-hours) and 15 lbs. (at 23-hours) after the fumigant initially reached the target MB concentration. The concentrations of MB in each of the four locations inside the railcar were monitored at different times and concentration results are shown in Figure 14.

Table 5. Time of MB Releases (lbs.) and Measured Concentrations in Rail Car

Date	Time (hr.)	Elapsed Time (hr.)	Inside Conc. (mg/l)	Lbs. MB
07/10/2015	1630	-1.5	26	20
07/10/2015	1720	-0.7	133	79
07/10/2015	1800	0.0	212	51
07/10/2015	2055	2.9	200	20
07/11/2015	1700	23.0	170	15

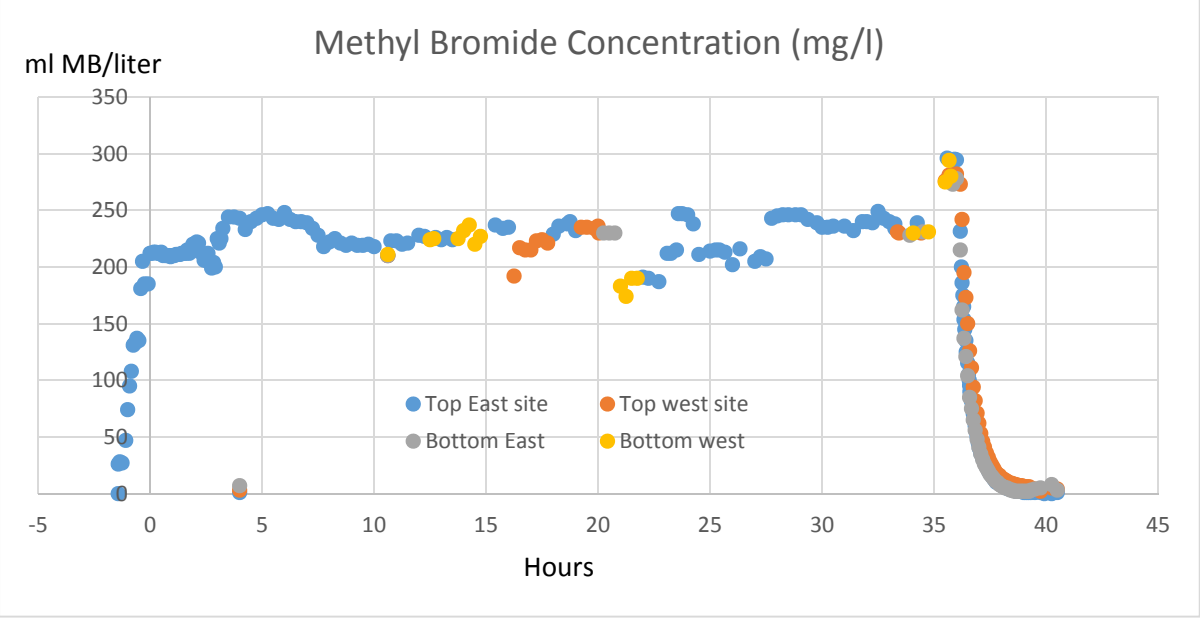


Figure 14. Concentration of MB (mg/l) inside the tented enclosure during fumigation.

3.2 Railcar Temperature and Relative Humidity Results

Radiant heaters and household humidifiers were used to raise the temperature and humidity in the railcar. Table 6 summarizes the average temperature and RH at each coupon location inside the railcar. The average temperature inside the railcar during fumigation was 75.4 °F, and the RH was 82.9%. These values slightly exceed the desired fumigation conditions of 75 °F and 75% RH.

Table 6. Average Temperature and RH at Designated Coupon Locations

Location ID	HOBO ID	Location	Temperature (°F)	RH (%)
1	34	Inside closed panel box, right rear of car	74.2	82.7
2	31	Inside closed panel box, left rear of car	74.0	85.6
3	10	Inside closed panel box, right side of car	73.7	83.2
4	49	Inside closed panel box, left side of car	75.3	83.1
5	20	In return HVAC duct under seat	76.2	82.2
6	11	Inside closed panel box, left above side door	71.8	84.2
7	22	Inside closed panel box, right front of car	76.8	81.3
8	55	Inside closed panel box, right front of car	76.7	80.1
9	47	Inside closed panel box, over front door	76.8	81.8
10	18	Inside closed panel box, conductors room left front	75.4	84.9
11	17	Inside closed panel box, conductors room left back	76.7	78.5
12	57	On seat in car	76.4	82.2
13	24	On floor between seats	74.5	86.0
14	19	Under car in HVAC duct right center of car	75.0	86.5
15	54	Under car in HVAC duct left center of car	74.9	84.9
16	29	Under car in HVAC red duct at center of car	76.4	82.2
17	48	Outside car but inside panel #372 right side of car	75.8	76.3
18	40	Outside car but inside panel #372 right side of car	76.9	78.8
19	3	Outside skin of right side of car	74.7	87.5
20	42	Outside skin of left side of car	75.1	86.7
		Mean	75.4	82.9

Note: HVAC = Heating, ventilation, and air conditioning

3.3 Test Coupon Results

This section discusses the pre- and post-fumigation coupon population comparison, spatial assessment of efficacy (qualitative test) results, and temporal assessment of efficacy (quantitative test) results.

3.3.1 Pre- and Post-Fumigation Coupon Population Comparison

The spore population densities before and after fumigation for the non-exposed test coupons were compared. As shown in Table 7, no significant differences were detected in the population densities.

Table 7. Spore Population Densities on Pre- and Post-Fumigation Control (Non-Exposed) Coupons

BI Coupon Type	Mean Pre-Fumigation Population	Mean Post-Fumigation Population	No. Before and After Fumigation
Stainless steel	2.5×10^6	Not determined	5 before
Nylon carpet	2.0×10^6	1.8×10^6	3 before, 6 after
Fiberglass wall paneling	1.3×10^6	1.4×10^6	3 before, 7 after
Aluminum	2.4×10^6	2.0×10^6	3 before, 5 after

Rubber flooring	2.4×10^6	2.0×10^6	3 before, 7 after
Mylar®	2.3×10^6	1.6×10^6	3 before, 7 after
Vinyl seating	1.2×10^6	1.4×10^6	3 before, 7 after

The abundance of viable spores on non-exposed coupons was similar before and after the field fumigation, indicating that time in storage did not significantly affect the spore titer on the coupons. Recoveries from stainless steel, aluminum, and rubber flooring were within the targeted range (2.0 to 5.0×10^6). However, recoveries from nylon carpet, fiberglass wall paneling, Mylar®, and vinyl seating coupons were lower than the amount inoculated onto these coupons but still resulted in the over 6-log detection capability needed to evaluate the efficacy of the fumigation. These results were expected because recoveries from steel typically are between 75 and 95% of the inoculum, while recoveries from more porous materials historically have been between 1 and 25% of the inoculum. All coupons were inoculated with a population density (as determined by the BI supplier) of 4.2×10^6 CFUs per carrier. Accordingly, the mean recovery efficiencies from stainless steel and other materials were around 60%. The lowest recovery was 29%.

3.3.2 Spatial Assessment of Efficacy (Qualitative Test) Results

Table 8 summarizes the spatial assessment of efficacy results for all 20 coupon locations.

Table 8. BI Results from Spatial Assessment of MB Fumigation Efficacy

Location	Material						Procedural Blanks BIs/Total BIs
	Carpet	Fiberglass	Aluminum	Rubber	Mylar®	Vinyl	
Procedural Blanks (growth-positive BIs/total BIs)							
1	0/2	0/2	0/2	0/2	0/2	0/2	0/3
2	1/2	0/2	0/2	0/2	0/2	1/2	0/3
3	0/2	0/2	0/2	0/2	0/2	0/2	0/3
4	0/2	0/2	0/2	0/2	0/2	0/2	0/3
5	0/2	0/2	0/2	0/2	0/2	0/2	0/3
6	0/2	0/2	0/2	0/2	0/2	1/2	0/3
7	0/2	0/2	0/2	0/2	0/2	1/2	0/3
8	0/2	0/2	0/2	0/2	0/2	1/2	0/3
9	0/2	0/2	0/2	0/2	0/2	0/2	0/3
10	0/2	0/2	0/2	1/2	0/2	2/2	0/3
11	0/2	0/2	0/2	0/2	0/2	0/2	0/3
12	0/2	0/2	0/2	0/2	0/2	0/2	0/3
13	0/2	0/2	0/2	0/2	0/2	0/2	0/3
14	0/2	0/2	0/2	0/2	0/2	0/2	0/3
15	0/2	0/2	0/2	0/2	0/2	1/2	0/3
16	0/2	0/2	0/2	0/2	0/2	0/2	0/3
17	0/2	0/2	0/2	0/2	0/2	0/2	0/3
18	1/2	0/2	0/2	0/2	0/2	0/2	0/3
19	0/2	0/2	0/2	0/2	1/2	0/2	0/3
20	0/2	0/2	0/2	0/2	0/2	1/2	0/3
Total	2/40	0/40	0/40	1/40	1/40	8/40	0/60
Switchbox			0/2				
Positive Controls (growth-positive BIs/total BIs)							
Not exposed	6/6	7/7	5/5	7/7	7/7	7/7	Not applicable
Negative Controls (growth-positive BIs/total BIs)							
Not exposed	0/6	0/5	0/5	0/5	0/5	0/5	Not applicable

As the table shows, none of the 40 fiberglass or 40 aluminum test coupons contained viable spores after fumigation. Out of the 40 coupons of each material type, the following numbers of coupons were positive after fumigation: 2 nylon carpet coupons, 1 rubber flooring coupon, 1 Mylar® coupon, and 8 vinyl seating coupons. No growth on any of the procedural blank (60 total) coupons suggests that contamination did not occur during field or laboratory procedures. All 39 positive-control coupons (inoculated but not exposed) were positive for growth. None of the 31 negative control coupons (not inoculated and not exposed) were positive for growth. The two aluminum coupons inside the New York City switchbox were negative for growth after fumigation.

3.3.3 Temporal Assessment of Efficacy (Quantitative Test) Results

Table 9 summarizes the temporal assessment of efficacy results for the quantitative test of spore survival.

Table 9. Results from Temporal Assessment of MB Fumigation Efficacy

Time Point (hours)	Test No.	Test Coupons and Procedural Blanks (total CFUs recovered)					
		Carpet	Fiberglass	Aluminum	Rubber	Mylar®	Vinyl
6	Test 6	603,500	532,500	588,500	721,000	240,000	611,000
12	Test 12	494,000	347,000	539,000	425,000	543,500	510,500
18	Test 18	186,000	164,500	133,000	184,500	183,850	146,000
24	Test 24	5,300	230	485	186	1,620	97
30	Test 30	0	5	0	0	0	0

Analysis of the time-series coupons showed viable spores (10 CFUs) were recovered during filter plating from only one of the two replicate fiberglass coupons exposed for 30 hours, resulting in an average recovery of 5 CFUs. The remaining 11 coupons of various material types showed zero recovered viable spores. Log reductions (LR) for all BIs during the quantitative temporal assessment portion at 30 hours after exposure were greater than or equal to 6 LR for all coupons except for the fiberglass coupon, which had an LR value of 5.5. At the 24-hour exposure time, efficacy was greater than or equal to 2.5 LR for all coupons.

3.4 Sponge Stick Sampling Results

Table 10 summarizes the results from the surface sponge stick wipe samples.

Table 10. Sponge Stick Sample Recovery Results

Sample No.	Sample ID	Location	Pre- or Post-Fumigation	Recovery of Target Organism (CFUs)
Swab1	S-BCK1	Floor, rear of railcar	Pre	0
Swab2	S-BCK2	Floor, center of railcar	Pre	0
Swab3	S-BCK3	Seating	Pre	0
Swab4	S-BCK4	Ceiling	Pre	0
Swab5	S-BCK5 (blank)	Blank	Pre	0
Swab6	S-P3	Inside panel	Post	0
Swab7	S-P4	Inside panel	Post	0
Swab8	S-P5	Inside panel	Post	0
Swab9	S-P6	Inside panel	Post	0
Swab10	S-P7	Inside panel	Post	0
Swab11	S-P10	Inside panel	Post	0
Swab12	S-P11	Inside panel	Post	0
Swab13	S-P30 Blank	Blank	Post	0

Four pre-fumigation and seven post-fumigation surface wipe samples were collected. An abundance of background organisms were found. However, *Ba* Sterne strain spores were not found on pre- or post-fumigation sponge stick surface wipe samples. The two blank surface samples collected showed no growth based on microbiological analysis.

3.5 Activated Carbon Scrubber System Results

Three activated carbon samples were placed on the inlet side of the first scrubber. Each of the three activated carbon samples was contained in a nylon mesh sock that allowed MB and all other potential contaminants to adsorb into the carbon. One of these carbon samples subsequently was analyzed to verify that the carbon met the regeneration acceptance criteria, which it did.

Once the 36-hour fumigation time had been achieved, the activated carbon scrubber system was used to capture MB from the tented area. MB levels were measured between the carbon vessels and at the exit of the second carbon vessel. This procedure allowed personnel to monitor breakthrough of the carbon beds and connect a third vessel into series, if necessary. Measurements were taken using a MultiRAE Pro Handheld PID (RAE Systems, Santa Clara, California). Figure 15 shows the results.

