Defensive Strategies for Pollutant Control in Indoor Environments

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Introduction

The buildings industry is severely challenged by indoor pollution and the building and human problems this causes. Pollutants and their sources are complex. Particulates, gases, and biologicals are all part of the pollutant mix assaulting buildings and their occupants. These pollutants come from the outdoors, building materials, activities inside the building, furnishings, supplies, and the occupants themselves. Buildings are filled with "out-of-sight" and "out-of-mind" spaces and routes of transmission for these pollutants.

Common Indoor Environmental Quality (IEQ) problems mimic the worst scenarios of a terrorist event where chemical or biological agents might be used.

When these problems occur in public buildings, we find ourselves severely challenged – not simply with keeping buildings suited for the occupants, but also with public visibility, legal scrutiny, legislative uncertainty, and regulatory oversight that make IEQ the single most significant environmental health and productivity issue as we move through the 21st century.

Asbestos, Radon and Lead – have all become part of our common vocabulary and part of our safety and compliance regimes. Yet, these pollutants are only part of the array of indoor pollutants affecting our people and the buildings they occupy.

This paper will provide a quick overview of problems, causes, and solution strategies – not just related to indoor air quality – but also to the broader concept of IEQ. It will hopefully provide you with insights useful in defining the building as a defensive tool in case of an introduced pollutant.

How this links to biological/chemical terrorist defense will be clear to everyone faced with keeping pollutants out of buildings and negating the damage to the facility and the occupants.

The Problems

Indoor environmental issues can be framed by the public preoccupation with the extreme IEQ problems – Building Related Illness (BRI) and/or Sick Building Syndrome (SBS).

The human symptoms involved are an array of physical and systemic reactions affecting the skin, mucous membranes, eyes, upper and lower respiratory tracts, and muscles. Some are short- term (acute) and others are long-term (chronic). All affect productivity, health costs, and well being.

The Causes

The important pollutants in the indoor environment include those listed in Fig. 1. Also shown are the contributing factors that directly affect comfort, health, and productivity. While each pollutant can be

Relevant Pollutants

- Radon
- Smoke
- Carbon Dioxide
- Asbestos
- Nitrogen Oxide
- Lead
- Ozone
- Carbon Monoxide
- Volatile Organics
- Pesticides
- Chlorine
- Particulates

Contributing Factors

Light • Noise • Temperature • Humidity

Figure 1: Relevant pollutants

significant in causing human ailments, they are only a part of the chemical, particulate, and microbiological "soup" causing problems in indoor environments.

In any survey of pollutants, microorganisms are of primary concern. They are diverse, found everywhere, and highly adaptive. They cause short- and long-term problems within buildings. Microbes cause direct damage to the building – odors, staining, and deterioration (corrosion, rotting, etc.). They also cause human problems such as BRI, SBS, Hypersensitivity Pneumonitis, allergic disorders, and infectious disorders (including Legionnaire's Disease).

Solution Strategies

If we look at microbes as a model, we can understand a great deal about the general sources of most indoor pollutants. Figure 2 shows some of these sources. Most or many of these sources, coupled with ideal temperatures, can be habitats for microorganisms – food, water, and receptive surfaces.

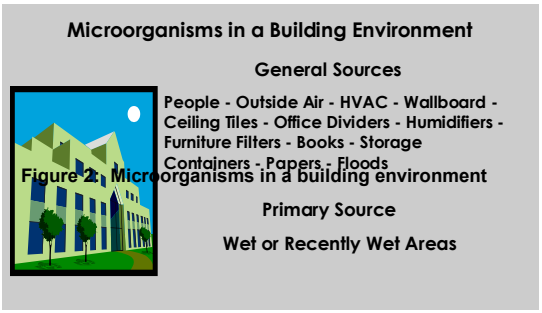

Figure 2: Microorganisms in a building environment

With this short preface on the impact of IEQ issues, the nature of IEQ problems and the range of causative agents, we now can introduce some concepts that are useful in identifying, solving, and preventing problems.

No effective testing, mitigation, or protection strategy can be created and implemented without a thorough evaluation of the building. The materials of construction, the operating systems, the furnishings, and the habits and practices of the occupants are critical components. Figures 3 and 4 provide for the holistic view that must be taken.

