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Buildings, Ventilation and Thermal Climate

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AIR QUALITY IN HOSPITALS AND HEALTH CARE FACILITIES

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Abstract

In addition to air quality problems encountered in other sealed buildings, both workers and patients in hospitals may be exposed to very special air contaminant problems. Levels and ranges of a variety of chemical pollutants measured in 16 hospitals are reviewed using a computer based Building Performance Information System (BPIS). A number of anaesthetic gases and sterilization agents (halothane, nitrous oxide [N_2O], and ethylene oxide [ETO]) appear at relatively high levels. Such heightened concentrations present hazardous conditions for hospital workers and patients. Energy conservation in buildings, hospitals included, has concentrated on reducing ventilation. Hospitals, because of special potentially hazardous conditions, may be even more prone to problems than office or other public buildings. Any energy conservation strategy must seek to guarantee reasonable air quality in hospitals.

Introduction. A computer-based Building Performance Information System (BPIS) was developed of reports of investigated epidemic outbreaks of building associated illness occurring in sealed, air conditioned public buildings, many of them hospitals, in order to explore the possibility of isolating antecedent conditions through this archive. In a review of 143 such studies contained in the BPIS data base, Sterling (29) reported that almost without exception in studies of office buildings, no specific cause or agent was found to be associated with complaints or illnesses. However, a careful review of studies of 16 hospitals and laboratories shows that, unlike office buildings, most investigations of building associated illness among patients and personnel have established a clear-cut cause.

Pollution burdens in hospitals. Table 1 shows median levels and ranges of various substances measured in the air of 16 hospitals. Despite the limited number of measurements, the most prevalent air quality problem both hospital staff and patients are exposed to seems to be anaesthetic gases from operating theaters and organic germicides from sterilization areas. Table 2 presents a compilation of government standards regulating occupational exposure to chemical air contaminants found in hospitals and laboratories in the United States and Western Europe. Comparison of Tables 1 and 2 show that not all substances exceeded occupational exposure limits. Enflurane measured at a median

Table 1: Median Levels and Ranges of 21 Pollutants Measured in 16 Hospitals. 16 Hospitals

POLLUTANT	MEDIAN VALUE	# OF REPORTS	RANGE OF VALUES
Acetic Acid	ND	1	ND
Alcohols	ND	1	ND
Ammonia	ND	1	ND
Aromatic Hydrocarbons	10.27 mg/m³	4	ND-104 mg/m³
Ethyl Benzene	8.14 mg/m³	1	8.14 mg/m³
Toluene	4.5 mg/m³	1	ND-12 mg/m³
Xylene	58.2 mg/m³	2	ND-104 mg/m³
Carbon Dioxide	612 ppm	1	500-800 ppm
Carbon Monoxide	4.12 ppm	5	ND-18 ppm
Dimethyl Acetamide	ND	1	ND
Enflurane	1.44 mg/m³	1	0.5-3.0 mg/m³
Ethylene Oxide	147 mg/m³	2	ND-770 mg/m³
Formaldehyde	ND	3	ND-0.12 ppm
Halothane	5.2 mg/m³	5	ND-33.6 mg/m³
Hydrazine	ND	2	ND
Hydrogen Sulphide	ND	1	ND
Nitrosamines	ND	1	ND
Nitrous Oxide	67.5 ppm	5	ND-1200 ppm
Particulates	0.027mg/m³	1	0.014-0.05 mg/m³
Solvent	ND	1	ND
Sulphur Dioxide	ND	1	ND

ND: tested but no detectable levels found

level of 1.44 mg/m^3 was well below the NIOSH standard of 15.1 mg/m^3. Formaldehyde was not detected at all or detected in levels well below the NIOSH standard of .8 ppm. Aromatic hydrocarbons, including ethyl benzene (median 8.14 mg/m^3), toluene (median 4.5 mg/m^3) and xylene (median 58.2 mg/m^3) all were measured below both NIOSH and OSHA standards. However, median levels reported for nitrous oxide (67.5 ppm) and ethylene oxide (147 mg/m^3) exceed both NIOSH and OSHA standards of 25 ppm and 50 ppm, respectively, while reported median levels of halothane (5.2 mg/m^3) exceed the NIOSH standard of .05 mg/m^3 for use in the presence of nitrous oxide.

Health Effects of Pollutants Found in Hospitals. Studies of hospital patients and personnel exposed to the anaesthetic gases, nitrous oxide and halothane, have reported increased risk of spontaneous abortions and congenital abnormalities in female workers and wives of male workers (5,6,7,8,19,31,32). Increased incidence of hepatitis and renal disease, as well as impairment of psychological functions, have also been reported (4,5,22). More recently, increased incidence of cancer among exposed personnel and children of exposed personnel has been described (5, 9, 31). Ames, et al, (1) found bone marrow and deoxuridine suppression among patients administered anaesthetics for extended periods.