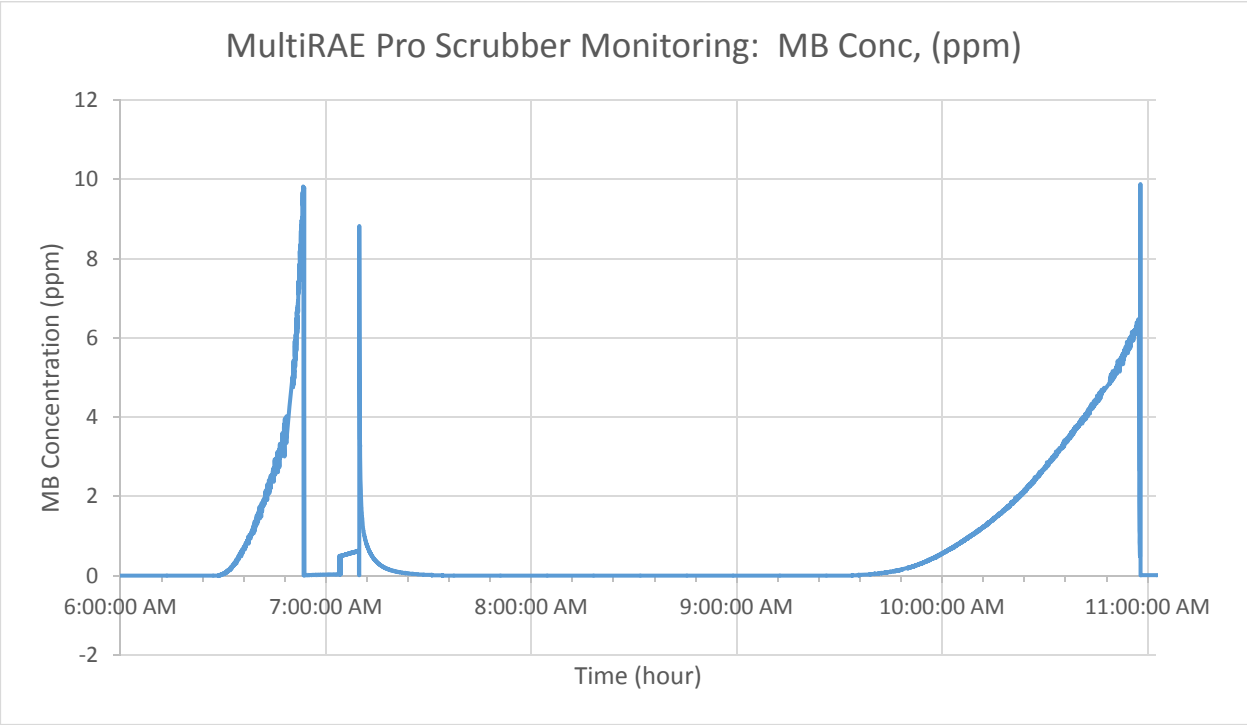


Figure 15. MB concentration between scrubbers and in-stack carbon breakthrough results

Scrubbing was initiated at 0600 on July 12, 2015, with breakthrough on the first scrubber occurring at 0630. The MB concentration in the outlet from the first scrubber was monitored until 0650, when the monitor read 10 ppm (Figure 15). At this time, the monitoring point was changed to the exit stream from the second scrubber. Breakthrough from the second scrubber occurred at approximately 0940. The scrubber operation continued until 1100, when the monitor readout from behind the second scrubber approached 10 ppm.

At the end of active aeration with the scrubber, the air inside the tented area was monitored using the MultiRAE Pro and read 20 ppm. The fumigation contractor pulled the tarp from the railcar at 1200, and the railcar was allowed to aerate for the rest of the day.

3.6 Ambient Air Monitoring Results

Outdoor ambient air was monitored throughout the fumigation process. Perimeter monitoring was continuously conducted during fumigation using four MultiRAE Pro units. The study team used the readings to determine compliance with the 0.5-ppm MB action level during fumigation operations developed for this study. Any readings exceeding the action level triggered the SNAPPER system, which collected a grab sample for analysis by the PHILIS mobile laboratory. The MultiRAE Pro unit readings exceeded 0.5 ppm nine times during the fumigation process, and each time, the SNAPPER system activated the sampling pump to fill a Tedlar® bag. In addition, the SNAPPER system was activated eight other times during the fumigation process to collect background samples. (During background sampling, the MultiRAE Pro units did not exceed 0.5 ppm). After a bag was filled at any of the stationary monitoring locations, it was transported to the on-site PHILIS mobile laboratory for analysis. Table 11 summarizes the PHILIS laboratory results.

Table 11. MB Concentration Results from Tedlar® Bag Air Samples Analyzed by PHILIS Laboratory

Sample ID	Sampling Location and Time	Result	Reporting Limit	Unit of Measure
09851	Location 1 Background SNAPPER 12, 07/10/15, 1325	U[2]	0.500	ppm v/v[3]
09852	Location 2 Background SNAPPER 15, 07/10/15, 1326	U	0.500	ppm v/v
09853	Location 3 Background SNAPPER 22, 07/10/15, 1327	U	0.500	ppm v/v
09854	Location 4 Background SNAPPER 24, 07/10/15, 1328	U	0.500	ppm v/v
09855	Location 1 Hit Linc 40, 440-ppb SNAPPER 12, 07/10/15, 1641	U	0.500	ppm v/v
09856	Location 4 Hit Linc 39, 310-ppb SNAPPER 24, 07/10/15, 1809	U	0.500	ppm v/v
09857	Location 4 Sample Linc 39, 420-ppb SNAPPER 24, 07/10/15, 1910	U	0.500	ppm v/v
09858	Location 1 Sample Linc 12, 300-ppb SNAPPER 12, 07/10/15, 2004	0.79	0.500	ppm v/v
09858	Location 1 Sample 300-ppb SNAPPER (repeat), 07/10/15, 2004	0.71	0.500	ppm v/v
09859	Location 2, 300-ppb Box 15, Linc 133, 07/11/15, 0001	U	0.500	ppm v/v
09860	Location 4, 300-ppb Box 24, Linc 39, 07/11/15, 1208	U	0.500	ppm v/v
09841	Location 1, Box 12 sample, Linc 40, 07/11/15, 1400	U	0.500	ppm v/v
09842	Location 2, Box 15 sample, Linc 133, 07/11/15, 1400	0.79	0.500	ppm v/v
09843	Location 3, Box 22 sample, Linc 127, 07/11/15, 1400	U	0.500	ppm v/v
09844	Location 4, Box 24 sample, Linc 39, 07/11/15, 1400	U	0.500	ppm v/v
09845	Location 1, Box 15, 460-ppb Linc 40, 07/11/15, 1701	0.52	0.500	ppm v/v
09846	Location 1, Box 15, 690-ppb Linc 40, 07/11/15, 1806	U	0.500	ppm v/v
09850	Location 2 SNAPPER 15, 300+ ppb grab, 07/12/15, 1115	U	0.500	ppm v/v

Notes:
U = below reporting limit
ppb = part per billion
ppm v/v = part per million, volume/volume

In addition to the SNAPPER samples triggered by MultiRAE Pro unit readings and the background samples collected, five other samples were analyzed using the PHILIS laboratory. The SNAPPER and background samples were collected in Tedlar® bags and taken to the PHILIS laboratory, where the MB in the bag was collected on carbon, followed by desorption and analysis. The five additional samples were not collected using this conventional method. Instead, they were collected by pulling air directly

into the carbon tube, followed by desorption and analysis of the MB on carbon. Table 12 summarizes the PHILIS laboratory results for these five samples.

Table 12. MB Concentration Results from Additional Samples Analyzed by PHILIS Laboratory

Sample ID	Sampling Location and Time	Result	Reporting Limit	Unit of Measure
09847	Between scrubber and 1 and 2 grab Pump 40, 07/12/15, 0725	3,100	100	ppm v/v
09848	Between scrubber and 1 and 2 grab Pump 40, 07/12/15, 0847	4,200	1,000	ppm v/v
09849	Between scrubber and stack grab 50-ppb Pump 40, 07/12/15, 0940	15	0.500	ppm v/v
09861	Off railcar seats, 07/12/15, 1304	140	5	ppm v/v
09862	Railcar air after fumigation, 07/12/15, 1304	36	5	ppm v/v

Notes:
ppb = Part per billion
ppm v/v = part per million, volume/volume

Three samples were taken from the scrubber air stream, and two samples were taken inside the railcar during aeration. Two of the scrubber samples were pulled well after the MultiRAE Pro registered breakthrough of the first carbon scrubber bed. MB concentration values were 3,100 and 4,200 ppm for these two samples. One scrubber sample was taken in the stack after the second scrubber bed. The time stamp on these samples (Table 12) can be compared to the time stamps on the MultiRAE Pro raw data (no correction factor used) shown in Figure 11. The sample taken in the stack had a reading of 15 ppm and was collected close to the breakthrough time given by the MultiRAE Pro unit at 0940 hours. Results for the two samples taken during aeration are discussed below in Section 3.7.

3.7 Post-Aeration Air Sampling Results

After initial active aeration through the activated carbon, the traps were opened and the railcar was aerated naturally, with the assistance of fans, for 19 hours. Personnel then entered the railcar with a MultiRAE Pro hand-held detector to verify that the MB concentration was below 1 ppm so that personnel could safely enter the railcar to collect the coupons. Subsequently, MultiRAE Pro sampling of locations near the rubber flooring (right at the floor, not near the breathing zone) resulted in readings up to 1 ppm. When the MultiRAE Pro was placed in an opening in the seat cushion fabric (not in the breathing zone), it had a reading above 10 ppm. Additionally, two samples were analyzed by the PHILIS Laboratory as summarized in Table 11. The PHILIS air sample result taken on charcoal carbon from under the seat cover correlates with the elevated MultiRAE reading taken at the same location. However, the result for the railcar air sample analyzed by the PHILIS laboratory did not correlate with the MultiRAE Pro monitor reading of zero throughout the railcar at that same time (see final entry in Table 12).

3.8 Displacement Bladder Observations

After railcar aeration, the Mylar® tubes were observed to have deflated during fumigation and contained some MB. This situation probably resulted from multiple tape-seal leaks that were exacerbated by the turbulent air flow from the circulating fans. The air leaking from the tubes diluted the MB-laden air and thus reduced the working MB concentration during the latter part of the fumigation process. In the future, the Mylar® displacement tubes should be heat-sealed with a “Hot

Jaw" sealer available from IMPAK Corp., and a valve should be used to fill the tubes before they are placed in the area being fumigated.

4 Conclusions and Recommendations

The main objective of this study was to evaluate the operational aspects and the efficacy of MB for inactivating surrogate *Ba* Sterne strain spores on a subway railcar. The study was conducted in an effort to gain large-scale information on the use of MB for the decontamination of *Ba* spores and to develop site-specific plans and guidance that could be modified and used for a real-world incident. At the conclusion of the 36-hour fumigation, the railcar was aerated and test coupons were collected and sent to a laboratory for analysis.

Study results showed that none of the 40 fiberglass or 40 aluminum test coupons contained viable spores after fumigation. Out of the 40 coupons of each material type, the following numbers of coupons were positive after fumigation: 2 nylon carpet coupons, 1 rubber flooring coupon, 1 Mylar® coupon, and 8 vinyl seating coupons. No growth on any of the procedural blank (60 total) coupons suggests that contamination did not occur during field or laboratory procedures. All 39 positive-control coupons (inoculated but not exposed) were positive for growth. None of the 31 negative control coupons (not inoculated and not exposed) were positive for growth.

Timed-series coupons removed from the fumigation envelope at 6, 12, 18, and 24 hours after the start of fumigation all contained viable spores on some materials. LRs from the quantitative temporal assessment portion at 30 hours after exposure were greater than or equal to 6 LR for all coupons except for the fiberglass coupon, which had an LR value of 5.5. At the 24-hour exposure time, efficacy was greater than or equal to 2.5 LR for all coupons.

The sections below discuss conclusions based on study findings for each study objective and presents recommendations based on the study findings.

4.1 Objective 1, Conclusion

Under this objective, a QAPP was developed for the fumigation of a subway railcar using MB for inactivating the chosen non-pathogenic surrogate spores. The QAPP was developed before the July 2015 field study and included a detailed HASP and AAMP. The SAP was incorporated into the QAPP and was not a stand-alone document for this study because most of the sampling was covered by using coupons made from railcar materials designed for this specific study. The HASP and AAMP are included in Appendices B and C, respectively, for modification and use during future incidents.

4.2 Objective 2, Conclusion

This objective was to conduct the fumigation process safely, economically, and effectively. The operational fumigation was conducted safely during July 2015. During the week of July 6, 2015, the activated carbon scrubber was set up, the subway railcar was covered with an EVOH tarp, and fumigation began. To prepare the railcar for this study, humidifiers, heaters, and fumigation equipment were installed. Coupons were placed throughout the railcar on July 10. Fumigation began that afternoon, and MB concentration inside the railcar reached the target concentration at 1800 hours that evening. MB concentration, temperature, and RH were monitored and maintained inside the railcar throughout the 36-hour fumigation period.

4.3 Objective 3, Conclusion

Under this objective, the efficacy of the fumigation was evaluated by measuring the post-fumigation viability of *Ba* Sterne strain spores. To achieve this objective, 40 test coupons were made of each of the following railcar materials: nylon loop-pile carpet, fiberglass wall paneling, aluminum, rubber flooring, Mylar® on polycarbonate, and vinyl seat covering. The coupons were cut into 10-mm-diameter discs and inoculated with approximately 10^6 CFUs per coupon using non-pathogenic *Ba* Sterne strain spores and placed in sterilized Tyvek® envelopes. The coupons were placed in 20 separate locations throughout the railcar before fumigation. Three negative procedural blanks were included at each location. Positive and negative controls of all materials also were taken to the site but did not undergo the fumigation process.

The evaluation of efficacy of the fumigation as measured by the deployment of coupons was successful. Contamination by non-target bacteria was not detected on any of the procedural blank coupons. For this study all interior cabinets and panels were left in the closed position to intentionally challenge the process. However, the standard practice for fumigation is to open as many doors, cabinets, enclosures, etc., to accelerate fumigant movement into these areas. Spatial assessment results show that 228 (95%) of 240 test coupons were completely negative for growth of *Ba* Sterne spores at the end of the 36-hour fumigation period. Based on the temporal assessment, at the 30-hour exposure time point, results show that on 11 of the 12 coupons, the spores were completely inactivated, resulting in a 6-LR efficacy for five of the six materials tested. Overall, the MB treatment was efficacious.

4.4 Objective 4, Conclusion

This objective required evaluating the effectiveness of activated carbon for capturing the MB fumigant during the aeration portion of the fumigation cycle and monitoring MB breakthrough status of the activated carbon during aeration of the railcar and when the railcar MB concentration fell below 0.5 ppm. An activated carbon scrubber system was used at the conclusion of the 36-hour fumigation period and monitored for breakthrough. The scrubber was effectively deployed and used to reduce the MB concentration inside the railcar from approximately 55,000 to 20 ppm in 5 hours. Breakthrough was monitored for both carbon beds set up in series using a MultiRAE Pro instrument.

