

**SPD Employee Continuing Education
Training Guides**



Ethylene Oxide (EtO) Sterilization

**Prepared by the SPD Advisory Group
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SUPPLY, PROCESSING & DISTRIBUTION (SPD) CONTINUING EDUCATION

ETHYLENE OXIDE (ETO) STERILIZATION

Upon completion of this session, participants will be able to:

- ◆ Explain the use of EtO in the hospital setting
- ◆ Define properties of EtO in regard to health and safety
- ◆ State guidelines for use of EtO
- ◆ Define typical parameters for EtO sterilization and aeration
- ◆ State factors to consider when determining which items to sterilize in EtO
- ◆ Discuss packaging methods and materials

1. Information relative to EtO sterilization

- a. Definition
- b. Requirements
 - 1. Effectiveness
 - 2. Safety
 - 3. Penetration
 - 4. Material Compatibility
 - 5. Monitoring
 - 6. Approval

1. Historical review of the use of EtO

- a. Mixtures
- b. EPA requirements
- c. Changes

1. Safety – Effects on the Human

- a. Classification – health risks
- b. Symptoms of exposure
- c. Exposure limits
- d. Monitoring (environmental)
- e. Minimization of risk, practices, and environmental controls

SUPPLY, PROCESSING & DISTRIBUTION CONTINUING EDUCATION

ETHYLENE OXIDE (ETO) STERILIZATION

1. EtO Sterilization Process

- a. Penetration
- b. Material Compatibility
- c. Monitoring
 - 1. Parameters, time, temperature, humidity and concentration
 - 2. Internal chemical indicators
- a. External chemical indicators
- b. Biological

1. Adaptability

- a. Cleaning
- b. Packaging

SUPPLY, PROCESSING & DISTRIBUTION (SPD) CONTINUING EDUCATION

ETHYLENE OXIDE (ETO) STERILIZATION

The ability to reprocess heat and moisture-sensitive items in the hospital is important because of the many synthetic materials that are used in the complex and expensive medical devices. EtO has been the primary sterilant of choice since the 1960's for items that cannot be sterilized with steam. EtO has excellent product penetration characteristics and broad product sterilization applications. However, cost issues, concerns about product residual levels, long aeration times, and environmental and safety concerns make this method of sterilization less than perfect.

Basic requirements important to any type of low temperature sterilization system used include:

1. Effectiveness – the sterilant must provide good microbial kill against the broad range of microorganisms encountered in today's healthcare environment. The sterilizer must provide an acceptable microbial safety factor (often referred to as Sterility Assurance Level – SAL).
2. Safety – there should be no toxic sterilant residuals remaining on the packaging or devices, and the system should provide a safe environment around the sterilizer. The sterilizer should not provide a safety risk to the patient or healthcare workers.
3. Penetration – the sterilant must penetrate through packaging systems and provide contact with all surfaces of all devices being sterilized.
4. Material Compatibility – there should be no changes in the functionality of the devices being sterilized after repeated sterilization cycles.
5. Monitoring – the process should be capable of being reliably monitored with readily available mechanical, chemical, and biological indicators.
6. Approval – the sterilization system must be cleared by or registered with the appropriate regulatory agencies.

To be effective in the hospital environment, the sterilization system must satisfy all the above requirements; failure to meet even one of the factors may pose a significant risk to the patients or the healthcare workers.

This paper will review the low temperature sterilization system known as EtO, EO, or Gas Sterilization.

EFFECTIVENESS

This sterilization system has been demonstrated to be an effective sterilizing agent against a wide range of microorganisms. To be legally marketed in the United States, the Food and Drug Administration (FDA) requires rigorous testing with a broad range of microorganisms. As long

as the process is used in accordance with the products' labeling, it is capable of providing the minimum required sterilization assurance level.

EtO is an organic chemical that is one of the most widely used industrial chemicals. It is used to make a wide range of products including detergents, polyester, and antifreeze. Less than 1% of all EtO produced is used for hospital sterilization. At room temperature and standard atmospheric pressure, EtO exists as a colorless gas but when exposed to temperatures below its boiling point of 50.7 degrees Fahrenheit (10.4 degrees Celsius) it condenses to a liquid. It is approximately two times heavier than air. For most people, EtO gas is also odorless at concentrations below 500 ppm. It is both flammable and explosive although liquid EtO requires extremely high temperature and high pressure for ignition. In the gas phase, EtO is flammable at lower temperatures if concentrations are above 3% in air. For safety reasons, EtO is often supplied as a mixture diluted with an inert gas, which renders it nonflammable and nonexplosive.

