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Both workers and patients in hospitals may be exposed to very special air contaminants including: 1) anesthetic gases from operating theatres, 2) organic germicides from sterilization areas, 3) toxic gases and biological organisms from laboratory areas, and 4) infectious disease bearing organisms from patients. We have reviewed levels and ranges of a variety of chemical pollutants measured in 16 hospitals. A number of hazardous pollutants appear at relatively high levels, for instance, halothane, nitrous oxide (N_2O) and ethylene oxide (ETO). Median levels of N_2O and ETO exceed both NIOSH and OSHA standards while the median level of halothane exceeds the NIOSH standard for use in the presence of N_2O. Clearly hospitals contain special potentially hazardous conditions which must be controlled to guarantee reasonable air quality for both staff and patients.

Air Quality in Hospitals and Laboratories

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Introduction

Over 200 reports are available of investigated epidemic outbreaks of building associated illness occurring in sealed, air conditioned public buildings conducted by investigators from Public Health Service or private institutions and organizations. This archive of reports includes hygiene measures, indoor air quality, health, and occupant comfort and possibly contains clues to the antecedents of discomfort and illness. Many of the outbreaks occurred in hospitals where potential or severe air quality problems exist.

A computer based building performance information system (BPIS) was developed to help explore antecedant conditions of building related illness through this archive. In a review of 143 studies contained in the data base Sterling (1) reported that almost without exception the buildings were modern, sealed, mechanically ventilated, air conditioned and very often considered energy efficient. In most studies of office buildings no specific cause or agent was found to be associated with complaints of illnessess. However, a careful review of studies of 16 hospitals and laboratories now included in the data base reveals that, unlike office buildings, most investigations of suspected building associated illness occurring among patients and personnel in hospitals have established a clear cut cause.

Results

Pollution Burdens in Hospitals

The most prevalent air quality problems to which hospital staff and patients are exposed are anesthetic gases from operating theatres and organic germicides from sterilization areas. Table I shows median levels and ranges of anesthetic gases, of sterilization agents and of other substances measured in the air of 16 hospitals. Not all substances exceeded occupational exposure limits. Enflurane measured at a median 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 90 mg/m^3 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. Unfortunately there are a number of severe health consequences associated with exposure to anesthetic gases and gases from sterilizing agents.

Table I. Anesthetic gases, sterilization agents and other substances measured in the air of 16 hospitals

POLLUTANT	MEDIAN VALUE	# OF REPORTS	RANGE OF VALUES
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
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
Nitrous Oxide	67.5 ppm	5	ND - 1200 ppm

ND: tested but no detectable levels found

Discussion

Health Effects of Anesthetic Gases

Nitrous oxide and halothane are the most commonly used anesthetic gases. Studies of hospital patients and personnel exposed to nitrous oxide and halothane have described various deleterious responses: An increased risk of spontaneous abortions and congenital abnormalities in female workers and wives of male workers (2,3,4,5,6,7,8); an increased incidence of hepatitis and renal disease as well as impairment of psychological functions (3,9,10); an increased incidence of cancer among exposed personnel and children of exposed personnel (11,3,7); bone marrow and deoxuridine suppression among patients administered anesthetics for extended periods (12); and early sensory complaints, loss of balance, leg weakness, gait ataxia, impotence and sphinctes disturbance among dental surgeons after exposure to anesthetics (13). (Strunim et al (14) had reported concentrations of anesthetics in operating theatres after dental operations greatly in excess of those in general surgical operating theatres.)

There are few health effects studies of halothane exposure using human subjects, however animal studies show central nervous system damage in young and unborn rats at exposures of 8-12 ppm and liver and kidney damage is typically seen at 50-150 ppm (10). Studies of combined exposure to halothane and nitrous oxide show increased fetus reabsorption (similar to spontaneous abortion in humans) in pregnant animals exposed to mixtures of 10-8000 ppm halothane and 1000-700,000 ppm nitrous oxide.

Exposure of nurses and anesthesiologists to nitrous oxide, ethane and halothane in operating and recovery rooms has been extensively monitored by NIOSH. (15,16,17,18,19,20,21,22,23). In all cases the investigators concluded that a

health hazard existed due to excessive waste anesthetic gases. These levels were presumably caused by a combination of:

1. Inadequate venting of the scavenging systems,

2. Contamination of the air supply by recirculated air,

3. Difficulty in administering gas to some patients,

4. Improperly fitted face masks, and

5. The technique of administration used by the anesthesiologist.

In these investigations, 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.