4.5 Objective 5, Conclusion

This objective was to monitor the effectiveness of MB containment and provide for the health and safety of workers during the entire fumigation process. Ambient air monitoring was conducted by placing PIDs at four stationary locations around the perimeter of the cordoned-off study area. In addition, hand-held monitors with the same technology were used to leak test the tenting materials and to monitor locations not covered by the four stationary monitors. This MB monitoring method was effective and provided a successful health protection measure. MB monitors detected small leaks near the tented area, and leak reduction measures were deployed as needed. Monitoring of the aerated railcar effectively provided health protection for re-entry. However, one PHILIS laboratory air sample reading did not correlate with the MultiRAE Pro unit. This discrepancy requires further investigation. In addition, when the MultiRAE Pro and the PHILIS sampled the seat cushion fabric (not in the breathing zone), reading were above 10 ppm. This result also requires further investigation related to aeration time, reoccupation, and reuse.

4.6 Recommendations

Based on several positive test coupon results from this study, it is recommended that the fumigation of a railcar for *Ba* be extended from 36 to 48 hours and that the temperature, RH, and MB concentration be maintained above the set points of 75 °F, 75% RH, and 212 mg/L, respectively, during the 48-hour fumigation period. In addition, based on the result of eight positive results for the vinyl seat covering coupons, it is recommended that railcar seating material be sprayed down with pH-adjusted bleach before fumigation to aid in the inactivation of *Ba* spores.

After the aeration phase, additional air samples were collected from surfaces in the railcar, and small amounts of MB appeared to be desorbing from some surfaces. Additional investigation is needed to characterize MB desorption from surfaces after fumigation.

This operational study and update of the operational documents improves the capacity of U.S. agencies to respond to and recover from a biological incident in a subway system.

5 References

Calfee, M.W., Y. Choi, J. Rogers, T. Kelly, Z. Willenberg, and K. Riggs. 2011. Lab-Scale Assessment to Support Remediation of Outdoor Surfaces Contaminated with *Bacillus anthracis* Spores. *Journal of Bioterrorism and Biodefense* 2, 1-8.

Centers for Disease Control and Prevention (CDC). 2012. Surface sampling procedures for Bacillus anthracis spores from smooth, non-porous surfaces. Revised April 26, 2012. On-line Address: http://www.cdc.gov/niosh/topics/emres/surface-sampling-bacillus-anthracis.html

Corsi, R. L., M.B. Walker, H.M. Liljestrand, H.F. Hubbard, and D.G. Poppendieck. 2007. Methyl bromide as a building disinfectant: interaction with indoor materials and resulting byproduct formation. *Journal of the Air & Waste Management Association*, 57(5), 576-585.

Hezemans-Boer, M., J. Toonstra, J. Meulenbelt, J.H. Zwaveling, B. Sangster, and W.A. van Vloten. 1988. Skin lesions due to exposure to methyl bromide. *Archives of Dermatology* 124 (6): 917-921. June

International Agency for Research on Cancer. 1986. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans: Some Halogenated Hydrocarbons and Pesticide Exposures. Volume 41. World Health Organization, Lyon.

Jordi, A.U. 1953. Absorption of methyl bromide through the intact skin: A report of one fatal and two non-fatal cases. *Journal of Aviation Medicine* 24, 536-539

Juergensmeyer, M.A., B.A. Gingras, R.H. Scheffrahn, and M.J. Weinberg. 2007. Methyl Bromide Fumigant Lethal to Bacillus anthracis Spores. *Journal of Environmental Health* 69, 24-26, 46, 50.

National Institute for Occupational Safety and Health (NIOSH). 2012. Pocket Guide to Chemical Hazards. Department of Health and Human Services, CDC, and NIOSH.

National Toxicology Program. 1992. Toxicology and Carcinogenesis Studies of Methyl Bromide (CAS No. 74-83-9) in B6C3F1 Mice (Inhalation Studies). Technical Report No. TR-385.

Serre, S., L. Mickelsen, M.W. Calfee, J.P. Wood, M.S. Gray, R.H. Scheffrahn, R. Perez, W.H. Kern, and N. Daniell. 2016. Whole-building decontamination of *Bacillus anthracis* Sterne spores by methyl bromide fumigation. *Journal of Applied Microbiology* 120: 80–89. doi:10.1111/jam.12974

United States Environmental Protection Agency (EPA). 1988. Health Effects Assessment for Bromomethane. EPA/600/8-88/022. Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Office of Research and Development, Cincinnati, OH.

EPA. 2006. Report of Food Quality Protection Act (FQPA) Tolerance Reassessment and Risk Management Decision (TRED) for Methyl Bromide and Reregistration Eligibility Decision (RED) for Methyl Bromide's Commodity Uses. Case No. 0355. EPA 738-R-06-026. August.

EPA. 2011. Systematic Investigation of Liquid and Fumigant Decontamination Efficacy against Biological Agents Deposited on Test Coupons of Common Indoor Materials. EPA 600-R-076. August.

EPA. 2012. Compatibility of Material and Electronic Equipment with Methyl Bromide and Chlorine Dioxide Fumigation. EPA 600-R-12-664. October.

EPA. 2013. Material Effects of Fumigants on Irreplaceable Objects, Short- and Long-term Effects. EPA 600-R-13-216. September.

EPA. 2014. Methyl Bromide Decontamination of Indoor and Outdoor Materials Contaminated with Bacillus anthracis Spores. EPA/600/R-14/170.

EPA. 2015. Methyl Bromide Field Operation Guidance (MB FOG) Report. Consequence Management and Advisory Division. April 13.

Weinberg, M.F., R.H. Scheffrahn, and M.A. Juergensmeyer. 2004a. PART 1: Efficacy of Methyl Bromide Gas against Bacillus anthracis and Allied Bacterial Spores in Final Report: Whole-Structure Decontamination of Bacillus Spores by Methyl Bromide Fumigation. EPA, Small Business Innovation Research Phase II.

Weinberg, M.J., and R.H. Scheffrahn. 2004b. PART 2: Whole-Structure Decontamination of Bacterial Spores by Methyl Bromide Fumigation in Final Report: Whole-Structure Decontamination of Bacillus Spores by Methyl Bromide Fumigation. EPA, Small Business Innovation Research Phase II.

Wood, J.P., M.J. Clayton, T. McArthur, S.D. Serre, L. Mickelsen, and A. Touati. 2015. Capture of methyl bromide emissions with activated carbon following the fumigation of a small building contaminated with a *Bacillus anthracis* spore simulant. *Journal of the Air & Waste Management Association* 65, 145–153.

Yamomoto O, H. Hori, I. Tanaka, M. Asahi, and M. Koga. 2000. Experimental exposure of rat skin to methyl bromide: a toxicokinetic and histopathological study. *Archives of Toxicology* Feb 73 (12): 641-8.

Appendix A. Lessons Learned

As part of the Department of Homeland Security's (DHS) Underground Transport Restoration (UTR) project, several federal agencies conducted a scientific study to evaluate methyl bromide (MB) as a fumigant for decontaminating subway railcars contaminated with *Bacillus anthracis* (*Ba*) using non-pathogenic *Ba* Sterne strain spores. At the conclusion of the project, important lessons were learned. One of the project goals was to document on-site observations and identify areas for potential improvement. These important findings are summarized below.

- When power is not available, redundant emergency power systems are essential. One on-site generator failed before the fumigation began and was replaced before the MB was added to the fumigation envelope.

- Samples should be aerated before shipment to the laboratory for analysis. Low concentrations of MB were desorbing from the Tyvek envelopes after removal from the fumigation zone.

- Most leaks around the system correlated with the removal of the timed-series sample from the fumigation envelope. During an actual event, this leaking may not occur, h However, the time for removing samples should be minimized to reduce the amount of fumigant that escapes the fumigation envelope.

- Adequate make-up air during the scrubbing phase may help expedite the scrubbing. This make-up air should be balanced with the desired space velocity through the carbon. Fresh air pathways are needed to flush out any remaining MB.

- Personnel blood samples should be collected after the fumigation to verify that personnel have not been exposed to MB. Individual air monitors also can be used on personnel entering the hot (exclusion) zone to monitor exposure to MB.

- Additional MB gas monitors are beneficial for multiple railcars. Redundant systems are needed in case a fumiscope fails. Non-dispersive infrared (NDIR) systems are available that are more accurate and less susceptible to positive and negative interferantsinterferents than fumiscopes.

- Additional work is required to study the desorption of MB from materials, especially for materialsfor materials containing closed cell foam.

- Fall protection should be considered for contractors personnel working at heights and/or in areasthat work where falls could occur.

  For this study, all interior cabinets and panels were left in the closed position to challenge the process. However, the standard practice for fumigation is to leave open as many door,

APPENDIX B

U.S. ENVIRONMENTAL PROTECTION AGENCY

CBRNE CONSEQUENCE MANAGEMENT ADVISORY DIVISION
& NATIONAL HOMELAND SECURITY RESEARCH CENTER

SAFETY, HEALTH, AND ENVIRONMENTAL MANAGEMENT PROTOCOL

FOR FIELD ACTIVITIES

referred to as

Health and Safety Plan (HASP)

for

The Field Trial Evaluation of Methyl Bromide Fumigation of a Biological Agent Surrogate in a Rail Car
Livermore, CA
6-15 July, 2015
(Fumigation 11-12 July 15)

Version 1.0

22 June 2015

SAFETY, HEALTH, AND ENVIRONMENTAL MANAGEMENT PROTOCOL
FOR FIELD ACTIVITIES
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina

PURPOSE

To identify site/project specific safety and health hazards related to the proposed methyl bromide (MB) fumigation test of a rail car as part of an underground transit restoration project. Additionally, this plan outlines emergency and environmental management and procedures.

All personnel involved in the project on site, regardless of employer, must read, understand, and acknowledge the contents of this plan.

SCOPE

The project will occur on the US Government property under control of the Department of Energy (DOE), Sandia and Lawrence Livermore National Laboratories. Site specific environmental health and safety requirements under the DOE will have overall precedence. Approval to allow Sterne strain (34F2) on site is authorized in Sandia document IBCPR #:2016-04-29-TW

PART I. PROJECT INFORMATION

Project Title: Methyl Bromide Fumigation of Surrogate Spores *(B. anthracis Sterne*) in a Rail Car

Dates/Duration of Field Activity: 6-15 July, 2015 (Fumigation 11-12 July)

Principal Investigator (PI): Shannon Serre (OEM); Leroy Mickelsen (OEM)

Laboratory, Division, Branch: Office of Emergency Management (OEM)/Chemical, Biological, Radiological, and Nuclear (CBRN) Consequence Management Advisory Division (CMAT); with safety support from Office of Research and Development (ORD) National Homeland Security Research Center (NHSRC)

Site (or Cell): Leroy Mickelsen: 919-937-7011

Field Site Name/Address:
Sandia National Laboratory
Livermore, CA

Site Type:
Federal government facility, national laboratory

National Environmental Policy Act (NEPA) Requirements

Will the project encounter / impact endangered species (plants / animals)? No
Will the project encounter / impact any historic sites (burial grounds, monuments, etc.)? No
Will the project involve drilling, soil samples, or any soil impact? No
Will the project involve any potential uncontrolled impacts to water / air and/or discharges approaching regulatory limits? None anticipated
NOTE: If YES to any of the above, the NEPA process must be completed prior to execution of field study.
ADDITIONAL NOTES:

(1) Structural fumigations using MB has been phased out under the Montreal Protocol and the Clean Air Act because it has been recognized as a stratospheric ozone depleting substance. Critical use exemptions (CUEs) are permitted under Section 604(d) of the Clean Air Act and the Montreal Protocol on Substances that Deplete the Ozone Layer (Protocol). The CUE must be obtained from EPA prior to use of the product. The MB will be contained within the structure during fumigation and scrubbed via a charcoal bed to eliminate intentional discharge to the environment.

(2) This is a joint project, with primary funding from the Department of Homeland Security, Science and Technology Directorate. The NEPA review specific to California requirements has been conducted by Sandia National Laboratories (SNL). SNL is in contact with all state and local authorities and has received appropriate approvals prior to start work.

SUBMITTED BY

PI Signature: _____ **Date: _____**
(Principal Investigator must be an EPA employee)

REVIEW:

NHSRC SHEM: _____ **Date: _____**

APPROVALS

NHSRC: _____ **Date: _____**

(Obtain signatures above prior to sending to the ORD SHEM Office (MD-D343-02 or archer.john@epa.gov)

ORD SHEM Office: _____ **Date: _____**

Acknowledgement:

Required by ALL personnel on site, including visitors, associated with this field study.

(1) I have read, understand, and will comply with the requirements of this site specific HASP;

(2) I will report all accidents, injuries, illnesses, exposures, and/or near misses immediately to the EPA Incident Commander;

(3) I possess current training (including daily safety briefings as required), medical surveillance, and clearances to perform the tasks assigned to me on site;

(4) I will at all times don the appropriate personal protective equipment (PPE) and following appropriate safety protocols/requirements for the tasks engaged in;

(5) I will comply with all Federal, State, Local regulations and site specific policy related to this activity.

NAME (PRINT)	EMPLOYER	SIGNATURE	DATE

PART II. PROJECT INFORMATION

A. Detailed Study Description (Research or Monitoring Protocol should be attached if applicable):

The United States Environmental Protection Agency (EPA) is conducting a project to evaluate methyl bromide (MB) as decontamination tool for mitigating *Bacillus anthracis* (*Ba*) contamination. This work is a component of the Department of Homeland Security (DHS) led and funded Underground Transit Restorations (UTR) program. Lawrence Livermore (LLNL) and Sandia National (SNL) Laboratories have been contracted by DHS to implement a rail car fumigation. EPA is the interagency lead for such activities and will be providing oversight and guidance, and much of the execution. The fumigation contractor will be hired by LLNL. SNL will obtain all required NEPA and state and local environmental permits, as well as provide a site for the fumigation, including site security. The Methyl Bromide Application Services Provider will fumigate a rail car mounted on a flatbed trailer, using MB at 200 - 300 milligrams per liter (mg/L) (51,279 – 77,291 parts per million {ppm}) for 48 hours as described in their Statement of Work. The fumigated rail car will contain surrogate spores that are enclosed in a Tyvek envelope and distributed throughout the structure. Samples of the surrogate spores will be collected at specified time intervals via a collection system outside of the rail car. Upon completion of the 48-hour contact time, the MB will be exhausted through carbon filtration and collected for recycling.

