

According to Hocking, a single-pass ventilation system brings air to a passenger's face and then to the floor, where it exhausts to the outside. In this scenario, an infected person might be a danger to his or her seatmates and a few other surrounding people due to air turbulence within the cabin. A recirculation system, however, takes the air, perhaps containing viruses or bacteria, from near the floor, mixes it with outside air, and recirculates it to the entire cabin.

Hocking suggests that if airlines are to use recirculation, they should also install and maintain HEPA filters to remove potentially infectious particles. Finally, Hocking recommends that the fresh air supply be kept at 15 cubic feet per minute per person during taxiing, ascent, and descent.

He supports his recommendations with an economic analysis that shows airlines save \$60,000 per aircraft per year with recirculation systems. While this seems like a large sum, it works out to about \$1 per passenger trip, based on a 200-seat aircraft that makes 300 trips per year. The figures would be different for larger or smaller aircraft and for longer flights. He contends that passengers have an

Table 5 — Calculated and Measured CO₂ Concentrations (ppm)

	Measured Concentrations			Calculated Concentrations
	1989 Flights (92)		1994 Flights (158)	
	Smoking	Non-smoking		
Mean	1,562 ± 685	1,765 ± 660	785	1,145
Minimum	597	766	464	771
Maximum	4,943	3,157	1,552	1,682
Distribution (%)				
<1,000	13	13	75	28
1,000-1,500	34.5	30.5	25	64
1,500-2,000	34	17		8
2,000-2,000	18	26		0
>2,500	3	13		0

Source: M.B. Hocking

interest in avoiding illness and therefore might be willing to pay the extra average cost of \$1.

While the airlines claim large savings, Hocking argues that this is a "one-stakeholder saving" and not a "system saving." The passengers who become ill, as well as their families and employers, must bear the cost of the illness caused by the airline saving money.

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Case Study

[In each issue, IEQS presents a case study on an indoor air investigation in a particular building. The information in the cases comes from various sources, including published material, reports in the public record, and, in some cases, reports supplied by the consultants involved in the case. IEQS presents a variety of approaches to investigation and mitigation implemented by consultants with a broad range of experience, philosophies, and expertise. Inclusion of a particular case study in the newsletter does not imply IEQS's endorsement of the investigative procedures, analysis, or mitigation techniques employed in the case. IEQS invites readers to submit comments, suggestions, and questions concerning the case. At the discretion of the editors, correspondence may be presented in a future issue.]

Investigators Link Building IEQ and Environmental Illness

This case involves a hospital complex, where IEQ problems went on for more than six years and affected hundreds of workers, causing what physicians described as environmentally induced dysfunction (EID). Despite the correction of the problems that caused the illnesses, 85 workers from the hospital still

suffer from adverse health effects, keeping them out of work on long-term disability.

The case focuses on the illnesses suffered by the workers and the correlation of the syndrome to the building conditions. Roy A. Fox, M.D., a physician at the hospital, reports on

the illness outbreak in the *Journal of Nutritional & Environmental Medicine* (1996: Vol. 6, pp. 351-358). We have prepared the case from that report and interviews with Dr. Fox.

The buildings involved are part of the Camp Hill Medical Center (Halifax, Nova Scotia) a metropolitan teaching hospital. The affected buildings include the Camp Hill Hospital (CHH), a 1917 structure with no mechanical ventilation; the Abbie J. Lane Building (AJL), which was 25 years old at the time the illnesses began in 1987; and the Veterans Memorial Building (VMB), which had opened in 1986. Both the AJL and the VMB had mechanical ventilation.

Onset of Symptoms

Symptom reports began in 1987 when kitchen workers at the VMB began complaining of various symptoms, including pruritis, folliculitis, wheezing, eye irritation, sore throat, and headaches. Within a two-year period, about 80% of the 160 workers in the kitchen experienced the adverse health effects.

Officials, suspecting an IEQ problem, conducted an investigation and determined that the likely problem was the sodium hydroxide used in the dishwashing machine. The dishwasher exhausted to a small courtyard, and the exhaust was located close to an outdoor air (O/A) intake. The officials corrected the situation and began to see some improvement in the irritation effects experienced by the workers. However, some workers still complained of cognitive effects and increased reactions to environmental chemicals. At the time, workers in other parts of the complex were complaining of adverse health effects, but these were not thought to be connected to the kitchen workers' complaints.

However, in 1989 workers on the second floor of the VMB began complaining of symptoms similar to those experienced on the first floor, and the symptoms for all affected workers seemed to be increasing in severity. The symptoms also began to spread to other areas in the three buildings. Compared with the kitchen workers, occupants in other areas presented with a greater prevalence of bronchial hyper-reactivity. Their symptoms also included nausea, diarrhea, weight loss, hair loss, recurrent infections, myalgia, and arthralgia.

