Functional Ambiance: Designing for Clean Air

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Just because we can't see indoor air pollution, we can't assume it doesn't exist. Evidence is mounting that natural and chemical agents make our buildings' interiors toxic for growing numbers of users. For architects and interior designers, designing for clean air is now part of the human health, safety, and welfare requirements for every project. Integrated project delivery plays a major role in addressing Indoor Air Quality, the invisible aspect of interior environments.

Instructions

Read the article with the following learning objectives in mind. Then complete the participant exercise online at www.metropolismag.com/ce.

Learning objectives

- Understand the critical relationships between indoor air quality and health considering the increasing prevalence of asthma and allergies, as well as the long-term health effects that accumulate from daily exposures to indoor pollutants
- Name at least three causes of poor indoor air quality
- Be able to explain multiple design strategies for promoting clean indoor air including the pros and cons of existing air cleaning technologies
- Identify emerging strategies and technologies for air purification

Breathing is living. At every moment of every day air enters and leaves our bodies, its cleanliness is our health. But each refreshing inhalation carries muck from the environment too. It's easy to feel protected inside, but the fact is that indoor air quality (IAQ) is generally much worse than outdoor air. The Environmental Protection Agency (EPA) estimates that air in homes is often five times more polluted than outdoors, and considering that most people today spend upwards of 80 percent of their days and nights inside, the interior atmosphere is a critical design criteria for functional environments. All too frequently, the responsibility for IAQ falls to the heating, ventilating, and air conditioning (HVAC) engineers. This is a missed opportunity for architects and interior designers.

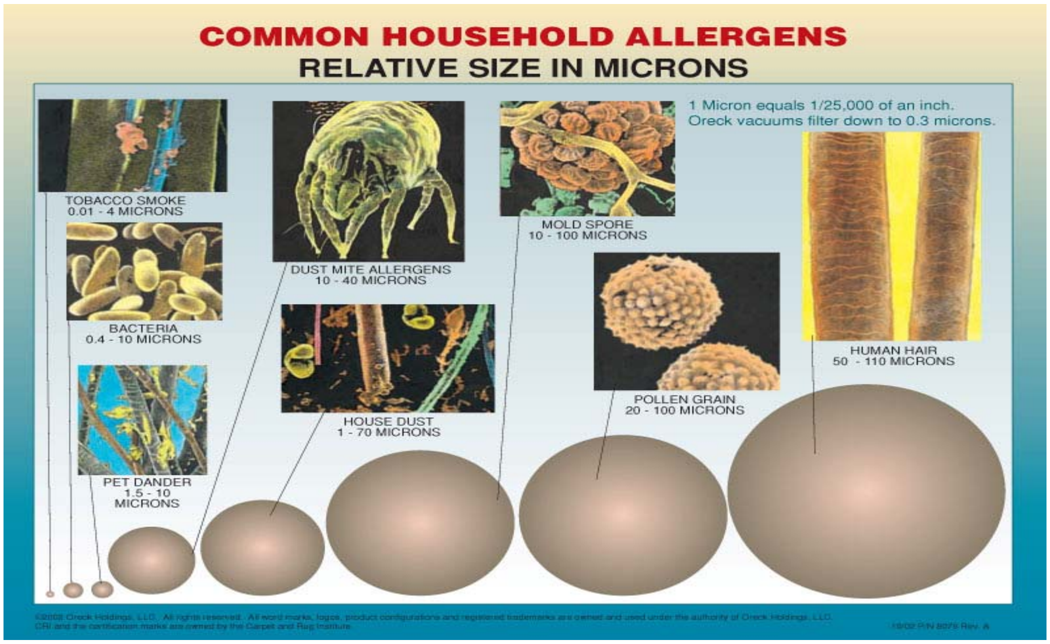
Day-to-day occupation of unhealthy space adds up to long-term affects, and the scope of the problem is staggering. The average adult breathes in around eight germs per minute, for a total of 10,000 per day, according to Philip M. Tierno Jr. Ph.D in *The Secret Life of Germs*. And those are just the biological contaminants. Hannah Holmes, in *The Secret Life of Dust*, explains that "even moderately grubby air can hold thousands of tiny particles per cubic centimeter," so that in addition to those eight germs per minute, we're also getting up to 30 million particles sticking to the walls of our respiratory tracts.

