Safety and Security of Indoor Air Quality (IAQ)

Henry M. Healey, P.E.
President
Healey & Associates
Merritt Island, Florida
www.flaenergy.com

ABSTRACT

Sick buildings throughout the nation have been vacated, demolished, or totally refurbished at costs that often exceed the original cost of the building because of indoor air quality (IAQ) issues. A valuable commercial building in South Florida sits vacant today because it's contaminated with anthrax. New exclusions are appearing on insurance contracts for architects, engineers, and contractors, as well as homeowners—*mold, an IAQ issue*. IAQ is today becoming one of the biggest concerns of a building's occupants, its owners, and its managers, as well as architects, engineers, and the construction industry. The recent increase in litigation related to mold, an IAQ issue, combined with the September 11th attacks and the bioterrorism events of the following October, has raised the issue of building air quality safety to the highest level.

While IAQ and mold issues are today not regulated by governmental agencies, building owners, managers, design professionals, and constructors are being held responsible for the health and safety of the air quality in buildings. Both OSHA and EPA have established guidelines and recommendations related to IAQ issues, and several organizations, including CDC, NIOSH, and USACE, are in the process of developing guidelines for "protecting" a building's indoor air quality. Today, it is absolutely essential that those responsible for buildings take actions to ensure that workplace air quality is maintained so as to be *safe and secure* from health hazards.

Events of 9/11 and the subsequent anthrax incidents, combined with the aging of our buildings and litigation related to mold and other

IAQ issues, have made it apparent that the air quality in our buildings is not as safe and secure as it should be. Given the present status of IAQ litigation and the heightened concerns of terrorism and other extreme incidents which could impact a building's air quality, action is required. Unfortunately, while a great deal of attention is being focused on the general infrastructure and responder training since 9/11, little attention is being focused on protection of our workplace's most critical asset—its people and the air they breathe in the workplace.

In order to fully address the health and safety of a building's air quality, an indoor or building air quality safety program is required. An IAQ safety program would be expected to provide the engineering controls and systems capable of protecting a building's air quality, in addition to the policies and training procedures of building operators, maintenance personnel, managers, and occupants in maintaining safe air quality in buildings and initiating appropriate response actions to protect occupants in the event of an IAQ incident or threat. This article, while presenting information on addressing the typical issues related to IAQ concerns, discusses protecting the air quality in buildings and developing the safety programs, plans, and procedures along with the engineering controls necessary to help ensure the health and safety of air quality in buildings.

The proactive and protective recommendations discussed in this article, starting with the installation of a dedicated outdoor air system designed to pre-condition the fresh air that enters a building, and development of an IAQ safety program can be readily implemented in any C & I facility. The concept of an IAQ safety program is not new. Some forward-thinking organizations have implemented such plans, even though it is not required by regulatory authorities (OSHA, EPA, or AHJs). The IAQ safety program recommended herein is intended to address conventional IAQ issues of mold, ventilation, and contamination, etc., but goes a step further and addresses the vulnerability of the BAQ from unexpected incidents including spills, fires, explosions or chemical, biological, and radiological (CBR) issues which, in our present environment, must be addressed.

This article also describes a dedicated outdoor air system intended to function as a BAQ protection system (building air quality protection system) designed to pre-treat all the fresh air to a building and protect a building's air quality from external sources of contamination. The BAQ protection system, a dedicated outdoor air system which functions as an outdoor air pre-treatment system with control dampers and associated interlocks capable of sealing the building's outdoor air ducts for protection, serves to address humidity levels and building pressurization in both new and existing buildings. The BAQ protection system significantly reduces HVAC system energy for both heating and cooling by eliminating the latent (moisture) load from the building's HVAC system. This system has been identified as one of the most promising energy savings technology by USDOE.