From the 1960's until 1995, 95% of all hospitals performing low temperature sterilization used the 12-88 EtO blend – 12% EtO and 88% chlorofluorocarbon-12 (CFC-12). The Clean Air Act of 1990 required removal of CFC-12 from sterilant gases by January 1, 1996. Consequently, all sterilizers that previously used the 12-88 CFC blend have either been converted to use a mixture of 10% EtO and 90% hydrochlorofluorocarbon (HCFC) or 8.6% EtO and 91.4% carbon dioxide – CO₂. Other alternatives were to replace the older sterilizer with a smaller unit that uses 100% EtO or use other low temperature sterilization alternatives.

CFC-12 was eliminated from use with EtO sterilant mixtures because of its ozone depletion properties. The HCFC blends which have been developed have approximately 1/20 of the ozone depleting potential of the CFC-12. Sterilizers that previously used the CFC-12 blend required little modification to accommodate the HCFC blend. Therefore, most of the EtO sterilizers previously using CFC-12 have been converted to the HCFC mixture.

A few CFC-12 sterilizers were converted to use a mixture of 8.6% EtO and 91.4% CO₂ because this mixture is less costly than the HCFC blend and CO₂ has no ozone depleting potential. However, the use of CO₂ has been limited because of its extremely high vapor pressure. Most of the CFC-12 sterilizers were limited by their working pressure and could not be converted to the high pressure EtO/CO₂ process. Another disadvantage of the CO₂ mixture is that separation of EtO and CO₂ can occur within the storage containers. This can create a container environment where EtO concentrations are both flammable and explosive.

When the CFC-12 blend was phased out of production, many healthcare facilities switched to sterilizers using 100% ethylene oxide. The cost of 100% EtO per cubic foot sterilizing capacity is significantly less than the HCFC blends. To minimize flammability and explosion risks, the 100% EtO sterilizers are only available in small chambers (typically 4-8 cubic feet) and small amounts of EtO are used. (Then, if a fire were to occur, it would result in very little damage.)

Regardless of the diluent used, EtO is a very effective alkylating agent. This makes it a good sterilant against a wide range of microorganisms because it reacts with the DNA that is essential to the living cell and destroys the cell's ability to metabolize or reproduce. However, it is not an effective sterilant against all microorganisms, i.e. prions (CJD) which have no DNA nor RNA.

SAFETY

The sterilizing agent discussed in this paper presents some safety risks and is toxic. (If it was not toxic, it would not be able to kill the microorganisms.) This sterilization system can be used safely if it is used properly.

EtO STERILIZATION PROCESS

Based upon data developed primarily in the 1980's, EtO has been classified as a mutagen, carcinogen and a reproductive hazard. Acute effects of inhaling EtO vapors include respiratory tract irritation and lung damage, headache, nausea, vomiting, diarrhea, shortness of breath and even death. Control of exposure to EtO by those using it as a sterilant and by those patients receiving treatment with EtO-sterilized devices is essential to its safe and effective use.

In 1984, the Occupational Safety and Health Administration (OSHA) established a 1 ppm (in air) permissible exposure limit (PEL) and an 0.5 ppm action level (AL) for EtO. Both the PEL and the AL are expressed as an 8-hour time-weighted average (TWA). The 8-hour TWA represents the total allowable exposure of a worker during an 8-hour period and expresses it as an average exposure during the period. If the facility can document that employee exposures are below the AL, the facility is not required to conduct routine monitoring or periodic employee medical examinations.

In 1988, OSHA amended its rule on occupational exposure to EtO by adding a 5 ppm short-term excursion limit (STEL) over a 15-minute period. The STEL is typically related to tasks such as transferring or handling non-aerated goods, performing sterilizer maintenance or changing gas cylinders.