With figures like these, it's no wonder that so many people have respiratory problems. The American Lung Association reports that 23 million Americans have asthma. This includes seven million children. According to the Asthma and Allergy Foundation of America (AAFA), 50 million Americans suffer from allergies—the AAFA says allergies are "among the country's most common, yet often overlooked, diseases"—and since 1995 the number of American allergy sufferers has nearly doubled. Scientists are undecided on why this is true. Hypotheses range from global warming causing increased pollen to greater levels of smog. And according to the World Health Organization, indoor air pollution on a worldwide scale is responsible for more than 1.6 million annual deaths and is the biggest environmental contributor to ill health behind unsafe water and sanitation.

We know that clean, fresh air helps prevent outbreaks of asthma and allergy symptoms, and polluted air exacerbates them. What's also clear is that the IAQ problem is getting worse, and fast.

Indoor air quality is the human factor that gets lost in design. Since air is invisible, it's easy not to notice. Companies are aware of employee efficiency so they invest in ergonomic furniture and lighting, but IAQ gets forgotten by clients and designers alike. This is a mistake considering the relationship between air quality and health. Reports from the Lawrence Berkeley National Laboratory show that the United States loses about 176 million days of work annually from common respiratory illnesses; this doesn't include people who show up feeling under the weather and work less effectively than their healthy co-workers. It adds up to an estimated annual deficit of $34 billion in lost work. All together, a huge proportion of our daily gripes can be blamed on compromised air quality, and over time these can add up to chronic health problems.

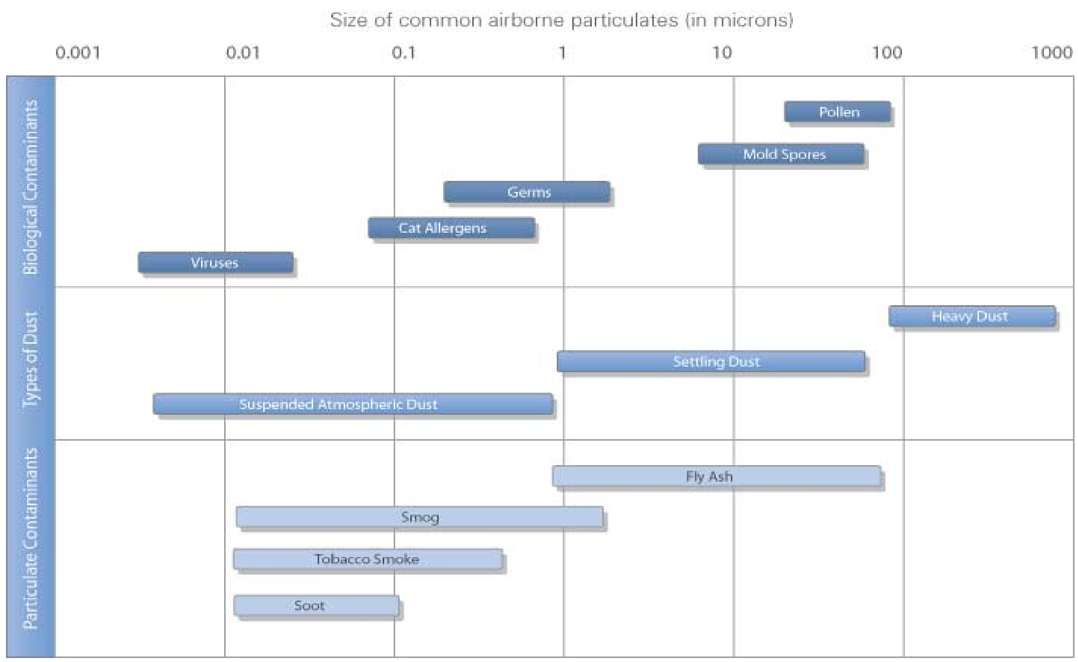
Particles and Chemicals



Particles and Chemicals to Blame

Indoor pollutants come from many sources, generally falling into the categories of particulate matter and gas-phase chemicals. Together, these create conditions for the now familiar Sick Building Syndrome, which has been blamed for such health problems as eye and throat irritation, headaches, dizziness, and fatigue associated with being in a particular building. A lot of times people are so used to living with symptoms that they don’t even notice there’s an air quality problem. Knowing the factors, however, can help occupants understand how their environments affect their health, and help designers provide “fresh spaces”. IAQ expert Alan Hedge, director of the Human Factors and Ergonomics Laboratory at Cornell University, explains that one way to know what the air quality culprits are is to pay close attention to symptoms. “If people are getting sick, it’s an organism. If the problem gets better when they walk away it’s an irritant.”