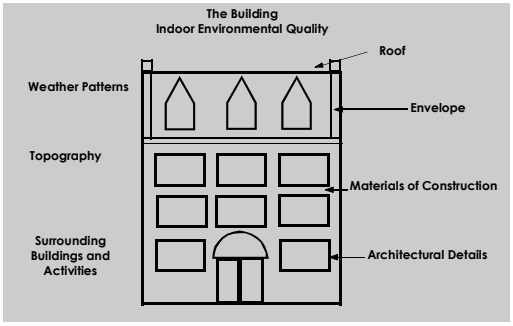

Figure 3: The building indoor environmental quality

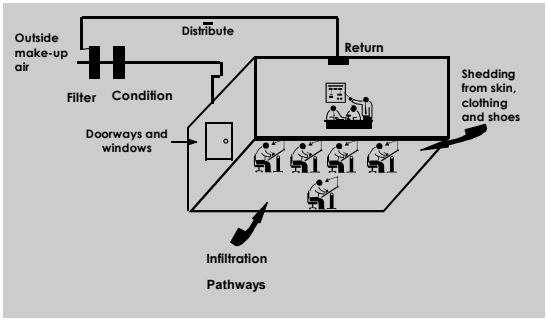

Figure 4: Airflow illustration

Auditing and understanding these critical pollutant generating and transmitting sources are vital to control.

To be appropriate and effective, strategies must contain a variety of control methods – source removal, dilution, filtration, and source control. This means eliminating materials which emit excessive amounts of known pollutants, pumping massive amounts of fresh air into a building to dilute what pollutants are already there and prevent greater concentration, using improved filtration methods to remove airborne contaminants, and directly attacking pollutant sources to prevent creation of new contaminants. All are helpful, yet limited in usefulness and have an associated price. Only effective source control and interruption of transmission delivers long-term benefits.

The cost/benefit ratio of many techniques is questionable, and many deal with short-term reduction of human symptoms rather than elimination of the basic problem. Much like taking aspirin for arthritis pain or the fever and headache of a cold, they address the symptoms rather than the cause. In areas such as control of bacteria and fungi, there are highly effective

services that provide long-term source control. By actively modifying the environmental surfaces in a building, the sources of microbial contamination can be greatly reduced.

This approach can be used to remove existing microbial infestations, prevent microbial colonization, and reduce transient microbial levels. For safety and technical performance, this approach needs to use a technology that is non-volatilizing and non-migrating (chemically durable), is non-toxic to higher life forms, and has a proven record of real-world problem solving. This is a systems approach as expressed in Fig. 5.

Figure 5: Pollutants in a building environment

With this basic approach to controlling pollutants in buildings, we can assess how we can detect, contain, mitigate, and prevent problems associated with a terrorist's introduction of their version of a chemical or biological "pollutant."

Defensive Strategies

Some of the widely accepted "solutions" to microbial contamination are essential, some are helpful, some are a waste of time and money, and some are clearly frauds. Understanding what the various options can and cannot achieve is critical. ÆGIS personnel hopes that we can provide some guidance and clear insight into what the ÆGIS Microbe Shield™ Technology can and cannot do to take microbial problems out of your concerns.

During the last year, professional and trade associations have recognized the linkage of existing problems and solutions associated with indoor pollution to the problems and solutions associated with chemical and/or biological terrorist events. This recognition has led to task forces and committees that are bringing forth some practical actions that can reduce the negative outcomes of a terrorist attack. All of these actions are built upon existing standards and guidelines and acknowledge the need for a holistic approach.

The Lawrence Berkeley National Laboratory has issued some "Immediate Actions to Safeguard a Building Against a Chemical or Biological Attack:"[1]

- *Prevent unauthorized access to air intakes; air exhausts might also be a concern.*

They explain many of the complexities of this strategy and explain the costs in terms of capital expenditures, increased maintenance, and increased energy costs. They also explain that air intakes are but one of the many infiltration routes into a building.

- *Secure building plans and HVAC plans from unauthorized access.*

Here they explain the importance of protecting such plans from potential terrorists. This directive should be extended to all building plans as terrorists can use knowledge of the building and the building's operating systems to gain access or block exits when executing their actions.

- *Plan and practice separate emergency response procedures for indoor and outdoor releases of chem/bio agents.*

Practical recommendations are offered regarding containment and evacuation and the need for practice and discipline. A logical extension of their advice is to have a meeting area where the degree that occupants are affected can be determined before people or animals move into the general population.