Direct reading, "real time" site monitoring (zone and perimeter) will be conducted by EPA Office of Emergency Management.

The site, although containing elements of Hazardous Waste and Emergency Response Operations (HAZWOPER) practices, is a field research evaluation and not subject HAZWOPER requirements specific to site clean-up.

The site will be attended during 24 hour/day during all active phases of fumigation (generation, contact time, scrubbing) by a minimum of an IC, SO, and monitoring staff.

In addition to EPA/RTP approval for use of *Ba* Sterne as a biosafety level 2 agent, the SNL, California Institutional Biosafety Committee has approved the use for this project under Project Title: Operational Testing Demonstration for Decontamination of a Railcar, Expiration date: 2016-04-29 (See attachment 1, OUO)

The conditions that will be evaluated for the study will be ambient temperature, relative humidity, elevated MB concentrations during fumigation, and increased time as compared to pest control structural fumigations.

The objective of the project is to:

- Conduct the MB fumigation process safely, economically and effectively.
- Monitoring MB concentrations inside the structure during fumigation to assure concentration-time (CT) requirements have been reached and maintained.
- Monitoring temperature (T) and relative humidity (RH) inside and outside the structure.
- Evaluate the efficacy of the fumigation by measuring the viability of surrogate spores placed on throughout the structure to be fumigated.
- Operationalize the use of activated carbon for the capture of the MB fumigant during the aeration cycle of the fumigation and evaluate its effectiveness at this field scale.
- Monitor to ensure the containment of MB and to ensure the safety of workers during the entire fumigation process.
- Assess the breakthrough status of the activated carbon and determine an estimate of fumigant off-gassing for re-entry time calculations.

This project is currently being planned by an interagency planning team and testing is expected to be conducted in mid July 2015 at Sandia National Laboratory outdoor campus, CA.

B. Personnel (List EPA personnel only)

See Attachment 1. EPA Personnel Qualifications

C. Medical Monitoring.

1) All personnel entering the contamination reduction zone (warm zone) or must have received medical clearance to don respiratory protection, up to SCBA, within one year prior to the study.
2) EPA staff likely to enter the contamination reduction zone must receive baseline bromide in urine (or equivalent as directed by board certified occupational and environmental medicine (OEM) physician) evaluation prior to site visitation. Any EPA personnel with likely exposure (even with respiratory protection) must receive post exposure bromide in urine and/or blood follow-up as directed by the site SO or OEM physician. Non EPA staff must be medically monitored in accordance with their employer's occupational health requirements.

D. Location(s) where work will be conducted (include site name and address)

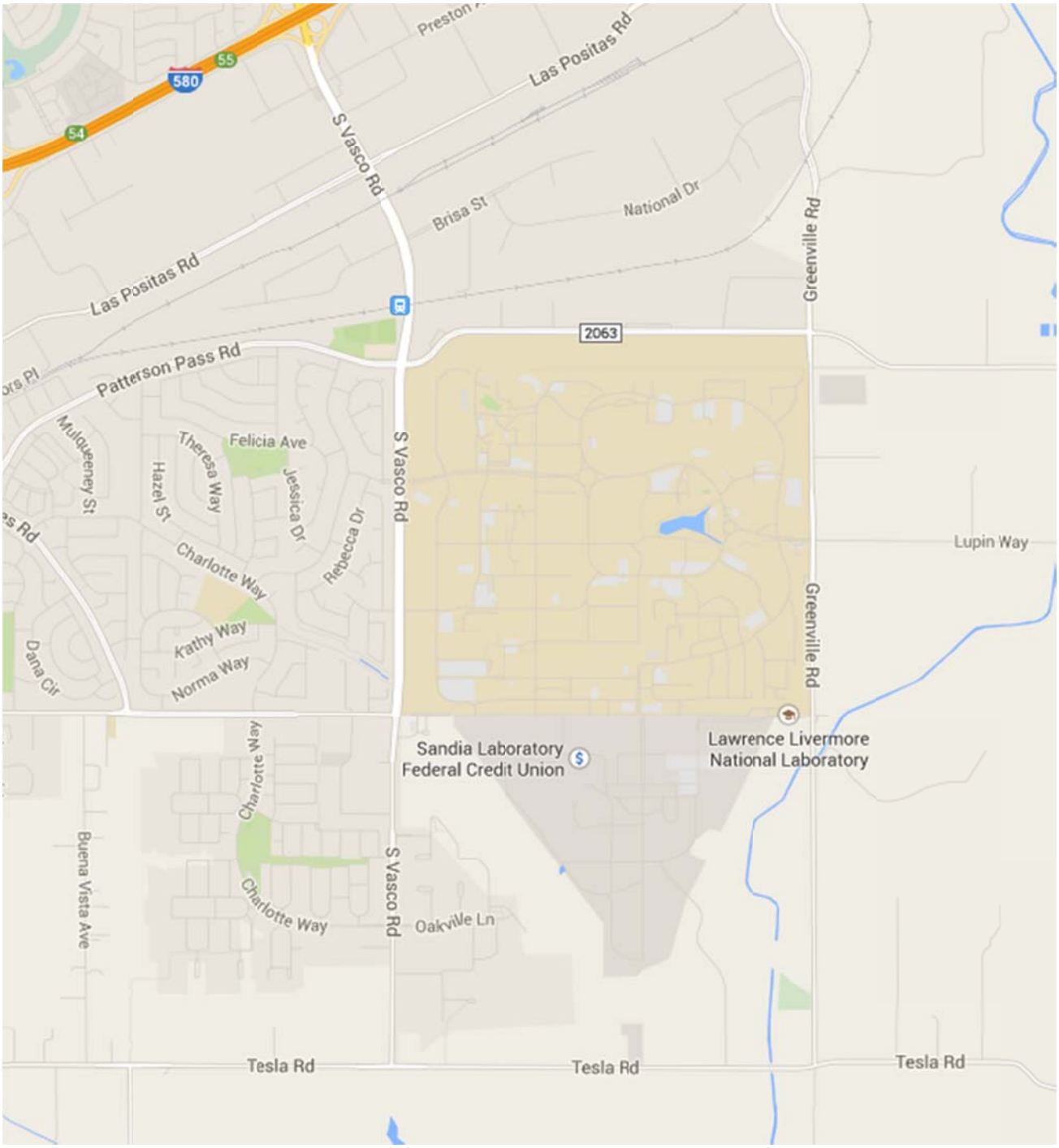
Site Name: Sandia National Laboratory

Address: 7011 East Ave, Livermore, CA 94550

Is this site a remote location __ or an urban setting **X** ?

Will the project require overnight operations? Yes **X** No

Site map identified below.



Will research equipment or other materials be decontaminated in the field? _ Yes _**X**_ No

If yes, describe decontamination procedures and waste generated.

MB fumigation of the rail car. Residual MB after fumigation will be scrubbed through carbon bed filters. Waste materials will include disinfected test surfaces (coupons) with indicator strips (*Bacillus* spores), PPE (non-contaminated), gas cylinders to be returned to vendor, and carbon contained in filtration unit(s) will be returned to vendor for recycling.

E. Contact Personnel for Field Site

Contact Name: Mark Tucker

Title: Program Manager

Phone #: (c) 505-235-6782

F. Transportation

Will a Government vehicle to be taken? _ Yes _**X**_ No

If yes, has the most suitable and fuel efficient vehicle for the task been chosen? _ Yes __ No: NA

Please describe.

If yes, is a first aid kit available? **X** Yes __ No

If yes, is a fire extinguisher available ? **X** Yes __ No

If yes, please list other supplies that will be available.

G. Copies of Forms (Motor Vehicle Accident, Injury/Illness) Available? Yes

H. Identify All Parties Involved in the Field Study:

ORGANIZATION	Federal / Contractor	ROLE	Est Personnel on Site
EPA	Federal	PI, PM, Safety	8
Sandia	Federal/GOCO	Logistics, Security,	2
LLNL	Federal/GOCO	Logistics, Security,	1
University of FL - Davie	State Govt	Fumigation Consultant	3
Clark Pest Control	Contractor	Fumigator	4
Dynamac	Contractor	Support to EPA	1
DHS	Federal	Oversight observation	2

PART III. HAZARD INFORMATION

A. Potential Hazards Encountered during Field Study

Task	Hazard Category	Hazard	Controls	PPE
Site Preparation	Physical	Physical - Climbing/Falling	Training & Education	Leather Gloves Hard hat
		Tarping rail car	Fall Protection	Fall Harness Reflective Vest
Site Preparation	Physical	Physical – Heat Cold	Monitoring	Sunscreen / clothing
		Slips, trips, falls	Site maintenance	
Fumigation	Chemical	Chemical - Gases	Process Isolation	Self-Contained Breathing Apparatus (SCBA) Loose clothing, long sleeve shirt, socks, shoes
		Methyl bromide exposure	Occupy Cold Zone as identified by Monitoring (Default, 50')	
Fumigation	Chemical	Chemical - Gases	Other - List Below	
	Fire/Explosion	Methyl Bromide interaction with incompatible materials	Distance / Initiate 911	
Site Ambient Air Monitoring (within exclusion zone)	Chemical	Chemical - Gases	PPE	SCBA Loose clothing, long pants, socks, shoes.
		Use of instruments to detect gas leaks, potential exposure to concentrations above Threshold Limit Value (TLV)	PPE	
Handling Surrogate Materials	Biological	B. *Anthracis Sterne* (vaccine strain) BSL-2 practices	Other - List Below Containment	N-95 (in event of spill) Nitrile Gloves, Tyvek suit (optional)
Handling Compressed Gas Cylinder	Physical	Physical - Impact	Other - List Below Secure Cylinder, cap on when not in use	Leather gloves Steel toe boots
			Leak/"bubble" test	Safety glasses
Sample collection	Chemical/ Biological	Methyl bromide exposure/ biological surrogate exposure	PPE/ Monitoring	SCBA Tyvek (optional) , Nitrile gloves
Project Oversight	Physical	Physical - Sunburn	Guarding	Sunscreen
Scrubber Operation	Chemical	Gasses, breakthrough of filter	Activated Carbon filtration; monitoring	SCBA (in emergency), loose clothing, long pants, socks,

Task	Hazard Category	Hazard	Controls	PPE
				shoes
	Physical	Noise (diesel generator)	Distance	Ear plugs or muffs

** When respirator is checked, personnel using respirators must have been properly trained and fitted for the respirator within the past twelve months. Individuals using a respirator must be enrolled in the Respiratory Protection Program to remain eligible to wear respiratory protection equipment of any kind.*

See attachment 2 for Site Specific PPE Requirements Summary Table

1. Identify any locations on the site that EPA personnel are restricted from entering. (Note: Employees are not authorized to enter confined spaces.)

Rail car while under fumigation conditions. Hot (Exclusion) zone and warm zone are restricted to personnel with direct task in those areas (i.e., ambient air monitoring, fumigation operations). Approval from Incident Commander is required for any entry.

2. Identify any pre-field visit vaccinations that are necessary.

__ Tetanus

__ Hepatitis A (wastewater)

__ Hepatitis B (blood, body fluids)

__ Other

X None required

NOTE: Pre visit baseline bromide in urine/blood is required for EPA staff who may enter the contamination reduction (warm) or exclusion zone. If any probability of exposure, post visit bromide in urine/blood will be required as an element of occupational exposure assessment.

3. Describe the level of physical exertion required:

__ Low (Office work)

X Moderate (Frequent walking)

__ High (Frequent climbing, lifting)

B. Toxicity of Materials to be Used

1. Will any chemical materials be used that are considered hazardous agents by the ORD Safety, Health, and Emergency Management (SHEM) Office?

A hazardous agent, as defined by the ORD SHEM Office, exhibits one or more of these characteristics:

- Has a lethal dose 50 (LD50) (oral, rat) < 50 mg/kg body weight
- Has an inhalation lethal concentration 50 toxicity (rat) < 2 mg/liter or < 200 ppm
- Has a dermal LD50 toxicity (rabbit) < 200 mg/kg
- Has an occupational exposure limit (Occupational Safety and Health Administration {OSHA}, National Institute for Occupational Safety and Health {NIOSH} or American Conference of
- Is an infectious biological agent (as defined by Centers for Disease Control and Prevention {CDC} and/or National Institutes of Health {NIH})
- Is an explosive or violently reactive agent (shock sensitive, peroxide forming, and/or incompatible with moisture/air)
- Is a sensitizing agent.
- Nanoparticle research involving the use or manufacture of particles (Bucky balls, nano

Governmental Industrial Hygienists {ACGIH}) ≤ 1 ppm • Causes teratogenic or mutagenic effects (in humans or animals)	tubes, quantum dots, etc.) that is not contained in solution and/or with the possibility of airborne exposure. • Is an agent whose toxicological characteristics are unknown, but it is suspected of meeting one of the above criteria

*EXCEPTION: Standards ordered from vendors in sealed vials or ampoules that are used directly in laboratory instrumentation are exempt even if they meet the above criteria.

X Yes __ No If yes, List in the table below:

C. Hazardous Agent(s):

Provide the following information for any hazardous agent that will be taken into the field by EPA personnel. – Note: Methyl Bromide will be delivered to the site by vendor in compressed gas cylinders and any remaining will be picked up by vendor at completion of study.

Material Name	**CAS No.**	**Physical Form**	**Quantity Taken in Field**	**Condition / Method of Storage and Transport**	**DOT Labeling Requirements**
Methyl Bromide (100%)	74-83-9	Gas	200 lbs	Compressed Gas Cylinder	UN 1062; Methyl bromide Division 2.3 - Gases, toxic/poisonous
Bacillus anthracis Sterne (BSL-2)		Solid	1 mg	Sealed, Tyvek envelopes	NA
		Choose an item.			
		Choose an item.			
		Choose an item.			
		Choose an item.			
		Choose an item.			
		Choose an item.			
		Choose an item.			
		Choose an item.			