Particulates include both organisms and irritants, such as mold, mildew, viruses, bacteria, dust, fibers, pollen, smog, and cigarette smoke. Some of the sources occur naturally, others are related to industry, transportation emissions, and today's built environment. The EPA warns about the health effects of smaller particles, 10 microns or less. Larger particles get filtered out in the nose and throat, but smaller ones hit the core, traveling straight to the lungs and heart. Limits on outdoor pollution levels are regulated by the EPA through the Clean Air Act, but indoor air pollution has its own sources and issues and is not governed by federal law. And any amount of airborne particulate matter can cause discomfort or worse, depending on an individual's sensitivity.



Mold is a fungus that creates larger airborne particles in the form of spores that can be suspended in the air for extended periods of time. Bad mold scenarios can make a building uninhabitable. Growth occurs when a building is damp, either from humidity, condensation, or water leaks. It can cause allergic or asthmatic reactions, or fungal infections in severe cases. Mold is an example of an air quality problem that is produced within a building through natural processes.

Other particulates get tracked in from outdoors. People can easily get dusted by pollen as they walk through landscaping, or carry pet dander on their clothes between home and the work place. Even the cleanest person still sheds skin cells, and dead skin is a favored ecosystem for dust mites. Dust mite particulates (body parts and feces) are particularly irritating to the general population. According to Philip Tierno we shed 1.5 million skin flakes hourly!

Infectious organisms, viruses and bacteria, get brought in by people, too. These germs live in humidity droplets as well as dust. And while they remain a year-

round problem, high concentrations of respiratory viruses tend to occur in the wintertime when building ventilation is reduced (to keep the heat in) and what gets breathed out by humans lingers in the air longer.
Pollen, in addition to coming from outside, is also present in indoor plants. While plants give off oxygen and are often prized for providing a connection with nature that makes people feel good, they are contentious from an indoor air quality point of view because they can introduce pollen, breed bacteria or insects, utilize pesticides in their upkeep, and can be a moist space for mold growth.

Combustion sources from a building's mechanical system can produce soot in the air. Architectural placement of HVAC equipment can therefore have a strong indoor air quality effect. Cigarette smoke, which contains 50 known carcinogens, is another pollutant that can be brought indoors by HVAC systems if their air intakes are anywhere near designated smoking areas. But even with proper HVAC system placement, smoke particulates can just as easily make their way indoors on clothing. Other particulates floating around the air include fibers from asbestos, another carcinogen which had long been used as insulation and is still in place in vast numbers of buildings.

The second dangerous air quality category is comprised of volatile organic compounds (VOCs). Chemicals evaporate into the air out of products and materials, a phenomenon known as "off-gassing." In their airborne gaseous phase, VOCs cause acute or chronic health problems, depending on type and exposure. Furniture, carpets, adhesives, paint, upholstery, and vinyl flooring are just a few potentially guilty suspects. Of the 10,000 or so commonly found VOCs, some flash off quickly, others remain menacing for months or even years. Even worse, different types of VOCs can interact with each other, creating an even more harmful "toxic soup" within a room.

VOC exposure is common. In many cases with adequate ventilation or entrapment, a quick toxic release can dissipate relatively quickly. For instance, wet paint or varnish can easily provoke headaches, due to inhaling the benzene, styrene, and dioxin, chemicals that are often found in solvents, but once dry and aired out the problem dissipates.

On the other hand, a VOC like formaldehyde can stick around causing health problems for many years. And exposure can build up over time. The first contact may go unnoticed, the second may result in watery eyes, and the third in asthma attacks. As air quality guru, Marilyn Black, told listeners of the online IAQ Radio station recently, over the past 20 years there has been a 75-80 percent reduction in formaldehyde emissions from office furnishings. This is a significant step in the right direction. On the other hand, formaldehyde was present in dangerously high quantities in the Federal Emergency Management Agency (FEMA) trailers used for Hurricane Katrina relief in 2005. According to recent reports, those same trailers were resold to house workers responding to the BP oil spill, and five years after the fact, their interiors are still making people sick.

