This paper was given at the 2003 AWMA/EPA Indoor Air Quality Problems and Engineering Solutions Specialty Conference and Exhibition, July 21-23, 2003, in RTP, NC.

Observations on Engineering Aspects of the Brentwood Postal Facility Fumigation

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ABSTRACT

The 14,000,000 ft^3 Brentwood postal facility in Washington, DC, was contaminated with anthrax spores contained in a letter addressed to Senator Thomas Daschle. Two postal employees died of inhalation anthrax. The U.S. Postal Service decided to fumigate the entire building with chlorine dioxide (ClO_2) to inactivate the remaining spores. This paper provides a summary of the four tests of the ClO_2 generation and scrubbing system at the building.

BACKGROUND

In October 2001, the Brentwood Postal Facility, located in northeast Washington, DC, was contaminated with *B. anthrasis* spores, believed to have originated from a letter addressed to Senator Daschle. Joseph Curseen, Jr. and Thomas Morris, Jr., two postal employees, contracted and succumbed to inhalation anthrax. The facility has been renamed the Joseph Curseen, Jr. and Thomas Morris, Jr. Processing and Distribution Center as a memorial. The facility is a 14,000,000 ft^3 (about 700,000 ft^2) warehouse-type building with a high ceiling and multiple loading dock doors opening to the outside. The central portion of the space was generally open and housed a large number of postal processing machines, including "Line 17" where the contaminated letter appears to have been processed. The two ends of the building have offices and other enclosed areas. The building was closed October 21, 2001, and the investigation and decontamination process commenced.

DECONTAMINATION EVENTS

The U.S. Postal Service (USPS) conducted a comprehensive sampling campaign and found that the anthrax spores were widely distributed throughout the building. The contamination was found to be centered around Line 17. To prevent the spores from getting outside the building, all openings were sealed with some combination of plywood, foam board, caulking, and tape. Initial decontamination included enclosure and decontamination of certain machines, decontamination and removal of some metal contents (e.g., mail racks), and spot decontamination. At the completion of these efforts, spores were still found dispersed throughout the building. This led to a plan to decontaminate the whole 14,000,000 ft^3 volume at one time.

WHOLE BUILDING DECONTAMINATION

The USPS decided to use chlorine dioxide (ClO_2) for the whole building decontamination, based in part on the successful operation at the Hart Senate Office Building. They engaged Shaw Environmental to run the overall effort with Sabre and Ashland Chemicals as the subcontractor for the ClO_2 generation systems. The urban location required extensive safety precautions to prevent leakage from the building resulting in unacceptable ambient ClO_2 concentration in the neighborhood. In addition, since ClO_2 is not listed under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) for anthrax fumigation, a crisis exemption from the EPA Office of Pollution Prevention and Toxic Substances was required. This section will discuss the events leading up to whole building fumigation: 1) the approach; 2) fumigation target conditions; 3) safety precautions; 4) the Office of Research and Development (ORD) role; 5) the ORD dispersion analysis; and 6) a series of four tests of the negative air unit (NAU) used to scrub ClO_2 from air removed from the building.

Approach

The fumigation approach required three major engineering systems: 1) control of temperature and humidity in the building; 2) equipment for generation of ClO_2; and 3) NAU equipment to ensure that ClO_2 was contained within the building during fumigation. Note that many of the details of this technology are considered confidential by the contractors. Therefore, only engineering aspects observed during tests of systems 2 and 3 above are discussed.

Fumigation Target Conditions

The fumigations were planned based on the experience at the Hart Senate Office Building and some previous testing of the effectiveness of ClO_2 to kill anthrax spores. The temperature and humidity were to be maintained at greater than 80 F$^{\circ}$ and 75% relative humidity, respectively. The target fumigation conditions were a cumulative 9000 ppm-hr based on a nominal concentration of 750 ppm for 12 hours. A concentration time (CT) clock record was kept for multiple locations in the building, with the provision that no individual clock was started until the ClO_2 was greater than 400 ppm.

