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The way of all flesh

**Michael Hinds, Hazard Assessment Team at SAIC,
looks at the issues and concerns of biological agent
fate and the residual hazard**

THE study of the fate of biological warfare agents, and their fate in the environment, has been chiefly done on the degradation of these agents during dissemination. The aerosol decay rate of a biological warfare agent was of great concern to those countries that were, or are, involved in such research, as this parameter allows for calculation of what the weapon loading must be to deliver the desired amount of agent upon the target to produce a certain level of effect. The study of what happened to the agent after delivery was left alone as this was not nearly as important. Now that such efforts, in most cases, have been turned toward defensive work, the question of the fate of the released agent should be an important one. The level of agent persisting in the environment creates the basis for decisions for consequence management. For example, does one need to decontaminate?

After a release of a biological agent, whether for the purposes of inflicting harm on people, livestock, or crops, the agent may have some level of persistence in the environment. This level of persistence is often referred to as “agent fate”; the final disposition of the released agent.

Studying fate

The first question one might ask is: after an attack, is there a potential residual hazard? A residual biological hazard may arise when an agent-bearing cloud deposits agent on the ground and other surfaces it passes over. Additional residual hazard may be created from inefficient submunition detonations and release from agent contaminated packages or letters. Deposited biological agent can create possible hazards via multiple routes in humans and animals. Reaerosolisation of the agent from ground or surface by mechanical disturbances can also pose an aerosol hazard. Agent may be reaerosolised by the removal of contaminated clothing. Furthermore, biological agents may be transferred from a contaminated surface via the hands or fingers to the mouth, posing a hazard to the alimentary tract, (ie digestive tract) and associated mucosa, (ie moist tissue lining certain organs and body cavities, to include mouth, nose, lungs, gastrointestinal tract, etc).

There are studies which provide evidence that residual hazard – or secondary hazard – can exist after a biological weapon attack. Studies conducted in the Hart Senate Office building 28 days post-attack observed lethal levels of *Bacillus anthracis* still present in the office suite where the letter containing the spores was opened. The contamination was chiefly contained in the office carpeting and was readily reaerosolised by normal walking, generating a secondary aerosol hazard. Studies of biological agent deposition and reaerosolisation rates show heavy deposition near weapon detonation points (0.02 m/s), lower deposition for other weapon types (0.002 m/s), and good efficiency (1 to 10 per cent) on mechanical resuspension (walking/vehicle) of surface contamination. Agent can even deposit and adhere to clothing, generating an aerosol hazard when the clothing is removed indoors. Biological agent can be transferred from surfaces by the hands to the mouth and nose in sufficient quantities to cause infection. Some biological agents are particularly robust under certain



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Interior areas without sunlight and little wind are excellent areas for bio agents to survive

environmental conditions and can pose a persistent hazard, whether by aerosol or by transfer of the material through other means.

The level of the residual hazard created by these methods depends upon several factors. The first, and most basic, factor is the amount of biological agent deposited. The rate, and ultimately the amount, of material deposited on a surface are highly dependent upon the type of surface the biological agent is depositing on. The second factor in determining residual hazard is the infectivity or toxicity of the biological agent. A biological agent with low deposition, but requiring only

‘For many agents of interest, the information is simply nonexistent, or nominally so as it may only reside in secret government archives.’

a few units (particles, cells, spores) may pose a greater residual hazard than a heavier deposition of an agent with low infectivity or toxicity. A third factor is the persistence of the biological agent after dissemination. A host of natural environmental factors, (such as radiation, relative humidity, and temperature) can degrade and destroy a biological agent. An

extremely infectious agent, disseminated with high efficiency but with extremely limited persistence, may not pose any residual hazard. A fourth factor is the protective state of the individuals likely to be exposed to the residual hazard. The protective state includes physical protection, such as filter masks and biological protection, such as vaccines and chemoprophylaxis. The interaction of these factors can result in a wide range of potential residual biological hazards, and in some cases, no hazard. The overriding factor controlling the presence of a potential residual biological hazard is whether the agent in question generating the hazard actually has to persist in the environment at sufficient levels to produce the hazard.