INTRODUCTION

At the present time, the commercial and industrial (C&I) sector does not appear to be fully prepared to address the ordinary indoor air quality (IAQ) threats related to mold and mildew, ventilation, contamination, and filtration, etc., to a building's air quality, let alone the more serious threats from spills of hazardous materials or extraordinary incidents such as chemical, biological, radiological (CBR), or other extreme incidents. It appears that we have the capability to respond to incidents like the anthrax incidents of 2001, but we have not, at the present time, prepared our buildings, their occupants, facility managers, custodians, and maintenance personnel for routinely handling such *extraordinary incidents*—we need to!

In mid-October 2001, the author became acutely aware of the shortcomings related to response actions to threats to building air quality from some bioterrorism incidents. At that time, the opportunity of being in a government building when a "suspicious," leaking package was reported and a response action initiated presented itself. Building personnel reported the incident to safety and emergency response personnel, who gave immediate instructions and dispatched security personnel to "secure" the building. The building was sealed, locked down by armed security personnel, and no one was allowed to enter or leave the building until emergency response personnel "cleared" the building. Unfortunately, several other incidents were occurring simultaneously and the response was slow (several hours) in coming.

The building manager and occupants of the building could only do as instructed by the response team (by telephone) while armed guards secured (locked down) the building. Occupants had to wait in the building, growing more nervous with the passing time. While the area with the package was vacated and the room door was closed, shutting it off from the rest of the building, the ventilation system continued to run and was not deactivated. It took approximately 3 hours to test the substance and "clear" the building and allow the occupants to leave and undergo decontamination (showers) if desired. Fortunately, the field test was negative and the confirmation lab test (24 hours later) verified the negative field test results. The occupants and the author were not happy campers as a result of this experience, and the questionable response actions were reported to safety as an issue that needed attention.

As a result of this incident report, the response actions and procedures were reviewed by a safety team, meetings were held, and procedures were changed. Recommendations related to engineering controls (a kill switch) and training were made to avoid such situations in the future, and long-range HVAC system modifications were recommended for the buildings. This first-hand experience made it only too clear that proactive procedures, training, and standard protective measures (engineering controls and personnel protective equipment) must be applied to protect the air in the workplace. Most building managers and occupants have little or no knowledge of the basic HVAC equipment, its service area, or its operation or controls (on-off). As a result of this incident, building air quality protection information was posted on the author's web site related to BAQ to make building owners and managers aware of BAQ safety issues.

It has become obvious that we need to do much more to protect air quality and maintain a safe environment in the workplace to avoid problems and eliminate the anxiety that such incidents create in employees. Training and engineering controls can help avoid IAQ problems and keep contaminated air out of buildings. The fresh air intake should be secured or relocated to reduce its vulnerability. Building managers should be able to deactivate the ventilation system quickly in the event of a release of contamination inside the building. In work areas that are likely to become contaminated unknowingly (i.e. post office sorting rooms), we might consider installing a high efficiency particulate air (HEPA) filtration system and making PPE available to workers. Workers need to be trained (awareness training) in building air quality safety and appropriate response actions to potential IAQ incidents.

To ensure the safety of occupants, building managers (and alternates) must have a basic knowledge of the air distribution system in the building they occupy. Information on air handling unit service areas, how the building's AHUs, ventilation, and exhaust fans can be quickly shut down, and appropriate response actions for threats or contamination from inside or outside the building must be displayed for use in emergencies. Shut down instructions should be posted or readily available in the event of emergencies, and all employees must have basic instructions related to these new threats to our workplace. The information presented in this article is intended to provide guidance to building owners and managers, architects and engineers, and safety personnel in ensuring the safety of a building's air quality.

INDOOR AIR QUALITY

An indoor air quality issue can refer to a multitude of perceived problems that range from general environmental concerns involving comfort (drafts, uneven temperatures, etc.), lighting (glare, frequency, etc.), noise, and general workplace conditions, or it can be the more significant "air quality" issues resulting from mold, contamination, ventilation, humidity levels, etc. The indoor air concerns addressed in this article and related presentation focus on the more serious issues that often are identified when investigating sick buildings (SBS). These issues include humidity extremes, building envelope problems, poor air distribution, air pollutants inside or outside the building, not enough or poor quality of fresh air, etc.

