

# Sick Building Syndrome

## When Good Air Goes Bad

Headaches, fatigue, respiratory problems, and dizziness may sound like side effects from a strong medication, but they can also be contracted just from sitting at your desk! While the consequences of outdoor air pollution have been topics of public concern for decades, the threats of poor indoor air quality (IAQ) are lesser known.

Outdoor elements such as ozone depletion, greenhouse gas emissions, and smog are widely discussed and harmful to the planet—but what about the air we breathe inside? Volatile organic compounds (VOCs) and sick building syndrome (SBS) aren't as well known as the previously mentioned threats, yet anyone who works or lives indoors is susceptible to the health effects of poor indoor air quality.

This paper presents the employee health and productivity risks of poor IAQ while examining the potential consequences to a business's bottom line, if the indoor environment is not properly maintained. Additionally, this paper will introduce the Leadership in Energy and Environmental Design (LEED) standards for monitoring indoor spaces and provide solutions to combat poor IAQ.

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# Executive Summary

Reading headlines and watching 24-hour news channels will alert anyone to the issues facing our environment. Global warming, ozone depletion, and smog are terms now commonly known to the public. And, while these concerns are valid, we face more danger when breathing indoor air than when exposed to outdoor pollution.

Most Americans spend the majority of their lives indoors. Between work, home, and outlets where we shop, eat, and lounge, the vast majority of the population's time occurs indoors. This means that everyone is counting on those spaces to provide healthy, clean air. Unfortunately, the last few decades provide plenty of examples of the dangers that can exist when proper care of the indoor air quality is compromised.

The most common condition associated with unhealthy indoor air is sick building syndrome (SBS). Building inhabitants suffering from this condition will exhibit any number of symptoms, from headaches to fatigue to difficulty concentrating and many more. These symptoms are typically acute, appearing soon after an individual enters the sick building, and will dissipate shortly after he or she leaves the premises. SBS is recognized by the medical community, but it can be very difficult to diagnose because individuals can exhibit such a wide array of symptoms.

SBS can also be difficult for facility managers and owners to diagnose because the sources of indoor air contamination are widely varied. The rise of SBS during the last 40 years is attributed to the oil embargo in 1973, which created a large push for energy efficient buildings. This led to tight, sealed buildings, which were great for controlling temperature, but critically hampered indoor air quality. Building inhabitants lost the ability to open windows, control temperature and lighting and access fresh air. Simultaneously, building owners and managers tried to save money by cutting back on ventilation systems. Thus, building inhabitants were exposed to dirty, unhealthy air, for the duration of their workdays.

Building ventilation is one of several building factors that can lead to SBS. There are industry standards in place today to ensure that fresh air is delivered to building occupants at all times. However, those standards can be harmful if the actual mechanical design of the ventilation system is flawed. In some cases, a building's air intake vents are located in areas where the air drawn in is already polluted. This can happen when the vents are located close to parking garages or gas stations, thereby pulling in carbon monoxide fumes. Additionally, there are cases where air intake vents are located too close to a neighboring building's exhaust vents, thus pulling in another building's dirty air. In these examples, the new air distributed throughout the building is already contaminated, leaving occupants to breathe dirty air all day long.

The other major source of SBS results from various environmental factors. Some of the largest offenders of indoor air quality are volatile organic compounds, or VOCs. These are harmful chemicals, emitted from many manmade products found in any office setting. Carpeting, paints, sealants, pressed-wood furniture and photocopiers can all emit toxic fumes into the air, affecting everyone exposed. In some cases, prolonged exposure to high levels of VOCs can lead to lifelong medical ailments. However, VOCs are not the only indoor air contaminant. Molds and bacteria can infiltrate buildings, spreading their dangerous spores throughout office spaces. Even common pollen and viruses can wreak havoc inside a building, particularly if the ventilation system is not operating properly.

There is no doubt that buildings suffering from SBS can have dire effects on occupants; but, how does SBS affect business' bottom line? The answer is that SBS and unhealthy indoor environments have a very negative impact on productivity and profitability. Studies show that cost-savings projects, that include reduced maintenance activities and energy cutbacks, are typically offset by increased absenteeism and a lack of focus from employees. At the same time, health care costs for employers can skyrocket if employees are making frequent doctor visits. This lost capital only worsens if a company is found to be libel for causing severe medical conditions in one, or many, of its employees, due to an unhealthy indoor environment.

The consequences of poor indoor air quality are very real, but can be avoided. Finding and removing sources of indoor contamination is step one. Third-party organizations like LEED and Greenguard are good resources for helping to identify potential sources of contamination and determine safer alternatives. Increasing ventilation rates to boost the amount of fresh air inside of buildings can help alleviate indoor air problems. Facility managers must make sure the ventilation system is operating at minimum standards. Air cleaning is another measure that managers and owners can take, but it has certain functional limitations. Additionally, open communication and education between building occupants, facility managers and building owners is crucial. Without being told by occupants, managers and owners may not know what type of indoor environment they are providing. Building occupants need to be aware of the dangers of poor indoor environments and what they can do to avoid it. Finally, understand that there is a human element in the fight against unhealthy indoor air, and that smart decisions can keep people safe and healthy.