Employers are required to ensure that employees are not exposed to airborne EtO in excess of 1 ppm as an 8-hour TWA. If initial monitoring indicates employee exposure below the AL, no further monitoring is required, unless (1) the monitored level is above the AL, (2) the measured level is above or below the PEL. The institution may be required to institute a medical surveillance program if specific exposure levels are exceeded. The employer may also be required to develop a written plan to reduce employee exposure to at or below the PEL using engineering and work practice controls. STEL monitoring is required for certain job tasks (such as changing gas cylinders, unloading the EtO sterilizer, etc.) where there is a potential for exposure to EtO. Monitoring may be discontinued if consecutive measurements taken seven days or more apart indicate exposure levels of less than 5 ppm. When the STEL is exceeded, a written plan must be developed to define actions that will reduce exposure and meet the standard.

To comply with the OSHA standard, employers must determine employee exposure to EtO using breathing zone air samples that are representative of 15-minute short term or the 8-hour TWA exposure levels. OSHA standards do not identify the specific type of monitoring devices required to comply with the standard, but they do define accuracy requirements which the monitoring methods must meet. Both personnel monitoring badges and environmental area monitoring can be employed to comply with the standard.

Personnel monitoring normally includes the use of devices that can be affixed directly to the employee's clothing in the breathing zone (within one foot of the nose). One limitation of the personnel monitoring devices is that results of the sampling are not available until after the actual sampling period. For this reason, OSHA also requires that facilities using EtO sterilization have a system and/or procedure to immediately alert the employees in case of an emergency.

The best way to identify an emergency situation involving employee exposure to EtO is through the use of area monitoring systems. These devices provide real-time, continuous monitoring of airborne EtO and will quickly detect emergency situations such as leaks, spills or failures in the ventilation system. However, area monitors may not provide reliable breathing-zone measurements and may not be appropriate for STEL or TWA data.

Many healthcare facilities use contracted environmental monitoring services to obtain independent monitoring data and to perform on-site assessments. The contractor should also check the ventilation systems (e.g., room air exchanges, local exhausts, air intakes). The facility should assure that the contractor has the appropriate qualifications and seek references from other hospitals.

To comply with OSHA regulations, the employer has the obligation to inform all appropriate employees of personnel and area-monitoring results. These records must be kept for 30 years after the employee termination from the last EtO-related tasks. The facility also must establish a written emergency action plan in case of an EtO leak or spill.

To minimize the risks associated with the use of EtO, employees should be instructed about the hazards of EtO, the status of procedures to reduce employee exposure, principles of EtO monitoring, interpretation of results, use of protective equipment, OSHA standards, material safety data sheets, and the EtO emergency plan. Appropriate processing procedures should be established and reviewed periodically. Storage and handling of EtO gas containers should follow the recommendations of the sterilizer manufacturer and the gas supplier.

The EtO sterilizer should be located in a well-ventilated area with a room air exchange rate of at least 10 air changes per hour. Ventilation systems and exhaust lines including floor drains should be periodically checked by qualified personnel. Area and exhaust ventilation alarms, both visual and audible, should be in place to alert personnel of potential leaks.

In addition to concerns relative to employee safety, the use of EtO has specific requirements as it relates to patient safety. EtO residues are chemical species that could remain associated with an EtO-sterilized device until its use on a patient. The most commonly referred to residues are EtO and its primary by-products, Ethylene Chlorhydrin and Ethylene Glycol. These residues are toxic and should be reduced to appropriate levels depending upon the type of medical device being sterilized.

EtO residuals are reduced to safe levels by mechanical aeration. The minimum generic recommendation for product aeration is 12 hours at 122°F (50°C).

Since the rate of aeration is dependent upon many factors, including the nature of the materials used for the device construction, the manufacturer of the medical device must be responsible to provide recommendations for the appropriate aeration time and temperature. Some types of devices have been found to require significantly longer aeration periods than the minimum recommendations mentioned above.

PENETRATION

Many of the medical devices and instruments used today are significantly more complex than those used just a few years ago. Not only must the sterilant penetrate through the packaging material (in some cases multiple layers), it must also penetrate down narrow lumens and between tightly mated surfaces. If the sterilant cannot penetrate to the most difficult site to reach where microorganisms may be harbored, it will not be an effective sterilization process.

There is no better penetrating gas sterilant than ethylene oxide. It has a high vapor pressure and a low boiling point (10.4°C) which means it is easily maintained in the gas phase. It is a relatively stable molecule so it will not break down to a non-sterilizing entity as it penetrates into difficult-to-reach sites. Due to its solubility and diffusion properties, EtO has the ability to penetrate directly through many types of polymers. These properties not only ensure good penetration of the sterilant, but they are also the properties that necessitate the long aeration periods.