Health Effects of Sterilization Agents

Occupational exposure to ethylene oxide has been reported to produce a sister chromated exchange, and NIOSH has recommended that it be considered a mutagen and possible carcinogen (10,24).

In a recent industrial hygiene study of a surgical daycare centre 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 photo chemical "smog".

Microorganic Air Contaminants

In addition to exposure to toxic chemicals hospital workers face the added danger of exposure to airborne organisms and infectious contaminants circulated through the ventilation system. One example are the increased incidence of pulmonary infections such as aspergillus pneumonia caused by the spore forming Aspergillus fumigatus species of fungi. Unlike most hospital acquired infections which result from transmission of organisms by direct contact, aspergillus relies on airborne dissemination (26). Air contaminated with aspergillus spores, supplied to operating theatres and post operative recovery rooms has been shown to be responsible for post operative infection of aspergillus endocarditis resulting in numerous deaths (27,28). Rose (29), based on a comparative study of aspergillus infections among patients moved from a 43 year old naturally ventilated hospital to a new mechanically ventilated facility, suggests that hospital acquired aspergillus infections could be eliminated if all incoming hospital air were filtered, properly vented and not recirculated.

Since its discovery in 1976 Legionnaires Disease has turned up in hospitals and in many cases has been traced either to contamination of the water supply, cooling tower or humidification system (30). Recently lowering the temperature of the hot water supply to conserve energy has been implicated as an

important source of Legionella. Prior to 1974 the hot water supply for most hospitals was kept at about 140°F. However, energy conservation guidelines instituted by the Joint Commission on the Accreditation of Hospitals in the United States have required a reduction of hot water supply temperature to 110°F. Based on a measurement survey of 6 buildings in the Ohio State University hospital complex, Plouffe (31) found that reduction of hot water supply temperature from 140°F to 110°F provided an ideal environment for growth of legionella. Because of special requirements two of the six buildings surveyed maintained hot water temperatures between 135°F to 140°F while the remaining four had lowered the hot water supply temperature to 110°F. The first two buildings showed no legionella bacteria colonization while tests on the water of the remaining four were positive for legionella bacteria. Researchers demonstrated in one building that flushing the hot water system with 160°F water killed the legionella.

Air Contaminants from Laboratories

Hospital laboratories use biological materials and toxic chemicals. Proper venting of these laboratories is crucial to the health of the general population of the building as well as the laboratory workers themselves. Improper installation, operation or design of laboratory exhaust may be responsible for insufficient removal of toxic substances in research laboratories. An additional problem which may exist when laboratories are contained within or near other buildings is contamination of the general air supply with laboratory exhaust. There are now many investigations which have demonstrated the potential for laboratory exhaust to be reintrained into the general ventilation system (32). (For example, one recent investigation of a Canadian Government Research Centre concluded that fume hoods intended to remove exhaust from laboratories were feeding laboratory exhaust back into the building).

Impact of Pollutant Burdents on Frequency and Length of Hospitalization

The health effects of pollutants are especially severe for individuals at low levels of resistance to toxic insults. Patients are just such individuals. The effect of even slight increases in levels of concentrations of particulates and of sulphur dioxide in the ambient air has been shown to increase the number of individuals in need of hospitalization and the length of time required to discharge patients once they become admitted. Studies using American Blue Cross - Blue Shield Data on 30,000 patients in 9 hospitals show a significant relationship between pollutant levels and frequency of admission and duration of hospitalization for diseases such as allergic disorders and acute upper respiratory infections (33,34,35). More recently Bates and Sizto (36) show a significant relation between excess respiratory admissions and exposure to elevated levels of sulphur dioxide and ozone.

These findings are of importance not only because they demonstrate the deleterious consequences of exposing patients to increased pollutant burdens, but also because they link the cost of hospitalization to the control of pollution in the hospital's ambient environment.

Conclusions

Two steps should be taken to achieve acceptable air quality for hospitals.

1. Complete isolation of industrial type source areas as well as laboratories and wards containing contagious human generated contaminants from the rest of the hospital in terms of exhaust ventilation and air circulation.

2. Minimization or elimination of sources for special air contaminants generated within hospitals.

Having isolated the industrial and eliminated the other unique problem sources the final step is to maintain adequate fresh air rates to all areas. However, recent energy conservation guidelines instituted for hospitals have included reduction of fresh air ventilation, to minimum levels, and increased recirculation of exhaust air (37). Although these strategies have created air quality problems in other building types, hospitals, because of potentially hazardous conditions, may be even more prone to such problems than are office or other public buildings.

Hospital air quality should not be compromised in the interests of energy conservation. Even in an energy conserving era, adequate hospital environment services must be maintained.

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