- *Develop an emergency response team and establish operational details.*

"Any emergency requires rapid response in a number of areas: evacuation assistance, communication with authorities, etc. A team of people with well-defined responsibilities should be created, with backups when the selected people are not available.

Among the responsibilities are: (1) main decision-making: should the building be evacuated, should the HVAC system be turned off, etc.; (2) contacting authorities (fire department, police, etc.), (3) providing instructions to building occupants, (4) manipulating the HVAC system as needed, (5) coordinating first aid."[1]

The added importance to this team is that by their actions, they can set the tone and agenda for dealing with the real and costly problems associated with current and episodic normal pollutants, not just terrorist events. Their view of the building also allows for optimizing energy usage. This is a win-win situation for building owners and occupants.

The Lawrence Berkeley staff further elaborated on the immediate action with a list of "Long-Term Actions to Safeguard a Building Against a Chemical or Biological Attack:"

- *Ensure building operators can quickly manipulate HVAC systems to respond to different types of attacks.*

"Manipulating the HVAC system can help slow the spread of a chem/bio agent or can rapidly clear a chemical agent out of a building. Rapid response could save lives."

- *Upgrade HVAC filters and seal gaps to prevent air bypass.*

"Particle filters can remove biological agents (such as anthrax) from the air handling system. However, the tighter the filter, the more air will try to leak around it."

- *Establish internal and external safe zones for people to use during a toxic release.*

"By manipulating (and perhaps modifying) the building's HVAC system, safe areas can be created inside the building when there is an outdoor hazardous release. Also, some external areas near a building will be safer than others during an indoor release."

"Manipulating the HVAC system can help slow the spread of a chem/bio agent or can rapidly clear a chemical agent out of a building. Rapid response could save lives."

- Lawrence Berkeley National Laboratory, http://securebuildings.lbl.gov.

- *Provide separate air exhaust systems for mailrooms and other high-risk locations.*

"Some areas are likely targets for introducing a chem/bio agent into a building. Isolating the air handling systems from these areas can prevent the agent from spreading throughout the building."

- *"Weatherize" the building by sealing cracks around doors and windows.*

"Gaps around windows and doors, and holes in the building shell, allow conditioned air to escape the building, and outdoor air to enter. Sealing these gaps can reduce the amount of outdoor contamination that enters the building."[2]

Technologies are available for scouring and neutralizing chemical and biological agents before discharge and to protect secure areas within the building. Some of these can be implemented as part of the building materials and furnishings, and others can be integrated into normal HVAC or smoke exhaust systems. The ÆGIS antimicrobial technology and ÆGIS/Diazem acid capture technologies are part of the tools useful in this respect.

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) has formed the Presidential Study Group on Health and Safety Under Extraordinary Incidents and the members have issued the "Risk Management Guidance for Health and Safety Under Extraordinary Incidents."

"Extraordinary incidents, whether caused by war, terrorism, accident or natural disaster, focus attention on such basic, immediate, human needs as survival and safety and longer-term needs such as water, food and shelter. To reduce risks under such situations, ASHRAE recognizes that its expertise in HVAC&R, and its knowledge of building envelope insulation, fenestration, air infiltration, intake and exhaust

air control, and filtration is critical in addressing occupant survival and safety. Advances in technology have also increased ASHRAE's responsibility for providing design, construction and operational information that integrates security, fire and smoke control, and indoor air quality with other building systems to enhance the safe operations of buildings. Recognizing this increased responsibility in providing guidance for enhanced building performance, the President of ASHRAE appointed a Study Group to provide initial guidance, through this report, on actions that should be taken to reduce the health and safety risks of occupants in buildings that might be subjected to extraordinary incidents." [3]

This group and the company's members are incredibly important to building owners and governmental strategists charged with developing and implementing plans for detection, mitigation, and clean-up of chemical or biological terrorist events. Without addressing the occupant health response side of the issue, six key observations provide the basis of their guideline recommendations:

- *Buildings in the U.S. have important safety factors that have proven effective against some threats because of the quality of the standards of care practiced in the U.S., the enforcement of building codes and standards during design and construction, and because of the legal liability of designers, constructors and owners of these buildings*

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- *If protection against aerosol attacks launched from a source exterior to a building is to be accomplished, then the openings into the building that could allow airborne aerosols to enter must be capable of timely closure, located sufficiently remote from any launch site, or equipped with adequate filtration.*