EtO is compatible with all commonly available hospital packaging materials, such as cellulosic-containing packaging materials, e.g., paper-plastic pouches, cellulosic-containing disposable wrappers, and muslin wraps.

MATERIAL COMPATIBILITY

EtO has excellent compatibility with nearly all of the materials used in the construction of both single-use and reusable medical devices. This is evidenced by the extensive use of EtO in the United States and other international communities. Historically, most heat-sensitive, reusable medical devices have been designed with EtO as the intended sterilant.

The new low temperature sterilizing systems do not have as long a history to evaluate material compatibility as does EtO.

MONITORING

All sterilization processes should be capable of being monitored with mechanical monitors, chemical indicators and biological indicators. None of these three, by themselves, are conclusive evidence of device sterility, but in combination, they provide a high degree of sterility assurance.

Mechanical monitors should measure the key parameters of the sterilization process. In EtO sterilization, these are gas concentration, temperature, humidity and time.

EtO gas concentrations typically used in hospital sterilizing systems range from approximately 500 to 750 mg/liter. As the EtO gas concentration is increased at a given temperature and relative humidity, the killing rate for the microorganisms also increases.

Moisture is critical to the effectiveness of EtO sterilization processes and a minimum of 35% relative humidity is required at the site of microbial inactivation. Moisture is critical to the process because it facilitates the alkylation reaction necessary for biological kill and also aids in the transfer of EtO through packaging materials.

Temperature exerts one of the most significant influences on the EtO sterilizing process. For every 10°C rise in temperature, the killing rate for the microorganisms will, in general, double. Increases in temperature may also facilitate the penetration of EtO through packaging and product. Hospital EtO sterilizing cycles are typically performed in the range of 37.8° to 60°C (100° to 130°F).

In general, there is a direct relationship between sterilizing time, gas concentration, moisture, and temperature. Hospitals normally rely upon the sterilizer manufacturer to define the processing time as well as the limits for the other process variables. If any of these variables fall below the minimal acceptable parameters, mechanical monitors should indicate a sterilization cycle failure. Typical hospital sterilization exposure times range from 1.5 to 3.5 hours for EtO.

Chemical indicators (CIs) are available for EtO sterilization systems. Chemical indicators can be divided into different categories. Process indicators are used to demonstrate that the package has been exposed to the sterilization process and to distinguish between processed and unprocessed units. At a minimum, process indicators should be included with each package processed in EtO.

Two additional classes of CIs are single-parameter and multi-parameter indicators. These CIs are designed for one or more of the critical parameters, respectively. Both types are available for EtO processes and can be used in place of, or as a supplement to, process indicators in order to provide additional information.

A final class of chemical indicators are integrating indicators which are designed to react to all critical parameters over a specified range of sterilization cycles. Chemical integrators are only available for EtO sterilization processes and provide monitoring capabilities similar to that of biological indicators (BI's).

Like mechanical monitors, CIs give an immediate indication that some minimal process parameters have been attained. The advantage of CIs is that they can be placed in each package processed in the sterilizer while mechanical monitors only provide information on general conditions within the sterilizing chamber.

In terms of monitoring, the most emphasis is placed on the results of the biological indicators (BIs). A BI can be defined as a unit containing microorganisms of known concentration and resistance to a given sterilizing agent that can be expected to follow a predictable death rate when exposed to physical and/or chemical parameters. The BI serves to demonstrate that conditions necessary for sterilization were achieved; it cannot independently validate product sterility. The BI will not compensate for lack of knowledge or improper procedures. It is simply one part of the quality assurance practices required to consistently produce sterile products.

The self-contained BI consists of both a growth medium and a carrier inoculated with the desired population of test organisms contained within an outer vial. Sterilant enters and exits the outer vial via a tortuous path or filter. Following the sterilization process, the growth media is brought into contact with the test organisms which eliminates the need to aseptically transfer the inoculated carrier to a separate vial of growth media. This eliminates the potential for contamination of the BI and a resulting false-positive BI. Self-contained BI's are only available for EtO and steam sterilization processes.

The BIs for EtO sterilization utilize spores of *Bacillus subtilis* var. *niger*. These spores represent a significantly higher challenge to the sterilization organisms in the hospital environment. The theory is that if one million of the most resistant organisms are killed by the process, then the actual devices which contain fewer and less resistant organism will also be sterile.