# Introduction

Americans spend 90 percent of their lives inside, and more than half of that at work (Conlin, 2000). But while the U.S. government spent its time focusing on outdoor air with the creation of the Environmental Protection Agency (EPA) and the Clean Air Act in 1970, it wasn't until 1989 that any agency began to regulate indoor air conditions (NEMI, 2002). Investigators involved with the EPA's Total Exposure Assessment Methodology Study revealed that sources of indoor pollution contribute more to an individual's exposure to toxic volatile organic compounds than those released into the atmosphere by industrial sources (Samet & Spengler, 2003). The EPA has declared indoor air quality (IAQ) to be one of the top five environmental health risks of our time. Poor IAQ has been linked to conditions like sick building syndrome and building related illness, which have been adversely affecting employee health and comfort for more than 30 years (NEMI, 2002).

This paper discusses the consequences of poor IAQ by examining the associated negative health and employee productivity effects. Solutions and best practices will be examined to assist small business owners in keeping their employees, and themselves, safe while maintaining a well run business.

# Sick Building Syndrome

One of the most common problems associated with poor IAQ is known as sick building syndrome (SBS). SBS is a broad condition with a wide array of known causes and symptoms (e.g., headaches, fatigue, lack of concentration, dizziness, etc.). As such, SBSs only concrete definition is that it is a byproduct of poor IAQ. However, a 1984 World Health Organization report suggested that 30 percent of new and remodeled buildings may be the recipient of a high number of health and comfort complaints due to poor IAQ, effectively confirming that there is an association between poor IAQ and building inhabitants' health and comfort (EPA "Indoor Air Facts", 2010).

SBS refers to situations in which building occupants experience acute health and comfort effects that appear to be related to time spent in a building. Contrary to the condition of building related illness, SBS is not associated with a specific illness or cause (EPA "Indoor Air Facts", 2010). Young people, smokers, females and atopic (susceptible to allergens) individuals have proven to be more susceptible to SBS symptoms (Apter et al., 1994).

Office environments can affect individuals as well. Things like overcrowding, carpets that emit high levels of volatile organic compounds (VOC), close proximity to photocopiers, and even job-related tension can add to existing symptoms. Employers and facility managers should be weary of recurring complaints, particularly those found in Table 1, which shows the most common symptoms related to SBS.

| Symptoms Related to SBS | |
|---|---|
| Headaches | Eye irritation |
| Lethargy/fatigue | Upper respiratory problems |
| Humidifier fever | Lower respiratory problems |
| Chest pains | Swelling |
| Skin rashes | Difficulty concentrating |
| Dry cough | Dizziness |
| Nausea | Sensitivity to odors |

**Table 1.** Symptoms attributed to sick building syndrome.

SBS presents a pattern of behavior and complaints along with these symptoms. First, the presence of some or all of the symptoms will appear once an individual enters the building and remains for some period of time. Upon leaving the building, the symptoms will dissipate. The symptoms will return once the individual returns to the building. Lastly, the presence of symptoms, and complaints, will be amongst multiple individuals in the building. Typically, a few are severely affected while a large number will show moderate symptoms. This pattern is shown in Figure 1.

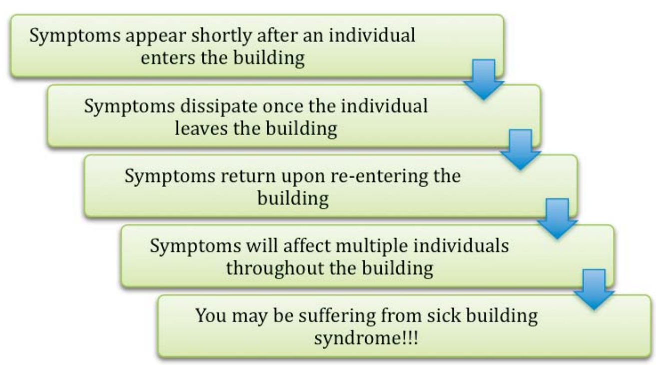


**Figure 1.** Pattern exhibited by sick building syndrome

# Building Related Illness

Sick Building Syndrome is widely considered a precursor to building related illness (BRI). While symptoms related to SBS are typically acute and subside once individuals leave the infected building, BRI symptoms are much worse. They are chronic, affecting individuals long after they leave the infected area, possibly for the rest of their life, and, in some cases, have proven to be fatal (EPA "Indoor Air Facts", 2010). The causes of BRI are approximately the same as those linked to SBS, but the symptoms can be clearly identified and attributed to specific building contaminants (Welch, 1991). Table 2 presents a quick comparison between SBS and BRI.

| | SBS | Building Related Illness |
|---|---|---|
| Type of symptom | Acute | Chronic |
| Identifiable source of indoor air contaminant | Sometimes | Always |
| Specific medical diagnosis pertaining to symptoms | Rarely | Always |

**Table 2.** Comparison of sick building syndrome and building related illness

However, while it is believed that SBS is an early indicator of BRI, occupants will not always have warning signs from SBS symptoms. In some cases, levels of VOCs and other indoor contaminants can gradually increase, in turn affecting building occupants more significantly. This scenario would alert building inhabitants of a potential IAQ issue before it became too serious. However, if the original sources of indoor air contaminants are gases, like benzene or radon, there will be no warning signs until permanent damage is done. In cases like this, SBS symptoms will actually disguise the larger problem at hand, resulting in future BRI symptoms.