***Attach a copy of Material Safety Data Sheet (MSDS) for each chemical listed above, or a copy of information found in NIOSH Registry of Toxic Effects of Chemical Substances**

Note: *Ba Sterne* will be handled as a Biosafety Level 2 agent. All Sterne will be delivered to the site in sealed Tyvek coupons, and stored in zip-lock bags prior to placement. Upon sample retrieval coupons will be stored in secondary and/or tertiary containment (zip lock bags inside of sealed container, or secondary container). At no time shall the Sterne be out of controlled custody of EPA staff.

D. Hazardous Waste Disposal

(Fill out the following information only if you are taking materials into the field and anticipate generating waste materials that must be returned to an EPA facility.)

Note: No hazardous wastes are anticipated to be generated. The activated carbon filters will be regenerated and the methyl bromide adsorbed within collected and re-used. Any residual gas in the cylinders will be returned to the vendor for continued use.

Type of Waste Generated	**Waste Volume**	**Time Period (e.g., weekly solvent waste)**	**Any unused stock? (yes or no)**	**If unused stock, will it be kept on site or disposed of?**
Non-regulated PPE	<1 Cubic yard	N/A	No	Kept

E. Occupational Exposure Limits

Agent	**8 Hr Time Weighted Average (TWA) ppm**	**Short Term Exposure Limit (STEL) (15 Min) ppm**	**Ceiling ppm**	**Immediately Dangers to Life or Health (IDLH) ppm**	**Notations**	**Action Levels (based on ambient air monitoring)**
Methyl Bromide	TLV=1 NIOSH = As low as reasonably achievable (ALARA)	-- Excursion* – 3 ppm(ACGIH)	20 OSHA	250 NIOSH	Skin (Liquid absorbs through skin) NIOSH considers MB a potential occupational carcinogen; ACGIH does not*; see International Agency for Research on Cancer (IARC) citation**	0.5 ppm, relocate work area or don SCBA, designate as "Hot Zone"; > 1 ppm, take action to control any leaks, fugitive emissions; Cold & Warm Zone shall be maintained at background or less than detect
Hydrogen Bromide (decomposition product)	3 ppm OSHA 2 ppm (ceiling) TLV	3 ppm (ceiling) NIOS	2 & 3	30		By product
Ba Sterne	Not applicable					

*** -** Excursion Limit Recommendation: Excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during a work day, and under no circumstances should they exceed 5 times

the TLV-TWA, provided that the TLV-TWA is not exceeded.
[American Conference of Governmental Industrial Hygienists. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. ACGIH, Cincinnati, OH 2012, p. 5] **PEER REVIEWED**

** - Evaluation: There is inadequate evidence in humans for the carcinogenicity of methyl bromide. There is limited evidence in experimental animals for the carcinogenicity of methyl bromide. Overall evaluation: Methyl bromide is not classifiable as to its carcinogenicity in humans (Group 3).
[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multi-volume work). Available at: http://monographs.iarc.fr/index.php p. V71 731 (1999)] **PEER REVIEWED**

Note: NIOSH Pocket Guide reports methyl bromide as a potential occupational carcinogen (in conflict with IARC) and thereby established exposure limits as low as reasonably achievable.

F. Symptoms of Exposure

Methyl Bromide
Skin, Eye and Respiratory Irritations:
Contact of the skin with high concentrations of vapor or with liquid methyl bromide produces a tingling & burning sensation.
[Braker W, Mossman A; Matheson Gas Data Book 6th ED p.457 (1980)] **PEER REVIEWED**

Liquid can cause eye and skin burns.
[Tomlin, C.D.S. (ed.). The Pesticide Manual - World Compendium. 10th ed. Surrey, UK: The British Crop Protection Council, 1994., p. 686] **PEER REVIEWED**

Methyl bromide irritates the respiratory tract and in the eye, can cause irritation, tearing, reddening or burning pain.
[Pohanish, R.P. (ed). Sittig's Handbook of Toxic and Hazardous Chemical Carcinogens 5th Edition Volume 1: A-H,Volume 2: I-Z. William Andrew, Norwich, NY 2008, p. 1671] **PEER REVIEWED**

G. Warning Properties
Methyl Bromide:

Usually odorless, sweetish, chloroform-like odor at high concentrations.
[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1041] **PEER REVIEWED**

Methyl bromide has practically no odor or irritating effects in low concentration and therefore does not provide any warning of physiologically dangerous concentrations.
[Braker W, Mossman A; Matheson Gas Data Book 6th ED p.457 (1980)] **PEER REVIEWED**

Burning taste.
[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1041] **PEER REVIEWED**

H. Fire and Explosion

Material	Lower Explosive Limit (LEL)	Upper Explosive Limit (UEL)	Incompatibilities
Methyl Bromide	**10%**	**15%**	Aluminum, magnesium, strong oxidizers. [Note: Attacks aluminum to form aluminum trimethyl which is SPONTANEOUSLY flammable.]
Hydrogen Bromide (decomposition product)	**N/A**	**N/A**	

1. Prior to the start of the field tests with methyl bromide, the local Fire Department (FD) shall be contacted by the Incident Commander or his/her designee to conduct a pre-fire walk-through and inform the local FD of the site hazards.

2. A pre-fumigation inspection must occur prior to the fumigation to remove any oxidizers, aluminum zinc, magnesium products. Information could not be found in the literature identifying the airborne concentrations necessary to initiate spontaneously flammable products. To that end, all preventive precautions must be taken.

3. Local fire and rescue must be readily available during the fumigation in the event of fire, explosion, or catastrophic release.

Fire Potential (MB):
Non-flammable in air, but burns in oxygen.
[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1041] **PEER REVIEWED**

Flame propagation is narrow range of 13.5-14.5% by volume in air.
[Clayton, G.D., F.E. Clayton (eds.) Patty's Industrial Hygiene and Toxicology. Volumes 2A, 2B, 2C, 2D, 2E, 2F: Toxicology. 4th ed. New York, NY: John Wiley & Sons Inc., 1993-1994., p. 4023] **PEER REVIEWED**

Not ordinarily combustible except in the presence of high heat or strong oxidizers.
[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 49-97] **PEER REVIEWED**

Mixtures of 10-15% with air may be ignited with difficulty.
[Lewis, R.J. Sr. (ed) Sax's Dangerous Properties of Industrial Materials. 11th Edition. Wiley-Interscience, Wiley & Sons, Inc. Hoboken, NJ. 2004., p. 2397] **PEER REVIEWED**

Hazardous Reactivities & Incompatibilities (MB): Note: Issues with aluminum related to liquid MB stored in aluminum cylinders (per discussion with manufacturer)
Risk of fire and explosion on contact with aluminium, zinc, magnesium or oxygen.
[International Program on Chemical Safety/Commission of the European Union; International Chemical Safety Card on Methyl Bromide (November 25, 2009). Available as of October 16, 2012: http://www.inchem.org/pages/icsc.htm **PEER REVIEWED**

Aluminum, magnesium, strong oxidizers. [Note: Attacks aluminum to form aluminum trimethyl which is SPONTANEOUSLY flammable.]
[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg **PEER REVIEWED**

Metallic components of zinc, aluminum and magnesium (or their alloys) are unsuitable with **bromomethane** because of the formation of pyrophoric Grignard-type compounds. A severe explosion is attributed to ignition of a **bromomethane**-air mixture by pyrophoric methylaluminum bromides produced by corrosion of an aluminum component.
[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 155] **PEER REVIEWED**

Forms explosive mixtures with air within narrow limits at atmospheric pressure, but wider at higher pressure.
[Lewis, R.J. Sr. (ed) Sax's Dangerous Properties of Industrial Materials. 11th Edition. Wiley-Interscience, Wiley & Sons, Inc. Hoboken, NJ. 2004., p. 2397] **PEER REVIEWED**

Attacks aluminum to form spontaneously flammable aluminum trimethyl. Incompatible with strong oxidizers, aluminum, dimethylsulfoxide, ethylene oxide, and water. Attacks zinc, magnesium, alkali metals and their alloys. Attacks some rubbers and coatings.
[Pohanish, R.P. (ed). Sittig's Handbook of Toxic and Hazardous Chemical Carcinogens 5th Edition Volume 1: A-H,Volume 2: I-Z. William Andrew, Norwich, NY 2008, p. 1670] **PEER REVIEWED**

PART IV. EMERGENCY PROCEDURES

This information must be coordinated with representatives from the field site. This refers to the emergency procedures dictated by the site personnel.

A. In the event of an accident or chemical/biological spill:

1. Describe procedures in event of personal exposure (inhalation, ingestion, inoculation, asphyxiates, flammables, corrosives, etc.):

MB or Hydrogen Bromide (HBr) exposure – remove to cold zone for fresh air. Document with IC and follow-up with medical treatment as necessary.

In event of tear or leakage from *Ba Sterne* coupon, evacuate area and don N-95, Tyvek coveralls, eye protection to prepare for decontamination.

2. Describe plans for containment to prevent spread of the agent from the immediate area, decontamination procedures and monitoring methods to assure decontamination.

MB will be contained in compressed gas cylinders and building "tented" during fumigation. Effluent from fumigation will be subjected to scrubbing via charcoal filtration. Area ambient air monitoring will be conducted throughout the fumigation and any leaks immediately addressed.

In event of accidental release of Sterne, don PPE (above) and decontaminate with 1/10 hypochlorite solution.

3. Describe the procedures for emergency evacuation of the facility.

The Incident Commander (IC) or Safety Officer (SO) will activate an alarm by producing three blast from an air horn. All personnel MUST evacuate upwind of the site to the pre-designated assembly area.

A. Activate 911, all personnel evacuate downwind to the emergency evacuation assembly point for individual accountability check.
B. Assembly points will be designated daily (based on wind conditions), posted on-site, and discussed during daily safety briefings.

B. In the event of a medical emergency:

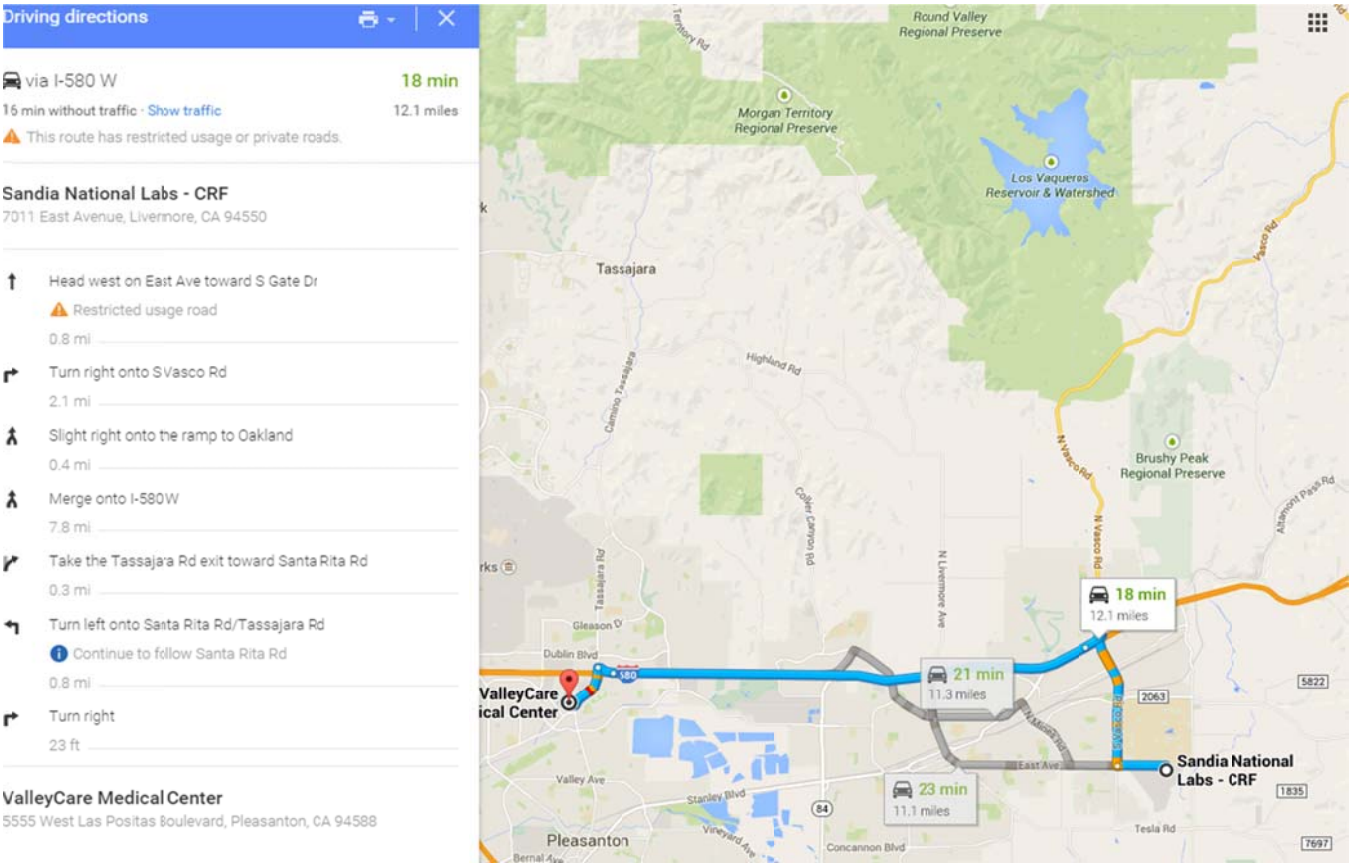
1. Emergency phone number (Is 911 available or does facility have its own medical emergency number)? Yes

2. Is response by EMS available? Yes

3. Include the hospital name, address, phone number **and** location relative to the site **if EMS crew will not be available** to provide emergency transportation.

Hospital: ValleyCare Hospital
Address: 5555 W. Los Positas Blvd, Pleasanton, CA 94588
Phone #: 929-847-3000

,
*Please attach (copy and paste) map or directions for first response hospital closest to site:



4. Is first response hospital equipped to handle:
   - o Burns? Yes
   - o Chemical splashes (skin, eye, respiratory)? Yes
   - o Chemical burns? Yes
   - o Severe trauma? Yes
   - o Insect stings, bites, etc. Yes

C. In the event of a FIRE:

1) The IC or SO will activate emergency evacuation by sounding three blasts from an air horn.
2) All personnel, must evacuate to the pre-designated assembly area for accountability.
3) Activate 911
4) If small scale, may be extinguished on site with extinguisher by trained staff.

