An Expanding Opportunity for
Engineers and Professionals

The Indoor Environment... Productivity and Health...and $$$

Editor's Note: New challenges (read "opportunities") for readers continue to arrive. The two related articles presented below are guides for readers who wish to extend their activities in improving HVAC systems while reducing energy costs.

When new regulations on both indoor and outdoor air quality take effect, readers will be directly involved in "getting the job done."

Mega $Billions Can Be Saved in the U.S. With Better Indoor Environments

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There is strong evidence that characteristics of buildings and indoor environments significantly influence rates of respiratory disease, allergy and asthma symptoms, sick building symptoms, and worker performance. Theoretical considerations, and limited empirical data, suggest that existing technologies and procedures can improve indoor

environments in a manner that significantly increases health and productivity. At present, we can develop only crude estimates of the magnitude of productivity gains that may be obtained by providing better indoor environments; however, the projected gains are very large.

For the U.S., we estimate potential annual savings and productivity gains of $6 billion to $19 billion from reduced respiratory disease; $1 billion to $4 billion from reduced allergies and asthma, $10 billion to $20 billion from reduced sick building syndrome symptoms, and $12 billion to $125 billion from direct improvements in worker performance that are unrelated to health.

Sample calculations indicate that the potential financial benefits of improving indoor environments exceed costs by a factor of 18 to 47.

Poor indoor environments can have several adverse health effects. These include communicable respiratory disease (e.g., common colds and influenza), allergy and asthma symptoms, and acute sick building syndrome (SBS) symptoms such as headaches, and irritation of the eyes, nose, throat, and skin. For example, in six studies, the number of respiratory illnesses in building occupants varied by a factor of 1.2 to 2.0 as a function of building characteristics such as rate of ventilation with outside air, type of ventilation system, and occupant density (see table). Allergy and asthma symptoms are often a consequence of indoor exposure to allergens that may originate indoors or outdoors.

Several methods can be employed to reduce allergen exposures. Changeable building factors such as ventilation rates, indoor pollutant concentrations, and quality of building cleaning can influence the frequency and severity of SBS symptoms. In addition to influencing health, research suggests that the indoor environment, especially temperature and lighting, can affect worker performance directly by a fraction of a percent to a few percent.

We estimated the costs of the building-influenced adverse health effects from statistical data and published papers. The annual (1993) health-care costs for acute respiratory infections are about $30 billion. These respiratory infections result in about $35 billion in annual sick leave plus restricted activity at work. The health-care costs and productivity decreases from allergies and asthma are about $13 billion per year. Productivity losses from SBS symptoms are quite uncertain but were estimated to be around 2 percent among office workers, costing an estimated $50 billion annually.

The most difficult step in the analysis was to estimate the percent-

Field Studies of Respiratory Disease as A Function of Building Characteristics

Setting	Populations Compared	Health Outcome	Results
U.S. Army barracks	Resident of modern (low-ventilation)	Respiratory illness with fever	50% higher incidence in modern barracks
Finnish office	Workers with one or more roommates vs. no roommates	Common cold	20% more colds with roommates
Antarctic station	Residents of smaller vs. larger quarters	Respiratory illness	100% more illness in smaller quarters
NY state schools	Fan-ventilated vs. window-ventilated classrooms	Respiratory illness, absence	70% more illness, 18% more absence in fan-ventilated rooms
Gulf War troops	Troops housed vs. never housed in different types of buildings	Symptoms of respiratory illness	Significantly more symptoms in air conditioned building
U.S. jail	>7.5 m^2 vs. <7.5 m^2 space per person and high vs. low CO_2	Pneumococcal disease	Significantly higher incidence if <7.5 m^2; 95% higher incidence in high-CO_2 group

age decrease in adverse health effects and the percentage of direct improvements in productivity that could be obtained by improving indoor environments. These estimates were based in part on the strength of reported associations, between health effects and indoor environmental factors. The estimates also reflected the degree to which it is practical to improve relevant indoor environmental conditions such as ventilation rate and pollutant concentrations. Based on these and other considerations, we estimated the potential decreases in adverse health effects from improvements in indoor environments to be 10 to 30 percent for infectious respiratory disease, and allergy and asthma symptoms and 20 to 50 percent for SBS symptoms. The potential direct increase in office workers' performance was estimated to range between 0.5 and 5 percent.

Because worker salaries exceed building energy, maintenance and annualized construction costs by a large factor, the cost-effectiveness of improvements in indoor environments will be high even when the percentage improvements in health and productivity are small. The costs of increasing ventilation and improving air filtration in a large office building were estimated and then compared to the value of projected health and productivity benefits. The resulting benefit-to-cost ratios were very high, approximately 50 to 1 and 20 to 1 for increased ventilation and improved filtration respectively.

Very strong evidence that better indoor environments can cost-effectively increase health and productivity would justify changes in building codes and in company and institutional policies related to building design, operation, and maintenance. Available data are not sufficiently specific and compelling to motivate these actions. The existing evidence of potential productivity gains is, however, clearly enough to justify an expanded program of research. A research investment on the order of $10 million per year for five years would answer many of the key questions. The total cost of this multiyear program of research would be only 0.2 percent of the most conservative estimate of annual productivity gains from improved indoor environments.

ABOUT THE AUTHORS

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Asthma, Roaches, and Regulations

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A study in the *New England Journal of Medicine* concludes that cockroach dust induces asthma attacks, and "may help explain the frequency of asthma-related health problems in inner-city children." The increase in asthma incidence and mortality is but one example of severe health effects linked to indoor air pollutants. Unfortunately, the federal government has exacerbated this problem, while wasting billions on false solu-