The ***ClO_2 Generation*** and distribution consisted of two systems, a small one used during the NAU tests, and a larger one used during the full building fumigation. Each system consisted of reagent storage, a generator unit producing a solution of ClO_2 in water, one or more emitters, and a recycle tank for a residual ClO_2 in water solution returned to the sump of the emitter(s). The emitters stripped gaseous ClO_2 from the water solution into a forced convection air stream and collected the remaining solution for return to the recycle tank. For the NAU tests, a single emitter was installed in the inlet duct from the building to the NAU. For the low level ClO_2 test and the full building fumigation, the larger system delivered the ClO_2 solution to over 20 emitters distributed around the building.

Two similar capacity ***Negative Air Units*** were available. The North NAU was used for the NAU tests, and both units were used for the low level ClO_2 test and the full fumigation. Each NAU drew air from the building through a series of cleanup steps including a HEPA filter to remove any spores that might be entrained, a demister to remove any condensation due to the high building humidity, a chemical scrubber to remove ClO_2 to 5 ppb, and a carbon bed to remove residual ClO_2. The system capacity was also designed to provide sufficient air flow to maintain the building pressure at least 0.05 inches of water below ambient. This should prevent any significant exfiltration of ClO_2 unless there was some failure of the sealing.

Safety Precautions

Extensive safety precautions were in place to ensure the safety of workers and people in the surrounding area. USPS established an alert level of 25 ppb and an action level of 100 ppb at any monitoring site. The alert level would trigger additional monitoring, and the action level would cause a shutdown of the ClO_2 generator system. ClO_2 monitors were located on the roof and around the generator systems and NAU's to provide early leak detection and to protect worker safety. Fence line monitors continuously evaluated the ambient concentrations. EPA's Trace Atmospheric Gas Analysis (TAGA) van and Shaw monitoring crews circulated through the areas outside the fence line. In addition, building pressure was continuously monitored to evaluate control of ClO_2 exfiltration.

ORD Role

The ORD role began with a review of the Remedial Action Plan (RAP) prepared by the USPS and its contractors, concentrating on engineering and safety aspects of the fumigation systems. There was frequent consultation with representatives of the Office of Pollution Prevention and Toxic Substances (OPPTS) and the Office of Solid Waste and Emergency Response (OSWER) over the duration of the effort. A dispersion analysis was performed to evaluate the ambient concentrations that might occur under a reasonable "worst case scenario." The key activity was observation of all NAU tests leading up to the full fumigation.

ORD Dispersion Analysis

The ORD dispersion analysis was conducted to evaluate a credible worst case scenario for release of fumigant due to the inability to maintain a sufficiently negative pressure differential (i.e., - 0.05 inches of water) from ambient inside all areas of the building. (Note that pressure differential measurements were made continuously at over 20 locations). This pressure differential should ensure that the building is "under control" and minimal exfiltration will occur. The assumption was made that this pressure differential would be maintained at the anticipated flow rate through the NAU, and a building leakage coefficient was calculated by Air Pollution Prevention and Control Division (APPCD) personnel. Assuming that the ClO_2 concentration in the building was 1000 ppm and that the building pressure differential rose to + 0.02 inches of water, a source strength was calculated. The National Exposure Research Laboratory (NERL) used this as a point source strength in a dispersion model analysis and calculated that the ClO_2 leakage could result in an ambient ClO_2 concentration of 1 ppm at 1 kilometer in the prevailing wind direction. As a result, the USPS increased efforts to ensure that the required pressure differential would be demonstrated in the NAU trials.

NAU Tests

Prior to the issuance of the crisis exemption, the USPS conducted a series of four NAU tests to demonstrate that the system was capable of achieving required destruction of ClO_2 in the air exhausted from the building to maintain negative pressure differentials. The first three tests were conducted on the north NAU with 1000 ppm ClO_2 introduced directly into the NAU duct. The fourth test was conducted with both NAUs operational and a low-level of ClO_2 (400 ppm) introduced through the emitters into the whole building. Each test in the series is described below.