- *If protection against aerosol attacks launched from a source interior to a building is to be accomplished, then the space in which the aerosol is released or present must be capable of timely isolation by the closure of all openings communicating with other spaces.*

- *Sensors, monitors, and other means of forewarning are not presently available or are not reliable for many contaminants. Therefore, strategies other than feedback control are relied upon, today.*

- *It is unlikely that areas of refuge are economically viable in many buildings. Therefore, a practical and commercially viable application of HVAC technology is the enhancement of building egress paths and the isolation of significant contamination to selected building volumes.*

- *Enhanced filtration is a desirable, but not sufficient, control strategy to reduce occupant risk to airborne contaminant. A comprehensive strategy is needed which includes enhanced filtration coupled with building pressurization of the building interior relative to the outdoors; this, in turn, requires improved air tightness.*[3]

"Because it is difficult to distinguish an introduced infectious disease from a naturally occurring one, the strategies to protect against either event in terms of new scientific and technical approaches and surveillance, prevention, and response are the same. "

ASM News, Public Affairs Report, Vol. 68, No. 9

This led to their ten recommendations: [3]

Understand your building

- *Ventilation System Operation*
- *Filter Efficiency and Bypass*
- *Quantity of Outdoor Air – Verify and Understand Routes*
- *Control Access to Air Handling Components*
- *Isolate Likely Entry Points*
- *Fire Protection and Life Safety*
- *Building Shell and Duct Tightness*
- *Areas of Refuge*

- *Preparedness Plan*
- *What Not to Do*

The following actions should not be taken unless under the written advice or direction of a professional engineer registered in the state in which the building is located.

- *Do not close outdoor air intake dampers or otherwise block ventilation air paths.*
- *Do not change the designed airflow patterns or quantities.*
- *Do not modify the fire protection and life-safety systems without approval of the local fire marshal.*

A complete building baseline analysis of existing chemical and biological pollutants and their probable sources and routes of transmission needs to be done. Detection of abnormal events can only be accomplished if a good understanding of "normal" exists. This needs to include not just the building materials and operating systems, but also the furnishings, supplies, work processes and products, and the habits and practices of the occupants.

The American Society of Microbiology (ASM) and the National Institute of Allergy and Infectious Diseases (NIAID) are added to the many professionals stepping forward with expertise needed for defining and dealing with chemical or biological terrorist events.

ASM has provided inputs on needed activities for the Department of Homeland Security (DHS) that relate to microorganisms and their interface between the outdoor/indoor environments, humans, disease, and cures.

"Because it is difficult to distinguish an introduced infectious disease from a naturally occurring one, the strategies to protect against either event in terms of new scientific and technical approaches and surveillance, prevention, and response are the same. There will also be dual benefits for public health in that investment in research to develop new therapeutics, vaccines, antivirals, genomics, and diagnostics will carry over to public health breakthroughs for all infectious diseases. ASM, therefore, recommended that Congress reverse the responsibilities in section 303 of H.R. 5005 so that the DHHS (Department of Health and Human Services) would retain responsibility for accelerated research and development programs, including the prioritization of those projects and set the priorities in collaboration with the DHS (Department of Homeland Security)."[4]

This is extremely important as it points out the complexities of the microbial and health related parts of the biological threats under a terrorist scenario.

NIAID points out added critical elements in their research on biodefense:

"The strategy for all aspects of NIAID's approach to bioterrorism preparedness involves cross-cutting research and development goals that approach each pathogen from multiple perspectives. The Institute's biodefense research agenda focuses on six unrelated areas: microbial biology, host responses to microbes, vaccines, diagnostics, therapeutics, and research resources."[5]

Furthermore, they address four key challenges:

"Biodefense research agendas at NIH and other institutions face several common challenges, including a shortage of trained scientists and research resources. If researchers are successful, the development and delivery of pharmaceutical or biological products for biodefense or other use will require corporate partners willing to manufacture them. Finally, the anthrax attacks and subsequent investigations have raised doubts about the security of potential pathogens in research laboratories as well as the accessibility of information related to these pathogens. The following challenges may have major implications for the way in which we conduct collaborative science."