Good News: We Can Design for Clean Air

Preventing and solving air quality problems are integrated issues that should include the participation of everyone along the design, construction, and occupancy process. In the first place, architectural choices set up initial air quality conditions that all other factors tie into. These need to be coordinated with the building's mechanical engineers. Even the order of a building's construction process can impact air quality if there are reactions between materials at different stages. And then interior design choices constitute a whole new layer of chemical interactions, followed by all the things building occupants bring in.

One example for architects to think about from the get go is the extent that design impacts mold-growth, which is specifically related to dampness. The same porous building material that works fine in an arid climate may be unsuitable for a humid one where absorbed moisture lingers. And of course actual condensation and leakage through building assemblies will have an impact. The *Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning*, portions of which are available for free download from the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE), is a useful resource for more information on architectural design for fresh air that goes into detail on this and other issues, such as the ways architects can limit entry of outdoor contaminants and control indoor pollution sources.

VOCs need to be controlled by both architects and interior designers. The main tactic is to choose low-emitting products and materials in the design phase, and then continuing to use healthy cleaning products for building maintenance. The marketplace is responding to demands for low-emitting products and the testing service, the Greenguard Environmental Institute, provides a list of products that meet the latest emissions standards. Any material that contains long-term emitting chemicals like formaldehyde should be rejected from the design palette, and those that flash off quicker still need to be used with caution for workers' and occupants' safety.

Centralized and Local Ventilation

Even buildings and interiors designed for the best IAQ will require ventilation to ensure their ongoing healthiness. Ventilation occurs actively through the HVAC system, as well as passively from the movement of air through and around windows, doors, and other openings in the envelope (known as infiltration). Standards for ventilation rates can be found in ASHRAE documentation.

In the world of sustainable design, there are trade offs between ventilation and energy efficiency. The Leadership in Environmental and Energy Design (LEED) certification program includes air quality concerns in both prerequisite requirements and credit options that give important guidance on IAQ choices. Though their recommendations are sound, the LEED program has been criticized for privileging energy efficiency over air quality—the more fresh air brought in from the outside, whether actively or passively, the more energy required to heat or cool that air. Re-circulating existing building air instead of conditioning outdoor air costs less and uses less energy, but that air is more polluted. These are complex problems that require case by case analysis of climate priorities, passive or renewable energy availability, and building program.

Mechanical ventilation provides a menu of good air filtering options but comes with limitations. HVAC systems, for instance, use mechanical filters to clean the air coming in from outside while increasing the airflow through a building. Greater ventilation is associated with health benefits, and filters are efficient at removing larger particles. On the down side, smaller particles are always more problematic. Delivering air to targeted areas is also tricky, for example to a specific workstation rather than overall in an open room. Also, air ducts in HVAC systems can harbor moisture, which creates breeding grounds for biological contaminants. Ultimately, it's not realistic to deeply clean all the air in a home or office building with only a centralized system.

HVAC air filter ratings are measured on a 1-16 scale called the Minimum Efficiency Reporting Value (MERV). A rating of 16 is defined as greater than 95% particle removal from 0.3 to 10 microns. Newer standards (and filtration levels) have been recently introduced that take the MERV rating to 20. The higher the MERV rating, the higher the back pressure of the filter, generally. Back pressure refers to the resistance of air moving through a filter. The higher the resistance, the less airflow, and the harder the system has to work to clean the air. Increased back pressure can put a strain on the design limits of the fan in a system, which can result in breakage, shortened life, and excessive energy usage. So while higher MERV ratings suggest better cleaning performance, there's a cost for that performance.

