



## ***Original article***

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## Effect of engineering controls and work practices in reducing ethylene-oxide exposure during the sterilization of hospital supplies

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Ethylene oxide is routinely used as a gaseous sterilant of steam- and heat-sensitive items in hospitals, in other health care facilities, and by many manufacturers of medical, dental, and health care products. It has been shown to be a carcinogen and a mutagen in animal toxicity studies (3). Human health effects that are suspected to be associated with occupational exposure to ethylene oxide include increased incidence of leukemia, adverse reproductive effects, and elevated mutagenic activity (1).

Researchers at the National Institute for Occupational Safety and Health (NIOSH) have evaluated the ranges of exposure to ethylene oxide among hospital workers and the various engineering controls designed to reduce such exposure. In-depth industrial hygiene surveys were conducted at 12 hospitals to characterize exposure to ethylene oxide during the utilization of various types of work practices and engineering controls. Engineering controls in eight other hospitals were evaluated to identify the best available controls to reduce the exposure potential of ethylene oxide. The hospitals included in these studies represented a wide range of exposure situations, various engineering controls, sterilization equipment, work practices, and administrative efforts to control ethylene-oxide exposure.

### Description of the surveyed hospitals

To characterize the exposure to ethylene oxide among hospital workers, 12 of 150 hospitals were chosen which were believed to represent a wide range of work practices and engineering controls. Eight other hospitals were selected for the evaluation of the "best available engineering controls." To select the 20 hospitals studied, the following information was obtained for each of the 150 hospitals: (i) size of hospital and extent of ethylene-oxide usage, (ii) type and size of sterilization equipment, (iii) extent of engineering controls employed, (iv) use of personal protection equipment, and (v) number of workers involved in sterilization with ethylene oxide.

The selected hospitals varied in size (containing from 120 to 750 beds), location of sterilizer, and the size or

number of sterilizers used. The number of sterilization loads processed each week ranged from 1 to 20 for these hospitals. The variety of ethylene-oxide sterilizers and aerators observed at these hospitals was representative, as all known sterilizer manufacturers and a wide variety of sterilizer models were found in these hospitals. The existence and extent of engineering controls in the first 12 hospitals ranged from very effective controls to none (2). The use of personal protective equipment in the hospitals surveyed was limited to gloves to transfer sterilized items from the sterilizer. Respirators were not used in any of the hospitals surveyed or contacted.

### Survey methods and results

Each hospital survey lasted 2 to 3 d. Personal exposure sampling of all workers potentially exposed to ethylene oxide on the first, second, and/or third shifts was conducted. NIOSH methods 1607 and/or 1614 were used to evaluate personal long-term time-weighted averages and short-term exposures (4). Recognized work practices and the existence, or lack, of effective engineering controls known to influence ethylene-oxide exposure potential were identified and noted for each hospital surveyed. The exposure sampling results for each hospital were compared with the summarized information on work practice and engineering control conditions found in that hospital, and also with the corresponding information from the other hospitals surveyed (5).

In the determination of whether exposure potential was influenced by the existence of engineering controls and/or the utilization of proper work practices, the 12 hospitals were classified according to the degree of engineering controls and work practices employed. Prior to receiving the exposure monitoring results, each hospital was placed in one of four categories according to the following criteria: (i) good engineering controls and good work practices, (ii) good engineering controls and poor work practices, (iii) no engineering controls and good work practices, and (iv) no engineering controls and poor work practices.

The arithmetic mean and range of the personal 8-h time-weighted average exposure to ethylene oxide for each hospital are shown in figure 1. These results in-

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dicating the variety of full-shift exposures observed across the hospitals. The time-weighted average exposure levels ranged from nondetectable to 6.3 ppm for the sterilizer operators and from nondetectable to 6.7 ppm for the folders and packers. The arithmetic mean of the short-term personal exposure to ethylene oxide for each hospital is shown in figure 2. These results

depict a broad range of short-term exposure levels; the short-term (2 to 30 min) exposure levels for the sterilizer operators ranged from nondetectable to 103 ppm.

The effect of proper work practices and effective engineering controls on exposure potential is characterized in figures 3 and 4. The range of the exposure levels and the arithmetic means, standard deviations,

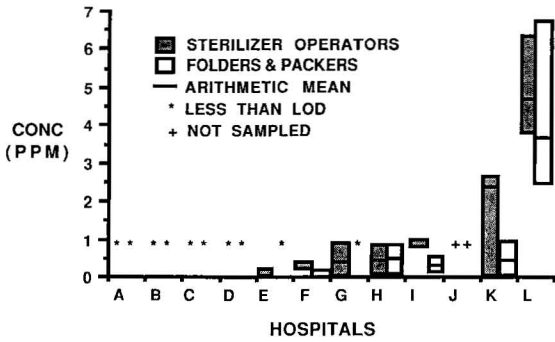


Figure 1. Ranges and means of the 8-h time-weighted average exposure to ethylene oxide (personal samples) in the 12 hospitals. (LOD = limit of detection, CONC = concentration)