For EtO sterilization, it is required that a BI be included with each load processed. This is because each of these processes is dependent upon multiple parameters to achieve sterilization. BIs and BI controls are the best means for measuring sterility.

ADAPTABILITY

The basic steps for the sterile processing of reusable devices within the hospital include cleaning, drying, packaging, sterilization, and storage/use. Appropriate procedures must be established for each of these steps because they are important if sterile products are to be delivered to the surgical procedure.

Cleaning is probably the single most important step in the reprocessing sequence. If devices are not adequately cleaned, then regardless what happens in the next operations, a sterile product cannot be consistently delivered. Data have demonstrated that EtO cannot reliably sterilize microorganisms in the presence of organic and salt residues.

Cleaning procedures recommended by the device manufacturer should be followed. If the device is composed of more than one part, it should be disassembled. All jointed or hinged instruments should be opened during the cleaning process to make sure all surfaces are clean. Cleaning agents selected must be compatible with the medical device.

If the cleaned agents are to be sterilized with EtO, they must be thoroughly dried before packaging and sterilizing. None of the sterilizing gases can adequately penetrate through liquids.

Packaging systems for gas sterilization processes should perform the following functions:

- Permit air removal during the vacuum phase of the process so the package does not rupture
- Allow penetration of the gaseous sterilant
- Provide a barrier against entry by microorganisms or dust during storage
- Resist tearing or puncturing during normal handling
- Allow for easy opening and aseptic presentation at the sterile field
- Contain no toxic ingredients or nonfast dyes
- Have proven seal integrity

Paper/plastic pouches, Tyvek pouches, paper or synthetic nonwoven wraps, textiles, and rigid vented containers are all compatible with EtO sterilization systems.

Glass, aluminum foil, polyethylene films or cellophane should not be used in EtO processes due to poor penetrability by the sterilant or humidity.

After cleaning, drying and packaging, the items can be loaded in the sterilizer in a way which allows adequate gas circulation between the packages. If Tyvek/plastic or paper/plastic pouches are used, they should be oriented with the plastic side of one pouch facing the paper or Tyvek side of the next pouch. Sterilant penetration and removal is through the Tyvek or paper surface. Overloading the sterilizer may interfere with sterilant penetration or aeration.

Use of EtO sterilizing systems also requires particular attention to the unloading process. It is preferable that sterilized loads be completely aerated in the sterilizer prior to unloading. If a sterilized load must be transferred to a separate aerator, follow the sterilizer and aerator manufacturer's instructions to minimize exposure to EtO. Carts removed from the EtO sterilizer prior to aeration should be pulled (not pushed) to minimize worker exposure.

ETHYLENE OXIDE (ETO)

QUIZ

1. EtO is the abbreviation for _____.
2. Aeration is necessary to _____

3. Name two of the three types of monitors used to check the efficacy parameters of sterilization.

True or False (Circle One)

4. T F EtO reacts to the DNA within microorganisms.
5. T F Hospital EtO sterilizing cycles are typically performed in the range of 37.8-60C (100-130F).

Multiple Choice (Circle correct answer.)

6. EtO sterilization is referred to as
 - a. Low temperature sterilization
 - b. Autoclaving
 - c. PAA sterilization
 - d. Hydrogen peroxide sterilization
4. Types of EtO sterilization used today (circle all that apply)
 - a. 100% EtO
 - b. 12-88 Blend
 - c. 10-90 EtO/HCFC
 - d. 8.6-91.4 EtO/CO₂
5. The health risks associated with EtO are
 - a. Mutagen
 - b. Contaminant
 - c. Carcinogen
 - d. Reproductive hazard

6. When removing a load from an EtO sterilizer, the technician should
 - a. Pull the load
 - b. Push the load

7. The 8-Hr TWA for EtO is
 - a. 1 ppm
 - b. 5 ppm
 - c. 50 ppm
 - d. 100 ppm

ETHYLENE OXIDE (ETO)

ANSWER SHEET

1. Ethylene Oxide
2. Reduce EtO residuals to a safe level
1. Mechanical, Chemical, Biological (must name two)
2. True
3. True
4. a
5. a, c, d
6. a, c, d
7. a
8. a