**Case Study: Massachusetts DMV – Hot Air Affects More Than Attitudes**

In 1994, the Massachusetts DMV moved from an older building into an office within a new, high-rise building. After occupying the space for less than six months, more than 50 percent of the employees had made health complaints, with some developing respiratory asthma conditions. The source of the problem was caused by the design of the ventilation system. Rather than using traditional ductwork, the building construction team had used the space above the ceiling tiles as a plenum. This design flaw allowed the warm, humid air from outside to mix with the cool, air-conditioned air in this space, forming condensation. This condensation settled on the cheap ceiling tiles below (made of perlite, cellulose and other materials glued together with a starch-based adhesive). The condensation caused the ceiling tiles to ferment, releasing butyric acid, along with other fermentation products, into the air. The building eventually had to be evacuated, while a renovations crew attempted to fix the issue.

# What Causes Poor Indoor Air Quality?

## Building Factors

The root cause of poor IAQ can originate from a variety of building factors, including poor or inadequate ventilation, low relative humidity rates and percentages as well as faulty mechanical system design and construction.

Ventilation systems are vital to the health and comfort of building occupants. These systems distribute air to all of the building's occupants and replace used air inside the building with fresh air from outside. At the turn of the 1900s, building ventilation standards called for 15 cubic feet per minute (CFM) of outside air per building occupant. However, due to the 1973 Oil Embargo, building rates were cut to 5 CFM per occupant, in an attempt to save energy (MIAQC "About Sick Building Syndrome", 2010). It didn't take long to notice that these low ventilation rates were a common factor within cases of sick building syndrome. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) have since changed that ventilation standard back to a minimum of 15 CFM per person, 20 CFM per person for office spaces.

It is important to remember that inadequate ventilation is not the only source of poor IAQ. If mold, bacteria, fungi or insects already exist within the duct system, increasing the ventilation will only help them to thrive while pumping even more pollutants into the building.

Humidity within indoor environments plays a key role in occupant comfort, but can also have an effect on health conditions too. Indoor environments that are too dry or damp can negatively affect occupant comfort. Low humidity (25 percent or less) in buildings with temperatures of 72°F or more are associated with large numbers of SBS symptom complaints from occupants. Studies have shown that raising the humidity rates to 30 or 35 percent can help reduce these SBS symptoms (Jaakkola et al., 1994).

There are several examples of studies that show sealed buildings with air-conditioning systems contain a higher presence of SBS. One side effect of the oil embargo in 1973 was the drive to seal all new buildings in an effort to maximize efficiency. Many of these buildings restricted occupants from opening windows or having control over their local ventilation controls. One study, focused on military housing records during a 47-month period, showed that incidences of febrile acute respiratory disease occurred 50 percent more frequently in newer barracks, built in the 1970s and 80s, than those built in the 1940s and 50s. The modern barracks tended to have mechanical ventilation and central heating and cooling systems while the older barracks had natural ventilation and local heating and cooling systems (Brundage et al., 1988).

These findings align with another study that found a higher prevalence of SBS symptoms in sealed buildings with air-conditioning systems than in unsealed buildings with no air-conditioning (Mendell & Smith, 1990). Another survey conducted compared occupants sleeping within air-conditioned to those in naturally ventilated rooms. The results showed that almost all occupants sleeping in air-conditioned rooms displayed one or more symptoms of SBS and usually exhibited more symptoms after sleeping in air-conditioned rooms rather than when sleeping in naturally ventilated rooms (Loftness et al., 2007).

Building lighting and electrical equipment can also cause adverse effects in occupants. The constant flickering of fluorescent lights, while invisible to the naked eye, can cause headaches and feelings of lethargy in building occupants (The Environmental Illness Resource "Sick Building Syndrome", 2009). In some cases, the frequency of the flickering is low enough to cause severe over-scanning and corrective movements in the human eye. In a building in London, occupants frequently complained of headaches. By changing the existing fluorescent lights, which flashed 100 times per second, to special fluorescent lights, that flashed 20,000 times per second, the building's management was able to cut headache complaints in half ("Can buildings make you sick?").

High frequency electromagnetic fields (EMFs) created by a building's wiring and electrical equipment can cause adverse effects in occupant health and comfort, as well. Electrical hypersensitivity (EHS) is a term used to describe the condition in which people are made ill by electromagnetic radiation and have common SBS symptoms, including headaches, inability to concentrate and fatigue (The Environmental Illness Resource "Sick Building Syndrome", 2009).

## Volatile Organic Compounds

The environmental factors that are known to contribute to poor IAQ typically come from chemical contaminants in the air. These contaminants originate from indoor or outdoor air or from biological contaminants such as bacteria, molds and pollen. Typically, VOCs are a major source of indoor contaminants. They are emitted as gases from both plants and manmade products. Those that are manmade are usually the most dangerous to humans (EPA "An Introduction to Indoor Air Quality", 2010). Chances are, any office space you enter will have some of the common sources of VOCs, shown in Table 3.

| Examples of Interior VOC Sources | |
|---|---|
| Paints, sealants, finishes | Paint strippers/thinners |
| Building materials and furnishings | Photocopiers and printers |
| Cleaning supplies | Pesticides |
| Carbonless copy paper | Glues/adhesives |
| Permanent markers | Photo solutions |
| Aerosol sprays | Air fresheners |

**Table 3.** Examples of Interior VOC Sources

Many interior products that you would find in common office spaces use organic chemicals as ingredients. Certain products release VOCs while in use (for example, aerosols and photocopiers) while other products emit VOCs even when stored (such as, paints and cleaning supplies). Other items, like office furnishings and carpets or the adhesives used to keep them in place, can potentially and constantly emit VOCs.