D. In the event of an EARTHQUAKE:

1) Stay inside if you are inside; stay outside if already outside.
2) If outside, stay away from buildings, utility wires, fuel and gas lines.
3) If sufficient warning, close valves to active Methyl Bromide cylinders and propane heater tank.
4) Outside: Move to your hands and knees, away from structures; Inside: take cover under an object such as a table, lay down, and cover your head and neck with your arms/hands.
5) If driving, pull over as quickly and safely as possible, away from utility poles, overhead wires, overpasses, or underpasses. Turn on radio to listen to emergency broadcasts. If power line fall on vehicle to move leave the vehicle until trained personnel arrive.
6) After the event assemble for individual accountability.

PART V. SITE MONITORING

A. Ambient air area monitoring will be performed in accordance with the project Ambient Air Monitoring Plan.

B. Personnel monitoring is the responsibility of the individual's employer. EPA with the potential to exposure at or above 0.5 ppm MB will be required to be monitored at the discretion of the site Industrial Hygienist**.**

PART VI. SITE MANAGEMENT / Security

A. The general site shall be controlled at all times during fumigation and until such time as the facility is cleared for re-entry at post fumigation. **NO ENTRY** shall be permitted into the test house at any time while under containment for fumigation.
   1. Entry post fumigation may occur when monitoring demonstrates a concentration at 5 ppm or less. The minimum PPE for entry into the no entry zone after fumigation (when concentrations below 5 ppm MB) shall be SCBA, loose fitting clothing, long pants, socks, no jewelry. No PPE is required when airborne concentrations are below 0.5 ppm.
   2. Approval to enter must be granted by the site incident commander or his/her designee.

   NOTE: In the event of unanticipated emergencies such as detached delivery systems, etc. that operationally necessitate entry:
      a. Approval must be granted by the site safety officer for any entry above 5 ppm.
      b. Level A shall be used, including a buddy system, back-up responders, and continuous communications.
      c. The level A ensemble must be rated for Methyl Bromide (breakthrough time greater than 480 mins).

B. The EXCLUSION ZONE (Hot Zone) is the area with actual or potential contamination and the highest potential for exposure to hazardous substances**.**
   1. The exclusion zone shall be established in areas where MB concentrations may reach or exceed 0.5 ppm.
   2. The minimum PPE for entry into the exclusion zone is: SCBA, loose fitting clothing, long pants, socks, no jewelry.
   3. Approval to enter the exclusion zone must be granted by the site incident commander or his/her designee.
   4. Either visual observation, a buddy system, or communications must be maintained at all times when in the exclusion zone.

C. **The CONTAMINATION REDUCTION ZONE** (Warm Zone) is the transition area between the exclusion and support zones. This area is where responders enter and exit the exclusion zone and where decontamination activities take place.
   1. Airborne concentrations of MB must be less than 0.5 ppm at all times in this zone.

D. **The SUPPORT ZONE** (Cold Zone) is the area of the site that is free from contamination and that may be safely used as a planning and staging area, including incident command.
   1. This area shall be established upwind of the operations.
   2. Continuous monitoring shall be conducted in accordance with the AAMP and the site relocated if contaminant levels above background are repeatedly detected.
   3. Airborne concentrations should be maintained at background, or less than detect at this site.
   4. In the event of wind change, or contaminants entering the support zone, the support zone location will be moved to an area free of contaminants.

E. **Restriction of Personnel** shall be limited to only those individuals involved in the project, providing project support, or approved by the Incident Commander.

F. **Visitor's access** shall be limited to the support zone unless approved by the incident commander and Safety Officer. Visitors entering the Contaminant Reduction Zone or Exclusion Zone must demonstrate a bona fide need to enter, along with SCBA training and medical monitoring.

PART VII. MANAGEMENT OF SPILLS OR LEAKS

A. Small scale – the highest probability of small scale leaks involve joints/ connections in the compressed gas delivery system, as well as any leaks from the containment tent.

1. Prior to initiating fumigation with MB, the compressed gas distribution system must be pressure tested using an inert gas (N, He, Compressed Air). Each pipe joint must be "soap tested" to identify and stop any leaks prior to fumigation.
2. If leaks occur during fumigation, staff must don SCBA, as PPE during abatement actions. A "buddy system" must be used by providing visual back-up, ready for SCBA entry, as needed (one person in exclusion zone, one visual back-up ready to enter with SCBA).

B. Moderate scale leaks – include breakthrough in the carbon filtration system.
   1. Leaks producing uncontrolled discharge of greater than 5 ppm MB shall initiate system shutdown and abatement action as appropriate.
   2. Abatement must include two personnel in SCBA, loose fitting clothing, including long sleeve, long pants, and nitrile gloves with two personnel assigned as back-up in the same level of PPE.

C. Uncontrolled, Catastrophic Release
   1. Level 1 – Broken distribution line in fumigation delivery system.
      a. Shut down system
      b. Concurrently notify Incident Commander to determine whether site evacuation is necessary.
   2. Large scale uncontrolled release, fire or explosion, loss of containment.
      a. Shut down system if possible.
      b. Initiate emergency evacuation of site.
      c. Concurrently notify 911 for emergency response and possible community evacuation.

PART VIII. EMERGENCY EVACUATION

See also Part IV above, Emergency Procedures

Evacuation assembly areas will be established and posted on site based on wind and other site specific conditions. Assembly areas will be discussed during daily safety briefings. Evacuation drill will be conducted at the discretion of the IC and/or SO.

Evacuation procedures are as follows:

1. An "air horn" will be activated by the Incident Commander or his/her designee. The evacuation alarm shall be three, one second audible blasts, at one second intervals. There shall be a five second delay, and the alarm repeated.
2. Staff must secure operations as necessary, without putting themselves at risk, and immediately report to the evacuation assembly area.
3. A "by name" head count shall be conducted by the Incident Commander or his/her designee. If staff are not present or accounted for, the information must be conveyed to local emergency response to determine if rescue is necessary.

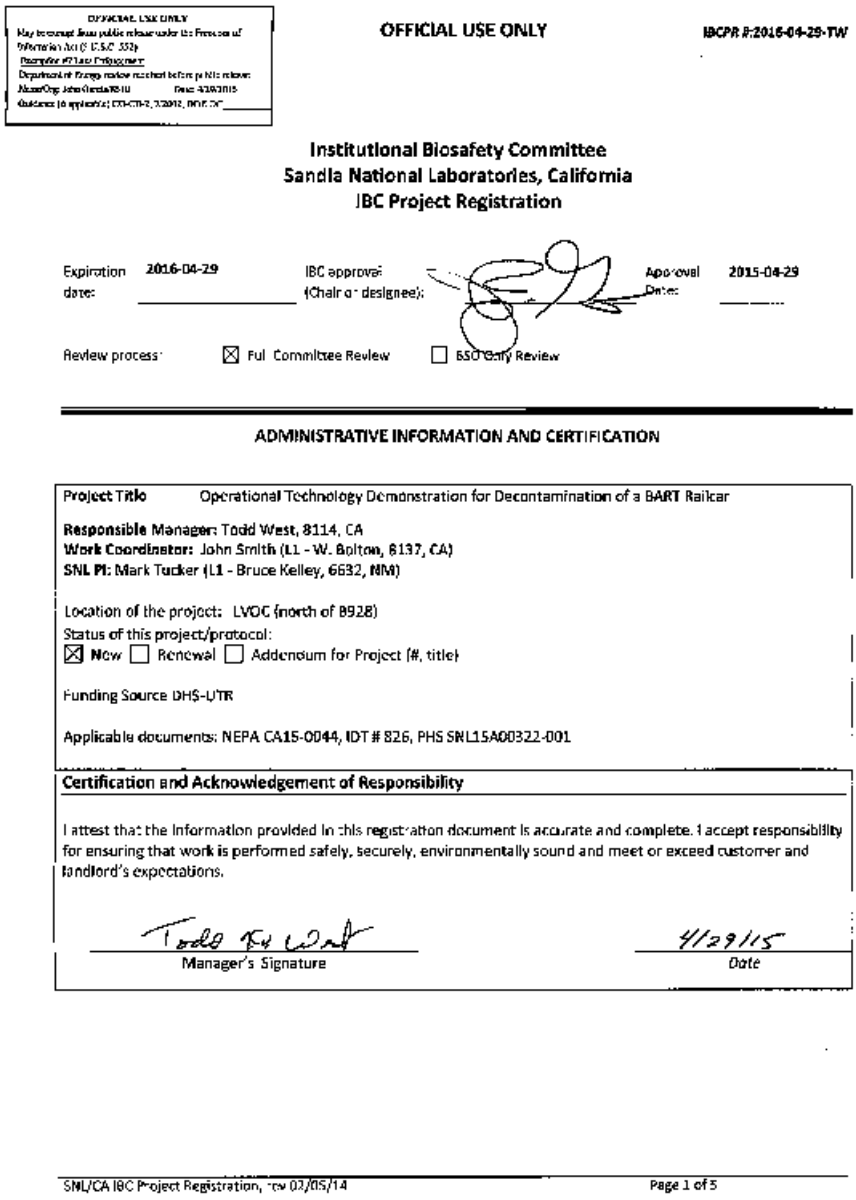
ATTACHMENTS

1) SNL CA Institutional Biosafety Committee Approval Cover Page
2) EPA Personnel Qualifications Table
3) Site Specific PPE Requirements Summary Table
3) IPCS Methyl Bromide Data Sheet
4) Hazardous Substance Data Bank Methyl Bromide document
5) Hazardous Substance Data Bank Hydrogen Bromide document
6) Centers for Disease Control and Prevention, Anthrax Sterne information document

LIST OF ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
ALARA	As Low As Reasonably Achievable
Ba	Bacillus anthracis
CDC	Centers for Disease Control and Prevention
CMAT	CBRN Consequence Management Advisory Team
CUE	Critical use exemption
CT	Concentration-time
DATS	Decontamination Analytical and Technical Services
FD	Fire Department
ft	Feet
HASP	Health and Safety Plan
HBr	Hydrogen Bromide
IARC	International Agency for Research on Cancer (World Health Organization)
IDLH	Immediately Dangerous to Life or Health
lbs	Pounds
LD	Lethal Dose
LEL	Lower Explosive Limit
MB	Methyl Bromide
mg/L	Milligrams per liter
MSDS	Material Safety Data Sheet
NEPA	National Environmental Policy Act
NHSRC	National Homeland Security Research Center
NIH	National Institutes of Health (US)
NIOSH	National Institute for Occupational Safety and Health
OEM	Office of Emergency Management (EPA)
ORD	Office of Research and Development
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
ppm	Parts per million
RH	Relative Humidity
SCBA	Self Contained Breathing Apparatus
SHEM	Safety, Health, and Emergency Management
STEL	Short Term Exposure Limit
T	Temperature
TBD	To be determined
TLV	Threshold Limit Value
TWA	Time Weighted Average
UEL	Upper Explosive Limit

Attachment 1, SNL CA Institutional Biosafety Committee Approval Cover Page



OFFICIAL USE ONLY

May be exempt from public release under the Freedom of Information Act (5 U.S.C. 552)
Exemption number and category:
Department of Energy review required before public release
Name/Org: John Smith/8888 Date: 4/29/2015
Guidance (if applicable): DOE-HDBK-3010-2000, DOE OC

OFFICIAL USE ONLY IBCPR #:2016-04-29-TW

Institutional Biosafety Committee
Sandia National Laboratories, California
IBC Project Registration

Expiration date: 2016-04-29 IBC approval (Chair or designee): Approval Dates: 2015-04-29

Review process: ☒ Full Committee Review ☐ BSO Only Review

ADMINISTRATIVE INFORMATION AND CERTIFICATION

Project Title Operational Technology Demonstration for Decontamination of a BART Railcar

Responsible Manager: Todd West, 8114, CA
Work Coordinator: John Smith (L1 - W. Bolton, 8137, CA)
SNL PI: Mark Tucker (L1 - Bruce Kelley, 6632, NM)

Location of the project: LVOC (north of B928)
Status of this project/protocol:
☒ New ☐ Renewal ☐ Addendum for Project (#, title)

Funding Source DHS-UTR

Applicable documents: NEPA CA15-0044, IDT # 826, PHS SNL15A00322-001

Certification and Acknowledgement of Responsibility

I attest that the information provided in this registration document is accurate and complete. I accept responsibility for ensuring that work is performed safely, securely, environmentally sound and meet or exceed customer and landlord's expectations.

Todd W West — Manager's Signature

4/29/15 — Date

SNL/CA IBC Project Registration, rev 02/05/14 Page 1 of 5

Attachment 2, EPA Personnel Qualifications Table

NOTE: Each signatory certifies the statement below:

"*I have reviewed this Safety Health and Environmental Management Protocol for Field Activities and agree to comply with all procedures and protective measures outlined in the protocol.*"

Name	*Medical Monitoring	Respirator	*Field Activity Training	*First Aid	*AED/ CPR	*HAZWOPER	Biosafety Training
Shannon Serre		7/2014	4/2013	4/2013		6/2015	4/2015
Leroy Mickelsen		11/2014				6/2015	4/2015
Elise Jakabhazy							
Mike Nalipinski							4/2015
Larry Kaelin							
Chris Gallo	5/2015		2/2015	2/2015	2/2015	2/2015	
Marshall Gray	6/2015	11/2014	11/2013	6/2014	6/2014	6/2015	4/2015
John Archer	2/2015	10/2014			7/2013	6/2015	2/2015
Francisco Cruz	07/2014		09/2014	01/2015	01/2015	08/2014	

**Indicate if personnel are: 1) Participants in the Occupational Medical Surveillance (Medical Monitoring) Program and 2) Up-to-date in Field Activity Safety Training and/or any other training.*

(1) Non RTP, EPA OEM Employees

If no, provide explanation in Comments section below.