Figure 2. Arithmetic means of the short-term exposure to ethylene oxide (personal samples) in the 12 hospitals. (LOD = limit of detection, CONC = concentration)

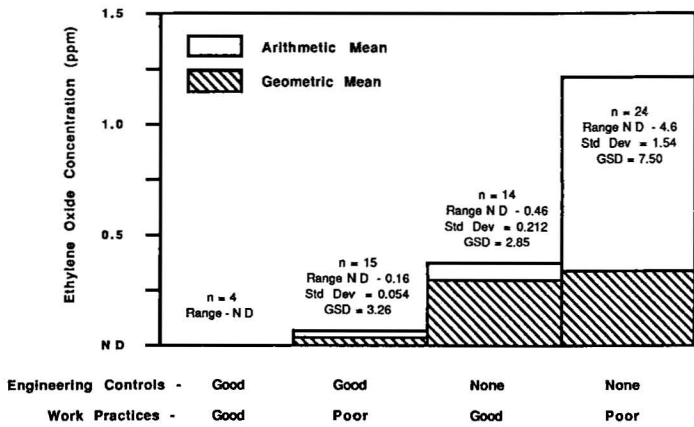


Figure 3. Mean 8-h time-weighted average exposure to ethylene oxide in association with the degree of engineering controls and type of work practices. (n = number, ND = nondetectable, Std Dev = standard deviation, GSD = geometric standard deviation)

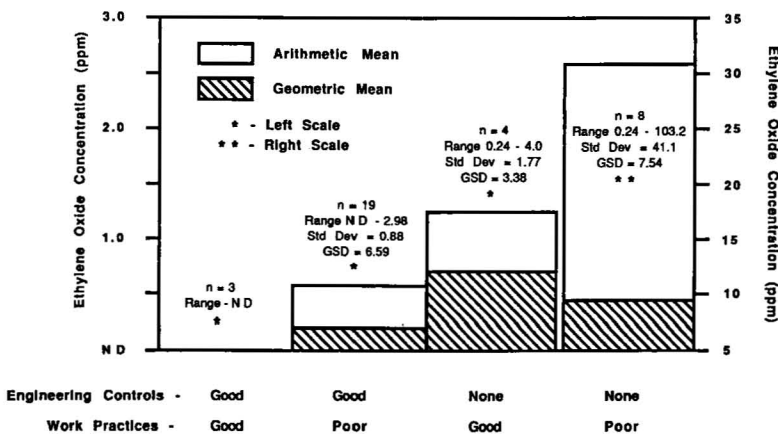


Figure 4. Short-term exposure to ethylene oxide in association with the degree of engineering controls and type of work practices. (n = number, ND = nondetectable, Std Dev = standard deviation, GSD = geometric standard deviation)

geometric means, and geometric standard deviations for each category are shown for the 8-h time-weighted average exposures and for the short-term exposures in figures 3 and 4, respectively.

As expected, effective engineering controls and good work practices reduced the ethylene-oxide exposure to less than detectable levels, while the lack of effective controls coupled with poor work practices resulted in unacceptable levels of ethylene-oxide exposure. The extent of engineering control needed by a hospital was found to depend on a number of factors, eg, the composition and size of the sterilized load, the location of the sterilizer, the time constraints on sterilization, the type of sterilizer, the types of controls selected, and the level to which the ethylene-oxide exposures are to be controlled (Mortimer & Kercher, unpublished results).

### Concluding remarks

From industrial hygiene surveys of 24 sterilization areas with exposure to ethylene oxide in 20 hospitals, on the basis of the existence of engineering controls and observations of work practices, it was shown that engineering controls and/or good work practices can effectively reduce exposure to ethylene oxide. Engineering controls are more effective than just good work practices in reducing exposure potential. Proper work practices, in the absence of good engineering controls, were also shown to effect a considerable reduction in ethylene-oxide exposure. Effective engineering controls in conjunction with proper work practices afforded the

best reduction in the ethylene-oxide exposure of hospital workers.

The following engineering controls collectively reduced ethylene-oxide exposure: local ventilation above the sterilizer door, local ventilation at the sterilizer drain, good general area ventilation of the sterilizer room, and additional vacuum purges. Work practices which collectively aided in a reduction of ethylene-oxide exposure included vacating the sterilizer room area during the exhaust cycle, opening the door 2—5 cm at the end of the cycle and again vacating the area to allow the ethylene oxide in the air to decrease, and limiting the handling time of and close contact with the sterilized items.

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