Physicians also reported neurotoxic effects, including memory loss, decreased concentration, decreased visual acuity, peripheral paresthesia, Raynaud's phenomenon, severe fatigue, dizziness, and lack of neuromuscular coordination.

By the time the outbreak peaked in 1993, various symptoms had affected 700 persons of the total workforce of 1,250. Because the symptoms were spread among three buildings with different ventilation systems, investigators began to focus on what would be common to the three buildings. Fox tells *IEQS* that one focus was the cafeteria, located in the VMB, because many workers from other buildings visited there on a regular basis.

Environmental Illness

Fox reports that while the clinical findings didn't fit neatly into any single disease category or syndrome, investigators felt the symptoms were related to the indoor environment in some way. Much of the symptomology, he says, was similar to reported cases of multiple chemical sensitivity (MCS). The workers' reactivity to chemical exposure seemed to be a major factor, although other clinical features didn't show the same relationship. Some of the affected persons showed sensitivity to other substances, and some had clearly diagnosed allergies to such things as mold and pollens.

Because they were unable to fit the symptoms clearly within an accepted disease syndrome, and rather than claiming that patients had multiple idiopathic conditions developing simultaneously, the investigators coined an operational definition of EID. Fox says the dysfunction had two main components:

1. A gradual and persistent decline in health, usually over a period of more than three months by the time the patients sought medical attention
2. Serious symptoms in more than one organ system brought on or exacerbated by exposure to environmental irritants

One similarity to MCS, according to investigators, was that the affected persons had adverse reactions to chemicals and other substances at concentrations that don't normally produce such reactions. When the patient was removed from the substance, the reaction would lessen.

Another phenomenon was that some patients began to exhibit reactions to foods — not discrete food allergies, such as some people have to seafood or peanuts, but rather reactions to foods they had previously eaten regularly. Patients also reacted to exposure to electromagnetic fields and were unable to be near computer terminals, television sets, and other electrical appliances.

Environmental conditions affected some patients. These persons were unable to tolerate changes in temperature and were affected by light, both natural and artificial, and by noise. The investigators detected multiple reactions, some of which were synergistic and brought on other reactions. The environmental irritants rarely acted alone. The symptoms of these reactions to irritants ranged from mild to disabling. One characteristic of the syndrome was fatigue, which was universally present. Some patients became extremely tired after exercise and suffered myalgia. They also required a long time to recover from the exercise-induced fatigue. Some patients reported mood swings, and others developed depressions and anxiety.

The investigators report that patients sometimes had a yellowish cast to the skin. Other skin disorders included adult-onset acne, edema, petechiae, livedo reticularis, follicular hyperkeratosis, and dark circles under the eyes. Fox says some patients had a positive Romberg's test and others exhibited peripheral neuropathy.

Investigators conducted laboratory tests that confirmed the dysfunction and supported the EID presumption. Some patients had abnormal pulmonary function tests, a positive methacholine challenge test, and abnormal neuropsychological tests. Blood tests revealed leucopenia, elevated liver enzymes, and abnormal lymphocyte subsets. These findings were similar to abnormalities reported in cases of MCS.

Building Problems

Fox tells *IEQS* that the investigators began to focus on the various buildings in the complex and factors that might be common to the three buildings involved, other than the fact many workers visited the cafeteria in the VMB.

Looking at the HVAC systems in the two mechanically ventilated buildings, investigators

determined that the system in the new building, the VMB, had never been commissioned, resulting in poor balancing. Also, there was significant reentrainment of exhaust, and an underground passageway had insufficient ventilation. Air monitoring showed elevated levels of phenol and formaldehyde in the building.

The AJL building, which was 25 years old at the time of the outbreak, had mechanical ventilation, but the system hadn't been maintained properly and, according to Fox, had probably never been cleaned. Workers removed considerable dirt and debris from the ducts within the building. Also, for energy conservation, workers had closed the O/A dampers, meaning that the building had no O/A supply.

However, neither of these situations was common to all three buildings, still leaving investigators with a puzzle. The one thing that was common to all three buildings was that they shared a steam heating system, and steam from the boiler was used in a common humidification system. According to Fox, the complex used anticorrosives in the boiler water that was eventually used for humidification. Instead of adding the anticorrosives in a steady feed, workers would add them in batches, often 5-10 times above the recommended levels. Investigators were able to recover amines from the anticorrosives in condensation in the ductwork.

Because of the condensate in the ductwork, mold and fungal contamination could have been a problem at the facility. Fox says that investigators looked at this and reported no significant mold contamination.

Acting on the recommendations from investigators, officials spent considerable money to upgrade and balance the ventilation systems. They also replaced the humidification system, installing one that uses a totally separate water supply without the anticorrosives.

As a result, reports of new illnesses have ceased. Many of the workers who were out sick from the initial outbreak have returned to work, although, according to Fox, about 85 are still out on long-term disability and are being treated for EID.

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