Most people can handle VOCs in small doses. However, studies have shown that interior VOC levels can be anywhere from two to five times higher than in outside air. Certain activities, like painting, can cause indoor VOC levels to be up to 1,000 times higher than outside air. This is particularly dangerous for office inhabitants, as many VOCs are known to cause cancer in animals while others, like benzene, a known human carcinogen, and methylene chloride, which converts to carbon monoxide in the body, can have dire effects on those exposed over a long period of time (EPA "An Introduction to Indoor Air Quality", 2010). Health effects vary (depending on the amount of exposure and time spent exposed) and can be devastating for any employee in the long run, unless indoor VOCs are managed.

Further contributing to the danger of VOCs is that there is no set standard for VOC exposure limits outside of industrial settings. Unfortunately, the high exposures allowed in industrial settings are much too high for the everyday office setting, yet there is no standard protecting "white-collar" workers. Formaldehyde, a well-known VOC, is one of the few VOCs that can be measured and, as such, the Occupational Safety and Health Administration (OSHA) has assigned a permissible exposure level to it (Colome et al.). Otherwise, testing indoor air can be convoluted because investigations of complaints don't typically identify a single air contaminant at high enough levels to account for the symptoms (Kreiss, 1990). This means that there are several sources combining to cause the effect.

## Environmental Factors

From bacteria and mold found in ductwork to dirty ceilings and carpets, biological contaminants can come from a variety of sources. While correcting ventilation rates and other ventilation system fixes can prevent the presence of these contaminants, the contaminants can still breed in stagnant water, that accumulates anywhere within the mechanical system, and in spills or pools that collect on interior surfaces (EPA "Indoor Air Facts", 2010). Other contaminants, like pollen and common viruses, can contribute to poor IAQ once inside indoor air environments.

**Think you might have elevated VOC levels in your office?**

If you answer yes to any of these questions, you may be at risk:

- Does your office contain a large amount of pressed wood furniture?
- Have you recently acquired new pressed wood furniture?
- Are chemical cleaners used extensively throughout the office?
- Do you have photocopying device(s) in the office?
- Has any remodeling been completed recently, including new carpeting, rugs, moldings, etc.?
- Have any surfaces been painted or sealed recently?
- Have any pesticides been applied indoors recently?

*From Indoor Air Pollution: An Introduction for Health Professionals*

Certain elements in the air can also contribute to IAQ. While the effects of asbestos are well known and documented, similar items, like fiberglass and insulation, can infiltrate indoor air, particularly affecting inhabitants' respiratory systems (Samet & Spengler, 2003). Simple particulates, like dust and dirt, can have similar debilitating effects on building occupants.

Environmental factors don't always have to originate from inside the building. A common contributor to poor IAQ are normal outdoor pollutants that get fed into or trapped within indoor air environments. This situation usually arises from a combination of environmental factors and poor mechanical ventilation but, nevertheless, it can still be the root source of poor IAQ. One example of this is when a building's air intake is located too close to outdoor exhausts produced by vehicles or other buildings. Air intakes are used to replace dirty air in the building with fresh, clean air from outside but, in this scenario, the building is distributing previously contaminated air, polluting the office environment at all times. This can be a serious problem for any building that is located close to parking garages, gas stations, or any other large source of combustion pollutants. Another way in which outdoor pollutants can become trapped indoors occurs when windows or doors are located near the exhaust of vehicles or other buildings. Additionally, designating outdoor smoking areas too close to a building's air intakes allows the mechanical system to pull in second-hand smoke and distribute it throughout the building.

**Case Study: Ohio Office Building – New Carpet Had Hidden Cost**

In 1999, Joann Taylor successfully sued her former employer over health conditions that she encountered while at work. Ms. Taylor was awarded a settlement after she claimed that her employer continued to force her to work in their newly renovated office. This was after Ms. Taylor had to be rushed to the hospital with chest pains and vomiting, symptoms she claimed resulted from the strong chemical fumes emitting from the new carpet. The court agreed with her and awarded Ms. Taylor $400,000.