The most serious building demolition-type IAQ problems are often mold-related, resulting from air, water, or moisture intrusion through the building envelope, air leaks in the building envelope, leaky ductwork that results in the entry of moist unconditioned air, or an oversized HVAC system with limited humidity control. Humidity levels above 60 percent are problematic and most often result in mold growth and bioamplification, leading to SBS. Addressing these IAQ problems can generally be accomplished by focusing on the issues of water and air leaks through the building envelope, impacting humidity levels in the building, ventilation rates and air distribution throughout the space, and contaminants in the air supply and/or building, as discussed below.

Control of Humidity Levels

Humidity levels in buildings should be maintained between 40 percent and 60 percent at all (occupied and unoccupied) times to ensure acceptable IAQ. Maintaining proper humidity levels requires treating water and/or air leaks into buildings as a serious health hazard requiring immediate response and correction. Solutions may simply require stopping leaks, adding humidity controls, and/or reheat strategies and/or reducing or eliminating the moisture load from the outdoor air or the building.

Eliminating the moisture load from outdoor air and the existing HVAC system is becoming one of the most cost effective and popular means of controlling humidity in the hot/humid climates of the southeast. This is readily accomplished with an outdoor air pre-treatment unit, which can often be implemented as an energy conservation project providing an energy savings (see Figure 1). Pre-treating the outdoor air with a dedicated unit to filter, dehumidify, and deliver it directly to the building's HVAC system or the occupied space will help IAQ by serving to pressurize the space while removing the latent (moisture) load from the building's HVAC system. This strategy can be retrofit into existing buildings' HVAC systems, and is recommended for all new systems for both building pressurization and moisture control. This approach, called an outdoor air pre-treatment or dedicated outdoor air system, has been identified by the US Department of Energy as one of the most promising energy savings technology for commercial buildings.

Ventilation Rate and Air Distribution

The ventilation rate, which can refer to either the air movement throughout the space or the amount of outdoor air supplied to the space, is often measured in cubic feet per minute per square foot of area served (cfm/sf). This determines the turnover rate of the building air by the AHU. The cfm/sf varies with building heat or cooling load and is generally between 0.8 and 1.5 cfm/sf for typical office buildings. The air change (exchange) rate, the ventilation rate for outdoor air, is a measure of the overall turnover or exchange rate of the room air. The ventilation rate for C&I buildings is mandated by code, which references ASHRAE Standard 62 (Ref. 1) to help control contaminant buildup. The 15 to 20 cfm required by most building codes for each occupant was derived from the ASHRAE 62-89 Standard and remains in common use today. Standard 62 undergoes continuous maintenance (updates) by ASHRAE and provides a variety of methods to determine the recommended quantity of outdoor air for different types of buildings and occupancies.

The ASHRAE Standard 62, as any other code reference, provides minimum requirements and may not be sufficient for all applications if