The availability of persistence data for select agents (those purported to be ideal or useful for a biological weapon) is slim. For many agents of interest, the information is simply nonexistent, or nominally so as it may only reside in secret government archives. When such data does exist, care must be taken in interpreting the test results and applying such results to the real world. For example, one paper suggested botulinum toxin would rapidly degrade under normal environmental conditions, but this was based upon a calculation using an aerosol decay rate.

Some basic persistence studies suggested normal environmental conditions have a

profound effect on the viability of *variola* virus. As temperature and relative humidity increase, the long-term viability of *variola* decreases. At between 31.5°C and 33.5 °C at 50 per cent and 80-83 percent relative humidity, there were only trace amounts (less than one per cent compared to initial release) of *variola* left after 23 hours. Other studies have shown *variola* destroyed within four-to-five hours upon exposure to direct sunlight. A recent study sought to determine outdoor persistence factors on various surfaces for *B. anthracis* and *Yersinia pestis*. Samples of agent were exposed to precisely controlled light and radiation mimicking the flux and intensity measured at a specific outdoor locale. This study found no surviving *Y. pestis* after two hours of exposure to the study radiation. *B. anthracis* has the potential for long-term survivability in the environment. Exposure to the study radiation did degrade the agent, reducing potential residual hazard to negligible levels after 24-to-48 hours. However, areas not exposed to the sun's ultraviolet radiation may harbour more agent over time, possibly posing a hidden reaerosolization hazard.

Away from the sun

So far, the studies discussed were for outdoor hazard. The study involving *B. anthracis* and *Y. pestis* did have a "dark control" – the samples were not exposed to any of the study radiation. While the study did show degradation of both agents, real-world data for *B. anthracis* and another study involving *Y. pestis* provide additional information.

As mentioned previously, a study was conducted within the *B. anthracis* contaminated office of the United States Senate Hart Office Building. The criminal release of *B. anthracis* in the office setting generated a residual reaerosolisation hazard 25 days after the release. The carpet in the contaminated office suite contained from 8,821 to 36,889 spores per square meter. The contamination on the carpet area near the point of agent release was too great to be accurately counted. Analysis performed on the data contained within Weis CP *et al* confirmed hazardous inhalation exposure concentrations. Using the same breathing rate as cited in Weis CP *et al* of 1.38 m³/hr, inhalation exposure concentrations were calculated when the carpeting was walked upon to stimulate reaerosolisation.

The estimated inhalation exposure was >15,000 colony-forming units (CFU)/hr. Based upon Anderson sampling data, (which measured spores, not CFU), the exposure concentration was measured between 82,000 and 120,000 spores per hour. An unprotected individual exposed to this level of agent would receive a lethal dose in just six minutes. This exposure level, however, was measured at floor level. Personal air monitors, worn by protected individuals walking through the contaminated suite, measured a much lower exposure of 119 CFU/hr, while Anderson samplers placed at 1.5 meters recorded 250

CFU/hr. At this level, an unprotected individual would have to be exposed for 32 to 67 hours (one-to-three days). The Anderson data corresponding with the personal air monitor data was taken at a different time than the floor level CFU data. An unprotected individual exposed to the breathing zone levels (1.5 meters) would inhale a potentially lethal exposure in 35 minutes.

For *Y. pestis*, Rose LJ *et al* applied the agent to various indoor surfaces (stainless steel, polyethylene, glass, and paper). There was a >3 log reduction after 24 hours. After 96 hours, no viable agent was detectable, except on paper, which persisted up to 120 hours. *Y. pestis* is highly susceptible to desiccation and the material it is suspended in can have a profound effect on its survivability. A less robust medium reduced the survival time significantly, such that on most surfaces (except paper) there was nothing detectable after seven hours.