# Productivity Losses and Costs

The symptoms related to poor IAQ are as clear as the associated comfort issues, but what does this all mean for the bottom line? The simple answer: lost capital. Table 4 shows that the combined cost estimates for health conditions related to poor IAQ can range from $50 to $100 billion (Mendall et al., 2002).

| | **Annual Economic Impacts** | | | |
|---|---|---|---|---|
| *Contaminant-Related Health Effect* | *Health Care Costs of Effects due to Work or Non-work Exposures* | *Costs from Absence due to Illness & from Other Performance Losses due to Work or Non-work Exposures* | *Estimated Economic Consequence for Indoor Workforce due to Work or Non-work Exposures* | *Estimated Economic Benefits Possible from Improved Indoor Work Environments* |
| Communicable respiratory infections: building-influenced, occupant sources (e.g., influenza, common cold, tuberculosis) | $10 billion in health care costs | $19 billion in absence from work; $3 billion from reduced performance at work | $32 billion | $3 to $4 billion (estimate has substantial uncertainty) |
| Asthma, hypersensitivity, pneumonitis, and allergic disease, building related | Asthma, $2.6-$2.8 billion; allergic rhinitis, $580 million; other, not estimated | Asthma, $340 million; allergic rhinitis, $377 million; other, not estimated | $3.9-$4.1 billion | $200-$600 million (estimate has substantial uncertainty) |
| Nonspecific building-related symptoms (acute effects of indoor exposures or conditions, including SBS) | Unknown (effects from work exposures only) | $20-$70 billion (effects from work exposures only) | $20-$70 billion (effects from work exposures only) | $4-$70 billion (estimate has substantial uncertainty) |
| Respiratory infections: building sources (Legionnaires' disease, Pontiac fever, fungal infections) | Legionnaires' disease: $26-$40 million in health care costs; Pontiac fever: minimal health care costs; fungal infections: unknown costs | Legionnaires' disease: $5-$8 million in absence from work; Pontiac fever: unknown absence costs (1-week/case); fungal infections: unknown costs | Greater than $30-$50 million | Tens of millions of dollars |
| Health effects of environmental tobacco smoke | $30-$140 million in health care costs for cardiovascular disease and lung cancer (effects from work exposures only) | Costs of absence from work & other performance losses not estimated | $30-$140 million (costs of absence from work & other performance losses not estimated; effects from work exposures only) | $30-$140 million (costs of absence from work and other performance losses not estimated) |

**Table 4.** Cost estimates for health effects from poor IAQ (Mendell et al., 2002)

From a business owner's point of view, air quality issues that lead to things like SBS can be devastating to the bottom line. SBS contributes to a lack of concentration and can lead to increased absenteeism, negatively affecting productivity (Tuomainen et al., 2002). SBS symptoms can also have an effect on employee attitudes and focus, leading to unnecessary job tensions for all occupants. If conditions worsen to the point that employees make multiple visits to the doctor that lead to insurance claims, workers compensation claims or even litigation, the owner will experience serious financial obligations. Research from five independent non-profit organizations, human resource research firms and the U.S. Government shows that the average employer cost for health insurance was $5,000 per employee in 2003. Some of the health conditions driving this value up can be linked to poor IAQ, encapsulating common SBS symptoms like headaches, colds and respiratory illnesses (Loftness et al., 2007). Figure 2 shows the employer costs related to health care and absenteeism.

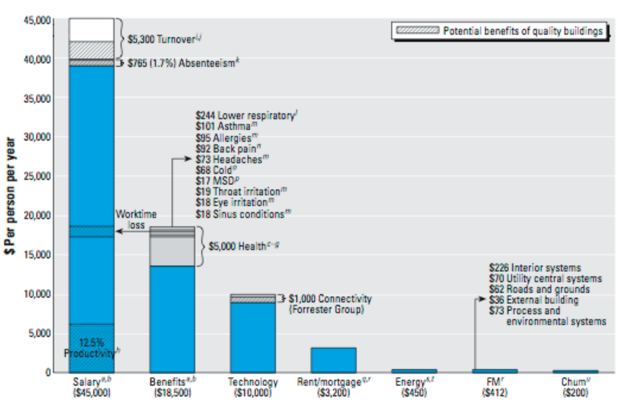


**Figure 1.** Improving the quality of the built environment will reduce the life cycle costs of business. Monetary amounts are in U.S. dollars per year. MSD, musculoskeletal disorders. Forrrester Group is part of Forrester Research (Cambridge, MA).
Data from [a]U.S. Department of Labor (DOL) (2004a); [b]U.S. DOL (2004b); [c]U.S. DOL (2002); [d]Kaiser Family Foundation and Health Research and Educational Trust (2003); [e]Towers Perrin HR Services (2003); [f]U.S. Chamber of Commerce (2003); [g]Deloitte & Touche (2003); [h]Leaman (2001); [i]U.S. DOL (2003b); [j]Fitz-Enz (2000); [k]U.S. DOL (2003a); [l]Birnbaum et al. (2003); [m]U.S. EPA (1998); [n]Guo et al. (1999); [o]Fendrick et al. (2003); [p]Silverstein et al. (2000); [q]General Services Administration (2003); [r]International Facility Management Association (IFMA) (2002); [s]U.S. DOE (1998); [t]U.S. Department of Energy (DOE) (2004); [u]IFMA (2001).

**Figure 2.** Employer costs for health care and productivity (Loftness et al., 2007)

On the opposite side of increased absenteeism is the motivated employee who refuses to stay away from work, even when sick. These employees put themselves right back in the very environment that made them sick in the first place, further worsening their condition. This kind of behavior can lead to serious medical conditions down the road and potential legal liability for the owner. In addition, these employees pose a threat to the health of all other employees in the building, even those not inflicted with SBS symptoms.