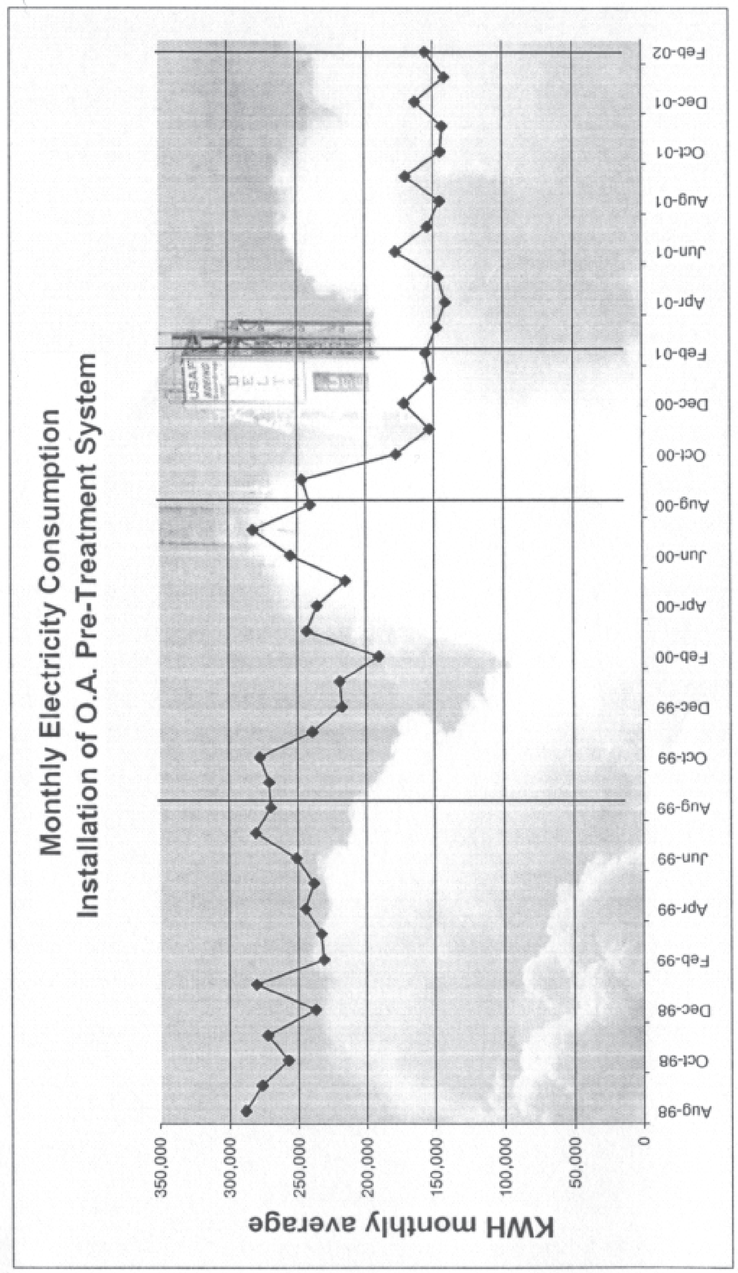

Figure 1. Energy savings (100,000 kWh/mo) resulting from O.A. pre-treatment system.

indoor air quality problems such as building envelope or ventilation system leaks exist. For example, to avoid humidity problems, a building in the southeastern U.S. requires "positive" pressurization to minimize the entry of unconditioned (warm-moist) outdoor air, while a building in cool climates such as Canada may require slightly positive pressure to avoid problems. Maintaining positive pressure requires delivering more fresh (outdoor) air than is exhausted and might leak out of the building through doors, windows, and cracks. The positive pressure is intended to overcome the normal infiltration that enters (infiltrates) a building through its windows and door cracks, exhausts, etc. Depending upon the building leakage rate (Ref. 2), excess air quantities as high as 0.6 cfm/sf may be required (60 percent more air is supplied to a typical commercial office type space then is removed from it). Bringing in such large quantities of untreated outdoor air may place too high a latent load on an existing AHU, which could result in humidity problems. Such issues support the idea of pre-treating the outdoor air, which is discussed and highly recommended in this article.

The uncontrolled entry of unconditioned air into buildings creates high humidity levels often resulting in indoor air quality problems. Building envelopes are not airtight and leak unconditioned fresh air into buildings at rates ranging between two and eight tenths air changes an hour (0.2-0.8 ach). The air that leaks into a building is moist air that can condense on the lower temperature interior surfaces, increase the relative humidity in the building, and result in mold growth. High humidity levels (relative humidity > 60 percent) often are not addressed properly due to the inability of a conventional HVAC system to control humidity. Most HVAC systems are controlled only by the thermal load and temperatures in the area served. The HVAC system simply operates the air conditioning or refrigeration system to dehumidify and cool the air flowing through the unit when cooling is required by the space. In most buildings, moisture in the space is not directly controlled. Since the thermal load in a building varies over the day and season, the cooling system operates at less than the "design" or peak load of the HVAC system 99 percent of the time, creating a problematic variation in the relative humidity in the space unless the HVAC system utilizes "*reheat*" to increase the space load.