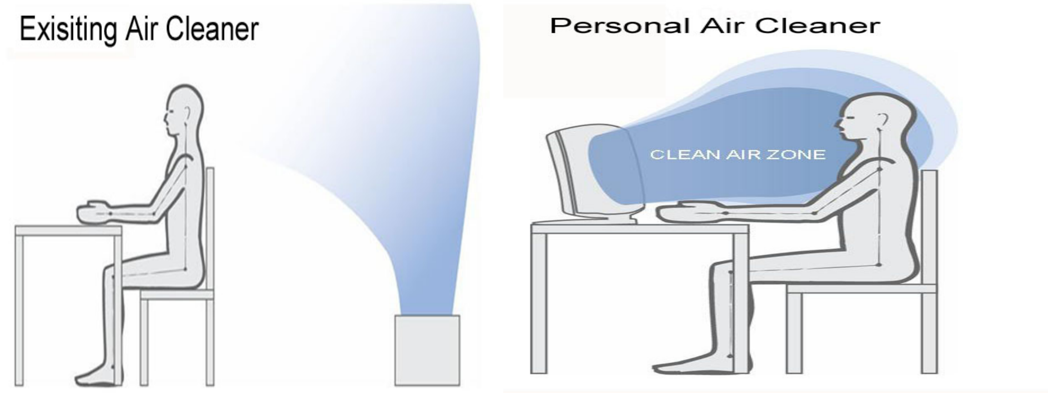
The most recognized technology for particle removal from the air is HEPA (High Efficiency Particle Arrestor). HEPA filters—a class of mechanical filters—are made from tightly woven fiberglass and capture at least 99.97 percent of airborne particles 0.3 microns and larger, but can be less efficient at capturing smaller particles that slip right through the fibers. HEPA filters are used in everything from vacuum cleaners to airplanes. The filters require significant pressure to force air through, so they tend to be used in larger units with bigger fans. The downside, in either a centralized HVAC or personalized air cleaning unit, is that these systems can be loud and also use a lot of energy. Care needs to be taken that filters are replaced on schedule. Otherwise particles build up and interact with harbored moisture so that biological contaminants may actually end up dispersing back into the air off the clogged filter.

In addition to HEPA, individual air purifiers may use other particle filtration methods. Electrostatic precipitation devices employ an electric current to charge particles as they come into the unit. An oppositely-charged metal collector plate then captures the particles as they pass by, similar to static cling. These units neutralize particles of all sizes, even those less than 0.3 microns. However, effectiveness and performance vary greatly between models. They can also be messy to clean. More importantly, electrostatic precipitators can produce ozone, which is dangerous to breathe. In fact, inhaling ozone can cause coughing, congestion, wheezing, shortness of breath, and chest pain in otherwise healthy people. For those who already have respiratory issues, the symptoms can be worse. Short-term exposure to low levels of ozone carries a minimal risk, but prolonged exposure has damaging, longer-lasting effects.

The standard measurement of the performance of an air cleaner defined by the Association of Home Appliance Manufacturers (AHAM) is called the Clean Air Delivery Rate. The CADR measurement is a function of air volume and collection efficiency. The measurement is taken in an air chamber using real-world standardized contaminants; dust, smoke, and pollen. Units with a high CADR provide more clean air at a higher rate, but tend to be large and loud. Smaller units are quieter, but since they move less air they, in turn, clean less air. When considering portable or room-size air cleaners to clean enclosed spaces, such as private offices or conference rooms, the designer must balance the needed CADR with the unit size and noise that comes with that level of performance. Generally, the size unit recommended for enclosed spaces with 8' ceilings is a CADR that equals two-thirds of the room size in square feet. For example, a 10' x 15' (150 square foot) office with 8' ceilings would require a CADR of two-thirds of 150, or 100 CADR. Rooms with taller ceilings require a higher CADR. Unfortunately, in open plan environments, room air cleaners are simply not effective as there's vastly too much air volume for them to effectively circulate and clean.

In addition to the air purifier performance standards defined by AHAM, the U.S. Department of Energy and the Environmental Protection Agency's Energy Star program has established criteria to measure air purifier efficiency, defined as the ratio of CADR per watt of energy usage. This standard allows designers to compare which units have the best air cleaning performance for the least amount of energy consumed, similar to how we use MPG to measure the efficiency of cars. For an air purifier to meet the Energy Star requirements, its CADR per watt must be 2 or greater, a number the vast majority of air purifiers don't meet. Energy Star also requires a minimum level of CADR and a maximum level of ozone allowed. Overall, Energy Star-qualified room air cleaners are 40% more efficient than non-qualified models.

The Future of IAQ



So how do you address air quality in open office plans? Centralized systems just can't clean air in a large open space with lots of air movement and where new sources of contaminants infiltrate the space at all times.

Personalized air purification systems are a hot topic in IAQ. In a large office with an open floor plan, having fresh air delivered directly to the breathing zone for individual workers is desirable for maximum health and comfort. Designers and scientists are working on the problem from various angles, trying to create systems for centralized cleaning with individual control. Alan Hedge is involved with an innovative ventilation prototype at the Syracuse Center of Excellence that's working to extend the field of IAQ options that are accessible and easy to maintain for both occupants and building facilities managers.