Other examples of productivity losses can be seen in service-based stores, such as restaurants and shopping boutiques. While customers will not typically occupy these venues for long periods of time, these spaces do tend to be extremely populated. If the ventilation system is not prepared to deal with overcrowding, the lack of air quality could cost the business future sales, as customers find themselves increasingly uncomfortable the longer that they occupy that space.

There is an obvious effect to productivity when the comfort and health of employees is compromised by poor IAQ, but is there a dollar amount attached to that lost productivity? One study performed by James E. Woods, PhD, PE, aimed to find that out. He examined how cutting costs, by reducing maintenance measures and energy usage, affects the overall bottom line. Through his calculations, he shows that an energy savings of 25 percent may be counterproductive if the byproduct of that energy savings leads to decreased employee performance that results from one to three days of missed work from each employee or two to six minutes of lost concentration each day. In other words, based on previous studies and known costs associated with buildings and employees, Woods was able to show that saving money by decreasing IAQ can lead to an overall loss when considering lost productivity as well (Woods, 1991).

This cost trade-off also applies to business owners who are building new properties to move their employees into. The culture of construction is to minimize costs at every step while building as quickly as possible. However, cutting corners during the construction phase can cause problems in the long run. Woods provides similar calculations, to those mentioned previously, to show that spending money on superior environmental quality during the construction of a building can result in paybacks in less than two years, if these improvements reduce the expected employee lost time (days absent) by 50 percent (Woods, 1991). The Senate believed so highly in the importance of this concept that it proposed a bill for the General Services Administration to set aside .5 percent of new construction costs for environmental control improvements, to be designed into any new federal agency owned buildings.

### Case Study: Brigham and Women's Hospital – Lofting Latex Proves Perilous

The Brigham and Women's Hospital responded to the AIDS crisis like every other hospital in 1993—with employees increasing their use of latex gloves throughout the hospital. Unfortunately, the manufacturers of these gloves were taking shortcuts during production, in response to the spike in demand for their products. The result was an abundance of latex particles lofted into the air when the gloves were removed from the box. Eventually, surfaces throughout the hospital were covered in these particles because the ventilation system was not equipped to handle the latex particles. The hospital decided to spend millions of dollars to upgrade the building's ventilation system, but not before 47 nurses wound up on disability leave and more than 50 employees had filed lawsuits against the hospital.

# What Does LEED Have to Say?

One source to look to for guidance and improvement in supreme indoor environment is the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification. As the most widely used green building rating system in the world, LEED offers strategies and certifications for new and existing buildings.

The LEED credit system has standards for all types of sustainable and environmental practices, from water efficiency to innovations during the design process. This includes a very thorough standard for indoor environmental quality with two prerequisites and 17 credits available for buildings that show strong sustainable characteristics. Table 5 lists each credit in the indoor environmental quality section and a brief description of how to earn each credit.

| LEED Indoor Environmental Quality Credits | Brief Explanation of Credit |
|---|---|
| EQ-Credit 1 – Outdoor Air Delivery Monitoring | Monitor the ventilation system to ensure achievement of minimum ventilation requirements and install $CO_2$ sensors where applicable |
| EQ Credit 2 – Increased Ventilation | Increase breathing zone outdoor air ventilation rates by at least 30% above minimum rates set by ASHRAE Standard 62.1-2004 |
| EQ Credit 3.1 – Construction IAQ Management Plan, During Construction | Develop a plan for construction phases regarding ventilation equipment protection during storage, installation and post-installation as construction continues |
| EQ Credit 3.2 – Construction IAQ Management Plan, Before Occupancy | Develop a plan to completely flush out the building's air after construction and before tenants occupy the space |
| EQ Credit 4.1 – Low-Emitting Materials, Adhesives and Sealants | Materials used in this category must not exceed requirements set by South Coast Air Quality Management District (SCAQMD) Rule #1168 and/or Green Seal Standard GC-36 |
| EQ Credit 4.2 – Low-Emitting Materials, Paints and Coatings | Paints must adhere to standards as follows:<br>Topcoat Paints – Green Seal Standard GS-11<br>Anti-Corrosive/Rust – Green Seal Standard GS-03<br>All others – SCAQMD Rule 1113 |
| EQ Credit 4.3 – Low-Emitting Materials, Carpet Systems | Carpet systems must adhere to the Carpet and Rug Institute's Green Label Plus requirements |
| EQ Credit 4.4 – Low-Emitting Materials, Composite Wood and Laminate Adhesives | Products must contain no added urea-formaldehyde resins |
| EQ Credit 4.5 – Low-Emitting Materials, Systems Furniture and Seating | All furniture, less than 12 months old, must be Greenguard Indoor Air Quality Certified or pass tests showing low VOC emission rates |
| EQ Credit 5 – Indoor Chemical and Pollutant Source Control | Must provide necessary filters and other media to capture particulates. Also, have separate ventilation to keep areas with significantly worse air quality isolated from common areas. Provide special containment for hazardous waste and new filter media when necessary |
| EQ Credit 6.1 - Controllability of Systems, Lighting | Provide lighting controls for individual occupants as well as groups sharing common space |