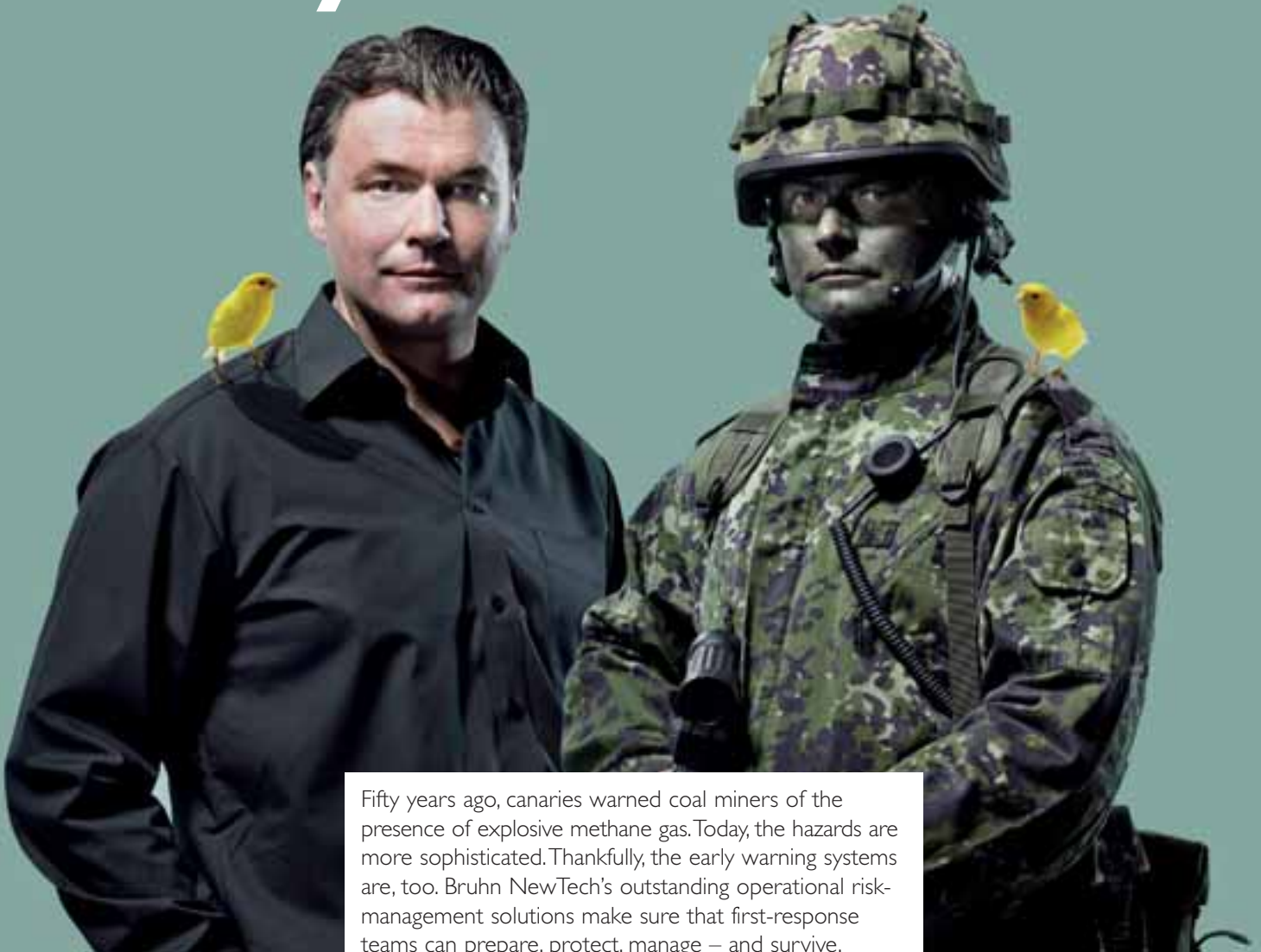
Given these limited studies, can one make a reasonable determination of post-attack residual hazard? Experimentation in this area has been slim to none in recent years, due to expense and nervousness in the use of agent simulants and actual agents. Instead of a full scale series of tests, computer modelling and simulation were performed to provide parametrically bound guidance on residual hazard and the need to decontaminate an area after an attack.