Comments

1) Site specific training will be provided by Safety Officer for HAZWOPER only trained personnel.
2) Bios safety training required for staff handling Ba Sterne coupons

ATTACHMENT 3 Site Specific PPE Requirements Table

PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS FOR UTR FUMIGATION PROJECT

6 – 15 JULY 2015, LLNL/SNL, CA

	Handling Cylinders or items over 50 lbs	**Site Set-up**	**Ambient Air Monitoring**	**Ba Sterne Coupon Placement/ Retrieval**	**Near Filter Fan / Noise Haz Areas above 85dBA**	In direct sunlight	Entry under Fumigation Conditions-*
Foot Protection	X	X					
Hard Hat		If overhead hazards on site					
Eye Protection	Face Shield	X		Safety glasses			
Hearing Protection							
Nitrile Gloves				X (double)			
Leather Gloves	X	As applicable					
N-95				X (If spill/leak)			
Tyvek Coveralls							
SCBA			If concentration > 0.5ppm MB				X
Level A Suit							Rated for MB
Sun Screen/Covered Skin		X				X	

*- Entry into the rail car under fumigation conditions is not planned or anticipated. However, if real-time situation mandates an entry for some reason it must be at “level A”, approved by the safety officer and IC under stringent condition (2 enter, 2 back-up, constant communications, limited time, etc.).

X

X

Appendix C

U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL HOMELAND SECURITY RESEARCH CENTER
AND CBRNE CONSEQUENCE MANAGEMENT TEAM

Ambient Air Monitoring Plan
For the Field Study of Methyl Bromide Rail Car Fumigation

June 26, 2015

LIST OF ABBREVIATIONS AND ACRONYMS

AAMP	Ambient Air Monitoring Plan
ACGIH	American Conference of Governmental Industrial Hygienists
Ba	Bacillus anthracis
BI(s)	Biological Indicator(s)
CDC	Centers for Disease Control and Prevention
CFM	Cubic Feet per Minute
CMAD	CBRN Consequence Management Advisory Division
CT	Concentration x Time
°C	Degrees Celsius
EPA	United State Environmental Protection Agency
ERT	Environmental Response Team
ERT	Environmental Response Team
ft	
HBr	Hydrogen Bromide
HSAP	Health, Safety, and Emergency Response Plan
HVAC	Heating, Ventilation, and Air Conditioning
IDLH	Immediately Dangerous to Life or Health
in.	Inch
lbs/hr	Pounds Per Hour
m	Meter(s)
MB	Methyl Bromide
mg/L	Milligrams per liter
mg-hr/L	Milligrams-hour per liter
MSDS	Material Safety Data Sheet
NHSRC	National Homeland Security Research Center
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Level
PHILIS	Portable High Throughput Integrated Laboratory Identification Systems
ppb	Parts per billion by volume
ppm	Parts per million by volume
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RAP	Remedial Action Plan
RH	Relative Humidity
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedure
STEL	Short Term Exposure Limit
TLV	Threshold Limit Value
TWA	Time Weighted Average

Table of Contents

1 Introduction

This Ambient Air Monitoring Plan (AAMP) describes the air monitoring procedures that will be employed during a rail car methyl bromide (MB) fumigation study. Ambient air will be monitored for potential MB emissions, and to assess ambient MB concentrations at the site and in the surrounding community. Although the fumigation process has been designed to contain MB within the tented area, the proactive measures described here will be taken to protect public safety should a release occur.

2 Site History and Background

In 2001, a series of letters containing *Bacillus anthracis* (*Ba*) were mailed to various locations throughout the United States. It was determined that initial and residual contamination from *Ba* spores was difficult to detect, identify, and decontaminate in an efficient and expeditious manner. Additionally, significant costs were incurred during decontamination of buildings and equipment that had been suspected of having been contaminated.

Comments from government reports and congressional inquiries pointed out that sampling and decontamination methods were not standardized or validated. Deficiencies were observed when attempts were made to locate, characterize and remediate *Ba* contamination. Recommendations were made by these agencies to standardize and validate procedures that could be used to characterize biological agent contamination and follow on with efficient decontamination measures that would effectively clear buildings and associated areas. The latter part of these recommendations will be addressed, in part, within the scope of this fumigation study and are described in the project Quality Assurance Project Plan (QAPP).

Environmental decontamination and clearance are critical components of the comprehensive public health and environmental recovery strategy employed in the aftermath of a biological agent release. Capacity to decontaminate structures plays a critical role in the nation's resiliency. Currently, there is limited capacity to decontaminate biological agents from structures and outdoor areas. Fumigation with a sporicidal gas may be the most thorough method for structural disinfection. For over 60 years, MB has been used as a pesticide for soil, foodstuffs, and structures. Studies have shown the MB is efficacious in inactivating *Ba* spores and other microorganisms (Weinberg, 2004; Part I and Part II). In addition, the technology and skilled labor force currently used in the commercial fumigation industry can be used in a cost-effective manner for deployment of MB in response to a biological incident. MB has been banned from structural fumigations and is now used under exemptions to fumigate mostly agricultural imports and exports. However, in the event of a national emergency resulting from a *Ba* incident, MB

may be a game changer, adding significantly to our resiliency by increasing our capacity to respond.

The site will be located at Sandia National Laboratory in Livermore, California.

Figure 1. Location of MB fumigation site shown by X in above photo.

3 Potential Compounds of Concern

The primary objective of the AAMP is to protect human health and the environment during the fumigation process. According to the MB label, the lower explosive limit can vary from 10-15 percent. The National Institute for Occupational Safety and Health (NIOSH) lists MB as a potential occupational carcinogen and recommends lowest feasible exposures and an immediately dangerous to life or health (IDLH) value of 250 ppm. OSHA's permissible

exposure level (PEL) is 20 ppm (80 mg/m^3) with a skin notation and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) is 1 ppm (3.9 mg/m^3) with a skin notation. (NIOSH, 2010) (http://www.cdc.gov/niosh/npg/npgd0400.html) (OSHA, 2004) (https://www.osha.gov/dts/chemicalsampling/data/CH_251900.html). Basic properties of MB are shown in Figure 2.

Methyl bromide

Synonyms & Trade Names Bromomethane, Monobromomethane

CAS No. 74-83-9	RTECS No. PA4900000	DOT ID & Guide 1062 123
Formula CH_3Br	Conversion 1 ppm = 3.89 mg/m³	IDLH Ca [250 ppm] See: 74839

Exposure Limits

NIOSH REL : Ca See Appendix A
OSHA PEL †: C 20 ppm (80 mg/m³) [skin]

Measurement Methods
NIOSH 2520;
OSHA PV2040
See: NMAM or OSHA Methods

Physical Description Colorless gas with a chloroform-like odor at high concentrations. [Note: A liquid below 38°F. Shipped as a liquefied compressed gas.]

MW: 95.0	BP: 38°F	FRZ: -137°F	Sol: 2%	VP: 1.9 atm	IP: 10.54 eV
Sp.Gr: 1.73 (Liquid at 32°F)	Fl.P: NA (Gas)	UEL: 16.0%	LEL: 10%	RGasD: 3.36	

Flammable Gas, but only in presence of a high energy ignition source.

Incompatibilities & Reactivities Aluminum, magnesium, strong oxidizers [Note: Attacks aluminum to form aluminum trimethyl, which is SPONTANEOUSLY flammable.]

Exposure Routes inhalation, skin absorption (liquid), skin and/or eye contact (liquid)

Symptoms irritation eyes, skin, respiratory system; muscle weak, incoordination, visual disturbance, dizziness; nausea, vomiting, headache; malaise (vague feeling of discomfort); hand tremor; convulsions; dyspnea (breathing difficulty); skin vesiculation; liquid: frostbite; [potential occupational carcinogen]

Target Organs Eyes, skin, respiratory system, central nervous system

Cancer Site [in animals: lung, kidney & forestomach tumors]

Personal Protection/Sanitation (See protection codes)
Skin: Prevent skin contact (liquid)
Eyes: Prevent eye contact (liquid)
Wash skin: When contaminated (liquid)
Remove: When wet (flammable)
Change: No recommendation
Provide: Quick drench (liquid)

First Aid (See procedures)
Eye: Irrigate immediately (liquid)
Skin: Water flush immediately (liquid)
Breathing: Respiratory support

Respirator Recommendations

NIOSH

At concentrations above the NIOSH REL, or where there is no REL, at any detectable concentration:
(APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode
(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:
(APF = 50) Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted organic vapor canister
Any appropriate escape-type, self-contained breathing apparatus

Important additional information about respirator selection

See also: INTRODUCTION See ICSC CARD: 0109 See MEDICAL TESTS: 0138

4 Figure 2. Basic chemical, physical, and health data for methyl bromide (NIOSH, 2010).

The risk of exposure to MB without warning is significant because MB is a colorless and odorless gas with a chloroform-like odor at very high concentrations. To address this significant risk, the AAMP details a MB monitoring plan with multiple and redundant measures.

5 Air Monitoring Objectives

For purposes of this monitoring program, ambient air is defined as air outside of the tented rail car being fumigated. In particular, the objectives of the AAMP are to:

1. Measure concentrations of MB in ambient air surrounding the fumigated rail car.

2. Compare atmospheric concentrations with site specific Action Levels developed during MB fumigation operations. The OSHA PEL ceiling[3] of 20 ppm of MB is dated and the ACGIH TLV of 1ppm will be used, since no short-term exposure limit (STEL) values for MB are published.

3. Describe operational response measures that will be taken in the event atmospheric concentrations of MB exceed established Action Levels during the fumigation period.

In order to achieve the program objectives MB gas concentrations in ambient air will be continuously monitored around the fumigated rail car and in the surrounding area. Air monitoring will begin during the set-up of the fumigation equipment. Air monitoring will be completed when the following conditions have been satisfied:

a) All fumigation activities have been completed.

b) The post-fumigation concentration of MB in the rail car is below the ACGIH's 8-hour Time Weighted Average value (TWA) of 1.0 part per million (ppm_v).

c) All tenting materials are removed from the rail car.

[3] **Ceiling limit** is an airborne concentration of a toxic substance in the work environment, which should not be exceeded. If instantaneous monitoring is not feasible, then the ceiling is a 15-minute time-weighted average exposure not to be exceeded at any time during the working day.

During the fumigation process, weather conditions will be continuously monitored in order to assess the direction of potential migration routes for MB detected in ambient air. The monitoring data will be used to relocate mobile gas monitoring units and/or implement corrective actions.

5.1 Data Quality Control Procedures

Information regarding the instruments is provided in Section 7.0. In order to collect accurate and usable measurements, data quality procedures will be implemented, including:

- Calibrating all instruments according to manufacturer's instructions;
- Verifying instrument calibrations and responses during monitoring events by using clean filtered air;
- Documenting all calibration activities; and
- Reporting and documenting all QC results.

In addition, United States Environmental Protection Agency (EPA) will utilize a tiered approach to monitoring. Multiple instruments will be used to measure MB in ambient air. These instruments will improve the data quality by increasing the ability to detect MB. They also utilize different monitoring techniques, thus increasing the likelihood that detections are accurate. Instruments to be utilized by EPA and its contractors include:

- RAE Systems AreaRAE and MultiRAE
- Portable gas chromatograph with MB compatible column and conditions
- Key Chemical and Equipment Remote Data Acquisition (RDA) Fumiscopes
- Colorimetric tubes (Draeger MB tubes, etc.)

5.2 Background Data Collection

Prior to the start of fumigation, ambient monitoring for MB will commence. Ambient air monitoring will be conducted during setup of fumigation equipment to establish baseline readings and to assess the effects of potential interferences from other compounds. These data will be recorded in an ambient air monitoring log.

6 Description of the Fumigation Process

The fumigation process will involve exposing the interior and exterior of the rail car to a target MB concentration for a set amount of time. Process parameters such as MB concentration, temperature and relative humidity will be monitored and controlled inside the tented rail car during the fumigation by subcontractor. The overall process will consist of the following steps:

1. The rail car will be fully encapsulated in a tarp to prevent leakage of MB gas to the atmosphere.

2. The rail car will be conditioned to maintain desired relative humidity/temperature levels as described in the MB Fumigation Guidance.

3. MB gas will be released into the tented area.

4. While MB is being released, the temperature will be maintained at or above 75 °F and the RH will be maintained at or above 75 percent.

5. MB concentration will be kept at or above 212 mg/L for 36-hours.

6. The 36-hour concentration-time (CT) clock will start once the temperature, RH, and MB concentration reach the desired levels.

7. The CT clock will be paused any time the temperature, RH, or MB concentration goes below one of these operational limits. It will restart once the limits are obtained again.

8. If MB concentration at or beyond the warning tape (30' from tented rail car) rises above a warning level, then checks will be made for leaks and corrective actions will be taken to mitigate them.

9. When fumigation reaches the desired 36-hour CT, the MB gas inside the tented area will be removed by scrubbing the exhaust flow with a series of activated carbon beds.

10. When the activated carbon bed scrubber system has reached its maximum effectiveness (scrubber stack concentration is equal to or greater than the concentration under the tented area), then workers in appropriate PPE will open the tarps and place fans to assist the final aeration.

11. The process will be concluded after MB levels inside the rail car decline to acceptable levels for site workers to re-occupy.

Any changes to the AAMP will be documented in section 10.0 - Modifications to the AAMP.

7 Implementation Schedule

Air monitoring will be started before any fumigant is released and continue until all fumigation activities have been completed, including aeration. The process will be concluded after MB levels inside the rail car decline to acceptable levels for site workers to re-occupy in Level D protection.

To ensure proper placement of ambient air monitoring units, a site specific weather station will be deployed during initial operations so that meteorological data can be continuously collected during the fumigation process.

8 Monitoring Equipment

As previously described, several tiers of ambient air monitoring instruments will be utilized during the fumigation. The purpose of this approach is to provide additional health and safety precautions, because a detector agent (chloropicrin) will not be utilized and MB at the levels used for fumigation does not have sufficient odor warning properties. The monitoring equipment will be co-located as much as possible so that multiple sensors are providing near-real time conditions for MB. The following subsections outline the various pieces of equipment and how they will be utilized for this project.

8.1 RAE System AreaRAE

EPA will deploy an interconnected system of four AreaRAE gas detectors as the primary means to assess MB concentrations around the structure. RAE Systems AreaRAE is a one- to five-sensor gas detector with a photo-ionization detector (PID) installed. The PID provides real-time monitoring capabilities in the range of 0 to 10 ppm as volatile organics. The detector is

responsive to MB and a 1.7 conversion factor[4] (RAE Systems, 2005) will be employed to correct its gross PID response readings to MB concentrations. The lowest reliable PID reading is approximately 0.1 ppm which is below the 0.5 ppm threshold for the AAMP air monitoring objectives. The AreaRAE can provide both time-weighted average (TWA) and STEL readings.