Table 2: Standards[+] Regulating Occupational Exposure to Air Contaminants Found in Hospitals

	NIOSH	OSHA	OTHER
Aromatic Hydrocarbons			
Ethyl Benzene		100 ppm (435 mg/m³) IDLH* 2000 ppm	
Toluene	100 ppm (375 mg/m³) 200 ppm 10 min Ceiling**	200 ppm 2000 IDLH 300 ppm ceiling 500 ppm peak***	
Xylene	100 ppm 200 ppm 10 min Ceiling	100 ppm (435 mg/m³) 10,000 ppm IDLH	
Enflurane	2 ppm (15.1 mg/m³)[x]		
Ethylene Oxide (ETO)	50 ppm (90 mg/m³) 75 ppm Ceiling	50 ppm (90 mg/m³) 800 ppm IDLH	USSR - 0.5 ppm (1 mg/m³) W.Ger. - 50 ppm Sweden - 20 ppm
Formaldehyde (HCOH)	0.8 ppm 30 min Ceiling	3 ppm 100 ppm IDLH 5 ppm Ceiling 10 ppm peak	
Halothane	2 ppm (16.2 mg/m³)[x] 0.5 ppm when used with N_2O		Denmark 1 ppm[x]
Nitrous Oxide (N_2O)	Less than 25 ppm[x] 50 ppm for dental offices		Denmark 10 ppm[x]

\+ are typically eight hour time weighted averages (TWA) unless otherwise specified.
* IDLH - immediately dangerous to life and health
** Ceiling - value for which recommended level can be exceeded for a 15 minute period unless otherwise specified.
*** Peak - level which should never be exceeded.
x For locations where anesthetics are administered. These are not necessarily safe levels, but are considered "readily achievable" levels (24).

NIOSH investigations have monitored the exposure of nurses and anaesthesiologists to nitrous oxide, ethane and halothane in operating and recovery rooms (10,11,12,13,14,15,16,17,18). Investigators report between 40% and 50% of operating room and recovery room personnel suffered from acute symptoms, including fatigue, headache, dizziness/lightheadedness, nausea, drowsiness, cough and skin irritation.

Strunim, et al, (30) reported concentrations of anaesthetics in operating theaters after dental operations greatly in excess of those in general surgical operating theaters. In a later study, Layzer (21) reported symptoms including early sensory complaints, loss of balance, leg weakness, gait ataxia, impotence and sphinctes disturbance among dental surgeons after exposure to anaesthetics.

Animal studies of halothane exposure show central nervous system damage in young and unborn rats at exposures of 8-12 ppm, while liver and kidney damage is typically seen at 50-150 ppm (22). Studies of combined exposure to halothane and nitrous oxide show increased fetus reabsorption in pregnant animals (similar to spontaneous abortion in humans) exposed to 10-8000 ppm halothane and 1000-700,000 ppm nitrous oxide.

Occupational exposure to the sterilization agent ethylene oxide has been reported to produce a sister chromated exchange, and NIOSH has recommended that it be considered a mutagen and possible carcinogen (23,24).

In a recent industrial hygiene study of a surgical daycare center in Vancouver, complaints of drowsiness, headaches, lethargy and swelling and irritation of the eyes among staff were found to be reduced after the use of organic germicides isopropyl alcohol, glutar aldehyde and parachlorophenol were reduced (25). The investigators also noted that the same organic compounds may further contribute to the formation of highly irritating organics in the air through reaction with ozone, nitrogen oxides and other urban air pollutants in a mechanism similar to the formation of photochemical "smog".

Discussion. In addition to excess exposure to anaesthetic gases and organic germicide, hospital workers face the added danger of exposure to airborne organisms, fungi and infectious contaminants circulated through the ventilation system such as aspergillus fumigatus and Legionella. Hospitals also contain laboratories using biological materials and many toxic chemicals. There are now many investigations which have demonstrated the potential for laboratory exhaust to be reintrained into the general ventilation system. (For example, one recent investigation of a Canadian Government research center found that fume hoods intended to remove exhaust from laboratories were feeding laboratory exhaust back into the building.)

Exposure to indoor pollution levels may increase hospital admission rates as well as extend duration of hospitalization required for patients suffering from certain relevant diseases. Studies by Sterling, et al, (26,27,28) using American Blue Cross/Blue Shield Data on 30,000 patients in 9 hospitals, show a significant relationship between pollutant levels and duration of hospitalization for diseases such as allergic disorders and acute upper respiratory infections. More recently, Bates and Sizto (2) show a significant relation between excess respiratory admissions and exposure to elevated levels of sulfur dioxide and ozone.

In the interest of both personnel and patient health, two steps should be taken: [1] Isolation and separation of ventilation air from industrial type source areas from the rest of the hospital. [2] Minimization or elimination of sources for special air contaminants generated within hospitals. For example, cleaning solutions should be selected which do not off-gas irritating materials into the ventilating air. Also, wards with contagious human-generated contaminants should be exhausted separately.

Recent energy conservation guidelines instituted for energy conservation in hospitals have included modifications to the ventilation system, reducing the amount of fresh air provided by increasing recirculation of exhaust air, tightening the building envelope and duct system, as well as increasing the range of temperature and humidity provided (3). These strategies have contributed to air quality problems in other building types. Hospitals, because of potentially hazardous conditions, may be even more prone to problems than office and other public buildings. As a consequence, fresh air supply to hospitals ought not to be restricted as is commonly done in other sealed buildings.

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