Obviously, the outdoor air ventilation rate has the potential to significantly impact humidity levels and indoor air quality. As the ventilation rate is increased to help ensure positive pressurization in buildings in hot and humid climates, the increases in outdoor air can negatively impact humidity levels. This negative impact can readily be turned into a positive benefit by pre-treating (filtering and de-humidifying) the outdoor air before it reaches the building AHU. A pre-treatment system should be configured to work with the existing system to minimize reheat by utilizing temperature reset or other techniques. Such approaches have been successfully employed in existing facilities (see Figure 1) to save energy and provide a positive payback for the installation.

Contaminant Control

Control of contaminants is crucial to maintaining suitable indoor air quality. The most common causes of air quality contamination have historically been inadequate filtration, poor housekeeping, and contamination from interior or exterior sources. IAQ investigations on many commercial and industrial buildings have found inadequate filtration (low efficiency filters) installation and maintenance problems. Filtration levels (efficiencies) often were less than recommended (Ref. 1) by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) and not properly maintained. Filtration must be appropriate for the size and type of contaminant as well as the properties of the air stream. The filters must be properly installed in racks that must not allow the air stream to bypass the filter.

While the efficiency of filters in the past has been somewhat confusing because of the multiple rating systems employed, the MERV or minimum efficiency rating value presently being used should simplify filter selection and help all users select an appropriate filtration system.

The MERV filter efficiency rating ranges from 1 to 17 or higher (Table 1) and essentially uses particle size as the basis for the rating. ASHRAE (Ref. 1) recommends filters rated at MERV 13 (65 percent efficiency) be selected (design basis) for new office buildings. However, one cannot simply install a MERV 13 filter in an existing building's air handling unit (AHU) to improve the efficiency without checking things. Unless the AHU can be adjusted to maintain airflow at the increased pressure loss of the filter (pressure loss of 0.6″ H_2O), the higher efficiency filter cannot be installed until modifications are made. Most likely a MERV 6 or 7 (30 percent) can be installed in most units using the typical spun glass filter (5 percent), significantly improving the efficiency. Recent publications (Refs. 3,4,5) on filtration clearly illustrate and explain filter use and testing.

Minimum Efficiency Reporting Value (MERV)				
MERV	ASHRAE	P Dp	Contamnts	Application
1	<65% A	0.3	Poln Moss	Min Fltr
2	65-70%A	0.3	D Mites	W AC
3	70-75%A	0.3	T Fibers	Res
4	>75%A	0.3	Carpet fbr	Res
5	80-85%A	0.6	Pdr milk	Paint Booth
6	>90%A	0.6	Dust	Industrl
7	>90%A	0.6	H Spray	B Res
8	>90%A	0.6	M spores	Coml
9	40-45%DS	1	fumes	Coml
10	50-55%DS	1	coal dust	S Res
11	60-65%DS	1	flour	Btr Cml
12	70-75%DS	1	Legionella	Labs
13	80-90%DS	1.4	Copiers	Sup Cml
14	90-95%DS	1.4	smoke	Smokg A
15	>95%DS	1.4	sneezing	Surgery
16	N/A	1.4	bacteria	Hosptl

Figure 2. Filter ratings.

SECURITY OF AIR QUALITY

Since 9/11 there has been a great deal of interest in protecting a building's air quality from terrorist threats and possible chemical, biological, or radiological (CBR) contamination. The fresh air intakes on most commercial, institutional, and governmental buildings are unprotected and open to the exterior at readily accessible locations. The fresh air intakes on most buildings cannot be quickly closed or sealed to prevent the entry of contaminants from unexpected incidents such as smoke, emissions from vehicles, chemicals spills, or other hazards from the exterior.