| LEED Indoor Environmental Quality Credits | Brief Explanation of Credit |
|---|---|
| EQ Credit 6.2 – Controllability of Systems, Temperature and Ventilation | Provide thermal and ventilation controls for individual occupants as well as groups sharing common space |
| EQ Credit 7.1 – Thermal Comfort, Compliance | Comply with ASHRAE Standard 55-2004 |
| EQ Credit 7.2 – Thermal Comfort, Monitoring | Provide monitoring system and process for corrective action to ensure system performance set forth in Credit 7.1 |
| EQ Credit 8.1 – Daylight and Views, Daylight 75% of Spaces | For 75% of occupied areas, achieve a minimum Daylight Factor of 2% |
| EQ Credit 8.2 – Daylight and Views, Daylight 90% of Spaces | For 90% of occupied areas, achieve a minimum Daylight Factor of 2% |
| EQ Credit 8.3 –Views for 90% of Seated Spaces | Provide a line of sight to the outdoor environment for 90% of regularly occupied areas |

**Table 5.** LEED credits for indoor environment quality (from LEED 2.0)

# Solutions and Preventative Measures

Solving and preventing IAQ issues requires a two-pronged attack. First, the building itself must be prepared and equipped to deal with all sources of poor IAQ. Second, the occupants themselves must shoulder some of the responsibility, maintaining the building and its protection systems while realizing that they can limit contaminant sources through their own good habits.

The EPA breaks down the solutions and prevention of poor IAQ into the following four categories, seen in Figure 3:

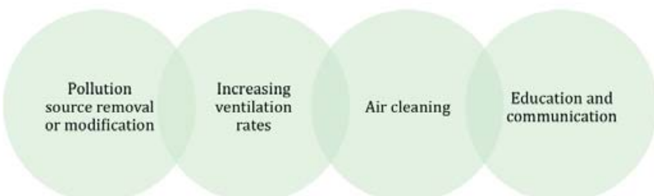


**Figure 3.** EPA's Four Categories for Correcting and Preventing Unhealthy IAQ

Obviously, if the source of indoor pollution or contaminants is known, it should be removed right away. If the source cannot be removed, perhaps the emitting surface can be sealed or stored in a separate area, away from building occupants. If the air itself is suspected of carrying contaminants, have it tested. It is important to remember that exposure levels of individual VOCs and other contaminants might be above normal limits, but the combination of several can lead to SBS symptoms.

Increasing ventilation rates and air distribution within a building is an easy way to solve IAQ issues, provided that the source of the problem is not within the ventilation system itself. The first step is to test the current ventilation system to find out if it is operating at the minimum American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 62-2007 standard. ASHRAE is an international technical society for all organizations within the heating, cooling and ventilation industries and sets building standards for these fields. This is particularly important for business owners that rent or lease office space, as most systems are designed to handle ventilation rates well over the ASHRAE Standard but cutting the ventilation rate is a cost-cutting method for building owners. Testing humidity levels in various areas of a building, during times of occupancy and non-occupancy can also uncover sources of discomfort. Providing local exhaust for areas with extremely poor IAQ (for example, storage rooms with paints and rooms with photocopiers) is an effective preventative measure, as well.

While air cleaning has potential, its current effectiveness is limited. There is no catchall filter for buildings; some catch gaseous pollutants while allowing small particulates through, while other filters catch small particulates and let gaseous pollutants through. High-performance air filters do exist and are capable of catching smaller, particulate type particles, but can be very expensive to own and operate.

Education and communication are important aspects of prevention. The topics of IAQ and SBS have been studied for decades, yet these issues are not pushed to the forefront of occupant and employee health issues. Keeping open lines of communication with employees allows air quality to remain on the minds of all who may become affected. Employees are on the front line in the fight against poor IAQ and their feedback can catch a problem before it becomes serious. It is important for building owners and management to take these complaints seriously and to support employee claims, thus maintaining open lines of communication.

Preventing poor IAQ goes beyond the four categories provided by the EPA. The LEED credits point out several ways to increase occupant comfort and health. Increasing natural sunlight inside the building is a great way to improve employee attitudes, if not their health. Research has shown that sunlight is extremely beneficial to people, through exposure to vitamin D, melatonin and serotonin. Overexposure to radiation from sunlight can potentially have negative health effects, but studies show that there is a much larger number of debilitating diseases and conditions caused by lack of sunlight (Mead, 2008). Serotonin is also known to result in calmer moods and increased focus. A *Business Week* article highlighted a Reno, Nevada postal sorting office that experienced a whopping 16 percent increase in productivity after installing skylights to improve lighting within the workplace (Conlin, 2000).

LEED also awards credits when ventilation and lighting control is given directly to building occupants. This allows the occupants to dictate their own comfort level. This also allows employees to be the first level of defense against ventilation and thermal control failures. Giving this control to occupants may result in slightly higher energy costs, but as stated previously, the productivity improvements far outweigh the associated energy costs.

Finally, remember the human element in the equation. Many sources of indoor air pollution can be avoided by making smarter decisions. Building systems require constant monitoring and maintenance. Be sure that all filters are cleaned and maintained at the appropriate intervals. Employ integrated pest management (IPM) systems as opposed to standard pest practices. IPM systems are environmentally conscious programs that are equally effective without posing the same risks associated with conventional herbicides and pesticides.