- ***Expanding the community of biodefense scientists.*** *There is a dearth of investigators involved in research on some of the most important pathogens that could potentially be used in a bioterrorist attack.*

- ***Infrastructure.*** *The biodefense research community finds itself, in many instances, to be lacking needed research infrastructure.*

- ***Industry involvement.*** *A significant challenge in the development and manufacturing of drug, biologic, and diagnostic products is the need for partnership with industry.*

- ***Biosecurity.*** *Much of what has been written above relates to efforts designed to enhance our defense against the potential of a biological attack. Equally important is the concept of "Biosecurity." Biosecurity can be defined as the set of activities designed to enhance the physical security of laboratories and their contents, especially laboratories in which research on so-called "select agents" is being conducted.*[5]

These, of course, are just a few of the initiatives that are on-going here in the USA and in other countries. They are used here to illustrate the need for varied expertise and a focused core charged with the integration of these expertise bases into strategies and actions that truly address all of the elements needed to protect against, and react to, terrorist events in buildings.

Problem/Response Policies

One extremely important safeguard, which is often overlooked, is that all buildings should have a clearly written policy designed to respond to building problems. Included in the policy should be a clear scheme of response to environmental issues. This is especially important as we anticipate biological or chemical terrorist events.

We have developed contingency plans for basic civil defense and applied these to weather or other natural disaster events. For buildings near chemical factories, reaction to accidental releases is in place. These readiness plans for reaction to catastrophic situations need to be complemented by plans for more subtle or localized pollutant events in buildings.

The value of quick, quality response is hard to quantify, but minimizing the risk of the psycogenic (power of suggestion) spread of a "bad" feeling, maintenance of productivity, and lowering of medical costs are all within reach. The need for quick response is magnified for biological or chemical terrorist events and education of the occupants for reaction to an event is critical.

Antimicrobial Intervention

The antimicrobial needs for anticipation and reaction to a bioterrorist event requires a variety of technologies and approaches. What we have learned in the IEQ industry provides technical tools for dealing with bioterrorist events.

Antimicrobial technologies for preventative treatment of building surfaces must have a broad spectrum and durable nature. The ÆGIS Microbe Shield Technology has met this challenge in use in buildings for over twenty years. The treatment of ceiling tiles, air filters, upholstery, and the full range of building surfaces and furnishings has been done.

Optimizing the effectiveness of this unique treatment requires an engineering and substrate specialist to assure proper use in the type of building and area of the building for which protection is desired.

Antimicrobials for mitigation require rapid and thorough action and a variety of these technologies are readily available although they all present risks to materials and people that must be considered.

For post clean-up treatments, ÆGIS again offers powerful long-lasting tools that can be used on all affected and peripheral areas.

Summary

The realities of random and massive strikes or terrorist acts do not change the basic need to understand the current status of our buildings in regard to pollutant sources and routes of transmission into, around, and out of buildings. The new importance is that we, as a global society, may have to broaden our views on how we define the stock of buildings that need protection and reaction strategies in place.

Strategies for control of bio/chem terrorist events are markedly similar to the control of IEQ problems. Understanding the external

ecosystem, surrounding environment, envelopes of the building, materials of construction, furnishings, operating systems (air, water, power), and habits and practices of the occupants are needed. Coupling this with an understanding of infiltration and exfiltration routes and general internal routes of transmission for pollutants provides a road map for bio/chem terrorist defense strategies.

Solving microbiological problems in buildings takes a holistic approach that considers all elements of a building's environment, construction, use, and abuse. A terrorist attack is the extreme of abuse.

Detection, isolation, capture, mitigation and inactivation, clean up, and clearance testing set out the basics for indoor pollutant control or for the control of biological or chemical toxic agents.

As people devise strategies for defensive tactics for a biological or chemical terrorist event, it is critical that mechanisms for detecting be understood and implemented. Without a thorough knowledge of the building infrastructure, no effective defensive posture or reaction can be implemented.
Expenses for such tactics are affordable under the needed expenses for energy and IEQ control.

References

[1] Lawrence Berkeley National Laboratory, *"Immediate Actions to Safeguard a Building Against a Chemical or Biological Attack."* Sept. 2002, http://securebuildings.lbl.gov/PA_I_Intake.html.

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[3] ASHRAE Presidential Study Group *"Risk Management Guidance for Health and Safety Under Extraordinary Incidents."* Jan. 2002, p. 1-8, www.ASHRAE.org

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