The building air quality protection system (Ref. 6), a dedicated unit designed to pre-treat, filter, and dehumidify the fresh air required by a building, essentially removes the moisture load in the outdoor air and is designed to work in conjunction with AHU and exhaust fan controls and dampers to provide the ability to instantly seal a building or its systems as appropriate to the threat. The pre-treatment system dehumidifies the outdoor air and pressurizes the building to minimize the uncontrolled entry of the warm and humid outdoor air. The elimination of the moisture load on the building's existing HVAC system allows the system to operate at higher temperatures (temperature reset) with dry coils minimizing "reheat" energy and reduces HVAC system operating costs. The reduction in moisture, combined with the addition of controls, provides a reduction in operation costs and a payback that can be used to implement the system as an energy conservation measure. This approach is recommended for all new buildings and should be considered for existing buildings with humidity related problems. The author is presently designing systems to be implemented under an energy performance contract based on the savings generated by the equipment in several government facilities.

BAQ SAFETY PROGRAM

The air quality in buildings can be easily contaminated by incidents and disasters such as chemical spills or releases, smoke from fires, or the intentional release of chemical, biological, or radiological materials inside a building or in its fresh air intake. Such extraordinary incidents are real threats to a building's air quality and its occupants and should be considered in developing protective systems and a BAQ safety program.

Extraordinary threats to air quality are most often sudden and unexpected, and they can be imperceptible at occurrence. To address and react to such incidents, engineering controls, administrative policies, plans, and procedures must be in place. The best way to prepare for extraordinary incidents is to implement an IAQ or BAQ safety program with its engineering controls and administrative structure, and train building facility managers, occupants, and maintenance personnel.

The safety program development would start with an IAQ hazard assessment for the building. The assessment would identify conventional air quality concerns involving the ventilation system, its filtration, make-up air quality and quantity, operational controls, and the entire distribution system, incorporating and/or developing appropriate policies and procedures to maintain acceptable IAQ during day-to-day operations. The development would then be expanded to assess the building's vulnerabilities to air quality threats. Vulnerabilities examined would include air intakes, receiving areas, entry areas, and any hazardous materials laboratory or storage areas. As part of the safety program, proactive security measures would be identified, safety procedures and response actions would be developed, appropriate engineering controls designed to secure and protect the building's air quality would be implemented, and appropriate PPE would be identified and made available to those who might be expected to require it.

Upon completion of the assessments, an all-inclusive safety program would be developed to help ensure the safety of the building's occupants in day-to-day operations and in the event of extreme incidents impacting indoor air quality in the workplace. A safety program generally consists of three distinct parts that are integrated into a program that addresses the issues in a comprehensive manner. The safety program first uses the hazard assessment to identify, and initiates actions to eliminate or control, the hazards, then develops the administrative structure to assign responsibilities for the monitoring, managing, implementing, and training necessary to carrying out the program. This includes providing personal protective equipment necessary to protect employees against hazards that cannot be controlled or eliminated. The three aspects of safety programs, usually implemented in a sequential manner are: (engineering controls, administrative controls, and personal protective equipment (PPE), as shown in Figures 3 & 4.

Engineering Controls

One of the most important parts of a the BAQ safety program is the implementation of engineering controls designed to eliminate or minimize the potential IAQ safety hazards and the need for personal protective equipment. Engineering controls that could be implemented as part of an IAQ safety and security system would be expected to include but not be limited to:

(1) Elevating and securing OA intakes.
(2) Installation of control dampers to seal building, OA intakes, exhaust fans, and other pathways.
(3) Installation of OA pre-treatment system.
(4) Installation of kill switches for HVAC systems for emergencies identifying associated service areas.
(5) Isolate entry and receiving areas.