Building owners must understand that certain actions, like reducing ventilation rates to save costs, may affect employee comfort, thus affecting productivity. These actions can also have long-term effects on the entire indoor environment and lead to further employee health issues and increased absenteeism.

Other simple tips fall into the realm of basic cleaning. Carpets and rugs are home to plenty of dangerous indoor environment contaminants. Vacuuming more frequently can help to prevent the contaminants from spreading. Placing photocopiers away from employees is a necessity, but finding an isolated location with its own local exhaust is even better. The same can be said for storing high VOC materials. If items like paints, sealants, and industrial cleaning supplies must be kept on the premises, find a suitable storage location that keeps these items away from employees and exhausts the VOC emissions in an appropriate fashion. If at all possible, keep building population to a minimum. Overcrowding can affect employee comfort and mood, as well as put additional strain on ventilation systems. If these systems are already running below set standards, IAQ conditions will worsen when increasing the number of occupants. Finally, if activities that will result in high levels of VOCs or other contaminants must take place within the office, plan ahead. The ventilation rates should be increased that day and remain elevated long after the work-day has ended. At the very least, open windows for natural ventilation, thereby assisting the ventilation system in exhausting the contaminants outside the building.

### Case Study: Levi Strauss & Co. – A Denim Debacle

Levi Strauss & Co. had an office located in the Stern building in San Francisco. This building was also home to Il Fornaio restaurant, which was located on the ground floor. Throughout the years, at least 60 Levi Strauss & Co. employees complained about the air quality in the office, all of whom seemed concerned about the smoke emitted from the Il Fornaio's wood-burning grill. The fumes from the grill were so heavy in the office that some employees assembled umbrellas over their desks due to falling soot. According to internal memos, at least three employees became disabled from acute asthma, severe allergies, and other environmental illnesses—a direct result of breathing in the carbon monoxide. After years of trying to resolve the problem, Levi Strauss & Co. finally put an end to the poor air quality by raising the air intake vents, thus eliminating the presence of smoke-infested air inside the office.

# Conclusion

Poor IAQ has very real consequences, to both occupants' health and business' bottom line. It's important for a business owner to realize that the space in which the business and employees operate has a direct effect on productivity. Business owners must be aware that problems can arise from several sources, be it ventilation systems, VOCs or other chemical contaminants emitted from surfaces within the office, or even the design of the building itself. Nevertheless, understanding the possible sources is a good start to staying ahead of any problem that can occur. Making smart decisions, employing preventative measures and keeping an open line of communication within the workforce can keep everyone healthy, comfortable, and productive.

# Glossary

*Acute Symptoms* – Refers to symptoms that are either quick to affect the individual or affect the individual for a short period of times, sometimes both.

*Air Intake* – An opening through which outside air is drawn into the building.

*American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)* – International technical society for all organizations and individuals within and interested in heating, air-conditioning, ventilation and refrigeration.

*Atopic* – A predisposition toward developing allergic hypersensitivities, i.e., more prone to allergic reactions.

*Building Related Illness (BRI)* – Situation where individuals suffer chronic and debilitating illness(s) directly related to specific and identifiable indoor air contaminants.

*Building Ventilation System* – System employed by buildings to circulate and/or replace air in any indoor space to improve indoor air quality.

*Central Heating and Cooling System* – System where the heat and cool air are generated from a singular source and distributed from that point of origin. These systems typically prohibit user control and flexibility.

*Chronic Conditions* – Refers to long-lasting or recurrent conditions due to a specific disease or illness.

*Condensation* – The change of a gas or vapor to liquid droplets, typically occurring when warm air is rapidly cooled or compressed.

*Ductwork* – A system of ducts, or pipes, used with ventilation systems to control and direct the flow of air throughout a building.

*Electrical Hypersensitivity (EHS)* – Condition where individuals are adversely affected by exposure to electromagnetic fields. This condition is not recognized by the medical community.

*Environmental Protection Agency (EPA)* – U.S. federal agency charged with protecting the environment and human health.

*Leadership in Energy and Environmental Design (LEED)* – Internationally recognized green building rating system developed by the U.S. Green Building Council.

*Local Heating and Cooling System* – System where the heat and cool air are generated from separate sources. These sources are typically in closer proximity to the spaces they serve and allow for more user control and flexibility.

*Mechanical Ventilation* – Ventilation system to control indoor air quality (excess humidity, odors, contaminants, etc.) that uses fans, vents and other mechanical devices to force air through the system.

*Natural Ventilation* – Ventilation system to control indoor air quality with outside air without the use of a fan or other mechanical system.

*Plenum* – A separate space provided for air circulation, which may be above a dropped ceiling or below a raised floor, typically in lieu of traditional ductwork.

*Respiratory System* – The system, comprising of the lungs, airways and respiratory muscles, within the body whose function is to take oxygen into the lungs.

*Sick Building Syndrome (SBS)* – Situation where multiple inhabitants of the same indoor space/building exhibit acute ailments (flu-like symptoms, headaches, lethargy, etc.) due to poor indoor air quality within the common space.

*Volatile Organic Compounds (VOC)* – Organic chemical compounds emitted from plants and manmade products that can adversely affect humans and the environment.

*World Health Organization (WHO)* – A specialized agency of the United Nations, acting as an international authority on public health.

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