First NAU Test

The goal of this test was to demonstrate that the NAU could run for 24 hours, which was the estimated duration of the fumigation of the building and purging of the ClO_2 at completion of the fumigation. The NAU was to be operated at the design flow rate with 1000 ppm ClO_2 in the gas stream. The planned amount of reagents to generate the ClO_2 was exhausted in about 10 hours, and the test was terminated. The reason for the failure was not known at the conclusion of this test. The pressure differential data were quite limited, but indicated value of atmospheric pressure plus or minus 0.01 inches of water.

Second NAU Test

The goal of this test was to successfully complete the 24 hours of continuous operation. After the start of the test, rapid depletion of reagents was noted. The cause was traced to an incorrect calibration curve being used for the NAU flow measurement instrument. The actual flow was coincidently almost exactly twice the indicated value. The flow rate was corrected and the ClO_2 scrubber portion of the NAU system worked as expected, achieving a less than 5 ppb ClO_2 exit concentration. A carbon bed completely removed this trace amount. At the conclusion of the test, a scrubber failure was simulated to evaluate the capacity of the carbon bed to deal with the full 1000 ppm in an emergency. The capacity was expected to provide a 2-to 4-hour time to breakthrough; however, it occurred in about 18 minutes. In addition, the required negative pressure differentials were not achieved.

Third NAU Test

The goal of this test was to evaluate an enhanced carbon bed and to demonstrate consistent negative pressure. The carbon bed test was successful, and no breakthrough was observed. The NAU system was tested in an automatic mode that regulated NAU flow to achieve the required pressure differentials, which were achieved in all zones. (Note that in the previous two tests the NAU flow rate was set and the pressure differentials were allowed to vary.)

Final NAU Test: Full Building Fumigation Simulation

The goal of this test was to demonstrate the performance of both the North and South NAUs and to ensure that the ClO_2 was successfully contained within the building. The ClO_2 level in the building was ramped up to an equilibrium concentration of about 400 ppm and held for about 6 hours. Although there were minor ClO_2 leaks from the building, which were quickly remedied, and a mechanical delay, both NAUs performed well. The pressure sensors at all locations indicated pressure differentials at or below negative 0.05 inches of water. At the conclusion of ClO_2 introduction, the decomposition rate in the building ClO_2 inventory was observed to be quite rapid.

Brentwood Fumigation

The full-scale fumigation was conducted in December 2002. The USPS stated that the fumigation had been successfully carried out with all CT clocks exceeding 9000 ppm hours and no ClO_2 leakage detected. In March, the USPS also announced that all spore strips and wipe samples were negative. The Environmental Compliance Committee had to give approval for reentry.

Costs

While exact costs for all anthrax remediation activities have not been documented, it appears that they will exceed \$200 per ft^2 of floor space. Following fumigation, the building is being restored including painting and replacing the furniture and floor covering. No information has been provided on potential damage to or replacements of the machinery in place during the fumigation.

OBSERVATIONS

Based on the experience at Brentwood, the following observations result:

1. During planning of a fumigation, a plausible worst-case scenario analysis needs to be conducted. It should include all risks reasonably under control of the performing organization. Among the things it should include: the likely sources of leaks and methods to control them, the toxicity of the fumigant, the volume and concentration of the fumigant present in the building, and the monitoring and emergency shut down plan to ensure worker and neighborhood safety.

2. Containment of the fumigant in the building is critical. Approaches can include sealing potential leaks, maintaining sufficient fumigation pressure differentials, testing or encapsulating the facility, providing a gas clean-up system for air intentionally exhausted from the building, and having an adequate clearance mechanism at the conclusion of the fumigation (probably a combination of ventilation with scrubbing and in-place fumigant decomposition).

3. Careful testing of the monitoring and safety systems is essential.

4. The experiences of Brentwood and other decontaminations need to be systematically analyzed and documented. This analysis should provide guidance to make any future fumigation safe and more cost effective.

5. Be prepared for the unexpected, since it appears that there may be any number of unanticipated problems that will arise during a fumigation. These preparations should include but are not limited to: spares for critical systems components, adequate supplies of reagents, emergency power provisions, and close coordination with community and local agencies.

6. A good QA plan for instrumentation is also critical.

Key Words

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Air Pollution
Biological Warfare Defense
Anthrax
Fumigation
Environmental Engineering
Chlorine Dioxide