As part of the process of working on the elimination or controlling the

SAFETY PROGRAM

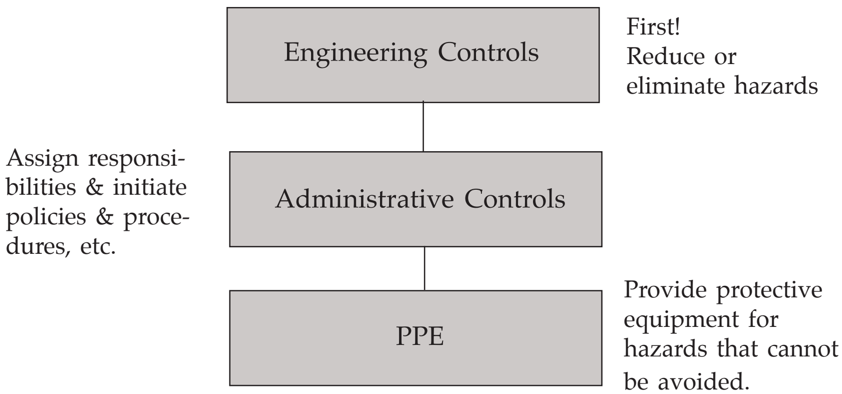

Figure 3. General safety program.

workplace hazards, consideration is given to identifying any personnel protective equipment required to ensure the safety of personnel.

Administrative Controls

Administrative controls are an important part of any safety program. An effective safety program requires both management commitment and worker involvement. Management must insure that responsibilities are assigned and adequate policies, procedures, practices, and associated training programs are developed that will protect workers from safety and health hazards as described in this article.

The policies and procedures related to operations and maintenance activities, renovation, and construction should be upgraded to reflect current indoor air quality management. Safety training would be expanded to provide IAQ specific training to instruct employees in appropriate job practices (i.e. IAQ management plans related to construction and renovation) and response actions to IAQ threats and/or incidents.

Training

The safety program should include training of all building personnel and assignment of responsibilities, and incorporate appropriate policies and procedures related to building operations maintenance, renovation, and construction. As part of the training, all occupants would be provided awareness training designed to help occupants understand