A similar idea with a different execution is to provide purification devices at each individual workstation. Humanscale's Shane Cohen explains that the ideal scenario in a large area is to enclose an individual worker in a "bubble of clean air", also known as the Clean Air Zone, instead of trying to clean all the air in that environment. This is proving to be both a more effective and a more efficient approach to air purification. With any effective air purifier, the cleanest air is always what comes directly out of the unit. But the problem with placing a traditional HEPA air purifier near a worker has always been the loud noise and the strong breeze they produce. New technology developed in Sweden and based on electrostatic purification methods using closely packed layers of nonconductive paper rather than the typical metal plates, solve these issues. This type of workstation device is capable of filtering out particles at a high level, including bacteria and viruses, without noise, breeze or problematic ozone production. Thus, this device can be placed very near and directed toward a worker to shower him/her with ultra clean air. And the technology uses little energy, making it by far the most efficient air purification solution yet with a CADR per watt ratio approaching 6.

Next generation approaches to IAQ are also in development at university research laboratories. Alan Hedge, for instance, is collaborating with fiber scientists on making a new kind of filter out of nano-fibers that are “sticky” to chemicals, but let fresh air through. A material like this could be part of a more standard filtration device. But he is also imagining fabricating it into drapery and fabric panels on office partitions. Instead of getting musty over time, these nano-fabrics could actually clean air! Another interesting scheme is connecting plants to a building’s HVAC system for hybrid-natural purification. Using this system, researchers at the Center for Architecture Science and Ecology are looking at producing 300 percent more cleansing power over that of regular plants when air is run across plants’ root structures in specialized modules.

The future of IAQ is promising. Today architects and interior designers have more solutions available to them as they design and plan spaces where people will work–and breathe. For a building to be sustainable, it has to be healthy, and that means the air must be clean. The trend in green building toward integrated design delivery is pushing teams to work together on every aspect of the project, including the invisible but ever-present quality of the air. At stake is the health of people and the planet.

Additional Resources

California EPA Air Resources Board:
http://www.arb.ca.gov/homepage.htm
EPA:
http://www.epa.gov/iaq/index.htm
OSHA:
http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_2.htm

Air Quality Sciences:
http://www.aqs.com
American Lung Association:
http://www.lungusa.org

ASHRAE Indoor Air Quality Guide:
http://www.ashrae.org/publications/page/1936
ASHRAE Standards and Guidelines:
http://www.ashrae.org/technology/page/548
Asthma and Allergy Foundation of America:
http://www.aafa.org
Clean Air Delivery Rate:
http://cadr.org/index.htm
Greenguard Environmental Institute:
http://www.greenguard.org/en/QuickSearch.aspx
IAQ Radio:
http://www.iaqradio.com/

Indoor Air Quality Scientific Findings Resource Bank, LBNL:
http://www.iaqscience.lbl.gov
International Centre for Indoor Environment and Energy:
http://www.iciee.byg.dtu.dk
Lawrence Berkeley National Laboratory, Commercial Building Ventilation and Indoor
Environmental Quality:
http://eetd.lbl.gov/ie/viaq
Minnesota Department of Health, Volatile Organic Compounds (VOCs) in Your Home: http://www.health.state.mn.us/divs/eh/indoorair/voc/
www.Energystar.gov
Interpreting Filter Performance By DONALD A. NEWELL, PE, HPAC Engineering, February 2006:
www.who.int/indoorair

News/Case Studies
Active Phytoremediation Wall System:
http://www.architectmagazine.com/greentechnologactive-phytoremediation-wall-system.aspx

Banned Trailers Return for Latest Gulf Disaster:
http://www.nytimes.com/2010/07/01/us/01trailers.html?_r=3&hp

Humanscale Humanair Purifier Brings Industrial Strength to the Desktop:
http://www.popsci.com/gear-amp-gadgets/article/2009-09/desktop-air-purifier-industrialstrength

LEED Certification Where Energy Efficiency Collides with Human Health, An EHHI Report:
http://www.ehhi.org/reports/leed/

Syracuse Center of Excellence Total Indoor Environmental Air Quality Lab:
http://www.syracusecoe.org/coe/sub1.html?skuvar=18

Daniela Morell holds a Masters in Architectural Science degree, with a concentration in Built Ecologies, from Rensselaer Polytechnic Institute's Center for Architecture Science and Ecology in New York City. Her research on next generation building technologies focuses on the energy and cultural transfer of responsive, bioclimatic façade systems. Previously Daniela she was Special Projects Editor at *Metropolis* magazine, and recently she served as the Construction Project Coordinator for the Living Pavilion on Governors Island.