Each AreaRAE will be equipped with a 10.6 eV lamp and a wireless RF (radio frequency) modem. A RDK Host Controller or a personal computer will be used as a base station to continuously monitor each wireless AreaRAE deployed during the fumigation process. The controller will also allow for remote data logging conditions at each locality.

The AreaRAEs will be deployed in close proximity (within 30 feet) to the tented rail car and at selected up and downwind locations. These "selected locations" will include any possible "sensitive receptors" or "at risk populations" that may be downwind or in close proximity to the rail car fumigation site.

8.2 RAE System MulitRAE

The EPA will deploy two (or more) RAE System MultiRAEs for leak detection and for personnel monitoring when checking the AreaRAEs or when entering within 30-feet of the rail car being fumigated. The MultiRAE uses a similar technology to the AreaRAE, but is slightly more sensitive (lower detection limit). The MultiRAE Pros are light, handheld instruments that are easy to use.

8.3 Field Portable Gas Chromatograph (GC)

The EPA may deploy gas collection bag technology at each stationary monitoring location to collect samples when high AreaRAE readings are obtained. The sampling bags will be collected and analyzed on site with the field portable GC (make and model TBD). The GC will be equipped with an appropriate MB column and operating conditions for optimal resolution of MB. This result will be our agent-specific analysis for identification and quantification of MB at the

[4] See RAE Systems TN-106 for the proper way to implement a conversion factor. For high concentration initial doses, it may be desirable to use a dilution fitting. See RAE Systems Technical Note TN-167.

time and place where and when the sample was pulled. Although the PID systems are great detectors for MB without this additional analysis step we could not be sure the PIDs were reading MB as opposed to some other interfering organic chemical.

8.4 Key Chemical and Equipment RDA Fumiscope

When not monitoring the inside-the-rail car MB concentration, the fumiscopes will be used to monitor ambient air around the perimeter of the tented rail car. The RDA Fumiscope provides essentially the same function as the standard fumiscope, such as measuring the thermal conductivity of various fumigants. The difference is that the RDA model can be left at the rail car that is being fumigated and remotely accessed via the standard telephone system or cell phone from a remote computer (called the host computer). In addition the RDA model can sample and test four independent test points as opposed to the standard model's single test point.

The sampling ports of the RDA will be located approximately 30 feet from the rail car similar to the AreaRAE sampling locations. Exhaust from the fumiscope will be routed back to the tented area.

8.5 Colorimetric Tubes

Colorimetric tubes are a good means of detecting MB. Draeger colorimetric tubes are glass vials, filled with a chemical reagent that reacts to a specific chemical or family of chemicals. A calibrated 100ml sample of air is drawn through the tube with a Draeger Accuro bellows pump. If the targeted chemical(s) is present, the reagent in the tube changes color and the length of the color change typically indicates the measured concentration.

Draeger MB tubes will be collected every six hours from four perimeter AAMP sampling locations. As much as possible, the tubes will be collected near AreaRAE locations. However, it may be necessary to collect samples along seams in the tarps or at downwind locations based on current site conditions. Personnel will utilize Draeger tube model CH27301, MB tube 5/B, 5-50 ppm. The tube has some sensitivity to HBr and other halogenated hydrocarbons.

9 Monitoring Program Description

The Site AAMP will provide ambient air monitoring for MB. The Site AAMP utilizes a

combination of stationary monitors and portable equipment, including PID based sensors (AreaRAEs and MultiRAE Pros), chromatography and colorimetric indicators. Their use will be orchestrated to yield an orthogonal approach to detection, increasing the safety for workers and the public.

9.1 Work Zone Monitoring

Multiple MultiRAE Pros will be deployed with workers entering the designated work zone near the fumigated rail car. MultiRAEs will be equipped with PID sensors corrected for MB response. Several MultiRAEs will be deployed for use by project personnel for leak detection and for personnel protection when near the fumigated rail car. The exact monitoring locations will be determined based on where workers are working.

Initial data from the instruments will be used to identify potential leakages of MB from the tented rair car, so that repairs and/or modifications can be made. Once these are corrected, the data will also be used to assist personnel with proper positioning of the instruments downwind to quantify MB concentrations at the property perimeter.

9.2 Perimeter Monitoring

Perimeter monitoring will be conducted using groups of AreaRAEs. Perimeter monitoring locations during fumigation will be approximately 30-feet from the rail car and based on meteorological data. The AreaRAEs will monitor MB continuously and provide readings on a real-time basis. Readings will be used to determine compliance with ambient concentration Action Levels developed by EPA for MB during fumigation operations.

Approximately four AreaRAEs will be setup at the perimeter and one unit will be in the support zone (additional monitors can be added if the structure is large, greater than 100,000 cubic feet). Generally, the locations will be downwind of the fumigation site or near a sensitive receptor populations, if any.

9.3 Scrubber Monitoring

Scrubber monitoring will be conducted using a MultiRAE (Plus or Pro model). Monitoring

will be done initially between the two carbon beds to determine breakthrough of the first bed. After breakthrough of the first bed has been reached the monitor will be moved to the stack that follows the second bed. When concentrations at the scrubber stack reach the concentration inside the rail car (as determined by the fumiscopes) then the scrubbing process will be discontinued, blower shut down, duct to the beds will be disconnected, carbon samples removed, and each bed will be capped off.

10 Assessment and Response

1. Air monitoring for purposes of comparison to established ambient concentration threshold Action Levels for MB will be conducted using AreaRAEs and other monitoring equipment, bag samples followed by gas chromatography, will be used to verify MB concentrations. If the ambient concentrations of each compound remain below their respective Action Level thresholds, the fumigation will proceed as planned. If confirmed MB concentrations exceed any of their respective ambient threshold levels, the EPA Principle Investigator will be immediately notified. Operational responses will be implemented in accordance with a series of proportionate measures that have been developed by EPA for the various Action Levels.

In general, the ambient Action Level for MB has been designed to serve the following purposes:

- Action Level 1 (0.5 ppm) provides an early warning that ambient concentrations of MB have exceeded an established threshold level for an extended period of time and staff should be alerted.

- Action Level 2 indicates that ambient concentrations of MB have remained above an established threshold for an extended period of time despite troubleshooting and corrective action, and that additional MB should not be added to the rail car until ambient concentrations again fall below the threshold. At this point staff should be notified of a possible evacuation.

- Action Level 3 indicates that: (1) ambient concentrations of MB have remained above an established threshold for an extended period of time despite troubleshooting, corrective action and cessation of MB addition to the rail car. If this level is achieved, the fumigation operation should be terminated until the source of emissions can be identified and corrected. At this level, the local fire department may notify nearby residents to evacuate or shelter in place as detailed in the HASP Evacuation Plan.

The respective ambient threshold Action Level for MB are shown in Table 9-1, along with a summary of the operational response measures that will be taken with respect to the fumigation in the event that any of the Action Levels are exceeded at any point during the operation. If the Action Level 3 threshold for evacuation for non-essential personnel is reached, then evacuation of these personnel will be conducted as described in the Health, Safety and Emergency Response Plan and the Evacuation Plan. If residential evacuations are necessary, the local authorities will coordinate the evacuations.

Table 9-1 Ambient Action Levels and Response Actions

Constituent of Concern	Monitoring Location	Action Level Definition / Response	
		EPA Limit	**Action**
MB	Perimeter	0.5 ppm_V 15-min TWA	Action level 1: if the AreaRAEs 15-min rolling average is 0.5 ppmv, then staff will be alerted. Action level 2: if a second consecutive 15-min rolling average is 0.5 ppmv, then troubleshooting and corrective action will be implemented. Staff will be notified of possible evacuation. Action level 3: if a third consecutive SPM 15-min average is ≥ 0.5 ppmv, then MB additions will be ceased, and the tented area will be actively scrubbed. Non-essential staff will be evacuated.
MB	Work Zone	0.5 ppm_V Peak	Action level 1: if the AreaRAE Peak is ≥ 0.5 ppmv MB, then the staff will be alerted. Action level 2: if the AreaRAE Peak remains at ≥ 0.5 ppm_V MB, then troubleshooting and corrective action will be implemented. Staff will be notified of possible evacuation.
MB	Work Zone	1.0 ppm_V Peak	Action level 3: if the AreaRAE Peak continues to be ≥ 1.0 ppm_V MB despite corrective actions, MB introduction into the tented area will be ceased and the tented area will be actively scrubbed. Non-essential staff will be evacuated.

11 Air Monitoring/Sampling Plan with SNAPPER and PHILIS

This section describes the air monitoring and sampling plan that will utilize the SNAPPER system and Portable High-throughput Integrated Laboratory Identification System (PHILIS) Mobile Laboratory Bus with Gas Chromatograph-Time of Flight Mass spectrometry (GC/TOF).

ERT/SERAS will be providing RAE System's AreaRAEs and/or MultiRAE Pros to perform air monitoring for VOCs equipped with ERT's VIPER Data Management System for real time analysis and data interpretation. ERT/SERAS will also be providing their SNAPPER air sampling collection software that can trigger an air sample to be collected either manually or placed on a timed collection protocol. The sample can be collected on a tedlar bag, SUMMA canister, and/or any media (filter, tube) that is designated. CBRN CMAD will be providing their PHILIS Laboratory to analyze the collected samples for Methyl Bromide.

Equipment:

1. 4 – RAE Systems AreaRAE Monitors and/or MultiRAE Pros with Photoionization Detectors (PIDs) for Volatile Organic Compounds (VOCs)
2. 4 – SNAPPER set ups with the ability to sample a tedlar bag, SUMMA canister, and/or any media (filter, tube) that is designated upon being triggered manually or by a timed collection protocol.
3. 1 – Host Computer that will run both the VIPER and SNAPPER Systems.

The perimeter AreaRAEs will be set up to monitor for VOCs while the decontamination operations are being conducted. VIPER will be collecting the data every second and pushing the data up to ERT.VIPER.ORG every minute. SNAPPER and VIPER are not fully integrated as of this time so the computer will not manually take a sample when an action level is reached. In lieu of that, the operator will monitor the computer in real time and take a sample if one-half the action level is reached. Methyl Bromide has 1.7:1 ratio for a PID reading so at the action level of 1ppm (ACGIH TLV) for worker exposure to Methyl Bromide there would be a 588ppb reading on the PID. The operator will trigger SNAPPER if the PID reads 300ppb. In addition to any samples taken at the one-half action level, samples will be taken before decontamination operations, after decontamination operations and every 3 hours during the decontamination operations even if the one-half action level is not reached. The sampling will continue at the 3 hour intervals during time the PHILIS laboratory is staffed to accept samples; overnight hours are not currently scheduled to be staffed in the PHILIS laboratory.

The air samples will be taken and analyzed by the CBRN CMAD PHILS Mobile Laboratory for Methly Bromide. This laboratory analysis would confirm the presence of Methyl Bromide and rule out any other contaminants that could be contributing the elevated VOC levels seen by the monitoring instrumentation. Detection limits and methods will be determined by PHILIS laboratory personnel. Any media specific, volume dependent requirements must be discussed prior to project mobilization.

The analytical instruments in PHILIS will only be used to confirm the presence of MB in collected samples down to a concentration of 1 ppm.

12 Modifications to the AAMP

If any modifications are made to the AAMP following approval, they will be documented in writing and attached to the original AAMP. Changes to the AAMP must be approved by the Unified Command.

13 References

NIOSH. National Institute for Occupational Safety and Health, Education and Information Division, NIOSH Pocket Guide to Chemical Hazards and Other Databases 22-0256. Methyl Bromide. NIOSH Pub. 2010-168c. 2010. (http://www.cdc.gov/niosh/npg/npgd0400.html)

NIOSH. National Institute for Occupational Safety and Health, Education and Information Division, NIOSH Pocket Guide to Chemical Hazards and Other Databases 22-0256. Hydrogen Bromide. NIOSH Pub. 2010-168c. 2010. (http://www.cdc.gov/niosh/npg/npgd0331.html)

OSHA. Occupational Safety and Health Administration. Chemical Sampling Information for Bromomethane. 2004. (https://www.osha.gov/dts/chemicalsampling/data/CH_251900.html

OSHA. Occupational Safety and Health Administration. Chemical Sampling Information for Hydrogen Bromide. 2004. (https://www.osha.gov/dts/chemicalsampling/data/CH_246200.html)

USEPA, Information on PHILIS, http://www.epa.gov/swercepp/web/docs/misc/PHILIS.pdf.

RAE Systems. AP-218: Measurement of Fumigants in the Food Storage Industry. 2005. (http://www.raesystems.com/sites/default/files/downloads/FeedsEnclosure-AP-218_Fumigants_Food_Ind.pdf)

RAE Systems. TN-106: Correction Factors, Ionization Energies, and Calibration Characteristics 2010. (http://www.raesystems.com/sites/default/files/downloads/FeedsEnclosure-TN-106_Correction_Factors.pdf)

RAE Systems. TN-167: Proper Use of Dilution Fittings. 2005. (http://www.raesystems.com/sites/default/files/downloads/FeedsEnclosure-TN-167_Proper_Use_of_Dilution_Fittings.pdf

USEPA, Information on VIPER, http://www.epaosc.org/site/site_profile.aspx?site_id=5033.

Weinberg, M.F., R.H. Scheffrahn, and M.A. Juergensmeyer, PART 1: Efficacy of Methyl Bromide Gas against Bacillus anthracis and Allied Bacterial Spores in Final Report: Whole-Structure Decontamination of Bacillus Spores by Methyl Bromide Fumigation, U.S. Environmental Protection Agency, Small Business Innovation Research Phase II. 2004.

Weinberg, M.J. and R.H. Scheffrahn, PART 2: Whole-Structure Decontamination of Bacterial Spores by Methyl Bromide Fumigation in Final Report: Whole-Structure Decontamination of Bacillus Spores by Methyl Bromide Fumigation. 13 2 2004, U.S. Environmental Protection Agency, Small Business Innovation Research Phase II.