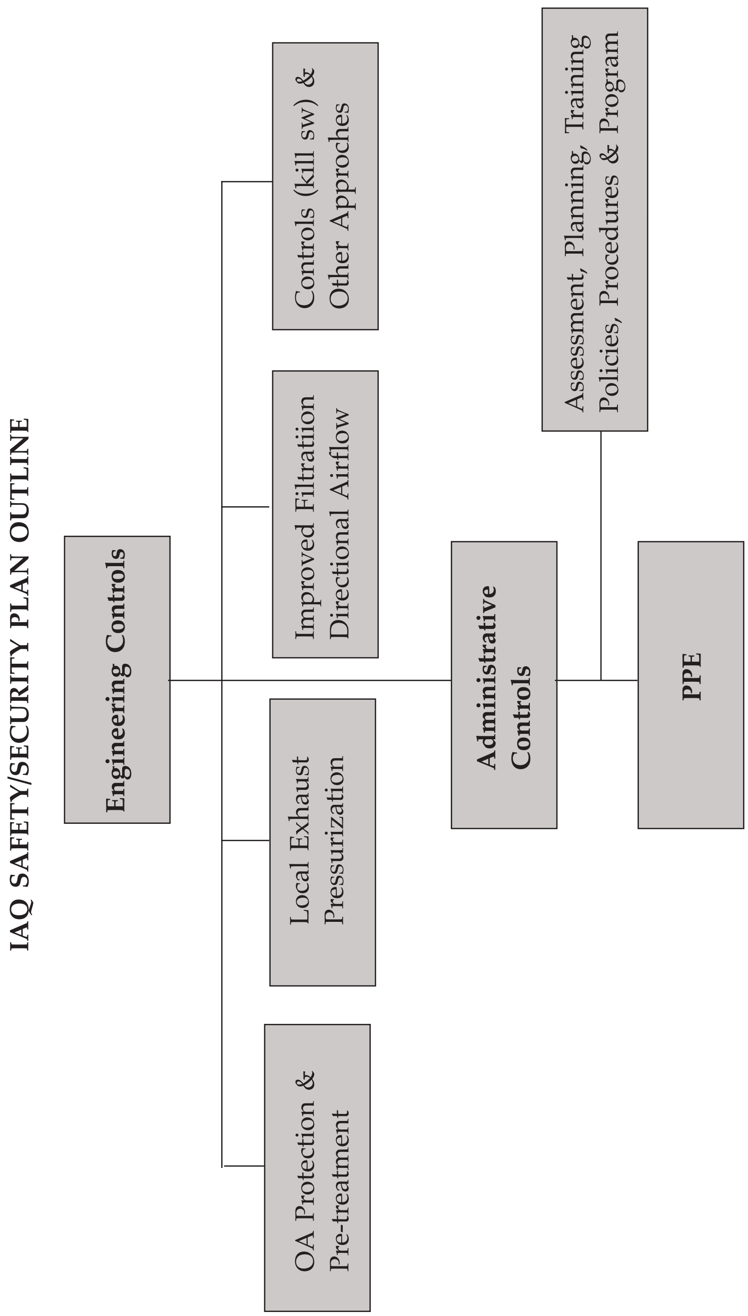

Figure 4. IAQ safety & security program.

IAQ and the necessity of reporting IAQ incidents. The occupants should be provided with information of the components of the HVAC system and its operation as well as factors impacting IAQ. The training of responsible individuals and alternates related to IAQ incidents and appropriate response actions or personal protective equipment required is absolutely essential to ensure calm, informed response actions and/or evacuations.

SUMMARY AND CONCLUSION

At the present time, workplace air quality is not being given the attention it deserves. The events of 9/11 and subsequent anthrax incidents have clearly demonstrated the vulnerability of our buildings and the concern of our workforce. At the present time, employees must weather such incidents without any organized safety plan, policies, procedures, or engineering controls that would help lessen the impact of such incidents and remove the anxiety of the workforce. It is essential that building owners and managers, architects, engineers, and safety professionals initiate actions to ensure the safety and security of workplace air quality.

The steps outlined in this article, starting with the development of an IAQ safety plan, can be readily implemented in any C & I facility. The concept of an IAQ program is not new and some forward-thinking organizations have implemented such plans. The IAQ plan recommended herein goes a step further and addresses the vulnerability of the BAQ from unexpected incidents including spills, fires, explosions, or CBR issues, which in our present environment must be addressed. Recommendations include considering the addition of a building air quality protection system designed to pre-treat the fresh air to a building and protect a building's air quality from external sources of contamination while saving energy.

A building air quality safety plan, serving to educate and inform the building's occupants, would be expected to take the terror out of bioterrorism by empowering the personnel in the workplace. The information provided in this brief presentation, supplemented with the increasing amounts of research and publications becoming available, make it possible for all building owners and managers to initiate action today to ensure the safety of our building's most valuable asset—its occupants.

This article has provided some suggestions to consider in ensuring the safety and security of indoor air quality in the workplace and protect employees from a significant safety and health hazard that is not being given the attention it deserves. The references cited have a wealth of information to assist building and safety personnel in starting the process.

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ABOUT THE AUTHOR

Henry Healey, president of Healey & Associates, an engineering firm, is a Professional Engineer who provides facility services related to energy and IAQ issues. Mr. Healey, an energy and IAQ specialist, is assisting governmental and C&I facility personnel in addressing building air quality concerns and implementing programs to help ensure the safety and security of indoor air quality. He has received numerous awards from governmental, technical and professional organizations for his energy and IAQ work.