The Headquarters United States Air Force Air Staff (A3SC now A5XP) conducted a long-term (two-year) analysis effort to provide operational answers to the decontamination question. Five thousand two hundred biological agent attacks were simulated using Hazard Prediction and Assessment Capability (HPAC) 4.04 to produce a spectrum of aerosol challenge levels across a known location. Attack scenarios consisted of combinations of the following: four biological agents used, each representing one of the four basic types (spore, vegetative bacterium, virus, biological toxin); five weapon systems: sprayers (air, ground, and sea), bursting missiles, and missiles with submunitions; three attack times (inclusive of day and night); and three weather conditions (spring/fall, summer, winter). Aerosol challenge output was subjected to post-processing and analysis: deposition of aerosol material; reaerosolisation of deposited aerosol material; transfer of deposited aerosol material; building infiltration by aerosol; degradation of the deposited material (agent persistence);

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and calculation of Percentage of Casualty (PCAS) based upon biological agent infectivity/toxicity (limited ingestion data). Parameters for post-processing were obtained from field trials and laboratory experiments.

Low casualties

The results of these modelling experiments were encouraging. In most cases, the risk associated with the residual hazard after 24 hours of environmental exposure was extremely low. Across all weapon/agent combinations, the PCAS associated with reaerosolisation was three per cent for the worst case parameters (heavy deposition/strong reaerosolisation). The minimum casualty, for outdoors, was considered to be anyone exposed to a dosage corresponding to an agent-specific concentration which may produce casualties 0.1 per cent of the time. In other words, the risk someone would come into contact with enough agent to produce disease was extremely low.

Indoor results had to be interpreted carefully. While the Hart Senate Office building study has been cited as providing evidence of *B. anthracis* persistence indoors, the attack which generated the contamination was inside the office suite. In the Air Force study, the attack was exterior

to any buildings and infiltration of the building by the agent was by the passage of the aerosol cloud over and around the building. In general, 20 per cent of the material in an aerosol cloud can penetrate a building. This can fluctuate wildly, from nearly none to 100 per cent, all having to do with the state of any one building. The worst case PCAS from reaerosolisation inside a building immediately after an attack, across all weapon systems and agents, was seven per cent. A minimal casualty in this case was anyone exposed to a dosage corresponding to an agent-specific concentration producing casualties 16 per cent of the time. Allowing for desiccation time, agents such as *Y. pestis* are no longer viable, with a PCAS of zero per cent after 24 hours.

The long term survivor in all of this is *B. anthracis*. This organism is well suited for life in the harsh outdoors and is a naturally occurring soil bacterium. More investigation needs to be done on the life of *B. anthracis* after a deliberate dissemination. Of the bacteria that do survive, what becomes of them? Are they bound together into particles too large to be a respiratory concern? Studies of saltation and other small particle effects suggest this may occur. Of the residual bacteria, what life do they have within the soil? Does this pose a hazard to animals or people for years

to come? How can you really clean the outdoors? Current detection technologies cannot test for zero, so reducing the level of contamination, should decontamination be demanded, may be done but very difficult to assess properly as the initial level may be below the testing threshold. Studies are ongoing on the life and times of *B. anthracis* and there needs to be further fate work on other threat agents, such as botulinum and ricin toxins, and viruses. Fortunately, most of the threat agents are not hardy in the environment.

The goal of the Air Force analysis was not to answer the question, "how clean is clean?" but instead to determine what the potential residual hazard was and what risk this might pose to unprotected individuals. With this type of information, informed choices may be made on decontamination decisions. A successful biological attack may indeed pose a residual hazard risk. Certain agents, such as *B. anthracis*, are remarkably persistent in the environment. Others, such as *Y. pestis*, have high infectivity, but are quickly destroyed by normal environmental conditions. Others pose somewhat nebulous persistent risks due to a lack of data. In time, and with new research, this modelling can be revisited to provide more complete residual hazard estimates.



Once there is effective agent fate correct PPE and decon levels can be set

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